The Federal Agency on Technical Regulation and Metrology

A Russian Federation
Standardization Document

BREF 1 - 2015

A BEST AVAILABLE TECHNIQUES REFERENCE DOCUMENT

Production of Pulp, Mechanical pulp, Paper and Board

The present draft reference document is not subject to implementation before its approval

MOSCOW
The BAT Bureau
2015

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INTRODUCTION

This BAT reference document is a standardization document, developed as a result of the analysis of technological, technical and management decisions, made during the production of pulp, mechanical pulp, paper and board.

A short overview of the content of the reference document

Introduction. A summary of the BAT reference document.
Preface. The aim of the development of the BREF, its status, the legislative context, a summary of the procedures of development of the BREF in accordance with the prescribed procedure as well as the interdependency with analogous international documents.
Field of application. A description of the main types of activities that are covered by the BAT reference document
Section 1 contains information on the status and status of development of the production of pulp, technical pulp, paper and board in the Russian Federation, as well as a short summary of the environmental aspects.
Section 2 presents information on the industrial processes that are used in PPI as certain process section, including:

- a short description of the functions of the main and secondary production lines
- information on raw material and chemicals consumption
- issues concerning energy and water consumption as well as wastewater disposal
- quantitative and qualitative composition of discharges and emissions of pollutants
- treatment methods for effluents, recycled water and gaseous emissions.
- the generation of effluents, emissions, waste and methods of recycling

Section 3 contains the assessment of energy resource consumption as well as the levels of emissions to the environment typical for the production of pulp, mechanical pulp, paper and board in the Russian Federation.
This section is prepared on the basis of the information presented by Russian Federation companies in the framework of the preparation of this BAT reference document, as well as on various literature sources.
Section 4 describes the characteristics of the approaches used when developing the present BREF and in general fulfilling the requirements of the Rules of Definition of a Technique as a Best Available Technology as well as the Development, Up-dating and Publishing of Information Technology Reference Documents on Best Available Techniques (Ministry of Industry and Trade Decree no. 655 of the 31 March 2015).

XI[1]

[1] Pagination according to the Russian original document for ease of comparison of the texts

Section 5 gives a short description of BAT for the production of pulp, mechanical pulp, paper and board, including:

- a system for environmental and energy management, control and monitor of the production processes
- the technical and technological solutions for an increased energy efficiency, resource conservation, lowering of the level of emissions of pollutants, as well as methods for waste and by-product handling

Section 6 provides the available information on the economic aspects of the introduction of BAT at Russian Federation companies.

Section 7 provides information on new technological and technical solutions (not applied in Russia at the time of the development of the reference document), aimed at increasing the energy efficiency, resource conservation, lowering of the level of emissions of pollutants, as well as efficient methods for waste and intermediate and by-product handling.

Final Conditions and Recommendations. Information is provided on technical working group members that took part in the development of the present BAT reference document. Recommendations to companies on further investigations of the environmental aspects of their activities.

Reference list. Provides information on the sources of information used when developing this BAT reference document.

Terms, definitions and abbreviations used in the present BREF are listed in accordance with [1], [2] and provided in Attachment A.

XII

Preface

The Aims, the main principles and the order of elaboration of the BAT reference document are established by the Procedure of Determination of a Technique as the Best Available Techniques well as the Elaboration, Up-dating and Publishing of the Digital versions of the Best Available Techniques Reference Documents (Government of the Russian Federation Ordinance no. 1458 of the 23 December 2015).

1 Status of the Document

The present reference document on best available techniques *Production of Pulp, Mechanical Pulp and Board, (*hereinafter: the BAT Reference Document) is a standardization document.

2 Information on the Authors

The reference document was elaborated by Working Group no 1 (TWG 1) *Production of Pulp, Mechanical Pulp, Paper and Board*, the composition of which was approved by the Rosstandart Decree no. 827 of the 17 July 2015.

The list of organisations and their representatives, who have been taking part in the development of this reference document, is presented in the section *Concluding Provisions and Recommendations*

The reference document has been presented for approval to the Best Available Techniques Bureau (The BAT Bureau) www.burondt.ru.

3 A Short Description

The present reference document contains a description of the production processes, equipment, technical means and methods used in the field of production of pulp, mechanical pulp, paper and board that i.a. allow for a reduction of the negative impact on the environment, water consumption, the increased cost efficiency, competitiveness, the advance of energy efficiency and resource conservation. Based on the list of described production processes, equipment as well as technical means and methods, a determination is made of the solutions that constitute best available technique. For BAT the corresponding technological characteristics are established in the reference document.

4 Interrelations with International and Regional Analogues

The present reference document was elaborated taking into account the best available technologies reference document of the European Union within the field of *Production of Pulp, Mechanical Pulp and Board,* 2015: (European Commission. Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board, 2015) as well as the characteristics of the production of pulp, mechanical pulp, Paper and Board, 2015 [3], also taking into account the specific situation in the Russian Federation in the field of production of pulp, technical pulp, paper and board.

5 Data Collection

The information on production processes, equipment as well as on the technical means and methods used in the field of production of production of pulp, mechanical pulp, paper and board, in the Russian Federation was collected in the process of elaboration of the reference document in accordance with the Order for Collection of Data, necessary for the Elaboration of a Digital Reference Document on Best Available Technique and the Analysis of Priority Problems of the Branch, Approved by a Rosstandart Decree no. 863 of the 23 July 2015.

6. The Interrelation with other BAT Reference Documents.

The interrelation of the present reference document with other reference documents, elaborated in accordance with the Government Decree of the 31 October 2014, no. 2178-r is described in the section ”Field of Application”.

7. Information on the Approval, Publishing and Enactment

The reference document was approved by Rosstandart Decree no 1571of the 15 December 2015

The reference document was put into force through its official publication in a information system of general use – on the official site of the Federal Agency for Technical Regulation and Metrology on the Internet www.gost.ru .

XIV

A
BEST AVAILABLE TECHNIQUES REFERENCE DOCUMENT

Production of Pulp, Mechanical pulp, Paper and Board

Effective 2016-07-01

Field of Application

The reference document covers the following main fields of activity:

- Wood material preparation (WP)
- Sulphate pulp production
- Sulphite pulp production
- Production of mechanic types of pulp:
    - Defibred pulp (DWP)
    - Thermomechanical pulp (TMP)
    - Chemomechanical pulp (CMP)
    - Chemo-thermomechanical pulp (CTMP
- Production of paper, including the use of regenerated fibre from recycled paper;
- Production of board, including the use of regenerated fibre from recycled paper

This

This reference document also covers the processes connected with the main types of activities, which may have an impact on the volumes of emissions or the size of the pollution of the environment:

The preparation of raw material;

The storage and preparation of fuel (black liquor, bark and wood waste);

- Methods for the prevention and reduction of emissions and the formation of waste
- Methods of recycling of secondary energy resources

The reference document does not cover:

- The production of packaging from paper and board
- Forest harvesting operations

1

Additional types of activities during the production of pulp, mechanical pulp, paper and board and the corresponding BREFs (according to the Russian Federation Government Resolution no. 2178-r of the 31 October 2014) are shown in table 1 under the condition that the installed capacity of the digesters are in the range of a first-category company.

-

Table 1 – Additional types of activities

Fields of Activity	Corresponding BREF
Steam and electrical energy production at thermal stations	Combustion of fuel at major industrial companies in order to produce energy
Industrial cooling systems (cooling towers, plate heat exchangers)	Industrial cooling systems

The field of application of the present digital reference document on BAT in terms of the code OKPD (All-Russian Classification of Products for Various Fields of Commercial Activity) and OKVED (All-Russian Classification of Economic Activities) code, is presented in Table 2.

Table 2 – The field of application of the digital reference document *Production of pulp Mechanical Pulp, paper and Board.*

OKPD	**Item name according to the OKPD**	**Name of the type of activity according to the OKVED** ***OK 020-214 (KDES version 2) All-Russian Classification of Types of Economic Activities (approved by a Rosstandart Order of the 31.01.2014 no. 14-st.)***	**OKVED**
Section C	Processing production goods		
17	Paper and products made of paper	Production of paper and paper products – production of pulp, paper of products out of additionally processed paper	17
17.1	Pulp, paper and board	The production of pulp, mechanical pulp, paper and board	17.1

2

OKPD	**Item name according to the OKPD**	**Name of the type of activity according to the OKVED** ***OK 020-214 (KDES version 2) All-Russian Classification of Types of Economic Activities (approved by a Rosstandart Order of the 31.01.2014 no. 14-st.)***	**OKVED**
17.11	Pulp	The production of pulp and mechanical pulp – the production of bleached, partly bleached or non-bleached mechanical pulp and pulp using mechanical, chemical (complete or incomplete dissolution) as well as semi-chemical processing method; - production of pulp out of cotton linter ф- cleaning to remove ink and typography paint during production of pulp from recycled paper	17.11
17.11.1	Wood pulp and pulp made out of other fibre materials	Pulp production	17.11.1
OKPD	**Item name according to the OKPD**	**Name of the type of activity according to the OKVED** ***OK 020-214 (KDES version 2) All-Russian Classification of Types of Economic Activities (approved by a Rosstandart Order of the 31.01.2014 no. 14-st.)***	**OKVED**
17.11.11	Wood pulp, soluble types		
17.11.12	Wood pulp, Soda or sulphate, apart from soluble types		

3

OKPD	Item name according to the OKPD	Name of the type of activity according to the OKVED *OK 020-214 (KDES version 2) All-Russian Classification of Types of Economic Activities (approved by a Rosstandart Order of the 31.01.2014 no. 14-st.)*	OKVED
17.11.13	Sulphite wood pulp, apart from soluble types		
17.11.14	Wood pulp, produced by mechanical method, wood semi-chemical pulp; pulp or of other fibre materials, except wood.		
		Production of mechanical pulp	17.11.2
17.11.9	Separate services within the production of pulp, rendered by a subcontractor	The production of other fibre semi-products	17.11.9
17.11.11	Wood pulp, soluble types		

Section 1. General Information on Russian pulp and paper industry

1.1. An analysis of economic Activities

1.1.1 The Standing of the Industry in the World Production of the Pulp and Paper Industry

Disposing of an enormous forest raw material base (about one fourth of the world timber resources), the Russian forest-industry complex and pulp and paper industry occupy a modest place in the economy of the country: 0,8% of the GDP, 3% of the

4

volume of the industrial production, and 2,5% of the export volume. If in 1992 Russia held the 10th place in the world in terms of paper and board output, then, in 2014, it occupied the 14th place having been passed by South Korea, Brazil, India and Indonesia. During the said period, the production volumes in these countries grew 2, 2, 3 and 5-fold, respectively. During the same period China (1st place) increased the production volume of paper and board 4,5 times (Fig. 1). The growth of paper and board production in Russian during a quarter of a century was 25%, whereas the proportion of the Russian production within the world paper and board production volume was reduced from 2,3 to 1,9%.

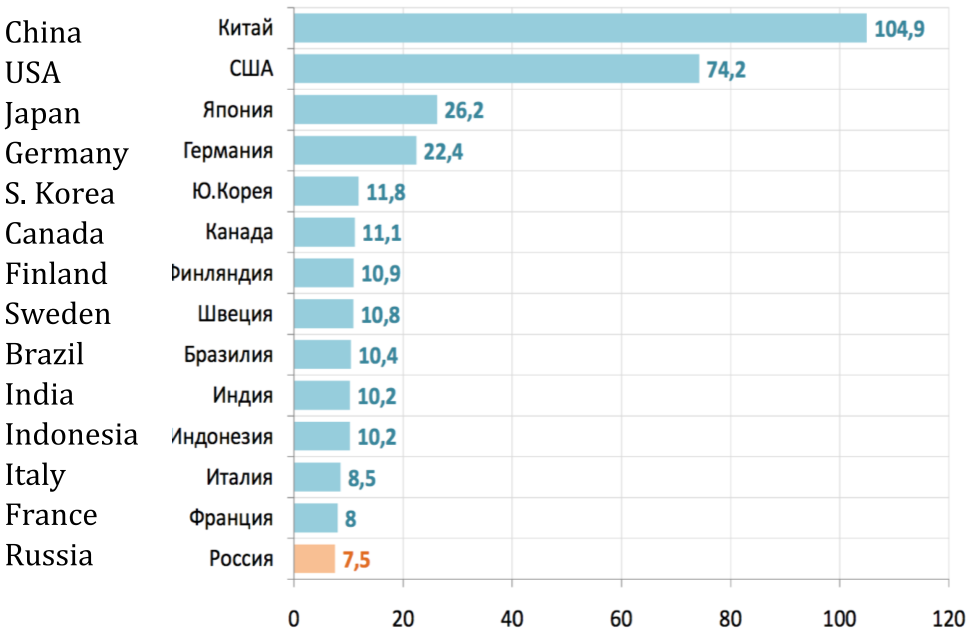

Figure 1.1 – The production of paper and board by leading countries in 2014; m tons (Source: *RAO Bumprom*)

1.1.2 Main Economic Parameters of the Forestry Complex Industries

In spite of the constantly growing competition in the world markets of forestry goods, the pulp and paper industry is still the most efficient base for the sustainable development of the whole of the Russian forest industry.

The national economic effect from the activities of the pulp and paper industry in the Russian Economy exceeds the internal branch profit by more than three times, since the pulp and paper production finds the broadest application in many branches of the national economy, such as construction, food, consumer’s goods, chemical, textile and furniture production industries, as well as within the production of packaging for various consumers' goods and appliances, creating added value to the whole range of products, produced by related production industries (Table 2). This is the reason why the appraisal of the pulp and paper proportion of the volume of the GDP of Russia, based on only the production parameters of the branch are - to a considerable extent - understated.

Table 1.1 – the main economic Table 1.1 - the Main Economic Parameters of the Branches of the Forest Industry Complex During 2013-2014 (Source: Information of the *RAO Bumprom)*

Parameter	Period		Pulp and paper	Wood processing	Furniture production	Logging
Production indices, %	2014		104,5	94,7	101,5	100,5
	2013		95,7	101,4	94,2	96,7
	14/13 %		9,2	-6,7	7,7	96,7
Profit before taxes, Bln roubles	2014		-11,1	-14,7	3,8	-12.2
	2013		4,8	8,5	4,0	-3,2
	14/13 %		-	-	- 5,0	-
Profitability level %	2014		11,3	13,0	6,4	1,9
	2013		9,2	8,1	9,0	-1,0
	14/13 %		122,8	160,5	71,1	-
Investment into fixed assets, bln RB	2014		32 524,0	39 173,8	-	5 975,6
	2013		41 251,4	42 655,9	-	7 502,0
	14/13 %		78,8	91,8	-	79,6
Number of employees	2014		103,1	230,4	156,5	185,5
	2013		107,9	237,4	144,2	192,7
	14/13 %		95,6	97,1	108,5	96,3
Workforce produc-tivity (output per person) K roubles	2014		5 634,1	1616,7	1 220,0	-
	2013		4 241,0	1656,2	1 304,0	-
	14/13 %		109,3	97,5	93,6	
Average monthly wages of the produc-tion workforce	2014		29,5	18,4	18,1	21,6
	2013		27,2	17,0	16,8	20,0
	13/14 %	nominal	108,4	108,2	108,3	108,1
		real	100,6	100,4	100,5	100,3

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1.1.3 The Main Production Processes in the Pulp and Paper Industry

In Russia, the production of paper and board is based on the use of fibre intermediate products, produced using chemical, mechanical, thermo-mechanical and chemo-thermal methods of processing of plant polymers (wood, reed, grain and rice straw, etc.).
One identifies sulphate, sulphite and the neutral-sulphate methods of pulp production, as well as the mechanical, thermo-mechanical, chemo-mechanical methods of production of pulp. Furthermore, during the process of pulp production, in the composition of the primary fibre, there is an active use of regenerated fibre, produced through the processing of recycled paper.
One typical characteristic of the branch is the use of techniques of regeneration of chemicals, which allows for the prevention of environmental pollution by alkali liquors, formed in the process of cooking. The use of liquors as an additional source of energy with the use of modern technologies allows for the sharp increase in the sulphate process efficiency.

1.1.4 The Produced Goods

Pulp and paper companies produce goods with a high added value, the demand of which in Russia has had a steady growth over the past 18 years. There has been a considerable change in the structure of the domestic consumption of paper and board – e.g. a reduction of the volumes of sales on the domestic market of newspaper paper as well as of non-printing and other special types of paper. The demand for packaging paper as well as hygiene and domestic products has grown more than two-fold and suddenly there appeared a demand for coated and laminated paper, high-quality copy paper as well as a significant widening of the range of the assortment of bleached paper products.

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Table 1.2 shows the main range of products of pulp and paper companies in Russia (thousands of tons).

Table 1.2 - the main range of products of pulp and paper companies in Russia (thousands of tons).

No.	Product name	Production volume	
		Thousand tons	%
1	Wood pulp and pulp made from other materials, including:	7 503,2	100
	• Sulphate and soda pulp	5 125,7	68,3
	• Sulphite wood pulp	3 370	4,5
	• Groundwood (mechanical) pulp	2 040,5	27,2
2	Commercial pulp, including	2 253,3	100
	• Sulphate pulp	2 219,7	98,5
	• Sulphite pulp	33,6	1,5
3	Wood pulp, including:	8 012,5	100
	• Thermo-mechanical wood pulp	522,5	25,6
	• Other types of wood pulp	912,0	44,7
	• Semi-chemical cellulose	606	29,7
4	Paper, board, etc.:	8 012,5	100,0
	• Paper	4 943,2	61,7
	• Board	3 069,3	38,3
5	Paper, including:	4 934,2	100
	• Newsprint	1 635,5	33,1
	• Offset	404,9	8,2
	• Corrugating paper (fluting)	1 390,7	28,1
	• Letter paper	5,8	0,1
	• Printing paper	11,1	0,3
	• Coated (dressed) paper	90,0	1,8
	• Kraft sack paper	430,0	8,7
	• Paper for the production of hygiene and cosmetic tissues, towels or tablecloths, pulp wool and fabric made out of pulp fibres	400,0	8,1
	• Other types of paper	580	11,70

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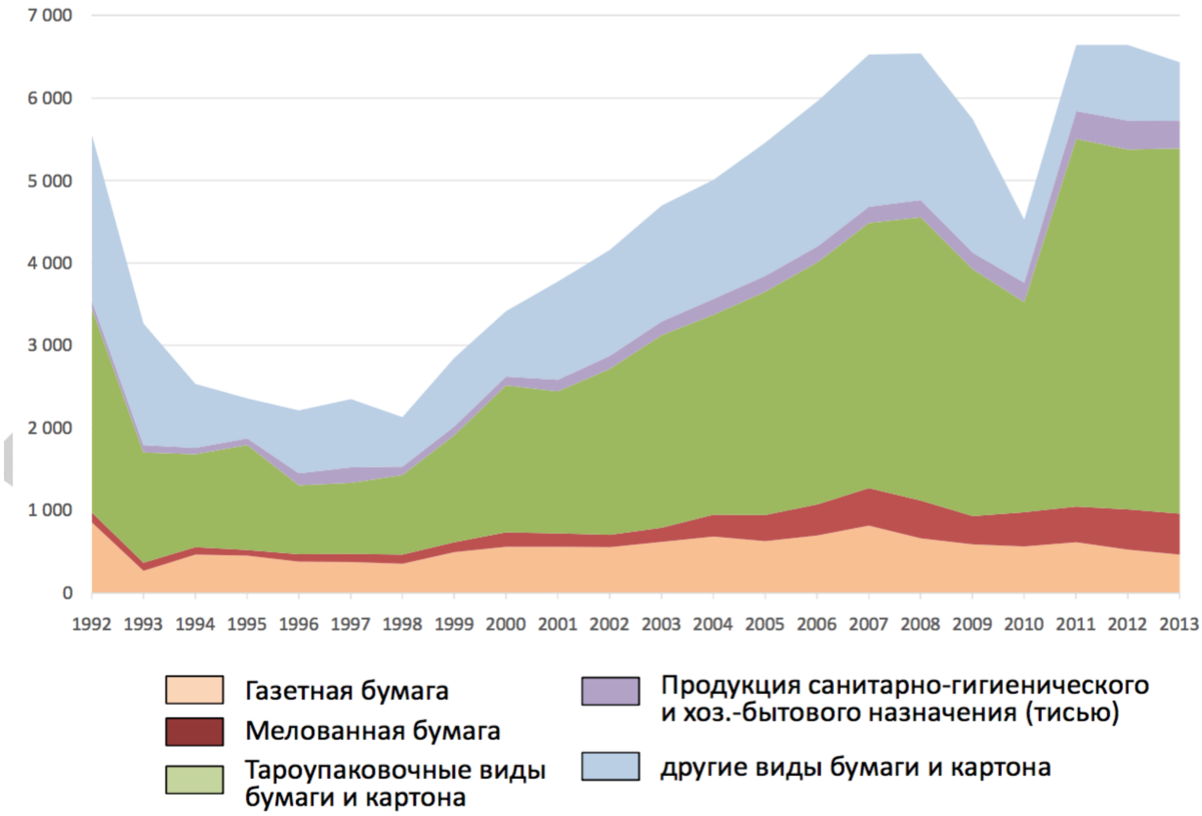
6	Board, including: • Box (container) board (kraftliner) • Testliner (paper or board used for the flat layers of the fluted board) uncoated. • Book-binder board • Technical board, other • Construction board, other • Linerboard • Coated board intended for manufacturing of consumption package • Other types of board	3 069,3 1 732,0 471,0 52,0 61,4 166,0 140,0 21,6 425,0	100,0 56,4 15,3 1,7 2,0 5,4 4,6 0,7 13,9

In figure 1.2 Paper and board consumption in Russia during the period 1992-2013 is shown in thousand tons.



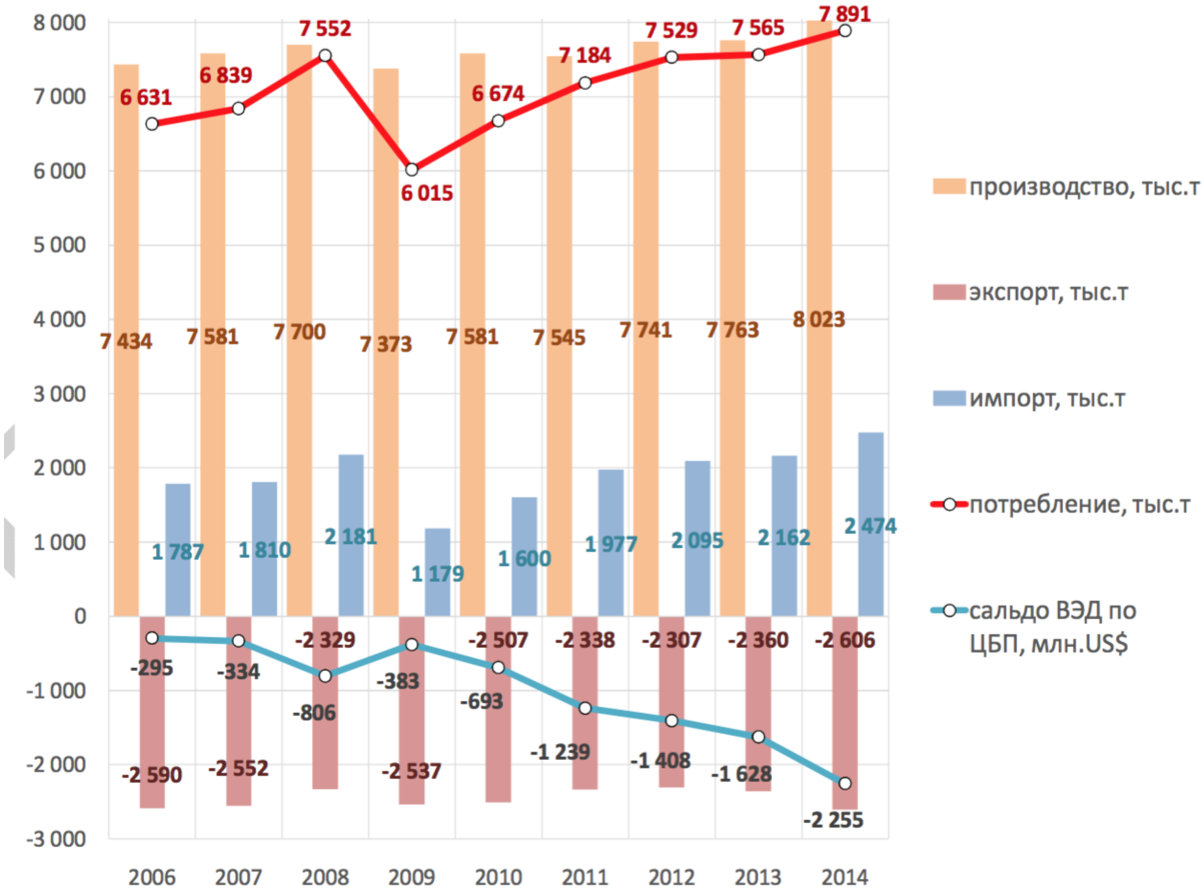
Orange: Newsprint; Red: Coated paper; Green: Packaging paper types and board; Lilac: Sanitary and hygienic paper and household paper; Blue: other types of paper and board
Figure 1.2: Paper and board consumption in Russia during the period 1992-2013 is shown in thousand tons. (Source: information from RAO *Bumprom*).

In spite of the enormous potential, the domestic forest sector is not a priority branch of the economy. In Russia there is a urgent lack of capacity for the production of consumers' goods from paper and board, while the increased demand for this kind of merchandize is satisfied, mainly, through import.

1.1.5 Production and Consumption of Paper and Board in Russia

The total consumption of paper and board as well as the net balance of the foreign trade activities in the field of pulp and paper production during the period 2006-2014 is shown in figure 1.3.

During the past 10 years, there has been no substantial change in the volume of production and export of Russian pulp and paper goods. Practically the total growth of the domestic consumption of paper and board has been covered by a growth of the import, mainly concerning higher price tiers products not being produced in Russia or produced in unsatisfactory volumes.



Orange: Production kt, brown: export kt, blue: import kt, Red line: consumption, kt, blue line: Foreign trade balance in the PPP sector, M USD.

Figure 1.3: Net balance of the consumption of paper and board and the foreign trade activities balance in the field of pulp and paper production during the period 2006-2014 (Source: information from RAO *Bumprom*)

The current lack of balance between the growing domestic demand of the Russian market and the lagging behind in terms of volumes and range of products of the paper and board production of Russian companies has led to a substantial increase of the imported volumes observed over the past twenty years. In 2006 the foreign trade balance in pulp and paper goods was negative and continues to grow at a high speed, reaching, in 20014, a level of 2,2 bln USD.

1.1.6 The Pulp and Paper Export and Import Mix

The pulp and paper export and import mix is shown in figure 1.4.
The main export items are the low-price tier categories – fibre intermediate products, newsprint paper, kraft and kraftliner. The main import items are coated and impregnated paper and board, sanitary and hygienic paper, wallpaper as well as high-quality consumer-end packaging.

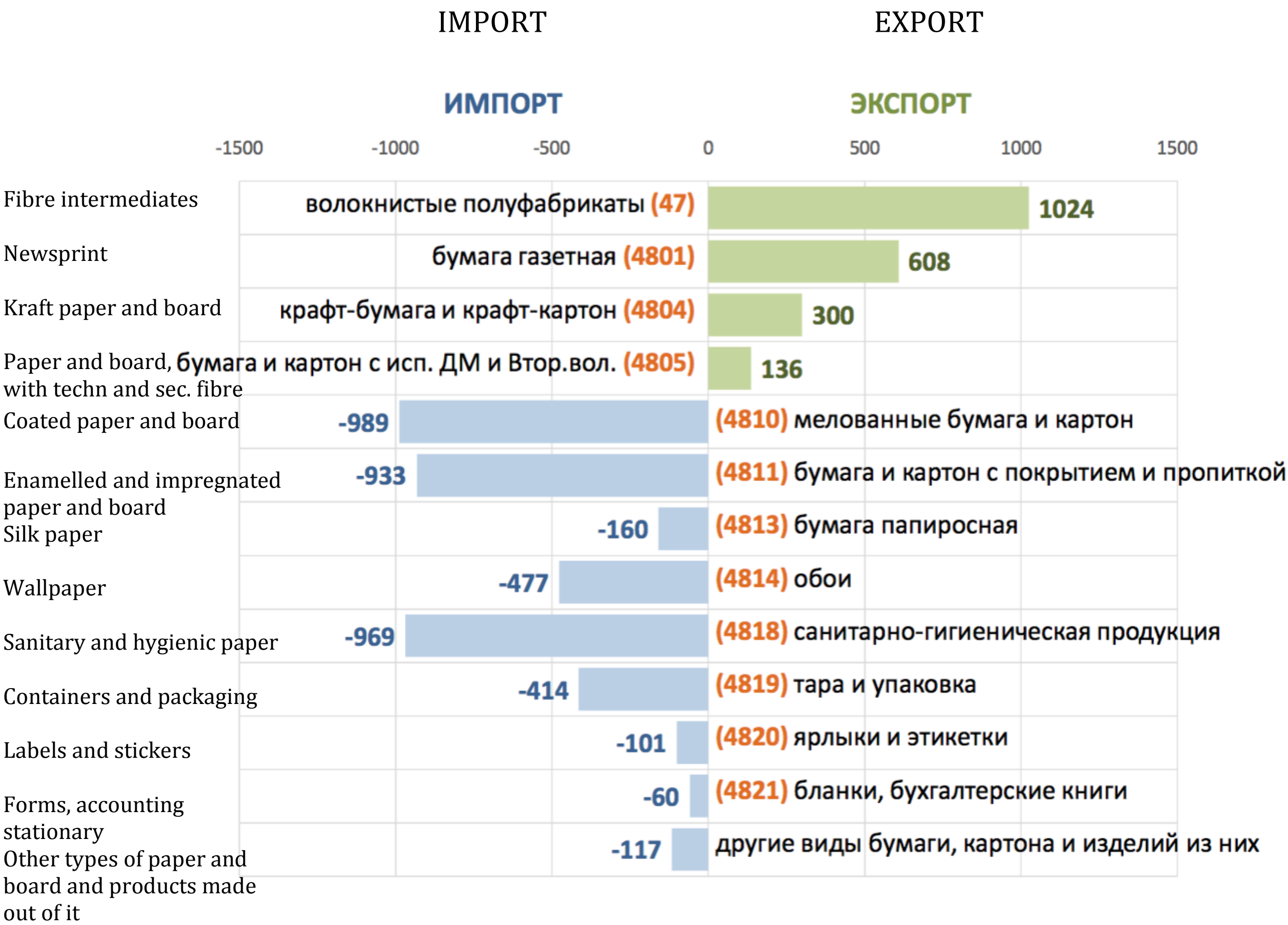


Figure 1.4 – Net export of pulp and paper products in 2014, M USD, (Source: information form RAO *Bumprom*).

The necessity of a more developed pulp and paper production in the Russian, as well as the introduction of BAT and biotechnology is determined by the high potential of growth of the domestic average per capita consumption of paper and board.

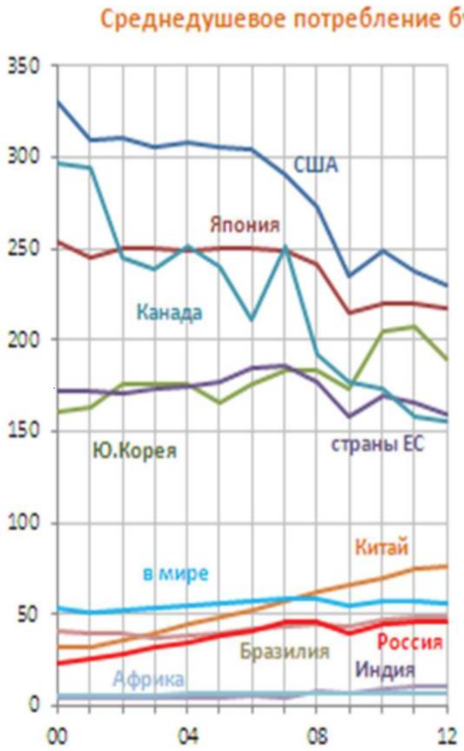
1.1.7 Per Capita Consumption of Paper and Board in Russia

The average per capita paper and board consumption is shown in figure 1.5.

Based on the figure, three groups of countries may be discerned. The first group is characterized by an average per capita consumption of 150-250 kg/pax and includes countries with a developed economy (USA, Canada, the European Union countries, Japan and South Korea). The typical feature of these is the decrease in the volume of consumption during the past few years (except for South Korea). The second group of countries consume about 45-55 kg/pax (among them we find Russia), whereas the third group – India and African countries have a consumption of about 10-15 kg/pax. These countries have the maximum potential for further growth.

The Average Per Capita Consumption of Paper and Board in the World, kg/pax

Graphs:
Blue: USA
Light blue: Canada
Brown: Japan
Lilac: EU countries
Green: S. Korea
Blue: The World
Orange: China
”light red-brown”: Brazil
Red: Russia
”dark blue”: Africa
”indigo”: India



Страна, регион	2000	2012	12/00,%
Финляндия	429,8	236,0	54,9
США	330,6	229,9	69,5
Сев.Америка	327,2	222,5	68,0
Япония	253,4	217,3	85,7
страны ЕС	172,7	159,8	92,5
Канада	297,3	155,6	52,3
Китай	31,8	76,3	239,6
в мире	53,0	56,7	106,9
Бразилия	40,6	48,9	120,4
Россия	23,3	48,6	208,6
Азия	27,7	45,0	162,7
Лат.Америка	34,9	41,4	118,8
Индия	4,1	10,1	244,7

Countries, Regions
Finland
USA
North America
Japan
EU
Canada
China
World
Brazil
Russia
Asia
Latin America
India

Fig. 1.5 – The Average Per Capita Consumption of Paper and Board in the World, kg/pax. (Source: source: information of the Federal Customs Service of the RF, processed by RAO *Bumprom*).

Table 1.3 – the volumes and indices average per capita consumption of paper and board in the world, kg/pax. ((Source: source: information of FAO of the UN processed by RAO *Bumprom*).

Country, region	**2 000**	**2013**	**13/00, %**
Finland	429,8	266,3	62,0
USA	330,6	224,6	68,4
North America	327,2	217,5	66,9
Japan	253,4	215,7	85,1
EU countries	172,7	156,8	91,5
Canada	297,3	153,6	51,7
China	31,8	72,6	320,2

Country, region	**2 000**	**2013**	**13/00, %**
The World	**53,0**	**54,9**	**103,5**
Brazil	40,6	49,7	122,6
Russia	**23,3**	**50,5**	**216,8**
Asia	27,7	43,7	156,4
Latin America	34,9	41,2	118,3
India	4,1	9,8	233,4

At present, the average per capita consumption of paper and board in Russia lags behind the world average by approximately 8 kg/pax. In order to be able to meet the increasing demand on the domestic market at the abovementioned level it is necessary to build up the domestic consumption to 1,12 M tons of paper and board. The growth of the domestic production of the types of paper and board products popular with the Russian consumer may become a logical aim when carrying out the program of imports substitution in the Russian Federation.

1.2 A Description of the Russian Pulp and Paper Production (PPP) Companies

1.2.1 The Technical and Technological Condition of the Russian Pulp and Paper Companies

One distinctive characteristic of the Russian PPP is its marked heterogeneity. Out of 212 pulp and paper-producing companies, only 17 are high capacity units (more than 100 kt commercial output per annum) producing 79,9% of the total volume of produced goods. Intermediate-size companies (14 units with a yearly capacity of 50-100 kt) produce 9,5% of the total production. The remaining 10,6% of the produced paper, board and merchandize produced from them are covered by the remaining 181 companies.
This speaks about a systematic longstanding insufficient level of investment in the development of this industry. Because of the lack of means, the majority of the companies are not able to do away with the technical and technological backwardness that has built up over many decades.
The PPP companies entered into operation in the first half of the last century have obsolete low-productive equipment with high consumption of energy, raw material and work force. The average age of the paper- and board production machinery, installed at Russian integrated mills and other mills is 40 years, whereas the unit yearly capacity is 65 kt of product. (figure 1.6)

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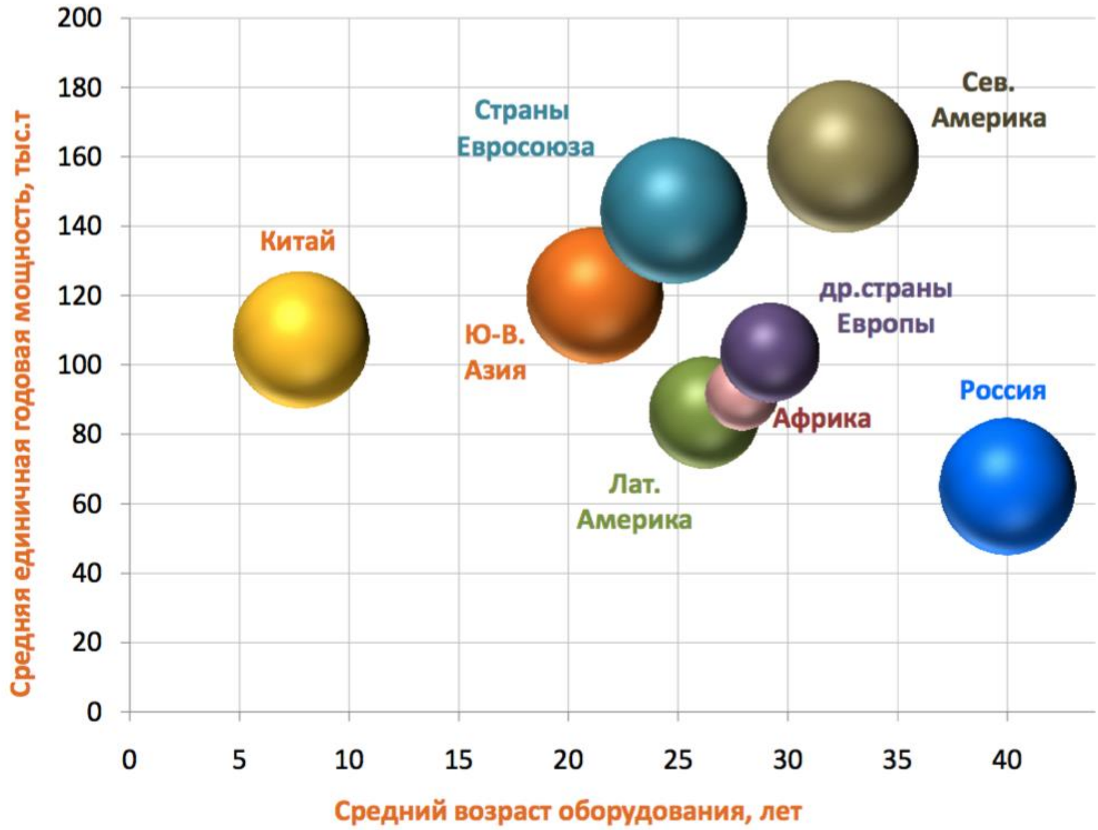
Av. capacity kt/y



Average age of the equipment, years

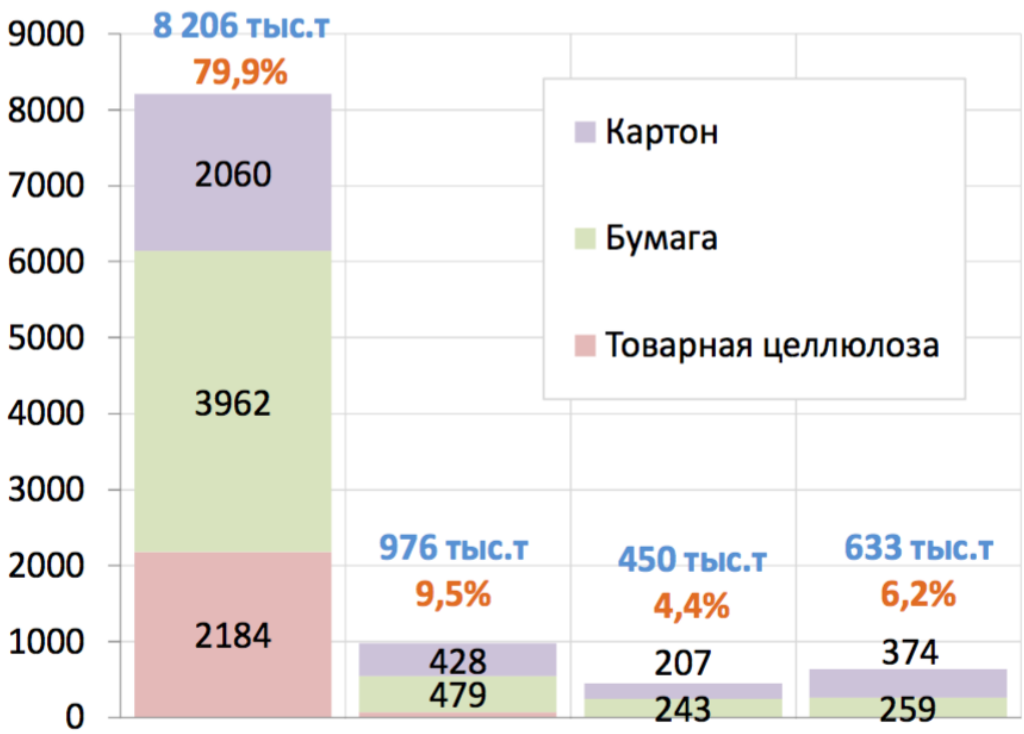
Figure 1.6 – Average Age and Average unit Capacity of Paper and Board Machines in the Respective countries and Regions
Yellow: China; Orange: S-E Asia; Light blue: EU; Green: Latin America; Light lilac: Africa; Dark Lilac: Other European countries; Greyish green: North America, Blue: Russia (Source: information from *RAO Bumprom*).

More than 60% of the paper and board production machines in the Russian pulp and paper industry were started in the industrialisation period of the 1920s and 30s. Typically, they have a small trim width (up to 2,5m), low speed and high specific consumption of energy, raw material and chemicals.

About 30% of the paper and board machines were mounted and introduced in the post-war period (1950s and 60s). These machines were more cost-effective and productive (their trim width was up to 4,2 m), and many of then are still in use after a modernisation of specific components (replacement of the industrial atomization components of the Automated Process Control System).

Only 8,5% of the machines used today (with a trim width above 4,5m) were introduced in the 1960s – 1980s, and those are the machines with which 80% of all paper and board are produced in the country.

The structure of the companies in the field of pulp and paper production in Russia as well as the production of merchandise in 2014 is shown in Figure 1.7.



Annual capacity kt	>100	50-100	20-50	<20
No of companies	17	14	19	162

Figure 1.7 - The composition of the companies in the field of pulp and paper production in Russia as well as the production of merchandise in 2014, kt. (according to information form *RAO Bumprom*).

1.2.2 The Largest Pulp and Paper Mills in Russia

In table 1.4 there is a list of the major pulp and paper companies, defining the Russian pulp and paper production mix. Many of these are large integrated mills and companies with a full cycle, producing a wide range of forestry and paper items.

Table 1.4 – The production of Finished Goods by the Leading PPP Companies in Russia (with a yearly production above 100 kt) in 2014, kt. (Source: information form RAO *Bumprom*).

No	**Company**	**Commercial pulp**	**Paper**	**Board**	**Total Commercial output**
Total production Russia		2 253,4	7 934,2	3 069,3	10 265,9
Main producers		2 184,1	3 961,8	2 059,9	8 205,8
Proportion of the major mills to the total production		96,9	80,1	67,1	79,9
1	ILIM group branch at Koryazma	299,0	449,5	470,9	1 219,4
2	Mondi Syktyvkar Forestry Industry Complex	31,4	772,9	247,0	1 028,3
3	ILIM group branch at Bratsk	743,2	0	179,9	922,8
4	ILIM group branch at Ust'-Ilimsk	804,3	0	0	804,3
5	Arkhangelsk Pulp-and Paper Mill	216,9	72,6	483,7	773,2
6	Kondopoga	0	610,3	0	610,3
7	Volga	0	508,4	0	508,4
8	International Paper, Svetogorsk	0	383,6	101,4	485,0
9	Solikamskbumprom	0	364,2	0	364,2
10	Segezha PPM	0	253,3	0	253,3
11	Mariyskiy PPM	55,9	103,8	82,8	242,5
12	Knauf Petroboard	0	0	240,2	240,2
13	Kamenskaya	0	148,0	70,3	218,3
14	Naberezhnochelninskiy Board and Paper Mill	0	111,8	91,2	203,0
15	Permskaya PPM	0	94,5	106,0	200,5
16	Nikol-Pak Mill at Uchaly	0	61,1	69,6	130,7
17	Vyborg Forestry Corporation	0	0	130,3	130,3
18	Syaskiy PPM	33,5	79,9	0	110,4

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The majority of the small-size mills are mono-companies, producing one or two items of finished consumption paper and board products from purchased raw material. Many of them use physically and morally worn out equipment and obsolete techniques and are in acute need of modernisation.

1.2.3 The Geographical Location of Russian Pulp and Paper Plants and the Issues of Opening up the Forest Material Base

The geographical location of the plants speaks about the main priorities when choosing them – the accessibility of the raw material base, energy and water resources.
Because of the distance to the main markets, the lack of necessary infrastructure and, first thing, forest roads, the vast forest riches of eastern Siberia and the Far East remain unexploited to a large extent. (figure 1.8).

Figure 1.8 – Pulp and paper production volumes in 2014 in the respective federal districts, kt. (Source: information form RAO *Bumprom*).

Columns: Green: Commercial pulp, brownish: paper, blue: board
Federal districts (and, in red, number of companies) from left to Right:
Pink: ЮФО, YuFO, The Southern Federal District; 8 companies
Beige: ЦФО, TsFO, The Central Federal District, 29 companies
Pale blue: СЗФО, CZFO, The North-East Federal District, 27 companies
Green: ПривФО, PrivFO, The Volga Federal District, 38 companies
Grey: УРФО, URFO, The Ural Federal District, 4 companies
Blue: СибФО, SibFO, The Siberian Federal District, 14 companies
Yellow: ДВФО, DVFO, the Far East Federal District, 3 companies.

The majority of the shown companies are situated in the forested regions of the North-West, Central, and Volga districts, close to population centres with a well-developed consumption demand (see fig. 1.9).

Figure 1.9. The leading companies of the pulp and paper industry in Russia (with a saleable production volume above 100 kt/y. (According to information of the *RAO Bumprom*).

The majority of the abovementioned companies have successfully and are still successfully continuing to carry out modernisation in the frames of a national programme of support called Priority Investment Projects (PIP). The largest companies have, at their integrated mills, started to roll out the programme of best available techniques introduction (BAT) and a biotechnology introduction programme is underway within the Russian forest technology programme BioTech-2030 (see fig. 1.10).

During the past few years, the lion's share of investment has been directed towards the modernization of the main process equipment (en accordance with the List of Priority Investment Projects, encompassing 145 forest industry plants). The total investment amounts to 428 billion roubles, including 13 pulp and paper mills with a funding volume of 241 bln roubles. The planned PIP capacity increase, production and consumption volume of paper and board in The Russian Federation are reflected in the Prognosis of the Russian Forest Industry Complex until the year of 2030, made by Russian Experts and based on a request made by the FAO.

Виды продукции ЦБП	2014*	до 2020
Целлюлоза (по варке)	7,2	+3,9
Бумага	4,9	+1,9
Картон	3,1	+3,4

Показатели	2014*	до 2020
Объем инвестиций в ЦБП, млрд.руб.	11,8	26,3
Объем древесного сырья, млн.куб.м	115	+40
Кол-во новых рабочих мест, тыс.	720	+4,5

Figure 1.10 – map showing the prioritized investment projects in the pulp and paper industry of the RF, target value for 2020.

Green dots: priority investment projects (PIP) – 13 companies (Svetogorsk, Segezhskiy PPM, Arkhangelskiy PPM, Koryazhma (ILIM group), Mondi Syktyvkar, Solikamskbumprom, Angara Paper, Kraslesinvest, Ust'-Ilimsk (ILIM group), Selenginskiy Pulp and Board Mill, Polyarnaya Zvezda

Red dots: Companies undergoing modernization, however not being part of the PIP: 9 companies: Famadar Cartona Ltd, Mayak, Kamenskaya BF, Aleksinskaya, Polygrafkarton, Mariyskiy PPM, Syaskiy PPM, Sukhonskiy PPM and Kama PPM.

Type of pulp and paper production	2014*	Until 2020
Pulp (cooking figures)	7,2	+3,9
Paper	4,9	+1,9
Board	3,1	+3,4

Parameters	2014*	Until 2020
Investment volume, pulp and paper production, bln rub	11,8	26,3
Volume of wood raw material, bln m^3	115	+40
Amount of jobs, thousand	720	+4,5

The *Prognosis of the Development of the Russian Forestry Industry up to 2030* is based upon the forecast made by the Ministry of Economic Development of the GNP growth rate as well as the three significant versions of development of the pulp and paper production in Russia (see fig. 1.11).

In accordance with the *Prognosis of the Development of the Russian Forestry Industry up to 2030,* until the year of 2030 the production of paper and board is planned to be increased:

- along with the innovative scenario – up to 25,5 M tons (whereas the consumption – up to 20 M tons);
- along with the moderate scenario – 18,8 M tons (and 16,8 M tons)
- and along with the conservative scenario- 17,7 M tons (and 13,9 M tons).

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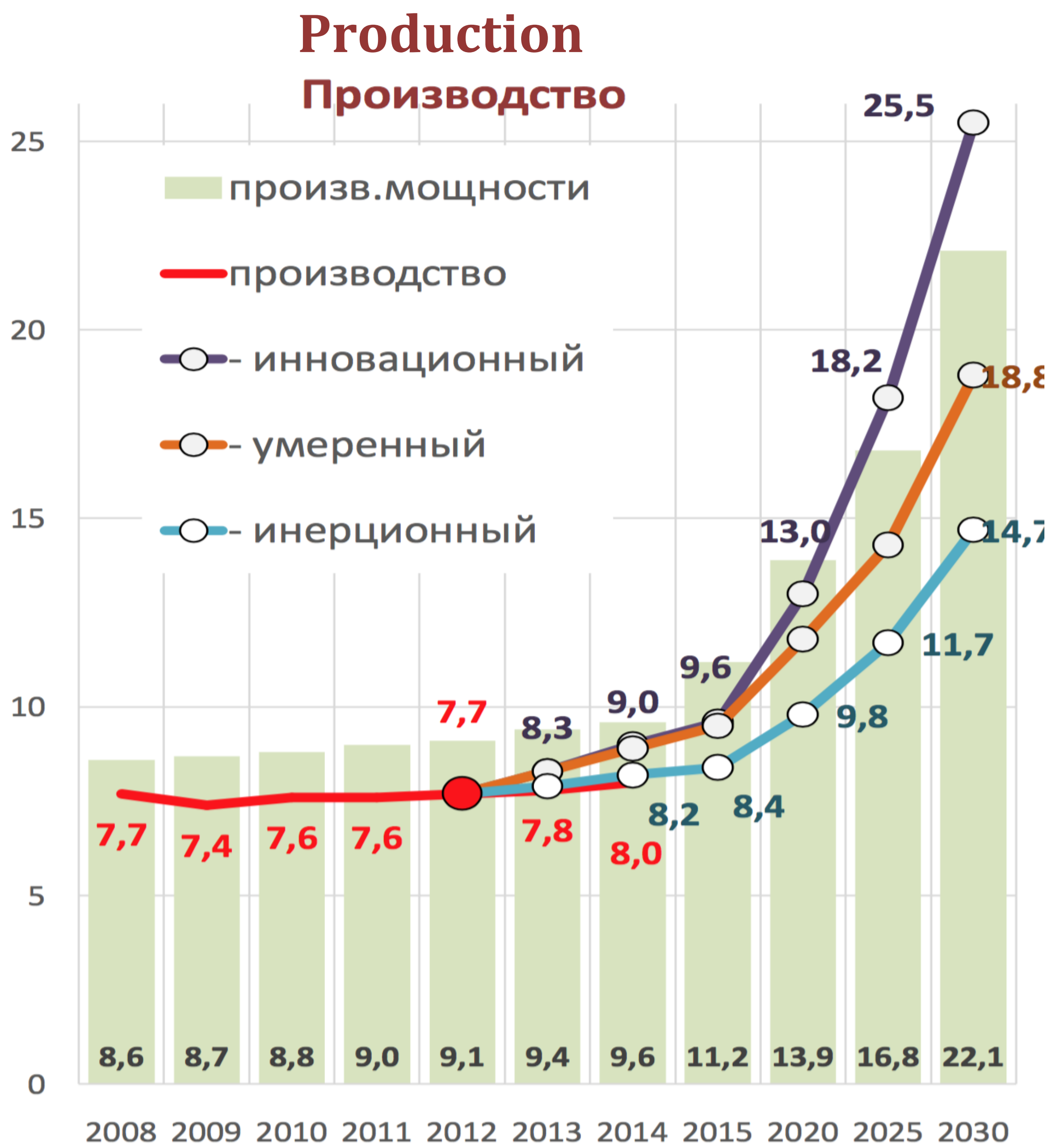

Green shade: Production capacity, Red letters: production, Lilac line: innovative forecast, Orange line: moderate scenario, blue line: conservative scenario (M tons)

Fig. 1.11a: Production of paper and board in the Russian Federation, forecast up to 2030.

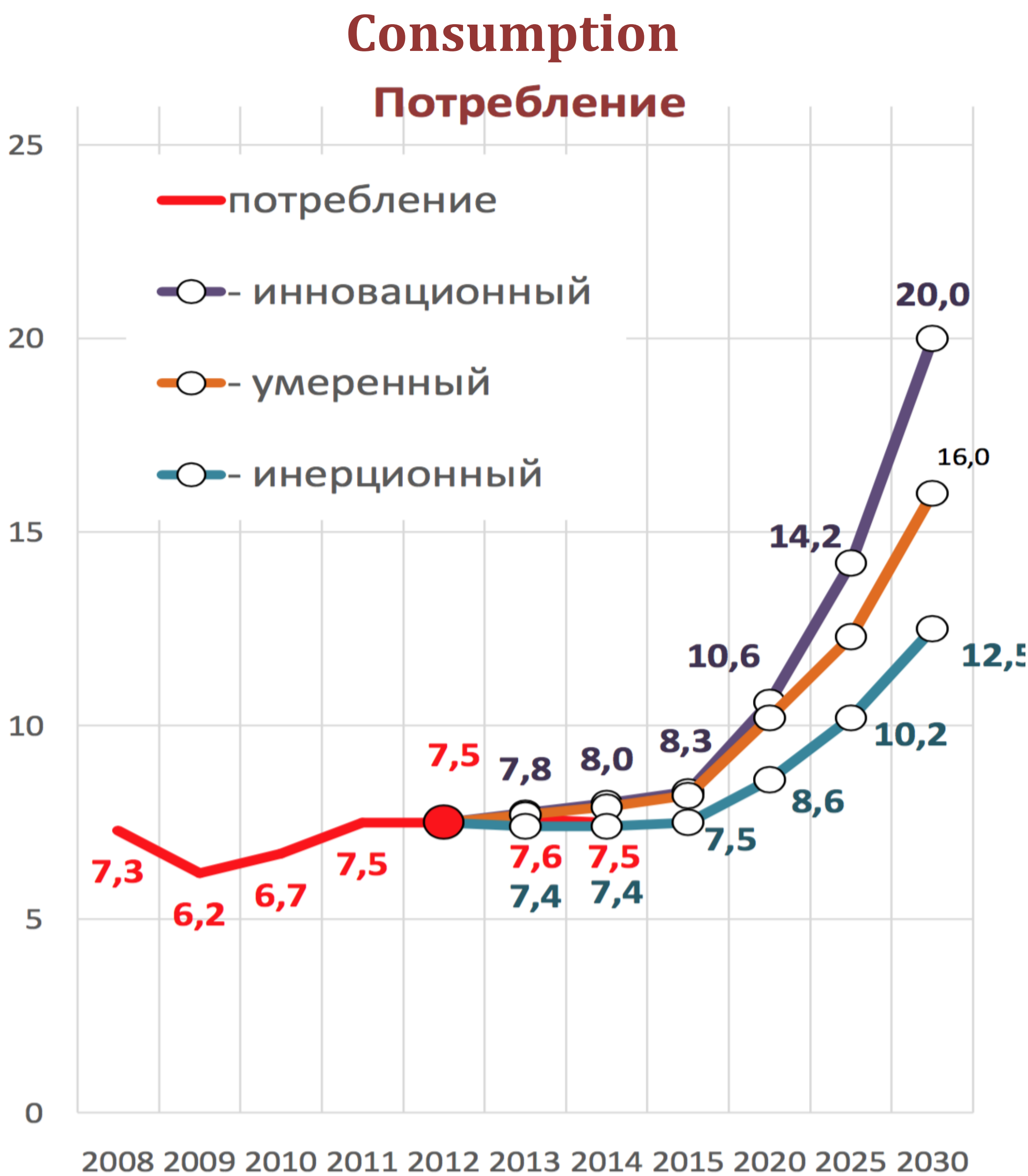

Fig. 1.11b: Consumption of paper and board in the Russian Federation, forecast up to 2030.

Red line: consumption, Lilac line: innovative forecast, Orange line: moderate scenario, blue line: conservative scenario (M tons)

When compiling the Prognosis, the main priority for the attainment of the targeted parameters was the creation of, mainly in the forest overabundant regions, new production capacity for the manufacturing of high-quality types of paper, modern packaging materials, sanitary and hygiene articles, oriented mainly towards the domestic market. However, the present crisis has affected the implementation of these plans, and – under conditions of stagnation of the Russian economy – the development of the Russian forestry economy sector has actually proceeded along the conservative path.

The new tendencies in the world economy has entail the necessity to develop industrial bio-technology based on renewable resources, and the Russian forest industry sector has received a chance to use its competitive advantages, in terms of unused supplies of wood, available energy and a growing domestic market.

Analysing the presented information, it is possible to make the conclusion that the pulp and paper industry in Russia disposes of an obsolete low-productivity equipment with high relative energy, raw material and labour force expenditure per unit of produced goods, which is why it cannot to the full extent realize its rich potential,

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– more than 83 M m^3 of timer reserves, accessible electrical energy, extractable resources, water resources, etc.

The priority of the development at present is the introduction of best available techniques, the lowering of the material intensity of the production, the increase of the use of waste and other renewable energy sources.
In the frames of the State Programmes (Support of the priority investment projects (PIP), the Development of industry and the Increase of Competitiveness, The Strategy of the Development of the Forest Industry Sector and other programmes) a number of leading companies (companies within the OAO Gruppa ILIM group in Koryazhma and Bratsk, the ZAO International Paper PPM in Svetogorsk, the AO Mondi Syktyvkar PPM, Arkhangelskiy PPM and others) have started to introduce best available technologies for the modernization of their competitiveness and the satisfaction of the growing consumers' demand of quality and environmental-friendly goods.

1.2.4 Environmental impact of PPI companies, tendencies and prospects

Table 1.5 – the main environmental parameters during 2012-2014 (Source: *Rosstat* information, processed by the *RAO Bumprom*

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Parameter	**Year**	**Russia total**	**Pro-cessing produc-tion**	**Wood processing and production of goods out of wood**	**Pulp and paper production, publishing and print production**	**Share (%) of the PPI, Publ. And Print prod. in the RF**
Waste generation, M tons	2012	5 008	291	3,7	6,0	0,1
	2013	5 153	254	5,3	8,9	0,2
	2014	5 168	243	5,8	6,2	0,1
Reuse and disposal of waste, M tons	2012	2 348	165	2,7	5,0	0,2
	2013	2 044	132	4,3	7,8	0,4
	2014	2 357	119	3,9	5,8	0,2
Emissions to air	2012	19 630	6 407	87	129	0,7
	2013	18 447	6 219	86	130	0,7
	2014	17 452	5 932	90	119	0,7
Capture and treatment of emissions to air	2012	56 834	28 251	661	686	1,2
	2013	54 834	28 900	1 244	651	1,2
	2014	54 099	29 031	1 264	604	1,1

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Parameter	Year	Russia total	Processing produc-tion	Wood processing and production of goods out of wood	Pulp and paper production, publishing and print production	Share (%) of the PPI, Publishing and print production in the RF
Discharge of polluted wastewater, M m^3	2012	15 678	2 882	19,7	905	5,8
	2013	15 189	2 711	15,4	906	6,0
	2014	14 768	2 523	21,8	860	5,8
Investments into the fixed assets for environmental protection, mil RUB	2012	116 543	33 727	148	1 121	1,0
	2013	123 748	42 207	435	1 824	1,5
	2014	158 589	67 017	158	1 235	0,8
Investments into fixed assets for the protection of water resources, M RUB	2012	52 520	13 989	127	250	0,5
	2013	59 505	17 792	0	275	0,5
	2014	76 315	35 403	59	683	0,9

22 (mid-page)

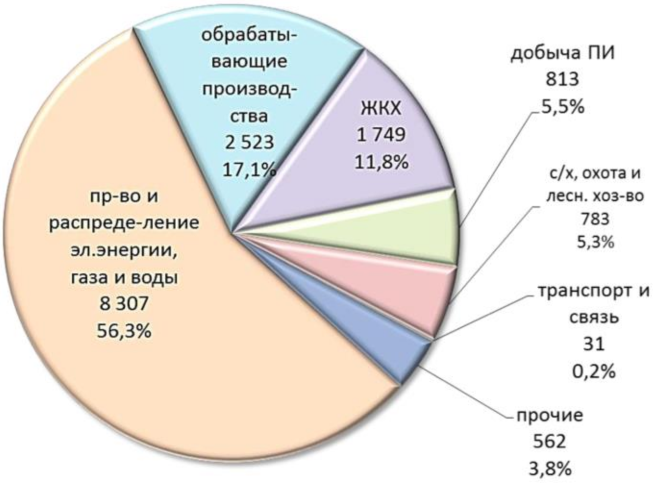
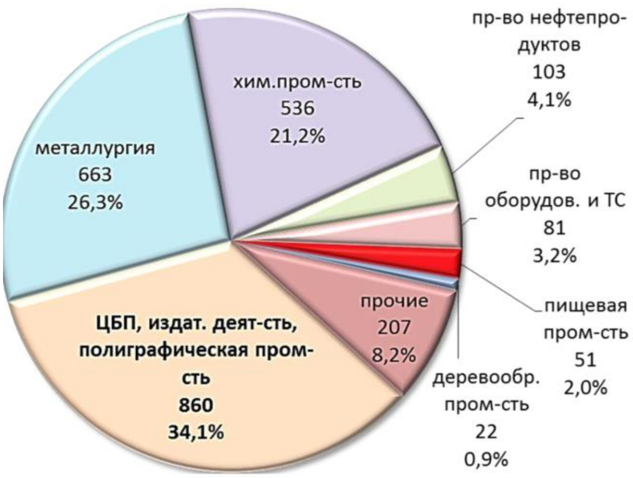


Fig 1.12a – volumes in 2014, M m³ of discharge of pollutants to recipients – **total figures for Russia**: Orange: production and distribution of electrical energy, gas and water (8 307kt - 56,3%), Pale blue: Processing production (2 523 kt - 17,1%), Lilac: housing and utilities infrastructure (1 749 kt - 11,8%), Green: mining (813 kt - 5,5%), Pink: agriculture, and forestry (783 kt - 5,3%), Blue: miscellaneous (562 kt - 3,8%)



по обрабатывающим производствам

Fig 1.12b – volumes in 2014, M m³ of discharge of pollutants to recipients –figures for **processing production:** Orange: Pulp and paper, publishing and printing (8 860 kt - 34,1%), Pale blue: metallurgy (663 kt - 26,3%), Lilac: chemical production (536 kt - 21,2%), Green: production of petroleum products (103 kt - 4,1%), Pink: equipment manufacturing (81 kt - 3,2%), Red: Food production (51 kt - 2,0), Blue: wood processing (22 kt - 0,9%), Brown: Miscellaneous (207 kt - 8,2%).

The relative share of the discharges from pulp and paper production, publishing and printing activities in 2014 was 34,1% of all processing manufacturing activities and 5,8% of all types of activities in the Russian Federation.

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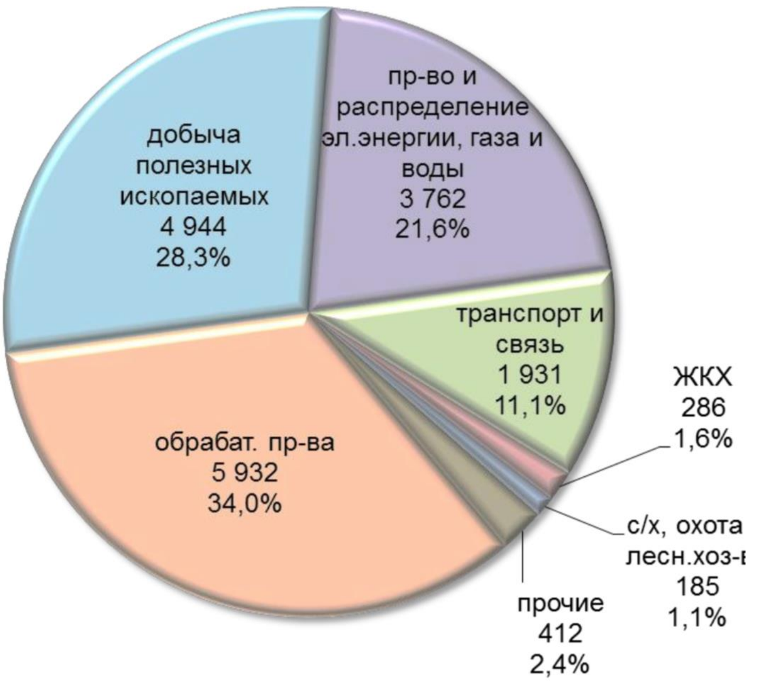
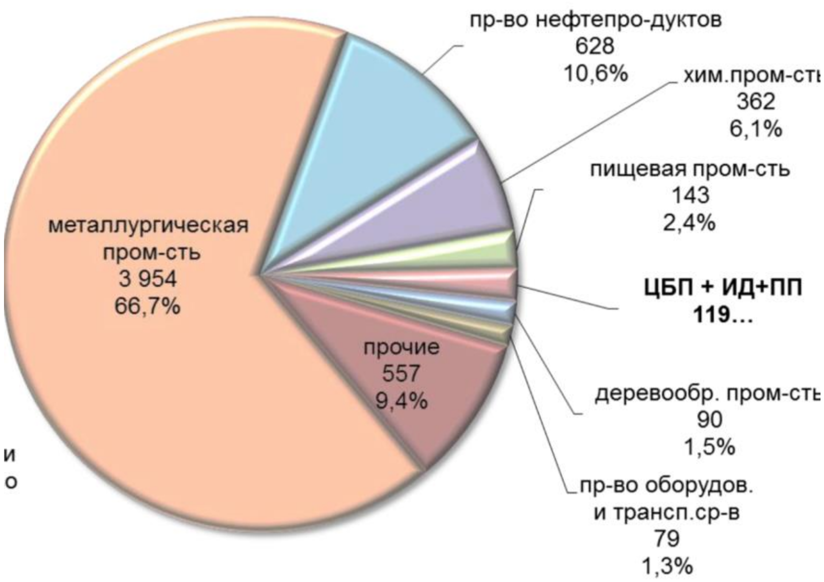
The reduction of the physical volumes of discharges in 2014 was 5% as compared to 2012 and 5,1% as compared to 2013.



Total Russian figures:
Fig. 1.13a. Emissions to air of pollutants from stationary sources in 2014, kt.
Blue: mining (4 944 kt - 28,3%), lilac: production and distribution of electrical energy, gas and water (3 762 kt - 21%), Green: transport and communication (1 931 kt - 11,1%), Pink: housing and utilities infrastructure (286 kt - 1,6%), Blue: agriculture and forestry (185 kt - 1,1%), Brown: Misc. (412 kt - 2,4%)



Processing industry:
Fig. 1.13b. Emissions to air of pollutants from stationary sources in 2014, kt.
Pale blue: Production of petroleum products (628 kt - 10,6%), lilac: chemical production, (362 - 6,1%), Green: Food (143 kt - 2,4%), Pink: housing and utilities

infrastructure (286 kt - 1,6%), Blue: agriculture and forestry (185 kt - 1,1%), Brown: Misc. (79 kt - 1,3%)

Fig. 1.14. Indices of pulp and paper production goods, volumes of discharge and emissions of pollutants by the pulp and paper subsector companies, % to the 2005 level. Blue line: Production of commercial pulp, paper and board, Red line: emissions of pollutants to air, Green line: discharges to surface water recipients

During the past 10 years there is a discernable reduction in the negative environmental impact from the pulp and paper industry companies. While the volume of production volumes has grown by 9%, the volumes of

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emissions of air polluting substances have been reduced by 30,9%, whereas the volumes of discharges of wastewater have been reduced by 27,4%. Taking on the global challenges of a responsible environmental stance towards the environment, as well as the global abatement of climate change and a maximum increase in energy efficiency in the framework of a so called *Green Economy*, the leading pulp and paper industry companies in Russia are carrying out a modernisation of the existing production plants and the opening of new high-efficiency plants.

1.2.5 The Main Problems of the Russian Pulp and Paper Industry and Possible Solutions

The pulp and paper industry is one of the most energy, material and capital-intensive sub-industry of the forest industry complex, with a production of high added value. Its main features are the multi-operational continuous processes with complicated technologies. This is why the cost of pulp and paper machinery is high, it is complicated to design, mount and adjust, it has long pay-back periods of the investments done, and it is necessary to make long-term plans of the economic results of its introduction and modernisation.

Factors having a direct impact on the development of the Russian pulp and paper industry:

- out-of date production capacity
- unfavourable investment climate;
- necessity of long overdue transition to new environmental legislation, aimed at the introduction of best available technologies;
- high-capacity, fast-developing markets for pulp and paper products in the Russian Federation and the Asian region;
- influence of global challenges (climate change and the related necessity of replacement of fossil energy resources by renewables);
- sustainable development of the forest industry subsector will be prioritized fields of activities in the world. The sustainability issues will increasingly gain importance in the Russian forestry sector as well.

The development of the forest industry complex in the country is limited to the largest active companies, which, in order to keep up the compatibility of their production, are carrying out priority investment programs, associated with the modernisation and technical retrofit of their production capacity.

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Means of solving the problems of the Russian pulp and paper industry:

- the creation, in order to carry out the priority investment projects, of the conditions that would guarantee the supply of wood raw material, energy carriers as well as accessible credits from domestic banks;
- the financing of the creation of an infrastructure of the major Priority Investment Projects (PIP) with the allocation of funds from the federal and regional budgets
- increased financing of scientific and technical activities aimed at the creation and deployment of mass production of in-demand and competitive merchandize for the implementation of the import substitution programme;
- creation of conditions for the development of biotechnology within the wood processing industry, including the production of biofuel; The promotion of the introduction of innovative techniques aimed at the reduction of the consumption per produced unit of merchandize of energy as well as the increase in environmental efficiency of the production;
- an increased share of the use of low-quality wood, as well as the processing of recycled paper in order to lower the consumption of raw material and supplies of the main production line per produced unit of merchandize;
- the perfection of the forest industry production mix through the implementation of production of innovative types of produce in the framework of the technological platform *BioTech-2030*, including paper and board with environmentally safe barrier coatings as well as composite materials with the use of technologies for the processing of by-products of the pulp and paper industry as well as the secondary products of wood chemistry.

In order to develop the forest industry complex in a whole-country scale, it is necessary to have a transparent, coordinated, long-term, rigorously performed state forest policy. The exploitation of forest wealth in uninhabited regions, the construction of new and modern companies is possible only with a direct participation of the state in the creation of the necessary infrastructure when rolling out new investment projects, related to the advanced processing of wood.

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Section 2 Description of the Industrial Processes used Today in the Russian Pulp and Paper Industry

Figure 2.1 – Bock diagram of the production of Sulphate Pulp and NSSC (Neutral Sulphite Semi-chemical Pulp)

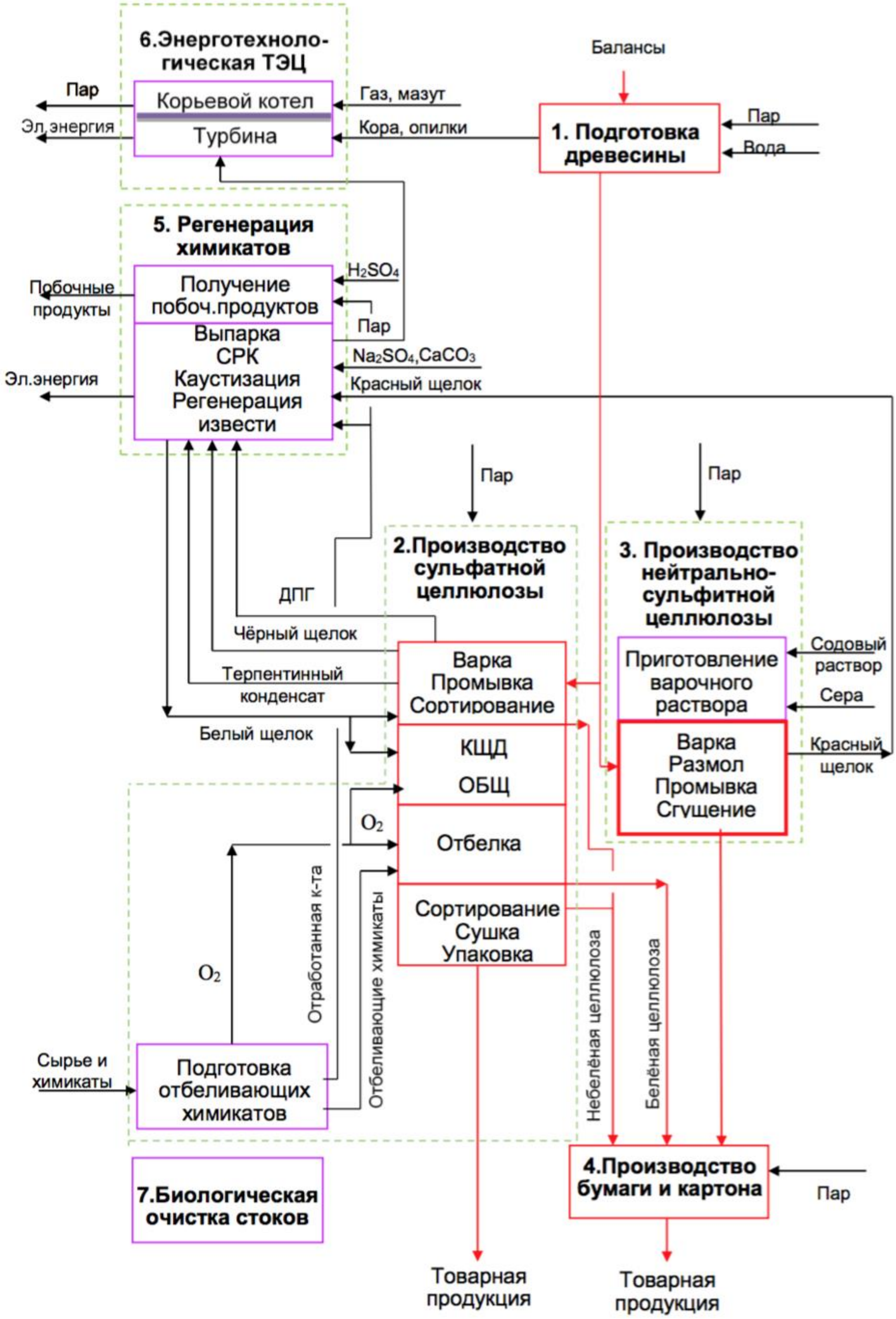

Figure 2.1 (previous page) – Bock diagram of the production of Sulphate Pulp and NSSC (Neutral Sulphite Semi-chemical Pulp)

1: pulpwood is treated with added steam and water and (red line) transferred to the (3) neutral sulphite semi-chemical pulp production line, where it is mixed with a cooking solution (lilac box) made out of soda liquor from the (5) chemicals regeneration and sulphur. This mix is then pulped, ground, washed and dewatered (red box to the right) and fed to the production (4, red box at the low right-hand side) of paper and board with the addition of steam (arrow from the right). The result is the commercial output seen as a red arrow at the low right-hand side. Red liquor is formed in the [3] process and directed to the [5] regeneration of chemicals.
6: The bark and sawdust from [1] is sent to [6], lilac box, upper left-hand side] to be burnt in the bark boiler (furnace) producing steam, which is led to a turbine also receiving steam from [5] the Chemicals regeneration unit. The output from [6] consists of electrical energy and steam.
Unit [1] material may also be directed towards the production of sulphate pulp [2] (central red box), where it is pulped, washed and screened (upper fourth of red box), after which it goes through oxygen-alkali cooking and is either turned into unbleached pulp or having gone through (the two lower fourths of the red box), bleaching (after which it may be directed to [4] production of paper and board or – after screening, drying and packaging – turned into commercial pulp (middle red line).
The by-products of the cooking [2], i.e. the non-condensable gasses, the black liquor, the turpentine oil, as well as the red liquor from [3] is led to the [5] chemicals recovery unit, where by-products, steam and electric energy are produced through the evaporation, soda recovery, caustization and lime recovery.

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2.1 Wood Preparation

The general process scheme of the process of wood preparation

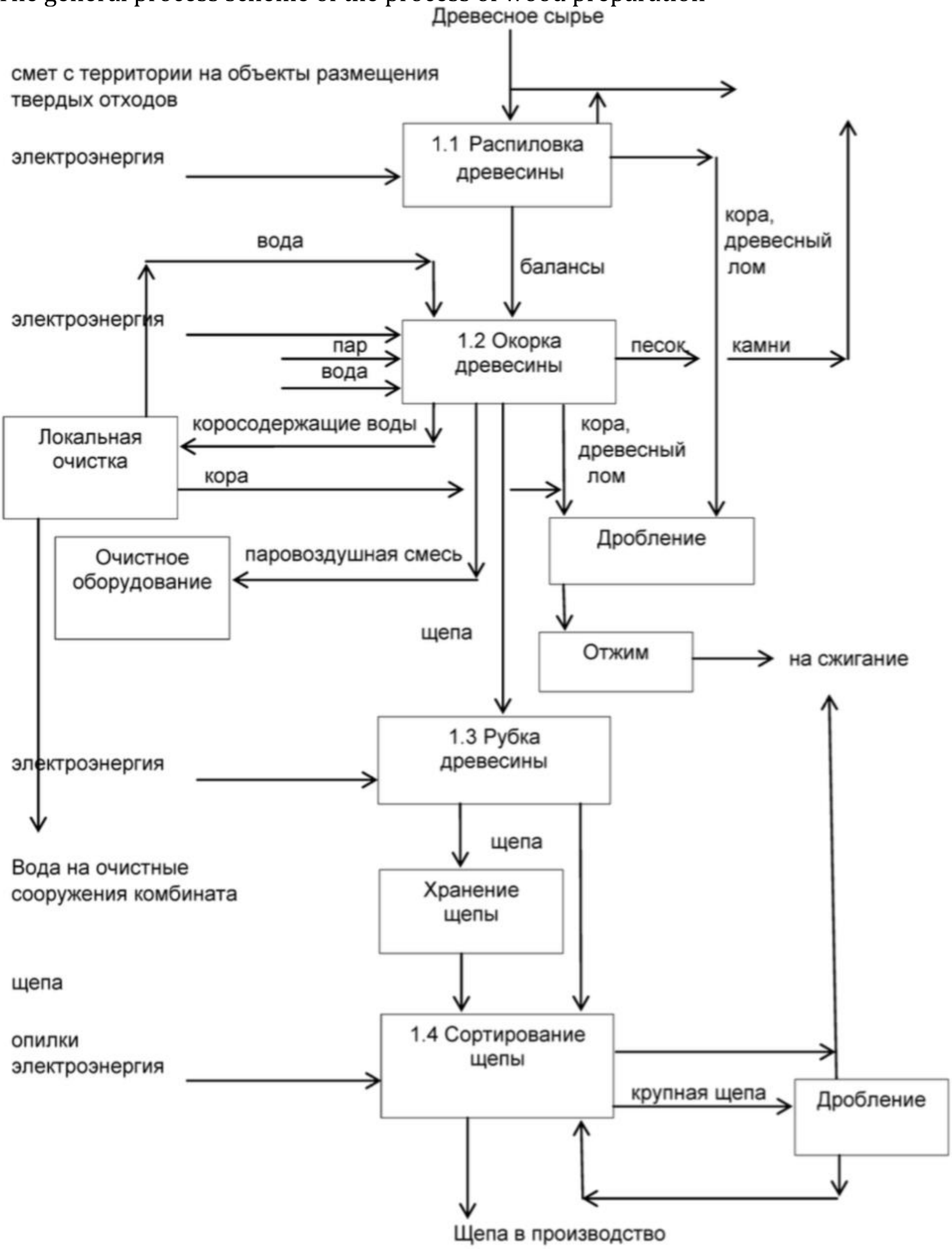

Figure 2.2 – Block Diagram of the Preparation of Wood Raw Material

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Figure 2.2 (Previous page) – Block Diagram of the Preparation of Wood Raw Material

By use of electrical energy wood raw material is milled [1.1] and, (together with sweepings from the area) divided into bark (and scrap wood) and pulpwood. The bark and scrap wood is ground, its water content extracted and it is subsequently burnt. However, pulpwood may also – after the separation of sand and stones, and with the use of electric energy, steam and water – be submitted to debarking [1.2] under the formation of bark-containing water, which is led to the local treatment facility (after which the bark is returned to the flow and ground), as well as a steam and water mixture, which is led to the treatment equipment. After debarking, the pulpwood is sent to [1.3] chipping, forming wood chips, which is stored and [1.4] screened after which it is either ground or transferred directly to production.

General information on the process of preparation of the wood raw material used at present in the Russian Pulp and Paper Industry us shown in table 2.1.

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Table 2.1: General information on the stages of the industrial by which the wood raw material is prepared.

Input	**Stage of the process**	**Output**	**Main process equipment**	**Emissions**
1	2	3	4	5
Longwood, non-debarked	1.1 sawing of the Longwood into short pulpwood	Non-debarked pulpwood	Unit for the reception and whole-log sawing	Bark waste Sawdust of natural clean timber
Group debarking				
Non-debarked pulpwood Steam Electrical energy Fresh water	1.2 Wood debarking	Unsorted wood chip Bark, wood scrap Bark-containing water Sand and stones Steam and water mix (if dry debarking is used)	Defrosting conveyer Debarking drum Equipment for the gathering and treatment of bark before burning (conveyers, sorting, press, bark chopper); Equipment for the gathering and cleaning of bark-containing water (drain conveyer, drag-conveyer, drain drum, filter, tanks, pumps)	Emissions to air Steam-water mix Discharge to the production wastewater system (suspended particles, COD, BOD) Solid waste (stones, sand) Noise from working equipment.

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Input	Stage of the process	Output	Main process equipment	Emissions
1	2	3	4	5
Debarked pulpwood Electrical energy	1.3 Wood chipping	Unscreened chips	Wood chipper Receiving bin with a discharge screw	Noise from working equipment
Unsorted chip Electric energy	1.4 Chip screening	Screened chips	Screening Shredder	Clean wood saw dust
Single-piece debarking				
Non-debarked pulpwood Electrical energy	1.2 wood debarking	Unscreened chips Bark	Outfeed table Split feeding system Debarking machine Equipment for the collection and preparation of the bark before burning (conveyers, sorting system, bark chopper)	Noise from working equipment
Debarked pulpwood Electrical energy	1.3 wood chopping	Unscreened chips	Wood chipper Reception pit	Noise from working equipment
Unsorted wood chip Electrical energy	1.4 chip sorting	Screened chips	Screening, Shredder	Clean wood saw dust

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2.1.1 Wood Raw Material Preparation Process

The wood raw material preparation may include the following technology sub-processes:

- wood conversion
- wood debarking
- wood chipping
- chip sorting

2.1.2 Wood Sawing

The wood raw material received for processing may arrive as tree length logs, longwood or shortwood

The most widespread system in Russia are the shortwood (1,2-2,2m) debarking drums, which calls for preparatory sawing up of the longwood in a slasher into the needed lengths. At present the length of the designed drums in use for wood debarking is 4,5 – 6 m, which is why there is no wood conversion at modern companies.

2.1.3 Wood Debarking

The wood raw material may be debarked using various kinds of debarking equipment. If the group mode is used – in debarking drums, if the single-piece mode is used – in a cambium-sheer debarker.

Drums are designed for wet, semi-dry or dry debarking. In the wet debarking process large quantities of water are used, since the drum is placed in a basin, covering 1/3 of the diameter of the drum. During semi-dry debarking, hot water is fed to the non-overflow section of the drum, which creates the conditions for defrosting (in wintertime) and moisturization of the bark, allowing for the efficient debarking of any kind of wood.

During the past few years many companies have started to use the dry method of debarking in drums. Water is used only for the sprinkling and thawing of the logs. Defrosting is achieved be feeding steam into the drum or by using hot water in a special conveyer, mounted before the drum.

The water used in the process is recirculated under a minimal formation of wastewater and pollutants.

During dry debarking, a minimal content of water in the bark is achieved, which leads to a more favourable energy balance of the company.
After the debarking drum, the bark is fed to a shredder, and, if it is moist, it is dewatered in a press before incineration. In some cases, it is sold to other companies, but when formed in large quantities it is preferable to incinerate it at the companies where it is formed, in special boilers.

2.1.4 Wood Chipping

In order to obtain pulp, the debarked roundwood is turned into chip in a wood chipper. Generally disk chippers are used. Depending of the type of pulpwood feed, there are various types of machines – either with a sloping or a horizontal feed holder. At present, the most widespread type is the chipping machine with a horizontal deed of the wood into the machine with a low chip ejection. This is determined by the increased length of the wood that is fed into the chipping machine up to 4 – 6 m and the decreased wood losses, since it is not shredded by the blades when tossed upwards.

2.1.5 Chip Screening

It is necessary to produce homogenous size chips in order to raise the efficiency of the cooking process and to achieve a high quality of the pulp. After the chipping machine, the chip is screened (today by a spindled breaker) in order to remove the size substandard chips and sawdust. The fine fraction of the chips should preferably be cooked in a special digester or it should be incinerated together with the sawdust or the bark. The large-size chips are to be shredded in special machines and returned to the general flow in order to be screened again. In order to raise the quality of the chips screening is performed in order to separate the thick fractions, which is despatched to be processed by a special equipment unit and – subsequently – to be returned to the production line. The thickness screening guarantees the homogenous size during cooking, hereby increasing the quality as well as the yield.
The characteristics of the equipment for the process of preparing the wood raw material are presented in table 2.2.

Table 2.2 – characteristics of the equipment for the process of preparing the wood raw material

Equipment unit name	**Equipment purpose**	**Technological characteristics[1)]**
1	**2**	**3**
Installation for the feeding and sawing of longwood	Feeding of tree bundles, unscrambling of bundles, feed into sawing, sawing of longwood into shortwood	Capacity, dense timber cubic meter/hour: 125-180 Log length: 6,5 m Saw diameter, 1500 – 1800 mm
Group method of debarking of wood raw material		
Defrosting conveyer	Sprinkling and defrosting of timber in wintertime	Capacity, dense timber cubic meter/hour: 250-390 Water temperature: 40-60°C
Debarking drum	Wood debarking	Capacity: dense timber cubic meter/hour: 120-390 Length, 25,0-42,0 m Diameter, 4,0-5,2 m Rotation velocity, 4-9 rpm
Chipper	Chipping of debarked wood	Capacity Dense m^3/h: 100,0 – 390,0 Disk diameter: 3,0-3,87 m Number of blades: 12 – 18 Rotation velocity min^{-1}: 220-300
Reception pit for chips with discharge screw	Reception of chips from the chipper	Capacity of the discharge screw: 750,0 – 1300,0 m^3/h
Disk screen	Separation of coarse wood waste from the bark	Capacity up to 220,0 m^3/h
Bark cutting	Shredding of the bark and wood scrap	Capacity up to 50,0 – 135,0 m^3/h Size of the shredded bark: up to 50,0 mm

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Equipment unit name	Equipment purpose	Technological characteristics[1)]
1	**2**	**3**
Group method of debarking of wood raw material		
Bark press (chain, screw, piston)	Bark pressing	Capacity: 30,0 – 100,0 m^3/h Wetness of the bark after pressing: 40 – 55 %. Other information depending on the type of press.
Unit interfaces	Belt conveyers and chain conveyers for the transport of material between equipment units	Capacity: m^3/h Length: m Width: mm Depend on the arrangement of equipment units
Single-piece debarking method		
Outfeed table	Reception of timber	Depends of the capacity of the line. Feed volume, 40 m^3/h Size of the fed wood: up to 6,6 m
Stepped feed	Single-piece feed of logs into the debarking mechanism	Feed speed: 40 – 75 m/min
Rotor debarking machine	Timber debarking	Type Diameter of the debarked wood: 10 – 80 cm
Chipping machine	Chipping of debarked wood	Type Capacity, dense m^3/h Disk diameter, m Number of blades, no. Rotary frequency, min^{-1}
De-loading pit with a discharger screw	Reception of chip from the chipping machine	Capacity, dense m^3/h Length of the screw: m Diameter of the screw: cm

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Equipment unit name	Equipment purpose	Technological characteristics[1)]
1	**2**	**3**
Bark chipper	Fragmenting large-size waste	Capacity, m^3/h, Size of the fragmented bark, mm Diameter of the rotor: mm Rotation frequency: min^{-1}
Unit interfaces	Conveyers for the transport of material between equipment units	Capacity: m^3/h Length: m Width: mm Depend on the arrangement of equipment units
Chip screening		
Chip screening	Chip screening	Type: gyratory screening, disk, cylinder screen
Chip shredder	Shredding of the large-size fractions of chip	Type- drum, cylinder type of chipping machine Capacity, m^3/h Other information depending on the type of shredder
Unit interfaces	Belt-type conveyers for the transport of material between equipment units	Capacity: m^3/h Length: m Width: mm Depend on the arrangement of equipment units
[1)]the technological characteristics depend on the type of wood, and the needed capacity of the production line		

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Table 2.3 – The environmental protection equipment for the preparation of the wood raw material

Equipment unit name	**Equipment purpose**	**Technological characteristics[1)]**
1	**2**	**3**
Dust removal system	A system for the removal of steam and air mixture from the debarking drum	Capacity: 10,0 – 12,0 m^3/s Pressure, : 3500 Pa Dust concentration: 15-50 mg/m^3h
Drain conveyer	Primary water removal from the bark	Capacity (in terms of water), 1 000 – 1 500 m^3/h Perforation diameter: 7,0 mm Width: 900 – 1 300 mm
Water removal drum	Primary water removal from the bark	Diameter: 1 500 – 2 000 mm Length: 5,0 – 5,0 m Perforation diameter: 6,0 – 8,0 mm
Mesh filter	Local water treatment	Capacity: 12,0 – 35,0 m^3/min Drum diameter: 2,0 m Mesh width: 8,0 – 10,0 m
Sand transporter	Separation of sludge from the bark-containing water basin	Width: 400 600 mm Length: depends on the arrangement of the plant
Washing rollway with a stone trap	Flushing of the pulpwood before cutting and stone removal	Width: 1 200 – 1 400 mm Length : dep. On the arrangement of the plant Speed: m/s
Chain conveyer for stones by the defrosting conveyer	Removal of stones during defrosting	Width: 650 mm Length: dep. on the arrangement
[1)]the technological characteristics depend on the type of wood, as well as the needed capacity of the production line		

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2.2 The Sulphate Pulp Production Process

At present, the sulphate method of pulp production with efficient and thoroughly tested system of regeneration of chemicals is the dominating chemical process and also the most efficient and cost-efficient type of production of technical pulp with high strength features, allowing for the processing of almost any kind of tree species wood (4,5,6).
At Russian pulp and paper producing companies the following items are produced:

- sulphate bleached softwood and hardwood pulp (commercial and for the production of newsprint)
- commercial sulphate, un-bleached softwood pulp
- sulphate unbleached softwood pulp for the production of board, fluting, sack, and package paper
- neutral sulphite hardwood semi-chemical pulp, NSSC, as well as sulphate hardwood semi-chemical with green liquor

The production of sulphate pulp includes the following main process blocks:

- Preparation of the wood raw material
- Production of sulphate unbleached or bleached pulp
- Recovery of chemicals and energy and the production of by-products
- Bleaching and the preparation of the bleaching chemicals
- Treatment system for the production wastewater at offsite wastewater treatment plants

The production of bleached and unbleached sulphate pulp may include the following sub-processes:

- Cooking
- Hot refining, washing and screening of unbleached pulp, as well as waste screening and refining
- Oxygen delignification and bleaching of the pulp
- Washing of the bleached pulp
- Drying, packaging and storage of the bleached and unbleached pulp

The combination of processes, their equipment set-up and arrangement in the production scheme for the production of sulphate pulp depend on the concrete type of produced goods and the production process used (see fig. 2.3).
The main information on the sulphate pulp production process presently used in the Russian pulp and paper industry, is presented in table 2.4.

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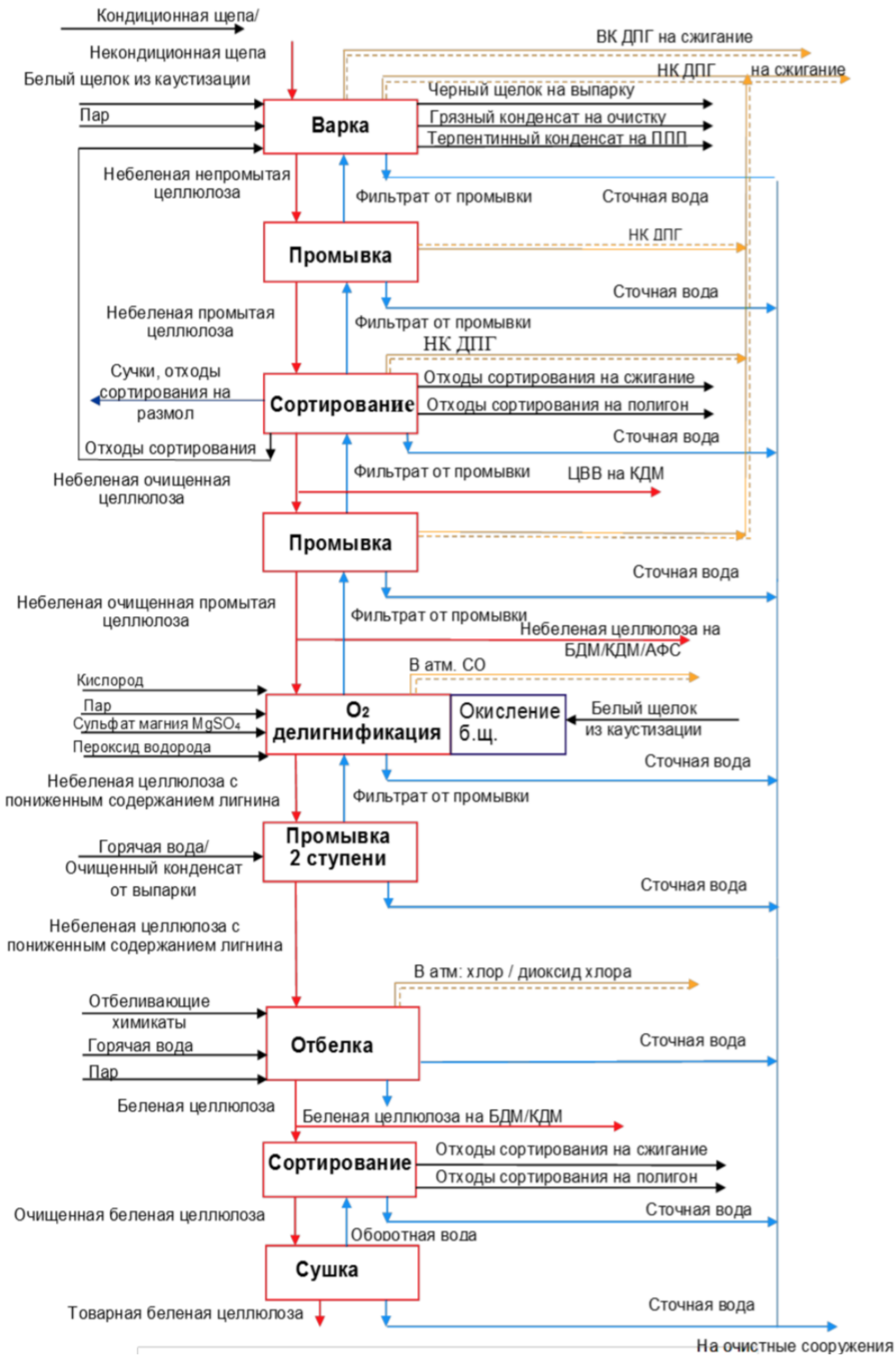

Figure 2.3 Block diagram on the technological process of production of sulphate pulp, Red boxes, vertically from above to below cooking, washing, sorting, washing, and O2 delignification, 2-step washing, bleaching, sorting and drying.

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Table 2.4 – A description of the sulphate production process

Input	Stage of the process	Output	Main process equipment	Emissions
1	2	3	4	5
Conditioned chip Sawdust, pin chips. Unpulped knots White liquor Filtrate from the washing station Steam Electrical energy	Cooking	Unbleached pulp Black liquor Foul condensate (hardwood pulp) Turpentine condensate (for softwood pulp). Low concentration non-condensable gases High concentration non-condensable gases	System for the loading of chip into the digester Cooking assemblage Blow (receiving) tank System for the condensing of steam from the boiling of black liquor Collection system for the Low concentration non-condensable gases Collection system for the High concentration non-condensable gases	Emission to air: of non-condensable gasses, turpentine, and methanol. Discharge to the production waste water disposal system: suspended matter, COD, alkali, mineral waste
Unbleached pulp Filtrate from the washing step Electrical energy	Washing	Unbleached pulp. Low concentration non-condensable gases Filtrate from the flushing	Washing mechanism Pump MC	Emissions to air, non-condensable gasses, turpentine. Discharge to the production waste water disposal system: suspended matter, COD, lye,

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Input	Stage of the process	Output	Main process equipment	Emissions
1	2	3	4	5
Unbleached pulp. Filtrate from the washing step. Electrical energy	Screening	Unbleached conditioned pulp. Knots and undercooked pulp Waste from fine screening Low-concentration non-condensable gasses	Knot and undercooked pulp trap. Knot and undercooked pulp washer Sorting Waste washer Refiner machine for the grinding of waste. Vortex cleaners for the separation of sand Refiner machines for the grinding of high-yield pulp	Emissions to air, non-condensable gasses, turpentine, methanol Discharge into the production waste water disposal system, suspended matter, COD, lye Mineral waste Knots and undercooked pulp Fine screening waste
Unbleached pulp. Filtrate from the washing step. Hot water/cleaned condensate Electrical energy	Washing	Unbleached washed pulp. Knots and undercooked pulp Low-concentration non-condensable gasses Washing filtrate	Washer MC pump	Emissions to air, non-condensable gasses Discharge into the production waste water disposal system, suspended matter, COD, lye Mineral waste

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Input	Stage of the process	Output	Main process equipment	Emissions
1	2	3	4	5
Washed and screened unbleached pulp Oxidized white liquor/lye Oxygen Hydrogen peroxide Steam Magnesium sulphate Electrical energy	Oxygen delignification	Unbleached pulp with a low Kappa number	Oxygen delignification reactors (1 or 2). Mixers wit steam and oxygen MS pumps Plant for the oxidation of white liquor by means of air or oxygen Unit for the reception, storage and feed into the process of magnesium sulphate	Emissions to air: CO
Pulp after the oxygen-alkali treatment/treated condensate from the evaporation station Electrical energy	Washing	Washed unbleached pulp with low lignin content. Filtrate from the washing process	Washing station Multi-stage pump	Discharge into the production waste water disposal network: Suspended matter, COD, lye

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Input	Stage of the process	Output	Main process equipment	Emissions
1	2	3	4	5
Washed unbleached pulp Bleaching chemicals: Chlorine, chlorine dioxide, oxygen, hydrogen peroxide, caustic soda, sodium hypochlorite, sulphuric acid, sulphurous acid, fresh, warm and hot water. Steam Electrical energy	Bleaching	Bleached pulp	Multi-step basin for the storage of pulp before bleaching. Bleaching tower with reactors. Washers. Mixers with chemicals by means of steam. MS pumps Gas washing scrubber for the chlorine-containing gasses	Emissions to air: chlorine (chlorine dioxide). Wastewater to the production wastewater network: suspended matter, COD, AOX
Bleached pulp Recycled scrap Steam Recycled water Fresh water Sodium hydroxide Sulphurous acid Electric energy Dilution water	Sorting	Washed bleached pulp Waste from screening Recycling water	Pressure screen Vortex cleaners Filter for fibre trapping	Discharges into the production wastewater disposal system, suspended matter, COD

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Input	Stage of the process	Output	Main process equipment	Emissions
1	2	3	4	5
Bleached pulp Steam Recirculated water Fresh water Electrical energy	Formation Pressing Drying of the pulp sheet.	Pulp on reels Scrap (cut-offs and during breaks) Recycling water Condensate	Stuff box Formation station Pressing station Drying station Reeling-up stand Hydrobeater (pulper) for scrap	Discharges into the production wastewater disposal system, suspended matter, COD Emissions to air: wet air mixture, paper dust.
Production of ClO_2 by the method of Metison and NR-A				
Chemicals: $NaClO_3$, H_2SO_4, SO_2, using the Metison (?) or H_2O_2, using the NR-A (??) method Technical air	ClO_2 generation	ClO_2 gas, by-product: solution of H_2SO_4, Na_2SO_4	Primary reactor. Secondary reactor. Stripper column Gas cleaning column	None
ClO_2 gas. Chemicals: NaOH solution Cooling water	Production of water solution of ClO_2 (absorption)	ClO_2 solution. Residue gases By-product: sodium hypochlorite (NaClO) solution	Absorption column Chemical scrubber	To air: Cl_2, ClO_2

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Input	Stage of the process	Output	Main process equipment	Emissions
1	2	3	4	5
Production of ClO_2 using the integrated Chemetics technology				
Electrical energy Chemicals: Chlorate-chlorine solution ($NaClO_3$, NaCl), Sodium hydroxide	Production of sodium Chlorate ($NaClO_3$) by electrolysis	Sodium Chlorate ($NaClO_3$). H_2 gas By-product: sodium hypochlorite (NaClO)	Chlorate reactor Electropolysers Degasser	To air: Cl_2
Chemicals: H_2, Cl_2, Demineralised water	Hydrochloric acid, HCl, synthesis	Hydrochloric acid, HCl,	Hydrochloric acid, HCl, synthesis reactor, Scrubber for residue gasses	To air: Cl_2, HCl
Chemicals: Sodium chlorate $NaClO_3$, hydrochloric acid (HCl) Sodium hydroxide (NaOH). Cooled water Technical air	Generation of chlorine dioxide (ClO_2)	Chlorine dioxide (ClO_2) solution. By-product: sodium hypochlorite (NaClO)	Chlorine dioxide (ClO_2) generator. Evaporator. Chlorine dioxide (ClO_2) absorber Hypochlorite tower	To air: Cl_2, ClO_2

2.2.1 Cooking

during the process of sulphate cooking, wood is subjected to cooking liquor during a few hours at high temperatures (usually 170°C).

The concrete conditions of the cooking process depend upon the composition of the cooking solution and is determined by the technical pulp produced: in order to produce paper and board or for chemical processing.

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The sulphate cooking liquor contain NaHO and Na_2S as active components, as well as added carbonate, tiosulphate, sulphate and sodium polysulphides, the presence of which is connected to the reactions proceeding in the process of regeneration of cooking components.
Under sulphate cooking conditions, all wood components are entered into reactions with the cooking reagents, as a result of which the major part of the lignin, part of the carbohydrates as well as the extraneous substances in the form of destruction products are turned into a solution and form the used (black) liquor.
The cooking process is accompanied by the formation of volatile sulphur-containing compounds, such as methyl mercaptan, dimethyl sulphide, hydrogen sulphide, possessing the characteristic feature of a foul smell, as a result of which they are called foul-smelling (odorous) gasses (NCG:s, non-condensable gasses). The reason why these foul-smelling compounds are formed is the presence in the cooking liquor of sodium sulphide and – in the wood – of methoxyl groups.
The main factors influencing the sulphate cooking process are: the consumption of liquor and its concentration, temperature and the duration of the cooking, the sulphide content of the liquor, the impregnation of the chip and the wood species.
As a result of the cooking of softwood (spruce, pine) it is possible to produce pulp for bleaching with a kappa number of 30 – 35, while retaining acceptable strength parameters of the pulp. For hardwood species wood (aspen, birch) pulp is produced with a kappa number of 14 – 22.
The cooking is carried out using batch or continuous operation cooking plants.
Batch cooking is carried out in stationary digesters with a system of forced circulation of the liquor and indirect cooking.
The main operations of a traditional batch cooking are: loading chip and cooking liquor into the digester (during the loading, chip is compacted with steam), penetration (raising of the temperature of the digester up to the cooking temperature, turpentine relief (removal of gases and air), cooking at the end temperature, the final blowdown in order to lower the pressure (if the brown-stock blowdown it not carried out at the full cooking pressure).
The total digester cycle lasts 4 to 6 hours.
The use of modern ”modified” techniques of sulphate batch cooking with a cold blowdown of the stock from the digester and a heat recovery of the black liquor allows for the: reduction of the steam used for batch (up till 50 – 60 %), reduction of the cycle of the batch digester, lowering of the consumption of batch chemicals by 5 – 10 %, increase of the

pulp yield, reduction of the quality of the undercooked pulp, increase of the pulp strength by 10 – 15%, improve the washing of the pulp through the washing stages in the digester, as well as a substantial reduction of the gaseous emissions.
Kamyr continuous cooking plants are subdivided into single- and two-vessel digesters, the hydraulic type of with a steam phase, with a zone of counter current diffuse washing or without it.
Before being loaded into the digester for continuous cooking, the chip is steamed in order to remove air, which inhibits the penetration of the chip by chemicals.
After the loading of the chip into the digester it is impregnated by the batch liquor and the temperature is raised to 155 – 175°C.
The cooking time at max temperature is 1 – 2 h.
At Russian companies, practically all digesters are of the continuous type.
Three batch set-ups use the LoSolids technique, and one plant uses the Compact Cooking G2 technique.
The used batch solution (black liquor) containing residue batch chemicals and the organic compounds of the timber transferred into the solution, after the separation of pulp fibre, are directed to the evaporation trains, which form part of the batch chemicals recovery system.
The NCGs escaping in the process of boiling of the black liquor and the chips steaming together with steam is fed into the chips steaming system, from which it is dispatched to be condensed.
The uncondensed high- and low concentration foul-smelling gases (strong and weak NCGs) are fed through separate collection and transport systems to the thermal treatment system or are emitted to air after treatment in the gas-cleaning equipment.
The turpentine-containing condensate from the black liquor boiling vapour condenser and the steaming tank is transferred to the production of by-products plant for the separation of raw turpentine.
The turpentine water from the settling of turpentine condensate and the condensate from the washing and cooling of the NCGs in the gas-cleaning scrubber is transferred to a stripping column to be cleaned (in the evaporation train or in a separate plant).

2.2.2 Washing of Unbleached Pulp

The reason why one would wash the pulp is to separate from the pulp fibre the dissolved mineral and organic compounds of the black liquor in order to increase the level of recovery of the batch chemicals, the reduction of bleaching chemicals and the reduction of the discharge of pollutants with the wastewater from the bleach plant as well as the drying and the paper machine.
The efficiency of the washing of unbleached pulp depends upon the quantity of the washing steps, the efficiency of the used equipment, the concentration of the stock fed into and transferred out of the washing station, the consumption of washing water, etc.
For modern washing set-ups (diffusors, filters and presses) developed for washing by diffusion, extraction and displacement or the combination of these three principles.
At Russian sulphate pulp plants a closed counter-current washing is used for unbleached pulp – in 3 – 5 steps (including a diffusion washing step in the cooking digester) with the use – as washing fluid - of hot water, treated condensate from the evaporation train including filtrate from the oxygen-alkaline batch step.
The major types of washing equipment at Russian companies are drum filters, washing presses, as well as atmospheric diffusors and pressure diffusors.

2.2.3 Screening of Unbleached Pulp

The reason for the screening of unbleached pulp is the separation of knots and undercooked pulp, bundles of unseparated fibres, bark, phloem (soft bast), resin and sand from the main flow of conditioned pulp by aid of various sorting equipment.
The pulp screening scheme, as well as the choice of equipment depend on the type of original pulp, its purpose as well as the requirements presented by the GOST, the TU (technical conditions) or the consumers as the residual dirt count.
The sorting of unbleached pulp, generally includes the following operations:

- Course screening of the unbleached pulp (separation of knots, undercooked pulp and coarse impurities) at a combined screening station, a thrust knot screen, knot washer, vibration screen and a hydrocyclone.

- Fine screening of unbleached pulp (separation of shives, bark, sand and other fine inclusions) using combined screening and pressure screening steps as well as waste wet washer as well as vortex screens.

Depending on the type of produced pulp and the concrete conditions of production:

- The knots and undercooked pulp separated during the coarse screening, after the separation of fibre and dehydration up to 30% concentration may be transferred to a secondary batch or be thermally recycled in a multi-fuel boiler or be disposed of at an industrial waste landfill.
- After the separation of the fibre and dewatering, the waste from the screening process also may be fed to be incinerated in a multi-fuel boiler or be disposed at an industrial waste landfill
- Fibrous screening waste (shives and undercooked pulp) may be fibrillated in a special grinding equipment unit and be returned to the main stock flow or be used in the paper and board production etc.
- When producing unbleached pulp in order to produce board as well as fluting, sack and packaging paper, knots and undercooked pulp usually are not separated out, all stock after the batch is subjected to hot milling, and the ground fraction is separated out during screening and is returned to repeated milling. The sorted out stock is returned to the main flow.
- Wastewater from the equipment of the washing and screening plant, the main quantity of which is constituted of weakly alkaline water from the non-hermetic sealing of the elements and units of equipment, as well as water from the washing of the floors, flushing of the equipment before repair, accidental spillage and the like is directed to the production waste-water network and, thereafter, to the sewage treatment plant.
- Alkaline-containing water, formed during the emptying of equipment and tubes during scheduled maintenance and emergencies, is returned tot he process or is fed to the evaporation train, subsequently to be recovered together with the black liquor.
- The source of the emergence of gas emissions in the washing set-ups and the screening of unbleached pulp are the tanks and washing equipment.

The total vapour and gaseous emissions are led to a collection and transport system for the weak NCG:s, and, thereafter to a treatment station or is emitted to the air without treatment.

2.2.4 Oxygen Delignification of Unbleached Pulp

The purpose of oxygen delignification is the lowering of the kappa number of the pulp before the bleach plant, the reduction of the consumption of bleaching chemicals, the lowering of the amount of discharged pollutants reaching the sewage treatment plant, and, correspondingly, the lowering of the environmental impact of the bleaching process.

The removal of lignin in the process of oxygen delignification is carried out through the processing of unbleached pulp by it being subjected to oxygen and lye in the digesters at a high temperature and under excessive pressure.

The oxygen delignification is carried out in one or two steps under modest pulp concentration.

The two-step delignification achieves a level of softwood delignification of 60 – 70 %, the one-step version – 40 %.

The position of the oxygen delignification in the production set-up is after the washing of the unbleached pulp.

In order to attain a selective delignification, an efficient washing of the pulp is needed before and after the oxygen-alkaline processing.

Before the oxygen delignification, it is necessary to perform an efficient washing to remove black liquor, since, if there would be a high residual content in the stock of dissolved organic compounds and sulphide, there would be a marked increase in the consumption of oxygen and lye and the mechanical qualities of the pulp would be impaired.

The COD content of the in the pulp stock entering the oxygen-alkali process stage should not exceed 100 kg/ADt

The washing of pulp after the oxygen delignification must also be as deep as possible, since the washing quality defines the size of the losses of chemicals.

The efficiency of the washing according the factor Norden ~ 15 before the oxygen delignification and ~ 8 – 10 – after.

The filtrate from the washing of the pulp after the oxygen-alkali treatment is forwarded to the washing of the stock after the batch, and, in this way, the lye, used in the oxygen-alkaline processing, is returned to the recovery cycle

In order to retain the balance of sodium and sulphur of the batch chemicals recovery system, the use of oxidized white liquor is used as the alkali reagent of the oxygen delignification process.
The prevention of destruction of softwood pulp during the oxygen-alkali processing, caused by the influence of mixed valence metals, is attained by the addition of magnesium compounds (usually $MgSO_2$) into the process.
At Russian sulphate pulp plants, the oxygen delignification of unbleached soft- and hardwood pulp is used at 6 production lines: for softwood the two-step oxygen delignification process is used, whereas for hardwood – mainly the one-step version.
The main emissions to air from the receiving tank of the oxygen delignification contain mainly water steam, carbon dioxide, unabsorbed oxygen, as well as a certain quantity of carbon monoxide and volatile organic compounds, are released into air without treatment.
Oxidised white liquor as the alkaline reagent is used at two plants. Two techniques are used for the oxidation:

- Air at atmospheric pressure
- Oxygen at elevated pressure

The steam and gas mixture from the white liquor oxidation reactor, containing an aerosol of lye and residue oxygen is released into air after treatment in a cyclone separator.

2.2.5 Pulp Bleaching

The bleaching is intended for the final delignification and to give the pulp a white colour while the lignin, extractives and other compounds, containing chromophore groups, giving the paper a dark colour are removed, at a minimal reduction of the mechanical strength parameters.
The kappa number for bleached pulp is lower than 1.
The bleaching equipment consists of a line of separate stages, at which several chemicals are used.
At every stage of the bleaching process there is:

- A pulp-chemicals mixer
- A pulp-steam mixer

- The bleaching reactor (tower) with external or internal columns or without columns altogether with a flow direction bottom-up or top-down, providing for the necessary pulp processing time for the chemical reaction to take place.
- Washing equipment for the separation of used chemicals, dissolved lignin and other dissolved compounds from the pulp (usually the washing filter of the drum type, washing presses and sometimes diffusers).

At Russian sulphate pulp plants, the softwood and hardwood bleaching is carried out according to the following schemes.

Softwood	**Hardwood**
Ch/D – AlkOP – G – D1 – Alk2 – D2 – (K)	OP – D0 – AlkP – D1 – Alk2 – D2 – (K) (ECF)
OO – Ch/D – AlkO – D1 – D2	O- Ch/D – Alk1 – G(??) – D1 – Alk2 – D2 – (K)
OO – D0 – AlkOP – D1 – AlkP D2 – (K) (ECF)	F – D0 – AlkG(Alk1= - D1 – Alk2 – D2 – (K)
D1 - AlkOP – D2 – AlkP – D3 – (K) (ECF)	OO – A/D0 – AlkOP – D1 – (K)
	O – D1 – AlkOP – D2 – (K) (ECF)
O – one-stage oxygen delignification	
OP – one-state oxygen delignification using hydrogen peroxide	
OO – two-stage oxygen delignification	
Ch/D – chlorination with the addition of chlorine dioxide D0, D1, D2 and D3 – bleaching with chlorine dioxide	
A – acidic processing	
F – fermentative (enzyme) processing	
Alk1, Alk2, AlkO, AlkP, AlkOP, processing using Sodium hydroxide, sodium hydroxide with oxygen, sodium hydroxide with hydrogen peroxide, and sodium hydroxide with oxygen and hydrogen peroxide as appropriate	
K – Acid treatment using sulphur dioxide	

At four companies the bleaching is conducted using ECF technology (without molecular chlorine), the main bleaching chemicals being chlorine dioxide, oxygen and hydrogen peroxide.
At 2 companies chlorine and sodium hypochlorite are used for bleaching.

Between the bleaching stages predominantly vacuum filters are used for pulp washing. At one company, a DDW wash (drum displacer washer) is installed after the D0 stage, while, at another company, wash presses are installed at all the bleaching stages.
The consumption of hot water for washing purposes is reduced by the use of a partial counterflow of the filtrates.
The surplus acid and alkaline filtrates from the pulp washing, containing residual chemicals and dissolved organic compounds is transferred to the biological treatment plant of the mill. Before the discharge to the industrial sewerage, the wastewater, as a rule is cooled.
At the first company a system for the trapping of fibre from the acid and alkaline wastewater of the bleaching assembly. The trapped fibre is returned to the bleaching process.
The wastewater from the bleaching units is not transferred to the chemicals recovery station, since it may increase the build-up of chloride and other unwanted inorganic elements, causing corrosion, the formation of deposit (fur) and other problems in the recovery system.
The chlorine containing gaseous emissions from the equipment of the Ch/D, D0, D1 and D2 before the emission into the atmosphere is treated at a gas treatment equipment unit. As treatment reagents are uses cooled liquor filtrate or a solution of sodium bisulphite.

2.2.6 Bleached Pulp Screening

After the bleaching process, sometimes a final screening of the pulp is performed. The secondary screening is performed at an equipment unit of the same kind and the screening of the unbleached pulp. Sometimes centricleaners, radiclones (straight and reverse) are used, especially for hardwood.

2.2.7 Drying of Pulp

In order to produce commercial bleached or unbleached pulp drying machines are used, in which the pulp is dewatered until it reaches air-dry condition.
The design of the drying machine is analogous to the paper machine.
The composition of a dryer:

- The mesh part with dewatering elements and a formation mechanism
- The press part

- Dryer

The dried pulp sheet, after the dryer, is fed to the sheet-cutting machine, for the cutting of sheets and the formation of bale packs. The formed bales are packed and formed into transport packages.

2.2.8 Production of Bleaching Chemicals

At Russian sulphate pulp mills, the most widely used chemicals for bleaching purposes are chlorine, chlorine dioxide, oxygen, hydrogen peroxide and sodium hypochlorite. Chlorine dioxide, sodium hypochlorite and oxygen are produced on-site.
Hydrogen peroxide, chlorine and sodium hydroxide are mainly brought to the mill from external suppliers.
At one of the companies, chlorine and chlorine dioxide are produced on-site.

2.2.8.1 Production of Chlorine Dioxide

In connection with the thermodynamic instability of chlorine dioxide, it is usually produced at the place of consumption.
At pulp production mills, chlorine dioxide is produced through the reduction of the chlorate ion (ClO_3^-) in an acid environment. The source of the chlorate-ion, used in industrial scale, is sodium chlorate.
The choice of reagents is very important from a cost-efficiency point of view, and from the viewpoint of the by-products produced. As a reducing agent in order to produce chlorine dioxide at Russian companies sulphur dioxide, hydrogen peroxide and chloride ions are used. At foreign companies methanol is also used.
In general the process of chlorine dioxide can be represented by the formula:
Chlorate + reduction agent + acid -> chlorine dioxide + by-products
The development of technology during many years has been directed towards the maximum increase of the yield of chlorine dioxide from the chlorate, the minimization of the formation of by-products while guaranteeing the stable and easy management of the process. This is accomplished through the use of a stoichiometric excess of acid and reduction agents (see table 2.5).

In production settings, where the process proceeds under boiling vacuum conditions, the consumption of acid is lower, since the only discharge from the reaction solution is ClO_2 gas, which subsequently is absorbed by water in an absorption tower, and a by-product – the acid reactor residue (sodium salt and sulphuric acid), which is formed in the reaction solution, after which it is removed out of the process.

In the processes, which proceed at atmospheric pressure, by-product salts are mixed with excess acid and removed from the process together with the used acid.

Table 2.5 shows the most important modern world techniques for the production of chlorine dioxide.

At Russian companies, chlorine dioxide generally is produced in Metison method set-ups. Furthermore, at present, at one of the companies chlorine dioxide is produced according to the HP-A technique, at another company – the method SVP-Classic, and at yet another the integrated technique Chemetics R6.

Table 2.5 – the most widespread techniques for the production of chlorine dioxide

Reducing agent	**Foreign matter in the produced ClO_2**	**By-products**	**Process technology**		**Specific potential environmental problems**
			Vacuum	**Atmospheric**	
Methanol	Formic acid	Sodium sulphate	SVP-LITE SVP-SCW R8, R10		-
Hydrogen peroxide		Sodium sulphate	SVP-HP, SVP-PURE, R11	HP-A	–
Sulphur dioxide	-	Sodium sulphate	-	Metison	SO_2 handling
Chloride ions	Elemental chlorine	Sodium chloride	R6, SVP-total HCl, Lurgi, Chemetics		The water solution of ClO_2 contains Cl_2
Comment: Source: Best Available Techniques (BAT) Reference document for the Production of Pulp, Paper and Board Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control) 2015.					

Table 2.6 shows the parameters of raw material consumption and the formation of by-products when using various means of chlorine dioxide production (in t/t ClO_2).
The main method, which gives the lowest concentration of free chlorine in the chlorine dioxide solution as a by-product, is the Metison process, while the highest concentration would be the case if one would us the series R methods, i.e. R8, R10, R11, HP-A or the SVP processes.
By-product production is important for the economy of the process as well as for the quality of the produced ClO_2.
Table 2.6 compares raw material production parameters with the formation of by-products when using various methods of chlorine dioxide production (in t/t ClO_2). This table also shows that the main method that produces the minimal content of free chlorine in the solution of chlorine dioxide as a by-product is the Metison process, while the highest concentration would be the case if one would us the series R methods, i.e. R8, R10, R11, HP-A or the SVP processes.

Table 2.6 –Raw material consumption and yield of by-products when producing chlorine dioxide with the most widespread techniques.

Production technology	**Metison**	**HP-A**	**SVP-LITE, R8**	**SVP-SCW, R10**	**SVP-Hp, R11**	**Integrated Lurgi, R6, Chemetics**
1	**2**	**3**	**4**	**5**	**6**	**7**
Chemicals consumption (t/t ClO_2)						
Sodium Chlorate	1,8	1,65	1,65	1,64	1,65	
Sulphuric acid Sulphur dioxide						
Methanol	0,8					
Hydrogen Peroxide		0,29			0,29 – 0,32	
Elemental chlorine						0,73
Steam			4,2	5,5	5,5	8,0
Electric energy kWh	80	80	130	160	130	8900
By-products (t/t ClO_2)						

Production technology	Metison	HP-A	SVP-LITE, R8	SVP-SCW, R10	SVP-Hp, R11	Integrated Lurgi, R6, Chemetics
1	2	3	4	5	6	7
Chemicals consumption (t/t ClO_2)						
Chlorine	0	0	0	0	0	0,18 – 0,24
$NaH(SO_4)_2$			1,35		1,35	
Na_2SO_4	1,20	1,10		1,1	1,1	
H_2SO_4	1,5	1,3			0,29 – 0,32	
O_2		0,26			0,26	0,73
Source: Best Available Techniques (BAT) Reference document for the Production of Pulp, Paper and Board Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control) 2015.						

A principal scheme of the Metison and HP-A technologies is shown in Fig 2.4 – and table 2.7 whereas table 2.8 shows the features of the main production line and environmental equipment depending on which technology is used.

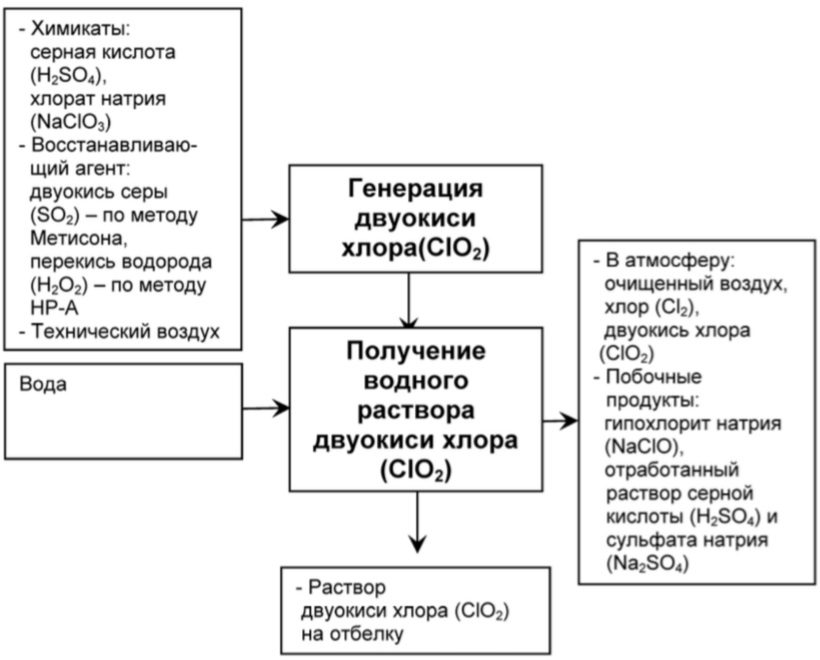

Fig 2.4 – A block scheme of the production of chlorine dioxide using the Metison technology and the HP-A technology:

LEFT: Input (above, left): chemicals: H_2SO_4, $NaClO_3$, reduction agent (metison) SO_2 or (HP-A) H_2O_2. Input (below left): Water
CENTRAL: above: the generation of ClO_2 middle: the production of a ClO_2 water solution that will be used in bleaching (below)
Output: treated air, Cl_2, ClO_2 by-products: NaClO, used H_2SO_4 and Na_2SO_4

A principal scheme of the Chemetics integrated technologies is shown in Fig 2.5 – and table 2.7 whereas table 2.8 shows the features of the main production line and environmental equipment depending on which technology is used.

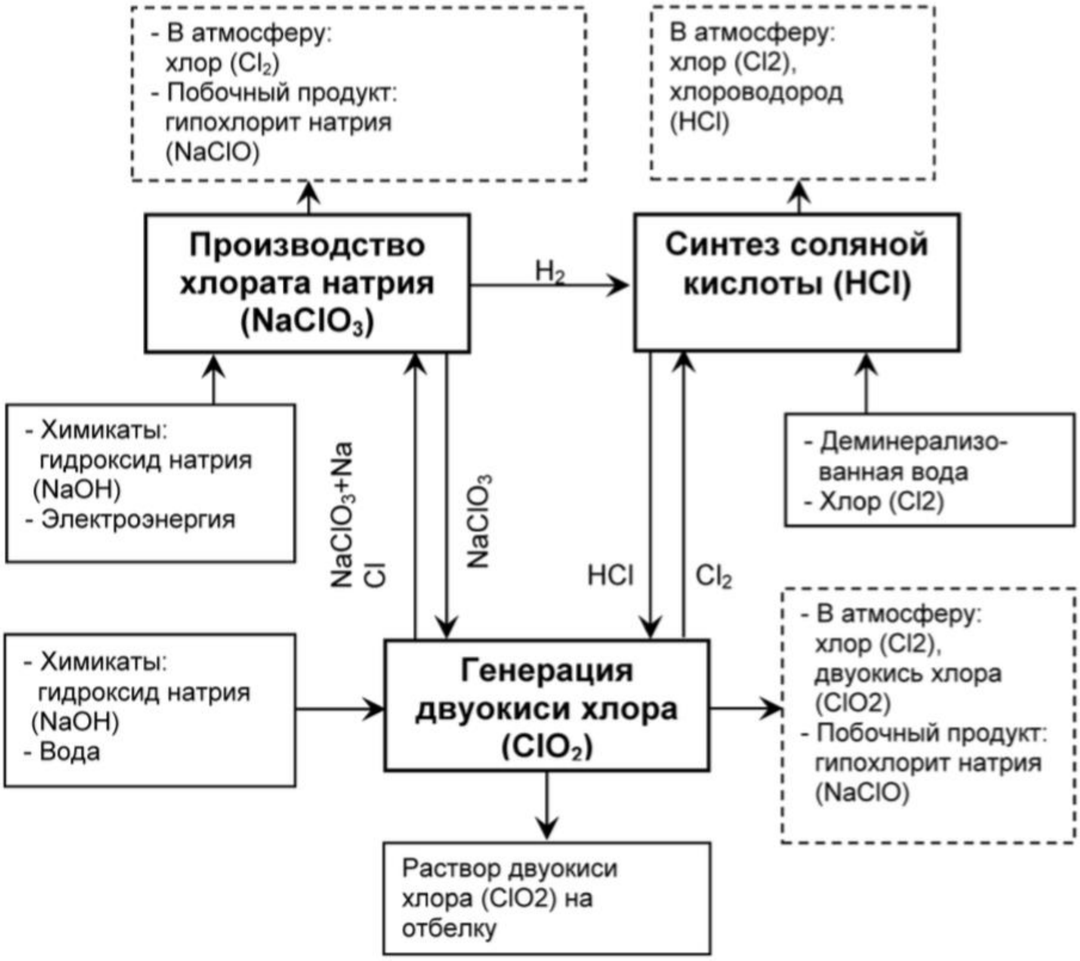

Fig 2.5 – A block scheme of the production of chlorine dioxide using the Chemetics integrated technology

The aim is to fully utilize the sodium- and sulphur-containing by-products formed during the production of chlorine dioxide at the pulp mill, e.g. by adding them to the concentrated black liquor before it is transferred to be incinerated in the recovery boiler (RB) or by using them for the regulation of the pH of the pulp production or during the decomposition of soap when producing tall oil.

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Description of the Applied Technical Equipment

Table 2.7 – Description of the main Equipment

Name of equipment unit	**Application of the equipment unit**	**Technical and technological features** [1)]
1	**2**	**3**
Batch		
Chip hopper	Securing the short-term chip supply Securing the steady charging of the batcher rotor pockets Preventing of gases escaping from the low pressure feed unit to air through their absorption by the chip	Capacity: 32,5 – 1 000 m^3 Diameter: 4,5 – 6 Total height: 8 – 15 m
Low pressure feed unit	Continuous feed of chip from the batcher into the steam pit Shutting-off device between the excess pressure in the steam pit and the atmospheric pressure in the batcher and chip hopper	Type: rotor Number of pockets: 5 Volume of the rotor pockets: 0,295 – 0,779 m^3/cycle Revolution frequency of the rotor: 17 – 29 rev/min Working pressure: not exceeding 0,2MPa
Steam pit	Primary chip heating Removal of air from the chip	Volume: 1455 m^3 Diameter: 6,3 – 7,5 m Height: 45,7 m Pressure: atmospheric Working temperature: not exceeding 100 °C

1	**2**	**3**
Steam pit	Primary heating of the chip	Process time: 20 min Volume: 284 m^3 Operating pressure: 14 kg/cm^2 Temperature: 200 °C Diameter: 2 m Height: 8 m
High pressure feed unit	Transfer of the chip from the steam pit or the impregnation tower to the pipe of the of the upper charging circulation of the	
Digester	Cooking of the chip Extraction of black liquor Diffusion washing of the pulp in the lower part of the digester	Volume: 200 – 2 697 m^3 Capacity: 200 – 1931 t/day air-dry pulp Working pressure in the upper part of the digester max 0,0 MPa – 1,2 MPa Working temperature: 130 – 180°C
Washing		

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1	2	3
Washing		
Vacuum filter	Washing of the pulp by dewatering, diffusion and substitution of the filtrate by hot water, cleaned condensate or a cleaner yet filtrate of the subsequent stages	Capacity: 500 – 990 t/day of air-dry pulp Surface of the filtration: 57 – 176 m^2 Feed concentration: 1 % - 1,5 % Exit concentration: 10 % - 12 % Dilution factor: 2,5 m^3/t of air-dry pulp (ADt) E_{10} = 3,0 – 4,0
Wash press	Washing of the pulp by dewatering, diffusion and substitution of the filtrate by hot water, cleaned condensate or a cleaner yet filtrate of the subsequent stages	Capacity: 600 – 1 500 t/day of air-dry pulp Surface of the filtration: m^2 Feed concentration: 2,5 % - 10 % Exit concentration: 25 % - 35 % Dilution factor: 2,5 m^3/t of air-dry pulp (ADt) E_{10} = 3 – 6
Diffusion-type washer	Washing of the pulp by diffusion and substitution of the black liquor a cleaner washing liquor of the subsequent stage	Filtration Surface, m^2 Feed concentration: 10 % Exit concentration: 10 % Dilution factor: 2,5 m^3/t of air-dry pulp (ADt) E_{10} = 5,0 – 5,5 %

1	**2**	**3**
Washing		
1- and 2 stage atmospheric continuous action diffusion-type washer	Washing of the pulp by dewatering, diffusion and substitution of the black liquor by a cleaner washing liquor of the subsequent stages	Surface of the filtration: m^2 Capacity: 200 - 700 ton/day ADt Volume: 133 – 222 m^3 Feed concentration: 10 % Exit concentration: 10 % Dilution factor: 2,5 m^3/t of air-dry pulp (ADt) E_{10} = 3,4 – 4,0 Number of stages: 1
DD washer	Washing of the pulp by dewatering, diffusion and substitution of the filtrate by hot water, cleaned condensate or an even cleaner filtrate of the subsequent stages and circulation of the washing filtrate	Surface of the filtration: m^2 Feed concentration: 4 % - 10 % Exit concentration: 12 % Dilution factor: 2,5 m^3/t of air-dry pulp (ADt) E_{10} = 5 - 10 Number of stages: 1,5- 4
CB (compact baffle) filter	Washing of the pulp by dewatering, diffusion and substitution of the filtrate by hot water, cleaned condensate or an even cleaner filtrate of the subsequent stages,	Surface of the filtration, m^2 Feed concentration: 3 - 4 % Exit concentration: 12 % Dilution factor: 2,5 m^3/t ADt E_{10} = 3.5 – 4,5 %
Intermediate concentration pulp pump	Feed of thickened stock of medium concentration from the washing equipment to the OD or to a storage tower	Capacity: 200 – 2 100 t/day ADt concentration: 10 - 12 %

1	2	3
Screening		
Combined pressure screen	Separation out of knots and undercooked pulp, 1st stage of fine screening	Capacity: 965,4 ADt/day Volume: 133 – 222 m^3 Screening mesh for coarse screening - aperture diameter: 8- 10 mm Screening mesh for fine screening - aperture diameter: 0,22 – 0,28 mm Concentration: 3,5 - 5 %
Pressure knot screen	Separation out of knots and undercooked pulp	Capacity: 250 – 1 200 ADt/day Screening mesh - aperture diameter: 7- 12 mm Concentration: 3,5 - 5 %
Centrifuge knot screen	Separation out of knots and undercooked pulp	Capacity: 420 ADt/day Screening mesh - aperture diameter: 7- 9 mm Concentration: 1 – 1,5 %
Cyclone washer	Removal of fiber from knots and undercooked pulp Thickening of knots and undercooked pulp	Capacity: 200 - 300 ADt/day Screening mesh - aperture diameter: 1,8 – 3,0 mm Concentration: 1 – 1,2 %
Vibration knot screen	Removal of fiber from knots and undercooked pulp Thickening of knots and undercooked pulp	Capacity: 46,5 - 105 ADt/day Screening mesh - aperture diameter: 6 - 10 mm Concentration: 0,9 - 1 %

1	2	3
	Screening	
Fine pressure screening	Separation out of foreign inclusions including shives, from the fiber	Capacity: 133 – 1 120 ADt/day Width of the screen spaces: 0,15 – 0,28 mm Concentration: 2 - 5 %
Waste washer	Separation out of fiber from shives and shives thickening	160 ADt/day Filtration surface: 20 m^2 Screening mesh aperture diameter: 2- 12 mm Concentration: 1 – 1,2 %
Vortex cleaning device	Separation out of mineral pollution from the fine screening waste	Volume: 0,13 m Capacity: 162 – 600 m^3/h Feeding pressure. 0,3 – 10 MPa Concentration: 1 %
High concentration stock refining machine	Refining of high-concentration pulp stock and waste	Concentration: 30 %
Low concentration stock refining machine	Refining of low-concentration pulp stock and waste	Concentration: 3,5 %
	Oxygen delignification	
Oxygen delignification reactor of the first stage with a mechanism for the unloading of stock from the reactor	Processing of the unbleached pulp by oxygen in a oxidized white liquor/sodium hydroxide environment	OxyTrac. Process Total volume: 360 – 400 m^3 Concentration: 11 – 12 % Temperature: 85 °C Pressure: 8- 10 Bar Processing time: 30 min

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1	2	3
Oxygen delignification reactor of the second stage with a mechanism for the unloading of the stock from the reactor	Processing of the unbleached pulp by oxygen in a oxidized white liquor/sodium hydroxide environment	OxyTrac. Process Total volume: 670 m^3 Concentration: 11 – 12 % Temperature: 95 - 100 °C Pressure: 3 - 5 Bar Processing time: 60 min pH: 10,5 - 11
Oxygen delignification reactor of the first stage with a mechanism for the unloading of the stock from the reactor	Processing of the unbleached pulp by oxygen in a oxidized white liquor/sodium hydroxide environment	Concentration: 11 – 12 % Temperature: 95 – 100 °C Pressure: 4 Bar Processing time: 90 min pH: 10,5 - 11
Oxygen mixer	Mixing of the pulp with oxygen	Capacity: 800 – 2 000 ADt/day Concentration: 11 – 12 %
MC pump	Pulp feed to the second stage of the delignification	Capacity: 800 – 2 000 ADt/day Concentration: 11 – 12 %
Steam mixer	Heating of the stock by steam	Capacity: 800 – 2 000 ADt/day Concentration: 11 – 12 % Δt = 12 – 15 °C
White liquor pressure oxygen oxidation reactor	White liquor oxidation by oxygen	Volume: 26 m^3 The OWL process Temperature: 135 – 160 °C Pressure: 10 bar Process time: 1 h

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1	2	3
White liquor pressure air oxidation reactor	White liquor air oxidation	Volume: 320 m^3 Temperature: 80 °C Pressure: hydrostatic Process time:~20 h
Magnesium sulphate supply bin	Storage of magnesium sulphate	
Bleaching		
Bleaching tower with discharger scrape of the A level	Pulp processing with sulphuric acid	Pressure: hydrostatic Temperature: 90 - 93 °C pH: 3 – 3,5 Process time: 90 - 120 min Pulp concentration: 10 – 12 %
Level D_0 reactor with a dilution mechanism	Chlorine dioxide pulp processing	Pressure: 60 kPa Temperature: 109 °C pH: 2 - 3 Process time: 15 min Feed concentration: 10 – 12 % Discharge concentration: 8,5 – 9 %
Bleaching towers with absorption columns with dilution mechanisms at stages Ch/D, D_0, D_1, D_2	Pulp processing with chlorine and chlorine dioxide	Pressure: hydrostatic Temperature: 45 – 80 °C pH: 2 – 4,5 Process time: 45 - 180 min Feed concentration: 10 – 12 % Discharge concentration: 3 -4 %

1	2	3
	Bleaching	
Bleaching towers with internal columns with dilution mechanisms at stages Ch/D, D_0, D_1, D_2	Pulp processing with chlorine and chlorine dioxide	Pressure: hydrostatic Temperature: 45 – 80 °C pH: 2 – 4,5 Process time: 45 - 180 min Feed concentration: 10 – 12 % Discharge concentration: 3 -4 %
Bleaching tower with a washing diffuser at stages D_1	Pulp processing with chlorine dioxide	Pressure: hydrostatic Temperature: 65 – 80 °C pH: 3,5 – 4,5 Process time: 120 - 180 min Discharge concentration: 10 – 12 %
Oxygen absorption tower at stages AlkO and AlkOP	Pulp processing with sodium hydroxide, hydrogen peroxide and oxygen	Process pressure: hydrostatic Process temperature: 70 – 80 °C pH: 10,5 – 11,5 Process time: 30 min Concentration: 10 – 12 %
Bleaching towers with dilution mechanisms at stages Alk, AlkO, AlkOP and AlkP	Pulp processing with sodium hydroxide, hydrogen peroxide and oxygen	Pressure: hydrostatic Temperature: 70 – 80 °C pH: 10,5 – 11,5 Process time: 60 - 90 min Feed concentration: 10 – 12 % Discharge concentration: 3 -4 %

1	2	3
Bleaching		
Reactor of the AlkO stage with a mechanism for the unloading of the stock from the reactor and a blow tank	Processing of the pulp with sodium hydroxide, hydrogen peroxide and oxygen	Total volume: 723 m^3 Process pressure: 3 bar (in the upper part) Process temperature: 70 - 80 °C Processing time: 60 - 90 min Concentration: 11 – 12 %
Bleaching towers with absorption columns with dilution mechanisms at stages Alk, AlkO, AlkOP and AlkP	Pulp processing with sodium hydroxide, hydrogen peroxide and oxygen	Pressure: hydrostatic Temperature: 45 – 80 °C pH: 2 – 4,5 Process time: 45 - 180 min Feed concentration: 10 – 12 % Discharge concentration: 3 -4 %
Bleaching tower level G with dilution mechanism	Pulp processing with sodium hypochlorite	Pressure: hydrostatic Temperature: 35 – 40 °C pH: 10,5 - 11 Process time: 90 - 120 min Feed concentration: 10 – 12 % Discharge concentration: 3 -4 %
Level D_0 reactor with a dilution mechanism	Pulp processing with chlorine dioxide	Pressure: 60 kPa Temperature: 109 °C pH: 2 - 3 Process time: 15 min Feed concentration: 10 – 12 % Discharge concentration: 8,5 – 9 %
Wash press	Washing of stock between the bleaching stages	Dilution factor: 2 – 2,5 m^3/ADt Feed concentration: 9 % Discharge concentration: 30 %

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1	2	3
	Bleaching	
Vacuum filter	Washing of pulp between the bleaching stages	Filtration surface: 150 – 176 m^2 Dilution factor: 2 – 2,5 m^3/в. с. т. Feed concentration: 1 – 1,5 % Discharge concentration: 10 – 12 %
DD washer	Washing of pulp between the bleaching stages	Filtration surface: m^2 Dilution factor: 2 – 2,5 m^3/в. с. т. Feed concentration: 8,5 – 9 % Discharge concentration: 12 – 14 % Number of stages: 1
Chemicals mixer	Mixing of the pulp with oxygen and chlorine dioxide	Capacity: 800 – 200 ADt/day Pulp concentration: 10 – 12 %
Single-shaft steam mixers	Heating of the pulp with low-pressure steam	Capacity: 800 – 2 000 ADt/day Pulp concentration: 10 – 12 % Δt = 12 – 15 °C
MC pumps with receiving pipes and vacuum pumps	Transfer of medium concentration stock	Capacity: 800 – 2 000 ADt/day Pulp concentration: 10 – 12 %
Filters for fiber capture	Capture of fiber from wastewater	

1	2	3
Bleaching		
Heat exchange equipment for wastewater cooling	Cooling of acid and alkaline wastewater	Feed temperature: 70 – 80 °C Discharge temperature: 40 – 45°C
Bleached pulp screening		
Pulp storage basin	Reception and storage of pulp	Volume: up to 8 000 m^3 Concentration: up to 12 %
Screening	Screening of pulp stock with the removal of foreign inclusions and pulp cakes	Type: vertical/horizontal pressurised; slot type Size of the mesh openings: 0,2- 4 mm Concentration: 2 – 4 %
Vortex cleaning with removal of heavy and light inclusions	Removal of mineral inclusions from the screening waste	Type: vortex conical cleaners Concentration at the coarse screening feed: 0,15 – 0,2 % Concentration at the light inclusions screening feed: up to 0,15 %
Pulp drying		
Dryer; including:	Felting, pressing, drying of the pulp sheet	Capacity: up to 1 900 t/day Weight of the pulp sheet: 800 – 1 500 g/m^2 Cutting width: 4 200, 6 300 mm Forwarding speed: up to 250 m/min

Pulp drying		
- stuff box	Pulp stock feed to forming station	Closed type. Feed concentration: 1,2 – 1,7 % Recirculation level: max 10% Max opening up to 120 mm
- forming station	Forming of the pulp sheet	Cantilever type, mesh table with a top (or without) forming system with a set of dewatering elements. Dryness of the pulp sheet at exit: up to 32 %
- Press	Pressing of the pulp sheet	Combined press part, including a ”Pickup” shaft and several presses of various types: combipress, shoe press and others Feed dryness: up to 32 % Dryness at exit: up to 48,5 %
- Dryer part	Drying of the pulp sheet	Type: Convective drying on an air pillow, cylinder type. Feed dryness: up to 48,5 % Dryness at exit: up to 80 - 90 % Diameter of the dryer cylinders – 1 500 mm Quantity of dryer cylinders: up to 125 Condensate return: up to 90 %

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Pulp drying		
Reel-up	Reeling up of the pulp sheet on a drum	Reeling type Drum diameter, mm Diameter of the reel, mm Mechanism for the change of drums
Scrap hydrobeater, (pulper) (under the machine)	Dissolution of broke (break of sheet, shavings, fillets, etc.)	Couch pit volume up to 80 m^3 Scrap hydrobeater of the pressed part: up to 70 m^3 Scrap hydrobeater of the dried part: up to 85 m^3 Concentration: 2,5 – 4 %
Vacuum pumps	Vacuum generation for the dewatering system of the formation and press parts	Water ring vacuum pumps, water removal units. Quantity of vacuum pumps: up to 5
Heat exchange equipment	Heat recuperation system for pulp production	The Assembly: air/air, air/water heat exchangers, fans, and scrubber.
Cutting and packaging		
Sheet cutter	Unreeling of reels, transverse and longitudinal cutting, format cutting, formation of sheet bales, packaging of bales, packing of bales into boxes, stacking	Capacity – up to 2 100 t/day Size of sheets: max 700 x 870 mm Bundle mass: up to 250 kg
Packaging	Weighing, packing of bales, formation of a transport package	Capacity – up to 360 bundles/h Number of lines: up to 2 Quantity of bundles in a transport package: up to 8 Package mass: up to 2 000 kg

1	2	3
Production of ClO_2 by the Metison and HP-A methods		
Primary reactor	The production of gaseous chlorine dioxide	Capacity – 7 ./. 31 t 100 % ClO_2/day
Secondary reactor		
Blow-off column		
Gas washing column		
Absorption column	Production a water solution of ClO_2	Type: gas absorption column Packing: ceramic or plastic rings Efficiency of trapping of Cl_2 , no less than 99,0 %, ClO_2: no less than 97,5 %. Concentration of the final solution: ClO_2: 7 ./. 10 g/l
Production of ClO_2 by the Chemetics method		
Chlorate reactor	The production of sodium chlorate ($NaClO_3$) and H_2 and Cl_2	Capacity: 15 5 100 % $NaClO_3$/day Chlorate yield: 94,1 %
Electropolysers		
Degassers		
HCl synthesis reactor Evaporation tank	Production of hydrochloric acid, HCl	Capacity: 24 t 100 % HCl/day
Chlorine dioxide generator	Production of gaseous chlorine dioxide (ClO_2)	Capacity: 26 t 100 % ClO_2/day
Absorption tower	Production of water solution of chlorine dioxide (ClO_2), removal of Cl_2 gas	Packing: plastic rings. Final solution concentration: ClO_2: 10 g/l Cl_2: 1,8 g/l
1) the production features depend upon the capacity of the production line		

Table 2.8: Environmental protection equipment

Name of equipment unit	**Application of the equipment unit**	**Technical and technological features 1)**
1	**2**	**3**
Batch, washing, screening and oxygen delignification		
Turpentine scrubber	Washing of weak NCG:s for the removal of turpentine	Volume: 0,24 – 0,873 m^3 Diameter: 800/300 mm Total height: 5 400 mm Operating pressure – underpressure Operating temperature: 50 – 70 °C
Gas Cleaning weak NCG:s scrubber	Washing of and water cooling of weak NCG:s	Volume: 22,5 m^3 Diameter: 2 000 mm Total height: 8 000 Cleaning efficiency: %
Bleaching		
Gas cleaning scrubber	Gas cleaning of the emissions from the bleaching units from chlorine, chlorine dioxide and sulphur dioxide	Capacity: 1 800 – 27 000 m^3/h Efficiency: 90 – 95 % Active chlorine concentration in the effluent gas: 20 mg/Nm^3 Neutralizing reagents: Sodium hydroxide, sulphurous acid. Volume: 16,5 - 46 m^3
Drying		
System for the removal of dust from the sheet in the dryer units	Dust removal from the surface of the sheet and treatment of polluted air	The assembly of the unit: fan, dust separator, filter

1	2	3
Pulp drying		
System for the removal of dust from the sheet in the sheet cutting units	Dust removal from the surface of the sheet	The assembly of the unit: Suction boxes in the zone of transverse and longitudinal cutting over the full width of the sheet, fan, dust separator
ClO_2 production		
Chemical scrubber (sanitary column)	Residual gas cleaning	Type: packed scrubber Packing: plastic rings Cleaning environment: NaOH solution Cleaning efficiency: Cl_2: no less than 99,0% ClO_2: no less than 97,5 %
Hydrogen scrubber	Removal of Cl_2 from H_2 gas	Type: packed scrubber Packing: plastic rings Cleaning environment: NaOH solution Cleaning efficiency: Cl_2 content in emissions: not exceeding 5 mg/Nm^3
Residual gas scrubber	Capture of HCl and Cl_2 gases	Type: packed scrubber Cleaning environment: demineralized water Cl_2 content in emissions: HCL: not exceeding 30 mg/Nm^3 Cl_2: not exceeding 5 mg/Nm^3

ClO_2 production		
1	2	3
Residual gas scrubber	Cleaning of the gas emissions from the ClO_2 production	Type: packed scrubber Cleaning environment: NaOH Cl_2 content in emissions: not exceeding 10 mg/Nm^3
1) The technological features depend upon the capacity of the production line		

2.3 The Cooking Chemicals Recovery Process during the Production of Sulphate Pulp

The recovery process of chemicals may include the following production sub-processes [4, 5, 6]:

- Evaporation of black liquor
- Incineration of the evaporated liquor in the recovery boiler (RB) and the formation of sodium sulphide and sodium carbonate
- Caustization of the sodium carbonate in order to transfer carbonate to hydroxide
- Burning of the lime sludge in the lime reburning kiln
- Production of by-products
- Uncondensed odorous gases collection and feed to the treatment unit.

2.3.1 Evaporation of Black Liquor

Before the evaporation the liquor is prepared by:

- Filtration of the weak black liquor in order to separate out slime pulp. The trapped fibre is returned to the batch unit;
- The strengthening of the weak black liquor with a mass share of 12 – 18 % ADW of the half-evaporated liquor (48 % ADW) to the optimal mass share of dry matter (20 % ADW)
- The extraction from the black liquor of sulphate soap by the sustained settling of strengthened and half evaporated black liquor (8 – 12 h) in tanks.
- The black liquor, received from the digester after cooking, usually contains 12 – 18 % dry residue (organic and inorganic compounds). An inherent part of the sulphate method of pulp production is the chemicals recovery, including the burning of the evaporated liquor.

In this way, chemicals are reintroduced into the production cycle, this production being fuelled by steam and electrical energy and emission of pollutants is avoided. Before the incineration in the RB, it is necessary to increase the content of dry matter in the black liquor up to 65 -75 %. The evaporation of the liquor is carried out in multi-unit equipment assemblies. The unit number of the assembly may vary between 5 and 7. Every unit works under conditions of a certain temperature and pressure.
In a multi-unit evaporation station a stage-wise lowering of the temperature of the boiling of the liquor is carried out. The lowering of the temperature of the units is created by the generation of vacuum by a special vacuum generation system.
In order to heat the first unit, secondary steam from the steam turbines with a pressure of 0,25 – 0,5 MPa is used, whereas in the liquor volume of the last unit a vacuum is generated, corresponding to an absolute pressure of 8 – 15 kPa. As a result of this, a temperature in the whole of the evaporation assembly varies in the approximate range 80 – 90 °C.
During the evaporation of liquor, in the secondary steam, volatile sulphur-containing odorous gases with a low boiling temperature are formed. During the condensation of the secondary steam in the last unit the major part of these products end up in the foul condensate, whereas the non-condensible gases are transferred either to a treatment unit or be burned.
The condensates usually contain DMDS, DMS, MM, and H2S and differ in the level of pollution by the abovementioned. The most polluted condensates – from the first condensing unit – are processed in a stripping column, usually a part of the evaporation station. In this column condensates are blown off by fresh or secondary steam, which allows for the repeated use for the washing of unbleached pulp and green liquor sludge in the caustization department.

2.3.2 Collection and Feed to the Treatment Unit of Uncondensed Odorous Gases.

The uncondensed odorous gases (NCGs) are formed in the cooking plant, washing and oxygen delignification plants, the evaporation stations and are characterized by a high content of sulphurous compounds (mainly DMS, MM, H_2S and turpentine).

The uncondensed NCGs are highly explosive and fire hazardous and are divided into two groups:

- Highly concentrated odorous gases (strong NCGs) with a pollutant concentration above the upper flammability limit concentration and with an oxygen volume concentration lower than 10% are transported by water vapour
- Low-concentration non-condensible gases (weak NCGs) with a pollutant concentration lower than the lower limit of combustibility whereas the oxygen content is up to 20 %, are transported with air.

The strong NCGs are transported by a steam ejector, whereas weak NCG:s are transported by a fan.
Before the feed into the transportation system, the weak NCGs from each of the process stages are cooled in scrubbers at the respective sites in order to remove moisture.
strong NCGs are incinerated in a separate furnace or in a lime furnace, or usually in a RB. In the kiln, the odorous gases are oxidized and transformed into sulphur dioxide.
The flue gases from the burning processes in the separate kiln or in the limekiln are cleaned in a gas cleaning scrubber, whereas the used solution from the scrubber is transferred to the caustization department.
The flue gases from the incineration processes of the RB are transferred to be cleaned in electrical filters. At a concentration of dry matter above 72 % in the black liquor fed to incineration in the RB, the sulphur dioxide usually is sorbed by the alkaline dust particles in the RB, and – therefore – no further chemical cleaning of the flue gases is required.
At a few companies, to a higher or lesser degree, there is a collection of the strong NCGs produced in the preliminary steaming of the chip, washing or screening of the pulp from the dissolving tanks, liquor tanks, etc.
For the safety of the burning of the NCGs, separate systems for the collection and transfer of high- and low-concentration NCGs is organized.
During periods of emergency shutdown of the RB, a strong NCG treatment system is provided for in a special flare device using supplementary fuel, whereas the weak NCG is forwarded to air without cleaning.
At Russian sulphate pulp mills the treatment of strong NCGs are organized:

- In the RB: at 2 companies
- In the limekiln: at 1 company
- In a separate recycling boiler – at 2 companies
- Treatment (full or partial) of the strong NCG in the RB: at 4 companies.

The main sources of odorous gases from the production of unbleached sulphate pulp are shown in table 2.9 and fig. 2.6.

Table 2.9: the main sources of odorous gases from the production unbleached sulphate pulp

Name of the source of NCGs	**Kg S/ton ADt**
High concentration gases	
Continuous cooking	0,4
Evaporation (from the water lock)	1,7
Stripping column	1,1
Methanol strengthening	2,2
Total	5,4
Low concentration gases	
Washing equipment	0,1
Liquor tanks	0,8
Caustization and dissolving tank	0,2
Total	1,1
Total NCGs to be treated	6,5
Flue gases	
RB	0,03
Level of neutralization of NCGs, %	99,5
Limekiln	0,01

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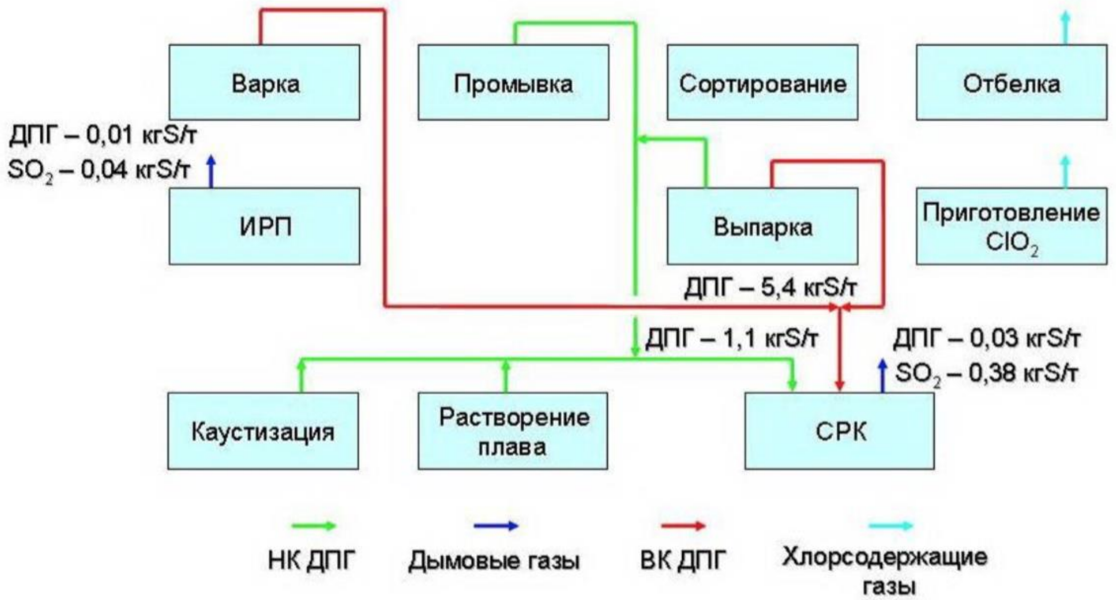

Fig. 2.6: the main sources of odorous gases in the RB during the production of unbleached sulphate pulp

2.3.3 Burning of evaporated liquors in the RB together with the Formation of Sodium Sulphide and Sodium Carbonate

In the process of burning of black liquor in the RB there is a process of organic matter pyrolysis, accompanied by carbonization of the liquor and the burnoff of carbon, taking place together with the reduction of sodium sulphate.

In the mineral part of the black liquor there is mainly a content of combined alkali, which in the organic compound pyrolysis and burn-off processes are subjected to carbonization according to the reaction:

$2NaHO – CO_2 = Na_2CO_2 + H_2O$

During the liquor pyrolysis process various organic and sulphur containing volatile compounds are released. These compounds are mainly burned in the furnace. The reaction of the sulphate reduction proceeds in the presence of carbon according to the following reactions:

Na_2SO_2 $2C = Na_2S + 2CO_2$

Na_2SO_4 $4C = Na_2S + 4CO$

The formed fusion cake is mainly composed of carbonate (Na_2CO_3, 70%) and sodium sulphide (Na_2S: 20 – 25%). From the RB the melt proceeds to a dissolution tank, where it is dissolved by weak white liquor, hereby forming green liquor.

2.3.4 Causticization of the Green Liquor

The caustization process is the transformation of sodium carbonate to hydroxide through the treatment of carbonate with quicklime – the concluding step in the chemicals recycling cycle during the cooking of sulphate pulp.
The green liquor from the dissolving tank is fed to be cleared in the settler tank equipped with filters of various constructions. The green liquor sludge (green sludge) after washing and dewatering is transferred to the waste landfill. The weak green liquor, however, after the washing of the sludge is directed to the weak white liquor tank.
In order to carry out the causticization, the cleared green liquor is transferred to lime slaker classifiers where quicklime or calcium oxide is continuously being fed. The slaker, lime is slaked and the separation out of inclusions (sand, small stones) including unslaked lime, from the reaction mix.
After washing, the settled heavy inclusions (sludge) are disposed to the waste landfill.
The causticization reaction goes through two stages. The first of the stages is the lime slaking, which proceeds according to the following formula:
$CaO + H_2O = Ca(OH)_2 + 270$ kcal/kg
The formed hydroxide reacts with the sodium carbonate of the green liquor according to the following reversible reaction:
$Na_2CO_3 + Ca(OH)_2 = 2NaOH + CaCO_3$
The reaction proceeds slowly, starts in the slaker and continues in the causticization vessels – 1,5 – 2 h.
The total reaction is defined by the level of causticization:
$NaHO \times 100 / (NaOH + Na_2CO_3)$
The magnitude of the level of causticization stays in the range 75 - 86 %.
In the process of causticization reaction a suspension of sludge is formed in the white liquor. In order to remove the strong white liquor the suspension is transferred to be cleared (or filtered). In the clearing process and the washing process, strong white and weak white liquor are withdrawn. They are sent to storage tanks. Thereafter the strong white liquor from the storage tanks is fed to the cooking department for the cooking of pulp, where as the weak is sent to the RB, where it is used as a smelt solvent.
The lime sludge is transferred to be washed, dewatered and thereafter to roasting.

The main processing parameters of the department are the level of causticization of the green liquor and also the fullness of the removal of sludge from the white liquor.

2.3.5 Lime Sludge Recovery in the Limekiln

The causticization (white) sludge, having been separated from the strong and weak white liquors and after it has been thickened is dispatched to a revolving lime recovery kiln to be roasted.
The lime production process is based on the reaction of calcium carbonate decomposition, proceeding at high temperatures:
$CaCO_3 = CaO + CO_2 + 42$ kcal
The level of recovery of lime is 85 – 95 %. The losses are compensated by the addition into the kiln of crushed limestone, which is roasted together with the causticization sludge. The temperature of lime ranges from 1 000 to 1 000°C. The burned is air cooled in the regenerative heat exchanger.
The fuel used in the roasting process may be fuel oil, gas, strong NCGs, methane, tall oil or biogas. The major emissions from the LK are sulphur dioxide, nitrogen oxides, dust and total reduced sulphur (TRS).
During the sub-processes of the causticization and the recovery of lime, the following process operations are carried out:

- The filtration of green liquor
- The washing and thickening of the green liquor sludge
- Lime slaking and causticization
- Washing and thickening of the lime (white liquor) sludge
- Lime burning
- Feeding of unslaked lime to be causticized.

2.3.6 Production of By-products

2.3.6.1 Production of Crude Tall Oil

Crude sulphate soap is the mixture of sodium salts have resinous and fatty acids forming part of pulpwood. In order to avoid the formation of foam and the formation of a deposit (crust) in the evaporation vessels, the sulphate soap needs to be removed from the liquor recovery process. The separation out of soap is accomplished by the clarification of the black liquor in the feed or half evaporated liquor or by separation.

The production of tall oil is based on the processing of the soap by an acid and may be carried out by the following methods:

- Batchwise – in batch reactors
- Continuous method with the separation of the oil in a centrifuge
- Continuous method with the separation by decantation

In order to decompose soap, sulphuric acid is used at the companies that have a department for the production of chlorine dioxide. Used acid is used as a reagent.
A disadvantage of the batch method of oil production is the low yield, the high consumption of sulphuric acid (250 -300 kg sulphuric acid per ton of oil) as well as the difficulty of automation. The efficiency of the washing of the sulphate soap and the production method (batch or continuous) are the main factors affecting the intensity of emission of odorous compounds. When using the batch mehtods to produce crude tall oil, there are peak emissions of hydrogen sulphide, however, when using the continuous method, the flow of gases from the reactor is considerably lesser. The gaseous emissions are treated in the scrubber by caustic soda.
The yield and the quality of the tall oil are defined by the tree species, the oil removal system as well as the oil production method. The yield of crude tall oil ranges from 10 to 70 kg per ton of pulp.

2.3.6.2 Production of Crude Turpentine

The yield of crude turpentine is defined mainly by the mass share of volatile compounds of the wood and the pulp cooking method. The highest content of extractive matter is found in pinewood (up to 0,55 %), whereas larch and spruce are species with a low content of volatile compounds (not exceeding 0,12 %).
Turpentine is removed from the system in a condensed phase with a so-called turpentine condensate, from which it is removed by settling, because of its lower density (860 kg/m^3)
When cooking pulp in the digesters of batch action turpentine may be removed to the extent of 75 % of its content of the wood, however when cooking using the continuous methods in Kamyr machines – no more than 20 %.
When applying the continuous method the major part of the turpentine ends up in the black liquor and the only possible way of extract it would be the deodorization of the heavily polluted condensates.

In order to separate and collect the sulphate turpentine during continuous cooking the following solutions are used:

- the installing of a cyclone liquor trap of the steam gas removal line for the from the flash tank
- the step-wise condensation of vapour from the flash tank;
- a unit for the separation of the turpentine fraction in the units for contaminated condensate treatment.

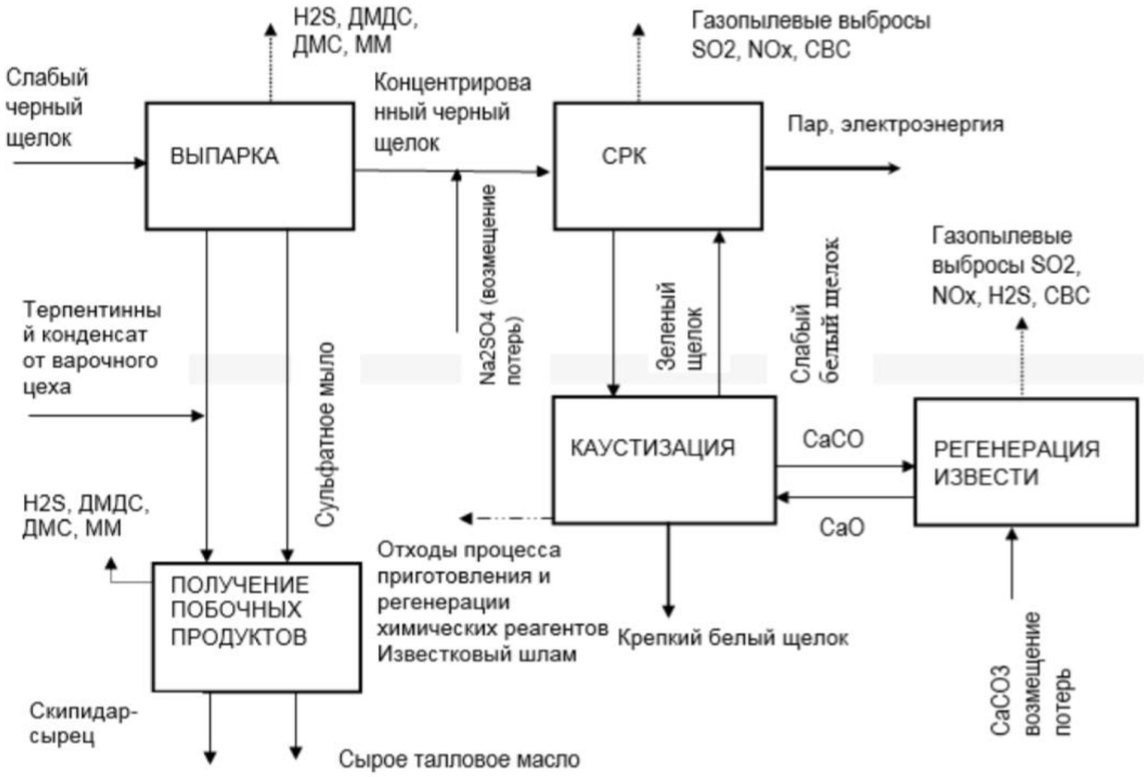

Figure 2.7 A block scheme showing the chemicals recovery process

The main information on the process of the chemicals recovery production, used at present in the Russian PPI, is shown in table 2.10

Table 2.10 A description of the sub-processes of chemicals recovery during sulphate pulp cooking

Input	Process stage	Output	Main equipment	Emissions
1	2	3	4	5
Black liquor from pulp cooking Acid residues from the production of chlorine dioxide Steam Electrical power Fresh water Sodium sulphate	Black liquor evaporation	Strong black liquor Turpentine condensate Contaminated condensate Weakly contaminated condensate Clean condensate strong NCG weak NCG Methanol Sulphate soap Warm water	Tanks Filters for the capture of fibres Evaporation units Circulation pumps Vacuum system	Emissions to air (DMS, DMDS, MM, turpentine, methanol) Discharges to the plant sewage system: suspended solids, COD, alkali (total Na_2O)

Table 2.10 (cont.) A description of the sub-processes of chemicals recovery during sulphate pulp cooking

Input	Process stage	Output	Main equipment	Emissions
1	2	3	4	5
Strong black liquor Demineralized water Weak white liquor Cooling water Sodium sulphate weak NCG strong NCG Electrical power	RB	Green liquor Steam Warm water Ash	RB Electrical filters Scrubber of the dissolving tank Scrubber Tanks	Emissions to air (sulphur dioxide, nitrogen oxides, suspended solids); Discharges to the plant sewage system (suspended solids, COD, alkali (total Na_2O)

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Table 2.10 (cont.) A description of the sub-processes of chemicals recovery during sulphate pulp cooking

Input	**Process stage**	**Output**	**Main equipment**	**Emissions**
1	2	3	4	5
Green liquor Quicklime Steam Warm water Contaminated condensate Sodium hydroxide Electric power	Green liquor caustization	Strong white liquor Weak white liquor Waste from the production and recovery of chemical reagents (green liquor sludge, waste from lime slaking, white liquor sludge)	Tanks Slaker/classifier Causticizer Filters Centrifuges	Emissions to air (DMS, DMDS, MM, H_2S, suspended solids) Discharges to the plant sewage system: suspended solids, COD, alkali (total Na_2O) Waste from the production and recovery of chemical reagents (green liquor sludge, waste from lime slaking, white liquor sludge)

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Table 2.10 (cont.) A description of the sub-processes of chemicals recovery during sulphate pulp cooking

Input	**Process stage**	**Output**	**Main equipment**	**Emissions**
1	2	3	4	5
White liquor sludge Hot water Limestone/lime Methanol Pitch Raw talloil Fuel oil Gas Electric power	Lime recovery	Quicklime	Limekiln Conveyors Elevators Lime storage bunker	Emissions to air (DMS, DMDS, MM, H_2S, suspended solids) Discharges to the plant sewage system: suspended solids, COD, alkali (total Na_2O)
Crude turpentine Common salt Turpentine condensate Sodium hydroxide Sulphate soap Sulphuric acid Cooling water Steam Electric power	Production of by-products	Crude turpentine Subturpentine water Crude talloil Black liquor weak NCG	Decanting vessel ”florentina” Scrubber Heat exchange equipment Separators Sedimentation basin Reactors Tanks	Emissions to air (DMS, DMDS, MM, H_2S, turpentine, methanol) Discharges to the plant sewage system: suspended solids, COD, alkali (total Na_2O)

The characteristics of the Equipment used in the sub-processes of chemicals recovery during sulphate pulp cooking are shown in table 2.11

Table 2.11 characteristics of the Equipment used in the sub-processes of chemicals recovery during sulphate pulp cooking

Name of equipment	**Application of the equipment**	**Technological characteristics**
1	**2**	**3**
	Evaporation of the black liquor	
Tanks	Settling of the black liquor Decantation of the soap Liquor storage Soap storage	Total volume: 10 350 – 20 700 m^3
Tanks under pressure for the evaporated black liquor	The entertainment of a high temperature of the liquor in order to lower its viscosity with a concentration of dry substances of 80 %	Calculated pressure: 0,3 MPa, absolute temperature: 140°C
Filters for the trapping of fibers	Removal of fibers from the black liquor	Type: drum Capacity: 2 – 3,9 m^3/day per 1 m^2 of surface
Pressured screen	Removal of fibers from the black liquor	Type: centrifugal Temperature: 80 – 90 °C Pressure: 0,5 MPa

Name of equipment	Application of the equipment	Technological characteristics
1	**2**	**3**
Evaporation of the black liquor		
Evaporation units	Evaporation of moisture of the black liquor up to 47 – 52 % dry solids content	Type: tubular with a free falling membrane Type: tubular with a forced circulation with a falling membrane Type: tubular with a rising membrane Type: lamellar with a free falling membrane Capacity of moisture evaporation: 150 – 600 t/h Quantity of tanks (including backup) 5 -8 Number of flows: 1 – 2 Pressure of the heating steam: 0,15 – 0,35 MPa Temperature of the heating steam: 126 – 140 °C Concentration of the evaporated liquor: 47 - 55 % Temperature of the original/evaporated liquor: 60 – 85/130 °C

Name of equipment	Application of the equipment	Technological characteristics
1	**2**	**3**
	Evaporation of the black liquor	
Concentration tanks	Evaporation of the moisture of the black liquor to 67 % bone-dry weight	Type: tubular with a free falling membrane Type: tubular with a forced circulation Type: lamellar with a free falling membrane Capacity of moisture evaporation: 27 – 41 t/h Heat transfer surface: 1 865 – 4 200 m² Quantity of tanks (including backup) 1 – 2 Number of flows: 1 – 2 Pressure of the heating steam: 0,15 – 0,35 MPa Temperature of the heating steam: 126 – 140 °C Concentration of the evaporated liquor: 57 - 67 % Temperature of the original/evaporated liquor: 98/120 °C
Superconcentrators	The evaporation of moisture of the black liquor to 85 % bone dry solids content	Type: lamellar, tubular with a forces circulation and a falling membrane. Capacity of evaporated moisture: 27.2 t/h Heat transfer surface: 3 138 m²

Name of equipment	Application of the equipment	Technological characteristics
1	2	3
Evaporation of the black liquor		
Recovery boiler (RB)	Burning of concentrated black liquor, reduction of sodium sulphate to sodium sulphide	Capacity: 540 – 1 932 t/day BDS Steam generation: 80 – 230 t/h Pressure of incoming steam: 34 – 90 Bar Temperature of the produced steam: 390 – 450 °C. Degree of sulphate reduction: no less than 88 – 93 %
Equipment for the removal of ashes (electric filter included in a system for the cleaning of flue gases and the transport and dissolution of ashes)	Cleaning of flue gases, return and compensation for losses of the chemicals	Capacity (gas): 330 000 – 492 000 m^3/h Entry temperature: 160 190 °C Treatment efficiency: 95 – 98,5 %
Causticization of green liquor		
Green liquor settlers	Preparation of the liquor before the reaction	Volume: 920 – 4 400 m^3 Settling surface:)4 – 154 m^2 Pressure: Atm
Sludge filter for green liquor	Sludge removal	Sludge capacity: 17 t/day Filtration surface: 35 – 42,4 m^2 Sludge concentration: 45 – 48 %

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Name of equipment	**Application of the equipment**	**Technological characteristics**
1	**2**	**3**
Causticization of green liquor		
Slaker classifier	Lime slaking, waste removal, beginning of the causticization process	White liquor capacity: 75 – 90 m^3/h Green liquor capacity: – 235 m^3/h Volume: 22 - 100 m^3 Temperature: – °C Pressure: atm
Causticization tanks	Causticization	Volume: 37,5 – 280 m^3 Temperature: – °C Pressure: – atm
White liquor settler tanks	White liquor clearing	White liquor capacity: – 1 500 m^3/h Volume: 720 – 4 400 m^3 Temperature: 80 – 90°C Pressure: atm
Filter for the washing and thickening of white liquor sludge	Washing and thickening of white liquor sludge before the limekiln	Lime sludge capacity: 585 t/day Filtration surface: 36 228 m^2 Temperature: 95 - 98 °C Sludge concentration: 65 %
Vacuum filter	Washing and dewatering of white liquor sludge before the limekiln	Filtration surface: 40 – 50 m^2

Name of equipment	Application of the equipment	Technological characteristics
1	**2**	**3**
Lime recovery		
Limekiln	Burning of lime sludge and production of quicklime	Burning temperature: 1 100 °C Capacity: 100 – 360 t/day
By-product production (crude tall oil and crude turpentine)		
Soap collector	Preparation of the sulphate soap Separation of the liquor	Temperature: 60 – 70°C Pressure: Atm
Reactor for the (continuous/batch action)	The carrying through of the decomposition of sulphate soap with sulphuric acid.	Capacity: 17,5 m^3/h Temperature: 100 - 105 °C Pressure: – Atm
Separator	Separation of oil	Capacity: 17,5 m^3/h Temperature: 90 °C Pressure: – Atm
Oil washer	Washing of oil Settling Separation of oil from the solution	Temperature: 80 – 95 °C Pressure: – Atm Settling time: – h
Vacuum dryer	Treatment of oil in order to remove moist and impurities	Temperature: 80 – 90 °C Pressure: 0,08 MPa
Decanter (Florentina)	Settling and fraction separation	Volume: 0,63 – 25 m^3 Settling time: 17 – 60 min
Rectification column	The separation of fractions (the production of commercial turpentine, tall oil, colophony (wood resin) and fatty acids)	Volume: 18 – 62 m^3 Number of plates: 40 - 123
1) The technological characteristics depend upon the capacity of the line		

A description of the environment protection equipment for recovery of chemicals is given in table 2.12

Table 2.12 A description of the environment protection equipment for recovery of chemicals during the production of sulphate pulp

Name of equipment	Application of the equipment	Technological characteristics[1)]
1	**2**	**3**
Cleaning of heavily polluted condensates		
Stripping column	The blowing, by steam, of sulphur containing gases and methanol from the heavily polluted condensates of the evaporation and cooking units.	Plate-type column Degree of cleaning: 80 - 90 % Number of plates: 24 Capacity: 133 -175 t/h Volume: 70 m^3
Condensate heat exchanger	Heating of the condensate before feeding it to the stripping column	Type shell and tube Heat exchange surface: – m^2
Distillation column	Separation of methanol	Plate-type column Quantity of heads: – Design temperature 159°C Design pressure: 0,5 – 0,1 MPa
Causticization		
Slaker scrubber	Trapping of dust particles of alkaline aerosol	Cleaning efficiency: 50 %
Bag filter of the aspiration unit for the unloading of lime into the pit		Cleaning efficiency: 93 %
Lime regeneration		
Jet gas washer (Venturi scrubber)	Treatment of flue gases	Cleaning (dust removal) efficiency: no less than 85 - 98 %

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Lime recovery		
1	**2**	**3**
Electric filter of the flue gases	Flue gases treatment	Cleaning efficiency: 99 – 99, 9 %
Production of by-products		
Scrubber for the treatment of gases	Treatment with the removal of sulphur compounds (DMS, DMDS, MM, H_2S) of the exhaust gasses from the soap decomposition reactor.	Volume: 8 – 56 m^3 Cleaning efficiency: 50 – 98 %
Bag filter of the aspiration unit for the unloading of lime into the pit		Cleaning efficiency: 50 - 93 %
[1)] The technological characteristics depend upon the capacity of the line		

The Sulphite Pulp Production process

The sulphite pulp production volume is lower than the sulphate pulp production volume. Sulphite pulp is mainly used for the production of paper and not as a commercial product for the pulp market.

Compared to sulphate pulp, sulphite pulp has a number of advantages: a higher yield from the wood, better features for bleaching and milling, better optical and deformation quality, a higher whiteness, which is why it may be used for the production of high-volume types of paper (e.g. newsprint) without bleaching, and there is no release of odorous gases to the atmosphere.

The sulphite pulp production process is characterized by a high flexibility as compared to sulphate pulp production. The use of the sulphite method of production allows for the manufacture of pulp with a wide spectrum of properties, including those needed for chemical processing and the production of viscose fibers and thread, as well as the production of special purpose goods.

The classification of sulphite processes of pulp production based on pH is shown in table 2.13.

Table 2.13 – the Main Sulphite Processes, used during pulp and paper production

Process	pH	Base	Active reagent	Cooking temperature, °C	Pulp yield, % of the stock BDS	Comment
Acid (bi) sulphite	1-2	Ca^{2+} MG^{2+}. Na^{+}	$SO_2 \cdot H_2O$ H^{+},HSO_3^{-}	125 – 143	40-50	Soluble pulp, sanitary and hygienic, letter and printing paper, special paper
Bisulphite	3-5	MG^{2+}.	HSO_3^{-}, H^{+},	150 – 170	50-65	Letter and print paper, sanitary and hygienic paper
Neutral sulphite, NSSC	6-9	Na^{+}, NH^{4+}	HSO_3^{-}, SO_3^{2-}	160 – 180	75 – 90	Middle layer of corrugated fibreboard, semi-chemical pulp
Alkaline-sulphite	9 – 13,5	Na^{+},	SO_3^{2-}, OH^{-}	160 – 180	55-60	Pulp as sulphate pulp

2.4.1 The Technological Process of Sulphite Pulp Production

In Figure 2.5 a block-scheme of the production of sulphite pulp is shown, as well as the input raw material and energy and the exit production of by-products and main products from a sulphite plant, and, also, the emissions.

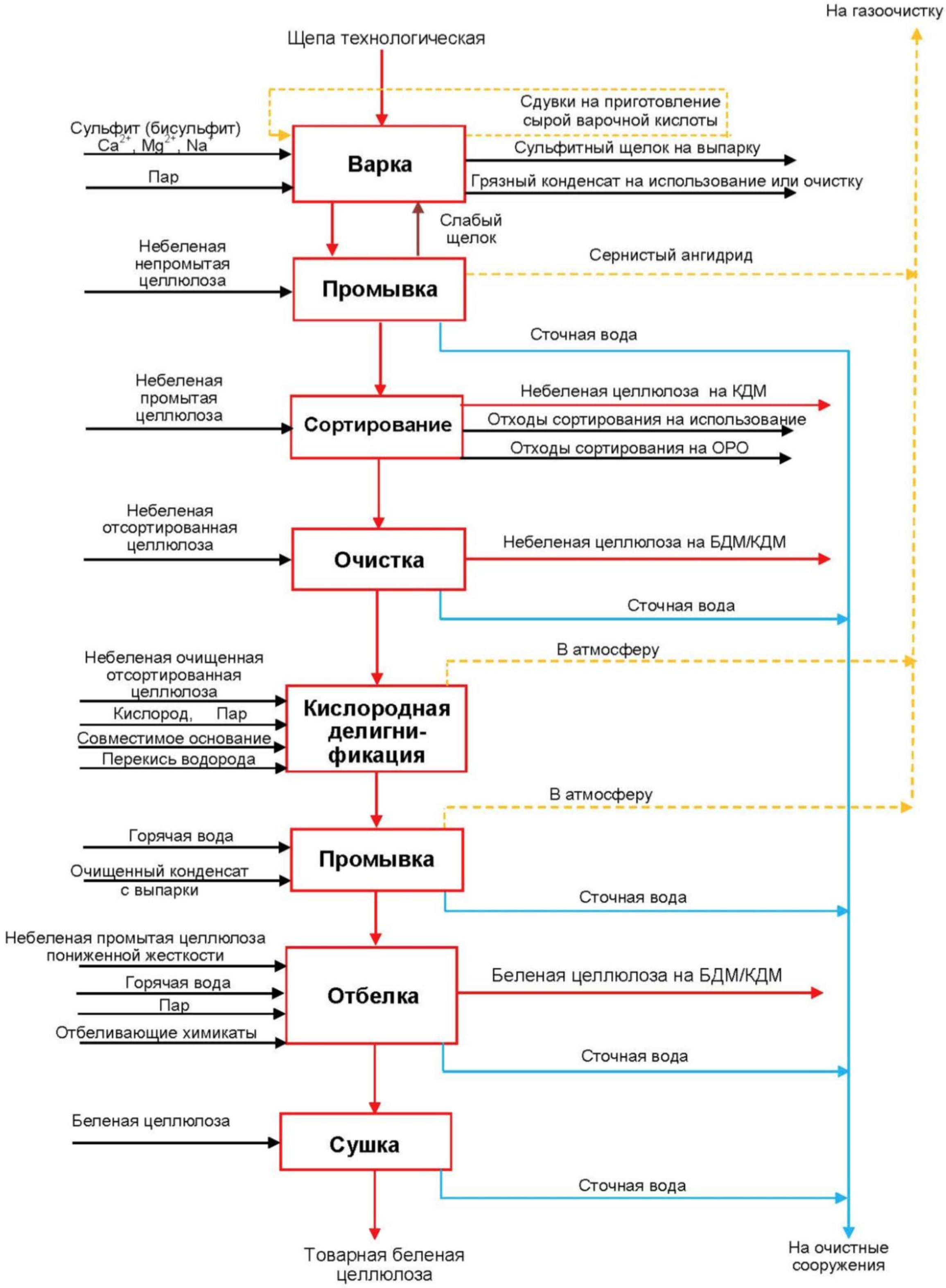

Figure 2.8 – A block scheme of the technological process of sulphite pulp production: The red central blocks: cooking, washing, screening, treatment (cleaning), oxygen delignification, washing, bleaching, drying.

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The sulphite cooking process is based on the use of water solutions o f sulphur dioxide (SO_2) and bases – calcium, sodium, magnesium or ammonium. The specific traits of the used base will influence the choice of the method of chemicals and energy recovery as well as water use. The used sulphite liquor may be used for the production by-products, i.e. technical lignosulphonates.
The hydrocarbons contained in the liquor from the acid sulphite cooking process may be turned into ethanol and yeasts by biochemical processing.

2.4.2 The Processes and Technologies Used.

The production of sulphite pulp consists of three main blocks:

- the production of pulp fiber
- the recycling of sulphite liquor
- The chemicals and energy recovery (with the exclusion of the cooking based on calcium, during which this recovery is impossible, however the used sulphite liquor may be evaporated while its components may be used for other purposes). Since the recovery based on sodium and ammonium (or mixed) is unfavourable economically, its suitability is considered individually for every concrete plant;
- Wastewater treatment at off-site wastewater treatment plants

As is the case with sulphate pulp production, some auxiliary systems, as for instance, the processing of waste, the production of bleaching chemicals and the generation of additional energy are fused with the main production shops. In many ways, the process of producing sulphate and sulphite pulp are similar, however differing as to the on-site and off-site measures in order to lower the level of emissions to the environment. Due to some similarity of the processes we will describe only a few of the production stages of the production of sulphite cooking. As for the stages that are identical to the production of sulphate pulp, we will be provide the reference links to the corresponding sections:

- The preparation and processing of wood (timber) (see item 2.1);
- The washing, screening and treatment of unbleached stock (see item 2.1.5);
- Screening and treatment of bleached stock (see item 2.1.8).
- Drying (only for commercial pulp) (see item 2.1.9).

As for these section we will only mention some distinguishing features, making sulphate and sulphite pulp production differ from each other. The existing differences cause different levels of emissions, and also some differences in the processes used in order to reduce these emissions. The main process stages of cooking using sodium bisulphite, ammonium and magnesium are shown in figure 2.9.

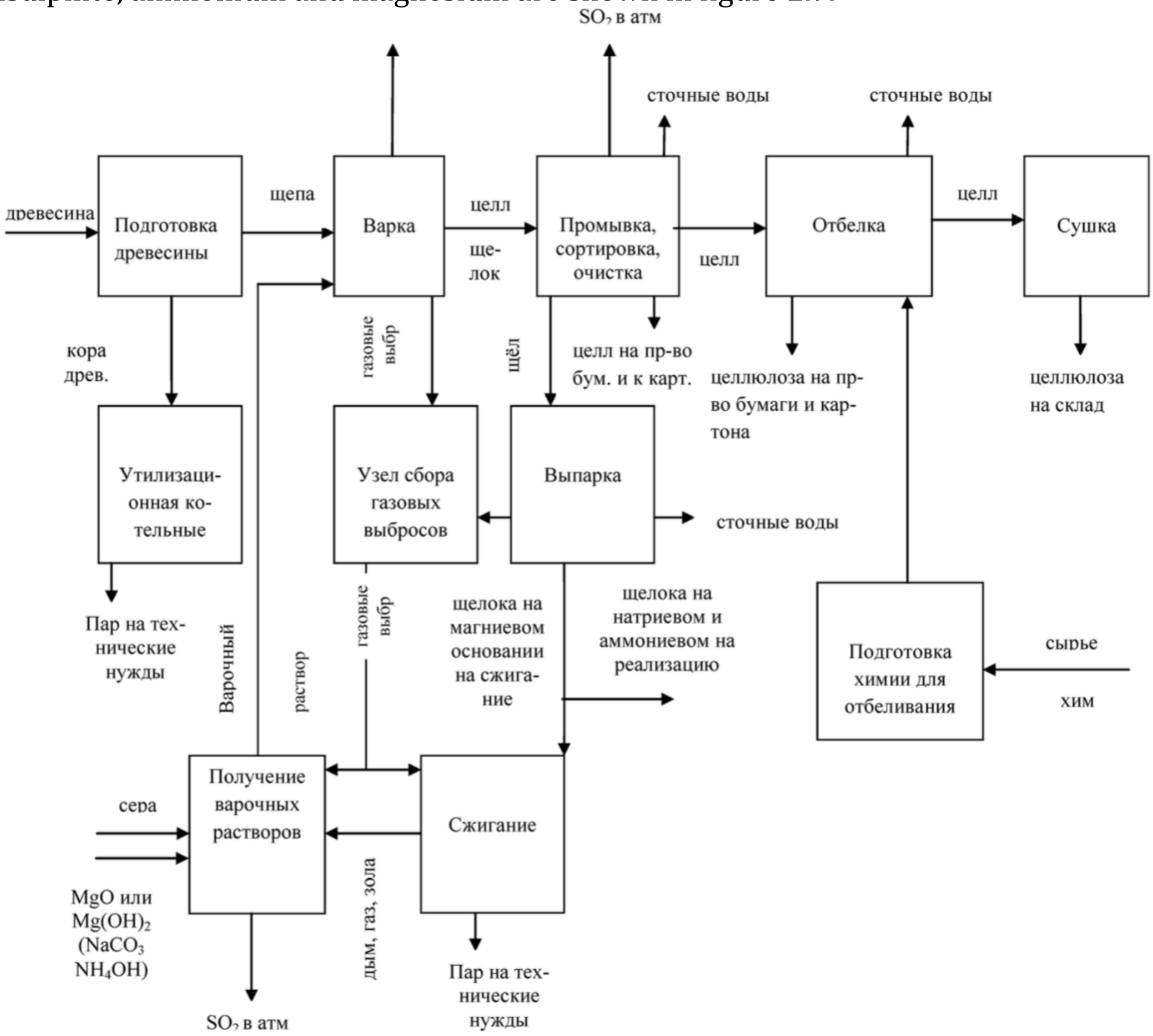

Figure 2.9 The main process stages of the production of bleached sulphite pulp with the use of sodium bisulphite, ammonium and magnesium

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Table 2.13.1 Description of the process of sulphite pulp production

Input	Stage of the process (sub-process)	Output	Main process equipment	Emissions
1	2	3	4	5
Conditioned chip Sawdust, pin chips. Knots Undercooked pulp Sulphur Base Steam Electrical energy	Cooking	Unbleached pulp Sulphite liquor Technical lignosulphonates	System for the loading of chip into the digester Digester Gas cleaning equipment Evaporator Dryer apparatus System for the burning of the evaporated liquor (MRB Magnesium recovery boiler)	Emission to air (of sulphur dioxide), Discharge to the production waste water disposal system: (suspended matter, COD)
Unbleached pulp. Electrical energy	Washing	Unbleached pulp.	Blow tank Vacuum filter Pumps	Emission to air (of sulphur dioxide), Discharge to the production waste water disposal system: (suspended matter, COD)

Input	Stage of the process (sub-process)	Output	Main process equipment	Emissions
1	2	3	4	5
Unbleached pulp Electrical energy	Screening	Unbleached conditioned pulp. Knots and undercooked pulp Fine screening waste	Knot and undercooked pulp trap. Knot and undercooked pulp washer Screening Waste washer Refiner machine for the grinding of waste. Vortex cleaners for the separation of sand	Emissions to air,. Discharge to the production waste water disposal system (suspended matter, COD) Mineral waste Knots and undercooked pulp Fine screening waste
Washed unbleached pulp Bleaching chemicals (chlorine, chlorine dioxide, oxygen, hydrogen peroxide, caustic soda, sodium hypochlorite, sulphurous acid, fresh, warm and hot water. Steam Electrical energy	Bleaching	Bleached pulp	Multi-step basin for the storage of pulp before bleaching. Bleaching towers Vacuum filters Chemicals mixers using steam. MS pumps Gas washing scrubber for chlorine-containing gasses	Emissions to air: chlorine (chlorine dioxide). Wastewater to the production wastewater network: suspended matter, COD, AOX

Input	**Stage of the process (sub-process)**	**Output**	**Main process equipment**	**Emissions**
1	2	3	4	5
Bleached pulp Recycled scrap Steam Recycled water Fresh water Sodium hydroxide Sulphurous acid Electric energy Dilution water	Screening	Washed bleached pulp Waste from screening Recycling water	Pressure screen Vortex cleaners Filter for fiber trapping	Discharges into the production wastewater disposal system, suspended matter, COD
Bleached pulp Steam Recirculated water Fresh water Electrical energy	Formation Pressing Drying of the pulp sheet.	Pulp on reels Scrap (cut-offs and during breaks) Recycling water Condensate	Stuff box Formation station Pressing station Drying station Reeling-up stand Hydrobeater (pulper) for scrap	Discharges into the production wastewater disposal system, suspended matter, COD Emissions to air: wet air mixture, paper dust.
Pulp sheet Fresh water Electrical energy	Cutting and packing	Commercial pulp Scrap (shavings, sheet scrap)	Sheet cutting machine Packaging line	Emissions to air (paper dust)

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Production of ClO_2 by the method of Metison and NR-A				
Chemicals: $NaClO_3$, H_2SO_4, SO_2, using Metison or H_2O_2, using the HP-A method Technical air	ClO_2 generation	ClO_2 gas, by-product: solution of H_2SO_4, Na_2SO_4	Primary reactor. Secondary reactor. Stripper column Gas cleaning column	None
ClO_2 gas. Chemicals: NaOH solution Cooling water	Production of water solution of ClO_2 (absorption)	ClO_2 solution. Residue gases By-product: sodium hypochlorite (NaClO) solution	Absorption column Chemical scrubber	To air: Cl_2, ClO_2
Production of ClO_2 using the integrated Chemetics technology				
Electrical energy Chemicals: Chlorate-chlorine solution ($NaClO_3$, NaCl), Sodium hydroxide (NaOH)	Production of sodium Chlorate ($NaClO_3$) by electrolysis	Sodium Chlorate ($NaClO_3$). H_2 gas By-product: sodium hypochlorite (NaClO)	Chlorate reactor Electropolysers Degasser Hydrogen scrubber	To air: Cl_2
Chemicals: H_2, Cl_2, Demineralised water	Hydrochloric acid, HCl, synthesis	Hydrochloric acid, HCl,	Hydrochloric acid, HCl, synthesis reactor, Scrubber for residue gasses	To air: Cl_2, HCl

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Input	Stage of the process	Output	Main process equipment	Emissions
1	2	3	4	5
Production of ClO_2 using the integrated Chemetics technology				
Chemicals: Sodium chlorate $NaClO_3$, hydrochloric acid (HCl) Sodium hydroxide (NaOH). Cooled water Technical air	Generation of chlorine dioxide (ClO_2)	Chlorine dioxide (ClO_2) solution. By-product: sodium hypochlorite (NaClO)	Chlorine dioxide (ClO_2) generator. Evaporator. Chlorine dioxide (ClO_2) absorber Hypochlorite tower	To air: Cl_2, ClO_2

2.4.3 Cooking and Delignification of Unbleached Pulp

When producing ordinary unbleached pulp, lignin is separated from the wood by the cooking solution, mainly containing magnesium (sodium, calcium or ammonium) bisulphite as the active component as well as sulphur dioxide if acid sulphide cooking is performed. At the cooking stage the wood chips and the cooking solution are loaded into the digester, where the cooking is performed under conditions of elevated temperature and pressure. When the desired content of residual lignin is reached (measured as a Kappa number), the content of the batch digester is blown off to the blow tank or is washed away to the wash tank and the cooking cycle is repeated. The cooking may also be performed in a continuous digester (the principles of its functioning are the same as those described in item 2.2). If sulphate cooking is performed, the Kappa number of the pulp varies between 14 – 22 for softwood and 10 – 20 for hardwood species. The Kappa number may be lowered also after this point with the aid of oxygen delignification before the bleaching. When applying the two-stage sulphite cooking, the Kappa number may be reduced to 10 or even lower. The cooking may be continued even further if it is necessary to produce special soluble pulp, but this will be accompanied by a substantial loss in yield.

From the blow tank and the washout tank, the stock is delivered to the screening unit, and thereafter to the washing unit (in a number of schemes the washing unit precedes the screening).

2.4.4 Screening and Washing of Unbleached Pulp

After the cooking the stock has been washed in washers consisting of vacuum filters, pressurized drum filters or double chest drum filters, it is screened in knot traps, and, usually, in centrifugal screens, working under pressure after which it is cleaned in centricleaners. The aim of the screening and the cleaning of the stock is the separate out undercooked stock, knots, shives, shives and mineral inclusions (sand) from the main pulp flow (see 2.3). The used sulphite liquor, containing the residues of cooking chemicals and dissolved components of wood, are separated from the pulp in a counter-flow washer which produces a liquor that is transferred to evaporation and drying. If economically viable, the liquor may be transferred to the recovery boiler for the recovery of chemicals and heat. The screening waste, mainly consisting of knots are dewatered and burned in the bark boiler or they may be used in the production of wrapping paper or cardboard. After screening the pulp may be bleached.

2.4.5 Oxygen Delignification

In Europe there are a number of sulphite plants that use this technique, thereby lowering the Kappa number by approximately 10 units. The restricted use of oxygen delignification is explained by the fact, that as a result of the easy bleachability of sulphite pulp even without oxygen delignification, in order to attain a high whiteness, only a short bleaching scheme is necessary. There are even other obstructions. The base used during oxygen delignification needs to be compatible with the base used during the cooking, i.e., in the case of magnesium bisulphide cooking, then for the purpose of oxygen delignification, the alkaline agent should preferably be MgO. Only in this case the organic substances dissolved during the oxygen delignification may form a part of the liquor produced in this process and transferred to the general system for chemicals recovery, without any dramatic changes in the production technique. At one plant in Germany this technique was used with a slight loss in pulp brightness. In this case it was shown that it was possible to concentrate the fluid from the oxygen step by ultrafiltration and to burn the concentrate in the bark boiler. The lowering of the COD of the effluents after the oxygen delignification was approximately 50 %.

2.4.6 Bleaching, screening, cleaning and drying

In Europe, at the plants producing sulphite pulp the bleaching is conducted without the use of molecular chlorine, and, at many plants, even without the use of chlorine dioxide, i.e. the bleaching is done without any chlorine compounds whatsoever (TCF bleaching). Usually, as bleaching chemicals oxygen, sodium hydroxide and hydrogen peroxide are

used. EDTA is added as a complex former (0,5 – 2 kg/t)
The main schemes of the bleaching used at European sulphite plats are shown in table 2.14.

Table 2.14: Examples of bleaching schemes, used at European Sulphite plants and of the discharge of organic compounds from the bleaching unit, measured as COD

Cooking technology	Kappa number	Bleaching Scheme	COD (kg/t)	Plants
Magnefite process	21-23	EOP-Q-EP-EP (HC)	90-115	Gratkorn, Austria
Magnefite process	21-23	EOP-Q-EP-EP	100-120	Plant 2, Sweden
Acid sulphite process	14-16	EOP -EP (HC)	50-60	Plant 3, Germany
Acid sulphite process	12-15	EOP-Q-EP (HC)	40-60	Plant 4, Germany
Acid sulphite process	11-13	EOP-Q-EP-EP	35-45	Plant 5, Austria

Generally, after the bleaching, the final screening of the pulp is made, the waste of which is burned in a kiln. The pulp produced as commercial pulp is dried, whereas the remaining stock is transferred to the plant for the production of paper for various purposes. The sulphite pulp producing plants are generally integrated companies (works), producing paper on site.

2.4.7 Chemicals and Energy Recovery System

The recovery of cooking chemicals is carried out mainly during magnesium based cooking. The degree of chemicals recovery (sulphur and magnesium) various in a range of 90 – 95 % (taking into account the level of waste liquor bleeding of 98 – 99,5 %).
The recovery of chemicals used in the production of unbleached pulp consists of the following main elements:

- Evaporation of the liquor produced in the system for unbleached pulp washing

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- The burning of concentrated liquor (biofuel) in the recovery boiler, which produces a substantial amount of steam, and – in a number of cases – electrical energy.
- In the burning process solid magnesium oxide (ash) and gaseous sulphur dioxide are formed. The magnesium oxide is separated from the flue gases, mainly in electrofilters, and, by being dissolved in water, are turned into a magnesium hydroxide suspension
- This suspension is used for the absorption of sulphur dioxide from the flue gases, arriving from the recovery boiler as well as from the relief gases from the cooking digesters and from the gases from the washing and evaporation apparatuses in the multi-stage Venturi plant (usually 4 steps). The solution produced in this way, mainly containing magnesium sulphite is cleared (by settling or filtration) and is resaturated by sulphur dioxide produced either during the incineration of elemental sulphur from the sulphur kiln, or during the addition of liquid sulphur. The newly produced cooking acid is transferred to the cooking plant after the separation of suspended matter.

A general representation of the circulation of chemicals is shown in figure 2.10, illustrating the main steps of the process and their purpose.
As a result of the recovery of the cooking chemicals in the recovery kiln steam is produced. This steam is transferred to turbines with counterpressure, producing electrical energy.

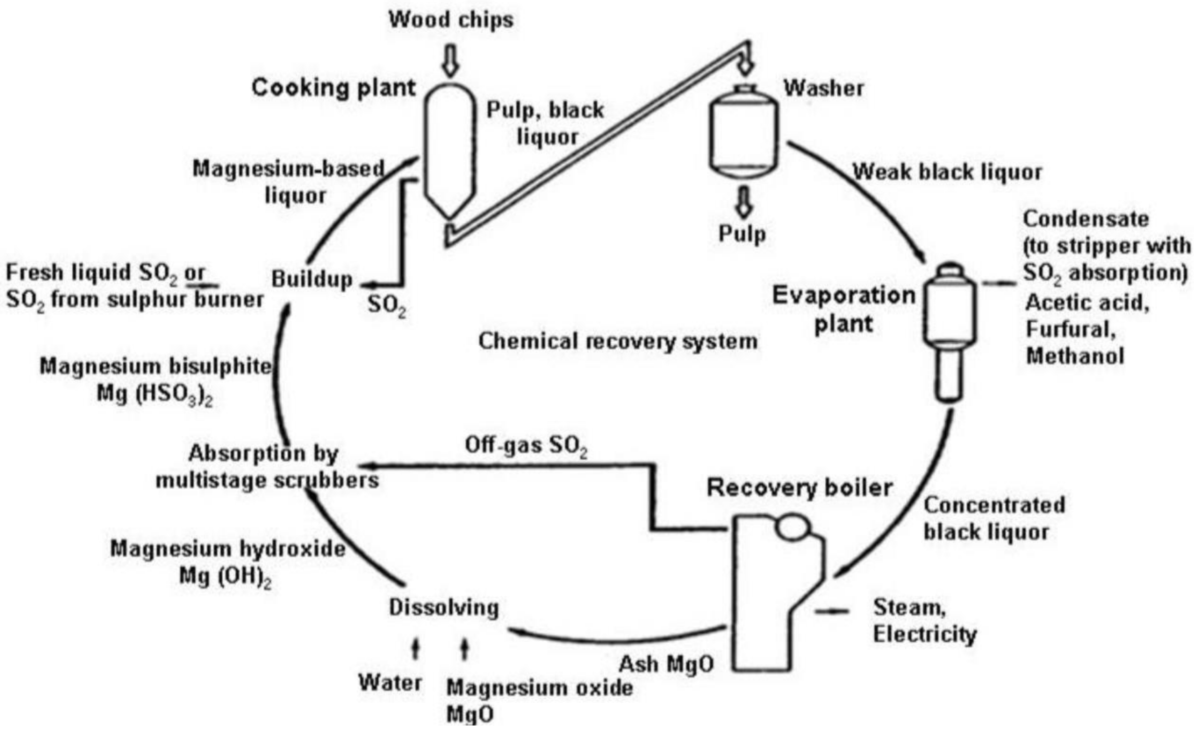

Figure 2.10 The recovery cycle of a magnesium based sulphite pulp production plant

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2.4.8 The Magnefite Process

During the Magnefite process, the pH level is higher (pH = 3-5), than during the bisulphite process, which is carried out at pH 1 – 2. This leads to milder conditions of the cooking with elevated strength properties of the pulp and s slightly higher yield as compared to the acid bisulphite process. In Europe, for both processes magnesium is used as the main base. There are two main technical differences that have to be taken into account. The Magnefite process, during the production of liquid it is possible to attain a pH of 4 without any surplus SO_2 in the fresh cooking solution. As a result of this, there is no need to use a pulp solution tank under pressure. The SO_2 in the cooking liquor is in the bisulphite form, which is why the subsequent stages of the production process for the production of bisulphite pulp are similar to the production stages of the acid sulphite process. The Kappa number of the unbleached pulp for the production of paper after the Magnefite method cooking is higher then after acidic sulphite cooking – ranging from 21 – 26, whereas when using the acid sulphite method it is possible to reach a Kappa number of 12 – 26. As a result of this, the bleachability of the bisulphite pulp is somewhat lower than the acid sulphite pulp. This is why it is necessary to use longer bleaching lines, in order to attain a high level of brightness. This leads to a slightly higher magnitude of COD and BOD in the effluents after bleaching. The Magnefite process is used at four pulp and paper companies in Europe (Nymölla and Utansjö (Sweden), Hudsfos (Norway) and Gratkorn (Austria).

2.4.9 The Neutral Sulphite Semi-Chemical Pulp Production Process

Semi-chemical pulp being an intermediate between mechanical pulp and pulp with a high yield is used in the production of kraftliner and fluting paper.
At present, in Russia, at integrated works with sulphate pulp production there are two plants used for the production semi-chemical pulp using different techniques: The neutral sulphite hardwood semi-chemical pulp (NSSC) and sulphate semi-chemical pulp using green liquor.

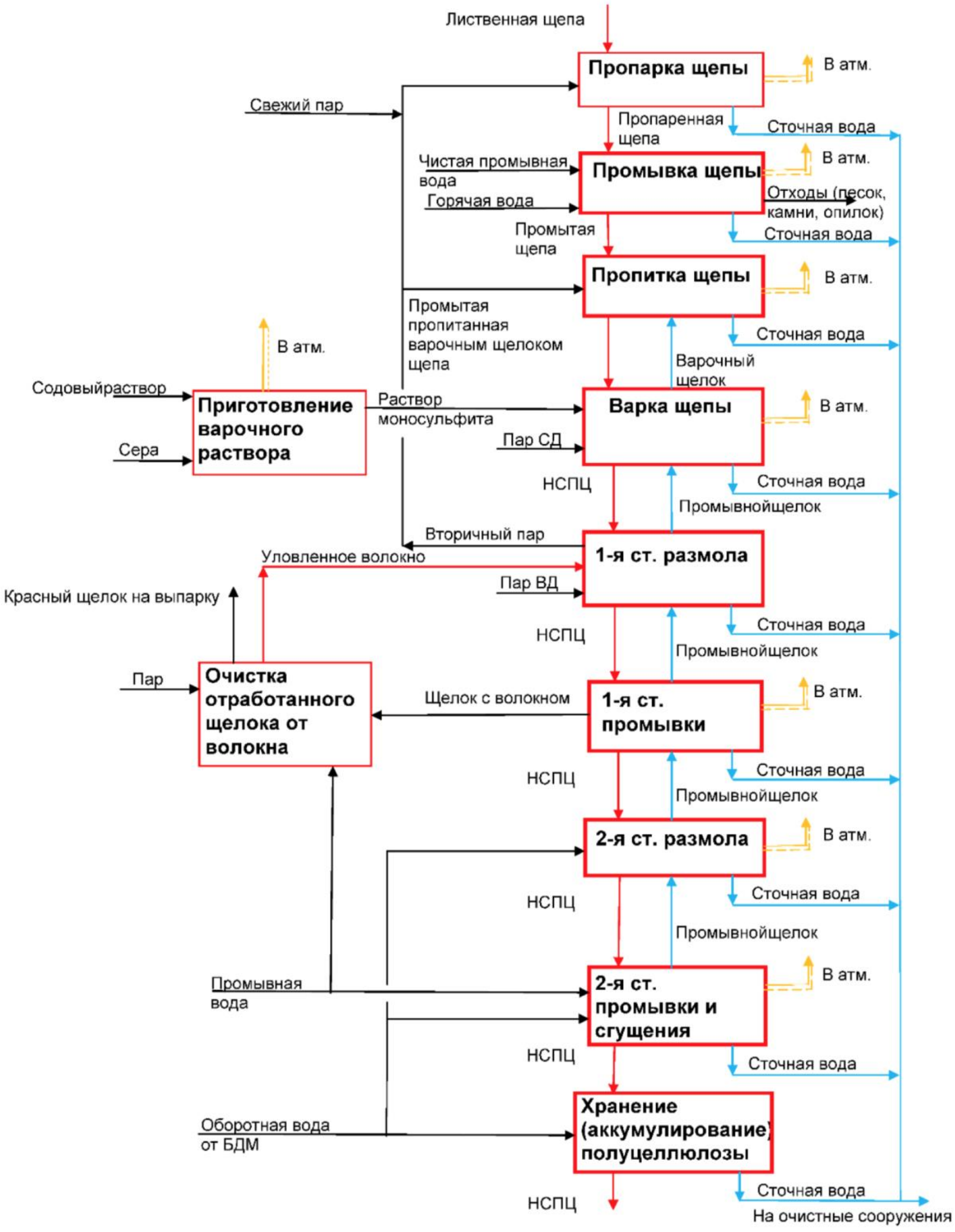

Figure 2.11 Block scheme of the process of production of neutral sulphite semi-chemical pulp.

The NSSC production process involves the combination of superficial chemical cooking and mechanical milling of the chips to produce an intermediate product with high yield

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and it also involves the steaming, impregnation and cooking of the chips, two steps of milling and washing.
The raw material is birch- and aspen wood and the cooking solution – sodium sulphite with a buffer addition (for instance calcined soda).
The NSSC yield from wood: Approximately 80 %.
The initial steaming of the chip at atmospheric pressure provides a high-quality impregnation of it by the cooking solution and promotes the increased yield of the semi-chemical pulp as well as an accelerated cooking process.
The use of milled chips after the cooking under pressure improves the properties of the fibers and provides the conditions to use a highly efficient washing equipment when washing the half-stock.
The use of modern presses for the washing of the semi-chemical pulp allows for the achievement of high efficiency of the separation of the dissolved substances from the fibers at a low consumption of washing water, while also providing a minimal escape of dissolved substances with the washed stock.
The used cooking liquor is transferred to be evaporated in order to produce commercial merchandize: technical lignosulphonates. The recovery of chemicals is not economically viable.
The main information on the neutral sulphite semi-chemical pulp production, used at present at one company in Russia, is presented in table 2.15.

Table 2.15: A description of the production of neutral sulphite semi-chemical pulp

Input	**Stage of the process (sub-process)**	**Output**	**Main process equipment**	**Emissions**
1	2	3	4	5
Soda solution Fresh water	Preparation of the cooking solution	Monosulphite solution	Reactor absorber	Discharge to the production wastewater system (SO_3, SO_4, liquor)

<table>
<tr><th>Input</th><th>Stage of the process (sub-process)</th><th>Output</th><th>Main process equipment</th><th>Emissions</th></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td colspan="5">Production of neutral sulphite semi-chemical pulp</td></tr>
<tr><td>Chips
Secondary steam
Electrical energy</td><td>Steaming of the chips</td><td>Heated chips</td><td>Chip pits
Steaming screw conveyor</td><td rowspan="4">Emissions to air (sulphur dioxide);
Discharge to the production wastewater system (COD, suspended matter)
Waste (sawdust)</td></tr>
<tr><td>Steamed chips
Hot water
Clean washing water
Electrical energy</td><td>Washing of the chips</td><td>Washed chips
Water to be transferred to treatment</td><td>Pollutants separator
Chip pits
Drying screw conveyor
Inclusions trap
Centricleaner
Waste thickener</td></tr>
<tr><td>Washed chips
Secondary steam
Cooking liquor
Electrical energy</td><td>Chip impregnation</td><td>Steamed chips impregnated by the cooking liquor</td><td>Steaming pit
Impregnation chamber of the digester</td></tr>
<tr><td>Impregnated chips
Cooking liquor (monosulphite)
Steam
Electrical energy</td><td>Cooking</td><td>Chips after cooking
Cooking liquor
Dirty condensate</td><td>Digester
Cooking solution heater</td></tr>
</table>

Input	Stage of the process (sub-process)	Output	Main process equipment	Emissions
1	2	3	4	5
Production of neutral sulphite semi-chemical pulp				
Chips after cooking fibers after the cleaning of the used liquor Filtrate of the 1st washing stage Steam Electrical energy	1st milling phase (defibration)	fiber/stock Secondary steam	Refiner (defibrator) Pressurized cyclone A system for the condensation of the steam-gas mixture	
fiber/stock Filtrate from the 2nd washing stage Electrical energy	1st stage washing	Washed stock Liquor with a content of fiber	Low concentration stock tank TwinRoll press Pulp pump	
Stock after washing Filtrate from the 2nd washing stage Washing water Electrical energy	2nd stage milling	Stock, milled to the needed degree of size reduction	Refiners	
fiber/stock Recycled water Electrical energy	2nd stage washing and thickening	Washed stock Filtrate	Intermediate concentration stock tank TwinRoll press Pulp pump	

Input	Stage of the process (sub-process)	Output	Main process equipment	Emissions
1	2	3	4	5
Production of neutral sulphite semi-chemical pulp				
Washed stock	Storage (accumulation)	Semi-chemical pulp	High concentration pulp tank	

Table 2.16: The main equipment for the production of neutral sulphite semi-chemical pulp

Name of equipment unit	**Application of the equipment unit**	**Technical and technological features** 1)
1	**2**	**3**
Steaming pit	Initial heating of the chips	Capacity: 125 m^3/h Volume: 130 m^3
Impregnation chamber of the digester	Impregnation of the chips	Equipped with vertical double screw conveyors (diameter: 2 000 mm, height: 8 000 mm)
Digester	Cooking of the chips	Capacity: 900 t/day of ADt Type: vertical with a conical body Diameter: 3 200 x 2 800 mm Height: 15 000 mm Cooking time: 20 – 30 min Cooking temperature: 165 – 170 °C
Refiner (defibrator) of the 1st milling stage	Milling of the chips into fibers	Capacity: 170 m^3/h
TwinRoll press	1st stage of washing	Capacity: m3/h Input concentration: 5 % Exit concentration: 30 %

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Name of equipment unit	**Application of the equipment unit**	**Technical and technological features 1)**
1	**2**	**3**
The main equipment for the production of neutral sulphite semi-chemical pulp		
Refiner (defibrator) of the 2st milling stage	Milling of the stock into the needed degree of size reduction	Capacity: 113 m^3/h Concentration: 30,0 %
TwinRoll press	2nd stage of washing	Capacity: 685 m3/h Input concentration: 5 %
Filters for the removal of used liquor from the fibers	Trapping of fibers from the 1st stage of washing	Capacity: 277 m^3/h Filtration surface: 13 m^2
1) the production features depend upon the capacity of the production line		

2.4.10 Soluble Sulphite Pulp (Sulphite Pulp for Chemical Processing)

In Europe, there are only a few companies producing soluble sulphite pulp. In principle, the production of such pulp is very similar to the production of sulphite production for paper production. The same chemicals as in the usual magnesium bi-sulphite process are used. This is the reason why the systems for energy and chemicals recovery are analogical. The main differences can be seen in the parameters of the cooking and bleaching processes. The aim of the cooking when producing soluble sulphite lies in the achievement of a set low level of viscosity, i.e. in the lowering of the length of the cellulose chain as well as in the full removal from the wood of hemi-cellulose and lignin.

2.4.11 Production of Technical Lignosulphonates

The sulphite liquor is evaporated in a multiple effect system (usually consisting of 5-6 bodies). The technical lignosulphonates are produced in the liquid state (with a dry matter content of the various brands no less than 46, 47 and 50%, a density of 1,2 – 1,3 kg/l) or as a powder (with a dry matter content of 76 – 96%).

2.5 The Process of Producing Mechanical Types of Wood Pulp

When mass producing paper and board the mechanical types of wood pulp are the main fiber intermediates providing the necessary physical and technical properties of the products, as well as a high profitability, environmental friendliness and a high yield per unit of the used wood raw material [3, 4].

The mechanical types of wood pulp in Russia, as is the case worldwide, are produced by two main types of equipment giving the name to the corresponding production processes:

- Pulpers (the technology of production of wood pulp from pulpwood: classical defibred pulp, defibred wood pulp (DWP) under pressure and thermodefibred wood pulp
- Refiners (the technology of producing wood pulp from chips in refiners: refiner wood pulp, thermomechanical wood pulp TMP, chemi-thermomechanical wood pulp CTMP and chemi-mechanical pulp, CMP.

The main process while producing any of these abovementioned types of pulp is the process of mechanical breakup of the wood into fibers – whether it be the milling of chips in refiners (the production of TMP, CTMP or CMP) or the process of defibration of the roundwood (pulpwood) directly in grinders (the production of SGW and PGW)

The classification of the processed used when producing various types of wood pulp is presented in figure 2.12.

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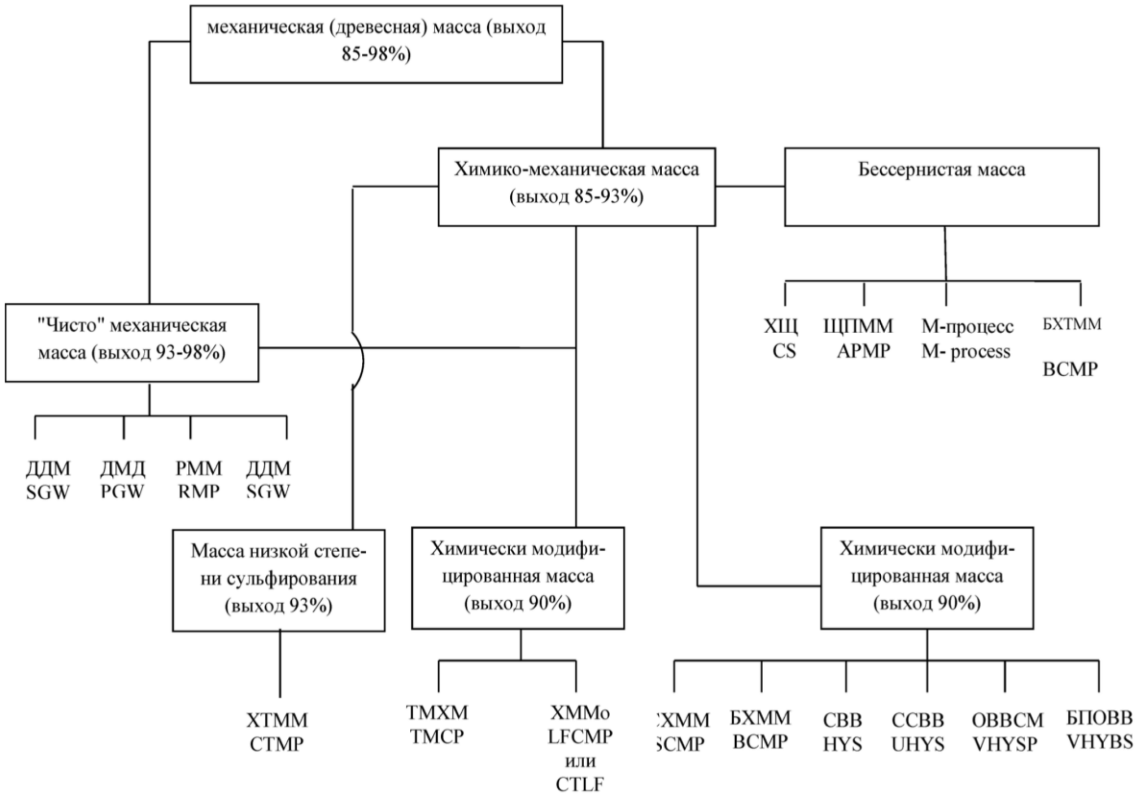

Figure 2.12 Classification of the various forms of wood pulp (from Technologiya TsBP. D 3 t. T. 1. Ch. 3.: The Production of Intermediates: Spb: Politekhnika, 2004,: C. 8)

Mechanical pulp is divided into two types (see figure 2.12).

The first type includes the various types of mechanical pulp produces through the use of chemical reagents and having a yield of 93 – 98 % (Pure mechanical pulp). Pure mechanical pulps include:
SGW, traditional defibred pulp (stone groundwood) with a yield of 93 – 98 %, produced by the abrasion of wood by defibration stones. There are pulpers of various types, chain, press, screw etc.; PGW – mechanical pulp, produced by the pulverization of wood by grinding stones under pressure at a double-press pulper (PGW – pressurized groundwood) or in the various versions of the set-up: (PGW Super, PGW-70, etc.)
PGW is mechanical pulp produced by the pulverization of wood with grinding stoned under pressure in a two-press grinder (PGW – pressurized groundwood or in the various versions of the set-up: (PGW Super, PGW-70, etc.).

RMP, refiner mechanical pulp, is an intermediate, produced as a result of mechanical processing of chips in disk mills at atmospheric pressure
TMP, thermomechanical pulp, is produced by thermo-hydraulic processing (100...300 kPa, T = 100 … 130 °C) and a chips grinding in 1 – 3 stages in a disk mill, the size reduction is accomplished under pressure.
The second type of mechanical pulp includes various types of chemi-mechanical pulp, i.e. mechanical pulp produces in the presence of chemical reagents. The mechanical processing of the wood raw material (milling) is the main operation during the production of these types.
The chemi-mechanical pulp in turn is subdivided into four types.
1. Pulp produced through the ”light processing of the chips with chemical reagents (up to 10 % of the mass bone-dry wood).
CTMP stands for chemi-thermomechanical pulp produced through the simultaneous chemical and thermo-hydraulic processing and milling of the chips in two stages under pressure.
2. Chemically modified pulps includes the intermediates or their separate fractions, subjected to chemical reagents:
TMCP stands for thermomechanical Chemi pulp , produced by the addition of reagents after the 1st sage of milling under pressure, during the milling process or after the milling.
LFCMP, long fiber chemi-mechanical pulp or CTLF, chemically treated long fiber – pulp from screening waste of for long-fiber fractions of all types of mechanical pulp.
The intermediate products production technology consists out of the separation of screening waste (long-fiber fractions) of mechanical pulp, the milling and processing of it at a temperature of 80 – 180 °C by sodium sulphite.
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3. the Chemi-mechanical pulp of high degree of sulphuration (CMM), produced by intensive processing of chips with chemical reagents (at a consumption of 10 … 1% or more). The grinding is performed at atmospheric pressure in two stages; the specific energy consumption when producing CMM is, generally, above 1 000 kW/t;
SCMP, sulphonated chemi-mechanical pulp; VHYBS, very high yield bisulphite
BCMP, Bisulphite chemi-mechanical pulp
HYS, high-yield sulphite, produced when carrying out intense processing of the chips with bisulphite.
UHYS: ultra-high yield sulphite
VHYSP: Very high yield sulphite pulp
4. sulphur-free chemi-mechanical pulp, produced without the use of sulphur:
Alkaline peroxide mechanical pulp, APMP; this intermediate product is produced by a one, two or three stage processing of the chips bye an alkaline solution of hydrogen peroxide and milling; as wood raw material chips from hardwood and softwood may be used and also a mixture of the both; the M-chip bleaching process as well as the BCMP – bleaching CMP processes, very similar as to the technology and equipment needed to eh production of APMP, as wood raw material hardwood raw material is used.
The CS, the cold soda method, mainly used when processing hardwood raw material, the chips is impregnated by soda at a temperature lower than 100 °C at atmospheric pressure, the yield being 85 – 90 %.
The main equipment, raw material and production yield and fields of application of the abovementioned intermediate products are listed in table 2.17.

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Table 2.17 The main types of equipment, raw material and chemicals for the production of mechanical pulp, the yield and field of application

Type of pulp	**Main equipment**	**Raw material and chemicals**	**Yield, % of bone-dry wood**	**Field of application**
PGW and PGW-P	Defibrator	Spruce and fir	95 – 95 %	Printing and letter paper, newsprint
TMP	Groundwood refiners (disk mills) impregnation chambers	Spruce and fir	93 – 95 %	Printing and letter paper, newsprint, cardboard boxes
CTMP, BCTMP	Groundwood refiners (disk mills) impregnation chambers	Mainly spruce, but also aspen and birch; NaOH, SO_2 and H_2O_2	90 – 93 %	Printing and letter paper, toilet paper, top-brand cardboard boxes
CMP	Groundwood refiners (disk mills) impregnation chambers	Spruce, fir, aspen and birch	80 – 92 %	Printing and letter paper, top-brand cardboard boxes

The main stages of the production of mechanical pulp are shown in fig. 2.13.

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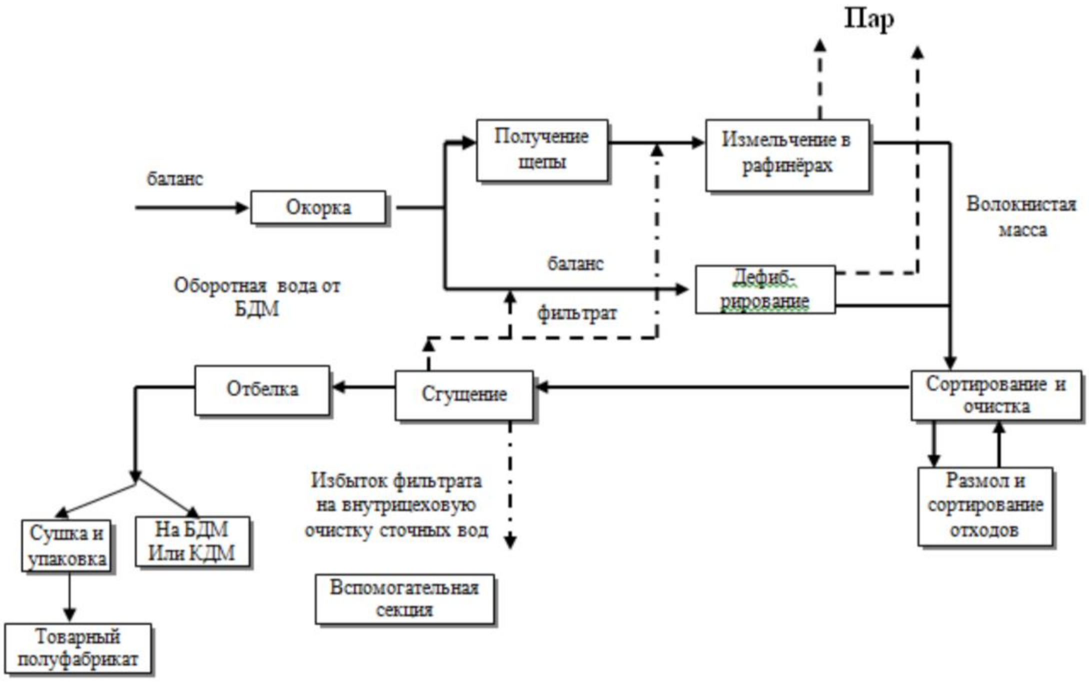

Figure 2.13 The main stages of mechanical pulp production

Thus, there are two main processes by which mechanical wood fiber pulp is produced:
In the course of the first of these:

- When producing SGW, stone-groundwood or PGW, pressurized groundwood;
- The fibrous pulp is produced as a result of the forcing of the logs towards a rotating cylindrical stone at the simultaneous feeding of waster to the zone of the rotation of the stone. During the second process the refiner mechanical pulp (RMP) and thermomechanical pulp (TMP) is produced in the process of milling (refining) of wood chips between the refiner discs. The mechanical action on the wood in the process of producing pulp by defibration is achieved by the abrasive surface of the pulper stone, the sharp-edged teeth of which plays the role of knives of the steel disk of the refiner in the second process.

The properties of the pulp may be affected by an elevated temperature of the process and, in the case of using the refining, the chemical action on the chips. Both factors call for a high-energy consumption. By doing so, the content of pollutants in the effluents increases as a result of a lowering of the pulp yield. The Chemi-thermomechanical process of pulp production CTMP, during which the wood, before being milled is plasticized (especially the intercellular lignin) with the use of chemi-

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cal reagents, usually are referred to as chemi-mechanical (or mechano-chemical) processes, since the linin in this case is not dissolved as in the process of producing pulp, but is merely plasticized with a breakup of certain bonds in its macromolecule.
The fibrous pulp is used in the production of paper and cardboard. The main goal of the exchange of a part of the pulp by such pulp, for instance, in the composition of printing paper is the lowering of the consumption of the expensive pulp, which allows for the substantial lowering of production cost of paper, but also the increase in the coefficient of opacity and its printing properties.

2.5.1 The SGW, Stone-groundwood Production Process

The SGW involves a fiber production line, screening and auxiliary systems, i.e. storage of chemical reagents and steam and energy production.
The main processes of SGW production are shown in figure 2.14. The stone-groundwood production is usually combined with the production of paper, which is why the stock is usually not dried.

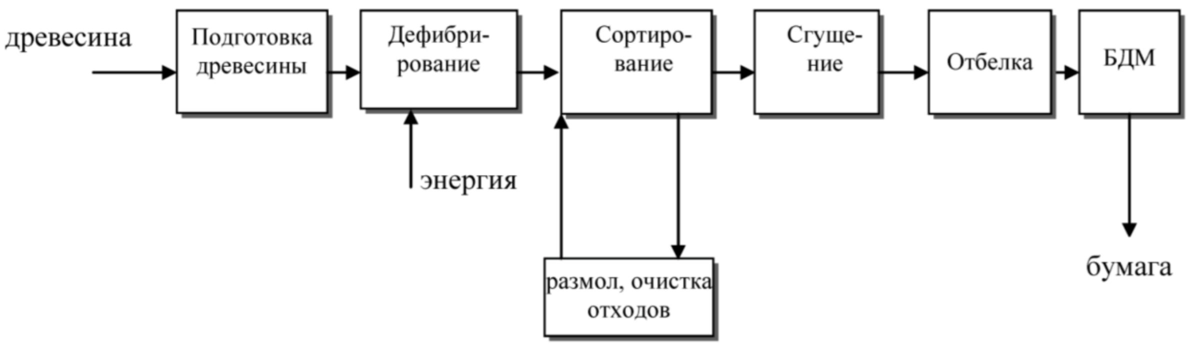

Figure 2.14 The stone-groundwood production process

Wood =>wood preparation=>Defibration (energy added)=>screening (circuit of screening=>waste treatment=>screening)=>thickening=>bleaching=>Paper machine=>paper

Due to some similarities of the described processes, we have described only some of the characteristic technological stages of the production of mechanical pulp. As for the stages that are identical to the production of sulphate pulp, links are given to the corresponding sections:

- Wood preparation and processing (see item 2.1.1 – 2.1.3).
- Screening and treatment of unbleached pulp (see item 2.1.5).

In the context of these sections only a few differences between sulphate and mechanical pulp production are indicated.

2.5.1.1 Pulpwood Defibration

The initial grinding of the wood into fiber is carried out in grinders, in which the logs are pressed against rotating abrasive stones. In the process, the woods fibers must be parallel to the rotation of the stone. The produced pulp has a concentration of about 2 %. Usually, ceramic stones are used, which have to be "dented" by a special device for the restoration of the needed cutting properties of the surface of the stone.
A large part of the energy used in the milling process is transformed into heat. The wood is heated, and in the absence of the needed quantity of waster, lignin is softened, and the fibers are freed in the spot of the contact of the wood with the stone. The abrasive stones are cooled and cleaned from fibers having been caught between the grains of the abrasive surface, by water, which is also used in the milling process as well as for the transfer of the stock to the subsequent processing stages. The presence of water in the process is important, since it promotes the diversion of heat from the defibration zone equal to its distribution, the wood plasticization in the contact zone with the stone as well as to the decrease in friction between the fibers.
The specific energy consumption (in kWh/t) (SEC) in the wood pulp production process is an important parameter. Thus, for instance, the increase in SEC is always connected with an increased strength of the wood pulp, however also connected with a higher degree of size reduction.
The necessity of a higher strength of the mechanical pulp types is a result of the further perfection of the ordinary process of defibration. A production process for the production of pressurized groundwood PGW-P has been developed, where the milling is performed at an elevated pressure (up to approximately 0,3 MPa).
This allows for the application of a process, during which a temperature of the recirculated water of 95 °C is attained, whereas the temperature of the defibration bath is 125 °C. A more intense plasticisation of the lignin due to the impact of the high temperature gives rise to a pulp with improved properties (higher strength); however, the technical and financial problems are increased in the process. When the pulp is decompressed, low-pressure steam used mainly for the heating of water is formed.
Another relatively cheap way of producing wood pulp with enhanced properties is the thermodefibration process, during which the heat loss as a result of water evaporation from the defibration zone is minimized through the

2.5.1.2 Screening and Treatment

In the pulp produced by a mechanical method, there is a certain content of unwanted components, such as large, insufficiently ground fragments of wood and shives. The latter need to be removed since they lower the strength and quality of printing paper. The screening includes a few stages, needed for a fuller separation from the pulp of relatively large fragments and shives, refine (grind) them and, after additional screening return them to the main flow of screened pulp, in order to minimize the quantity of final waste. The removal of large particles is easy, however the removal of shives (bundles of fibers) calls for more complicated equipment. The shives content in unscreened wood pulp may reach 5 %, depending on the type of process used. The screening scheme and treatment of the wood pulp, intended for production of high quality paper and board production is described below. When there are less stern requirements to the quality of the wood pulp, the screening scheme may be less complicated.
Large inclusions are removed from the flow of wood pulp with the aid of flat vibration screens, with vibrating perforated lamellae. The removed large fragments are milled in disintegrators and, together with the pulp from the general flow it is forwards to the first stage screening, performed in centrifuge screens wit cylindrical perforated sieves. The main pulp flow, after being screened, is thickened and accumulated in a basin, from which it is fed to the second stage screen, from which the good pulp is mixed with the main flow before the first stage screen, whereas the waste from the second stage screen is milled in a disk mill and fed to the waste screen. The good pulp from this screening procedure after being cleaned in centricleaners is united wit the main flow of screened pulp (before it will be thickened), whereas the waste is return to be milled a second dime (refined) in a disk mill. As a result of this scheme, the screening and treatment of the pulp it is possible to separate out all high-quality fibers from the waste, before it would be disintegrated (in order to preclude it unjustifiably being damaged during milling with the waste and the increase in SEC) and all the fiber part of the shives and other relatively large fiber

fragments, and to converse it to quality fibers. The final waste of such a screening scheme is only a very small quantity of waste from the centricleaner stage. This waste is composed of non-fiber inclusions, whereas out of the wood components – shives – the presence of which is extremely unwanted in the paper grade pulp composition, since it prevents the formation of connections of the fibers in the paper sheet, leads to defects at the pressing stage, and, furthermore, a small proportion of the presence of it increases considerably the paper dirt. Depending on the type and quantity of the wood raw material, the technique and technology of defibration, the type of the used screens and the scheme of screening, the content of waste separated from the main flow to be treated may range between 5 and 30 %. In the process of production of stone-groundwood quite a substantial amount of energy is consumed, as it is used in the processes of screening, thickening and additional screening – accounting for up to 25 % of the total energy consumption.

The main equipment for the production of SGW (chain grinders)

At Russian companies, Voith V size ”2B-Europa” and Russian chain grinders of the types DTs: DTs-01, DTs-02, DTs-03, DTs-04 (see table 2.18) have been installed. The capacity of these pulpers is 40 – 45t/day for single-type and 80 t/day for twin machines.

Table 2.18 The technical characteristics of DTs type chain grinders.

Indices	**DTs-01**	**DTs-02**	**DTs-03A**	**DTs-04-1**	**DTs-06**
Main engine power kWh	2 500	4 000	2 500	3 200	1 250
Length of pulpwood, mm	1 220	1 220	1 220	1 220	1 220
Diameter of the ceramic stone, mm	1 800	1 800	1 800	1 800	1 800
Stone rotation frequency, min^{-1}	245	250	250	300	300
Stone peripheral speed m/s	23,0	23,3	23,3	28,3	23,3
Capacity in ADt, t/s	40	80	40	55	20
Mass, t	132,6	193,0	123,8	125,0	60,0

The principal model is the DTs-04-1 grinder, the characteristic properties that distinguish it from the brands used at various plants is the following: a higher peripheral speed of the stone, a high power of the main engine, a high speed of the operation chains – i.e. a powerful jet system. This provides a 35 – 40 % higher pulper capacity of the DTs-04-1 as compared to the DTs-03 and the 2B Europa at equal mass and production area surface.

2.5.2 Refiner Wood Pulps (RWP)

The aim of the process of refining (grinding) is the process of plasticisation of the lignin and the whole wood matrix in the grinding zone, the weakening of the interfibre bonds and the separation of the fibers of the chips without any unnecessary damage of the cell wall of the fibers at the needed level of their shortening.

In the mechanical pulp production process, the chips are subjected to grinding between the refiner disks. Depending on the needed pulp quality, the grinding is carried out in one, two and sometimes even in three stages. The disk knives, acting upon the chips, disintegrate them into separate fibers, fiber bundles (shives) and pieces of wood. In the process of this treatment the surface of the fibers is changed. A large part of the energy used for the disintegration (mainly used in the form of friction) is transferred into heat, which releases part of the moisture contained in the chips. In order to avoid the ignition of and also in order to dilute the pulp, cooling water is led to the grinding zone. At the exit from the refiners usually high concentration pulp is produced (25 – 50 %). A large quantity of the steam that is produced in the grinding process is usually trapped in order to be used further on.

The original version of RWP production, seldom used nowadays, involves the milling of the chips at atmospheric pressure. Due to the low temperature of the process, a large quantity of damaged fibers was produced, however the optical quality of the RWP was relatively fair. In order to improve the quality of the produced pulp the process was modified in order to increase the plasticity of the lignin of the intercellular space, the fibers in general, etc. in the grinding zone in order for the process of dissociation of the chips into fibers could proceed with minimal fiber damage. In order to achieve this, one started to apply the initial heating of the chips at an elevated pressure in the refiner. These technologies allowed for the production of RWP pulp with a high strength and a lower content of bundles, however with almost the same optical properties.

The thermomechanical process for the production of pulp provides the possibility of production of a pulp with even higher strength and a lower content of bundles. During this process both heating of the chips before grinding (steaming) and pressure in the refiner are used.
The insignificant initial chemical processing of the chips promotes an even higher plasticization of the wood and the improvement of the quality of the pulp produced in the refiner process at atmospheric pressure (chemi-mechanical refiner pulp) of under pressure (CTMP).
In the process of a deeper chemical processing and grinding at atmospheric pressure a pulp is produced wit an even higher strength than the pulp produced both from softwood and hardwood species. Such pulp, chemi-mechanical pulp (CMP) is comparable as to its properties with cellulose pulp. The characteristics of various types of mechanical pulp are listed in table 2.19.

Table 2.19: A comparison of various types of mechanical pulp and sulphate cellulose pulp.

Tree species	Spruce							Aspen	
Type of fiber intermediate	SGW	PGW	RMP	TMP	CTMP	Bleached CTMP	Bleached sulphate pulp	Bleached CTMP	Bleached sulphate pulp
Properties of the intermediates									
Yield, %	96	95	94	94	92	90	46	85	57
Stock freeness ml (Canadian Standard Method)	100	100	100	100	100	400	400	40	400
Level of grinding Schopper-Riegler Freeness Tester	(68)	(68)	(68)	(68)	(68)	(32)	(32)	(32)	(32)
Bulkiness, cm^3/g	2,5	2,6	2,6	2,7	2,5	2,7	1,3	2,0	1,4
Burst diaphragm, km	2,8	3,6	4,0	4,4	4,8	4,4	10,5	5,0	8,0
Tearing strength $mN{\cdot}m^2/g$	4,4	5,1	7,4	8,0	8,8	1,3	10,0	6,2	9,1

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Tree species	Spruce							Aspen	
Type of fiber intermediate	SGW	PGW	RMP	TMP	CTMP	Bleached CTMP	Bleached sulphate pulp	Bleached CTMP	Bleached sulphate pulp
Brightness, %	59	57	57	55	60	78	88	80	90
Opacity	97	96	95	95	94	82	68	86	72

2.5.2.1 Thermomechanical pulp (TMP)

The thermomechanical process of fiber pulp production involves a line for the production of fibers as well as auxiliary systems. The latter include, for instance, the storage of certain chemical reagents and the production of energy. The main production processes of the thermomechanical technologies are presented in figure 2.24.

Below you can find a detailed description, mainly of the characteristics of the process of production TMP, which distinguish it from the production of stone-groundwood. The screening, washing, waste treatment and the thickening of mechanical pulp is analogous the cellulose pulp processes. The bleaching of mechanical pulp is discussed in 2.5.3.

In the thermomechanical process (TMP), the washed and screened wood chips are subjected to thermal processing, after which they are subjected to grinding with the use of disk grinders, working under an elevated pressure.

A certain amount of the wood may be received in the form of chips that are a waste product of the sawmills and wood processing industries. These chips, brought in from other companies, are screened and thereafter they are transferred to storage facilities. If pulpwood with bark is used, it is subjected to debarking, after which it is turned into chips in the chopping machine. The wood for TMP production process need to be free of stones, sand and metallic inclusions or any other hard inclusions, which may lead to a higher tear or destruction of the refiner disks. This is why, for the major part of the processes for the production of TMP, any foreign inclusions are initially removed, whereas the chips are washed in a special apparatus, as a result of which polluted water is formed.

After this, the chips are steamed, after which they are ground in one or two steps at an elevated temperature and pressure. The grinding of waste is usually performed at separate refiner. A part of the organic compounds, contained in the wood, is dissolved in the water and is transferred to treatment facilities at the works for the TMP production of from the technological flow of the paper machine.

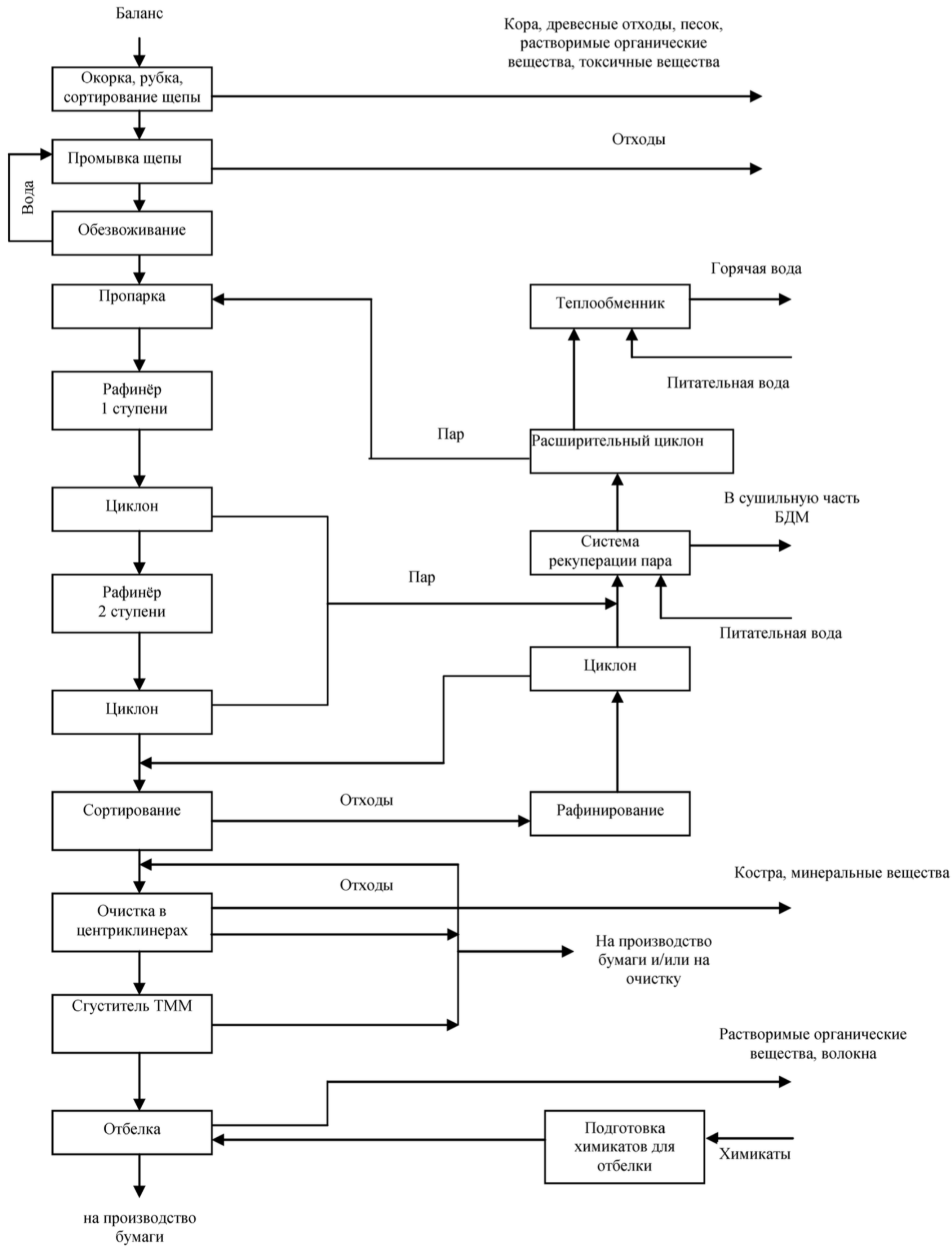

Figure 2.15: A principle scheme of TMP production and emissions

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The major part of the high electrical energy consumption, needed for the milling is transformed to thermal energy in the form of steam, which is produced from the moisture contained in the wood and the water fed in order to dilute the stock in the groundwood refiner. Since the process proceeds at a pressure of 0,5 MPa, at many companies, a considerable amount of steam may be recovered and reused after being treated in heat exchangers with the production of clean process steam to be used, for instance, for the drying of paper. Part of the energy content of the steam may be used to heat water. After the milling, the stock from the refiner is discharged through a cyclone, is diluted, goes through screening, is thickened and is stored in a high concentration stock tank.

Since, in the mechanical process for the production of TMP, water plays an important role, newly felled timber is the preferred raw material. If the wood intended for TMP production is stored in a depot, it is necessary to avoid it drying up, which is why the timber should be stored either in waster, or else, one should sprinkle the pulpwood with water. In order to be able to do this, at the timber yard one might use a water collecting system, allowing for the avoidance of environmental pollution by the organic compounds contained in the water used.

TMP production is almost always combined with paper or board production. If this is the case, the surplus heat, formed during milling may be efficiently used in the production of paper and board and, by being used in this way, providing a high level of recycling of secondary heat. The production of commercial TMP, however, where it is needed to arrange for the drying of the fiber, is not that common.

2.5.2.2 The Chemi-thermomechanical Process

The adding of chemicals to the milling process has become an important factor for process improvement, since the wood may be easily impregnated with it. A light initial processing of the raw material by the chemicals promotes the wood plasticization and improves the properties of the stock produced in the milling process at atmospheric pressure CMP or at an elevated pressure (CTMP). In the majority of cases, the initial processing of the timber (chips) by chemicals leads to the additional discharge of pollutants with the effluents. This is the result of the lowering of the yield of the stock as a result of the chemical processing, as well as the use of chemicals. The process used is modified depending on the wood species used, and, hence, there might be a considerable difference in the properties of the CTMP as well, if the dosage and type of the used chemicals vary. During the chemi- thermomechanical process a quite strong intermediate product with acceptable optical qualities. It may be used as the main fiber component for the production of printing paper, packaging cardboard and toilet paper.

CTMP production involves the production of fiber material and auxiliary systems, as, for instance, the storage of chemicals and an energy generation system. The stages of CTMP production are shown in figure 2.16.

The CTMP production involves the production if thermomechanical pulp as well as the use of chemicals for the initial impregnation of the chips of the stock between the milling stages. Below are described only the main processes distinguishing CTMP production from thermomechanical pulp production. The screening and washing processes, the waste treatment, the thickening and bleaching of the fiber stock is described in the appropriate sections.

After the debarking of pulp wood and cutting it into chips, washing and screening, the chips is impregnated in a tower by being immersed in an alkaline solution. Sodium sulphite (Na_2SO_3) is mainly used for softwood species. Lately, for hardwood species, mainly alkaline solutions of hydrogen peroxide are used. After the impregnation, the chips are steamed, after which its temperature is further increased when it is milled in one to two stages refiners. This gives rise to a softening of the lignin and the weakening of the inter-fibrous bonds. The stock produced is diluted by circulated water, which is also used ruing the refining step and the transfer of the wood stock to the subsequent production stages.

The production of chemi-mechanical pulp (CMP) is the further development of the process of CTMP production. In the course of a deeper processing through the use of chemicals and refining of the chips at atmospheric pressure of both softwood and hardwood, a wood pulp is produced with improved strength properties. After being impregnated wit chemicals, the pulp is boiled at a temperature of 70 – 170 °C from 15 minutes to 2 hours. For various species of wood, different versions of technology are used. The optical properties of CMP are considerably lower than the properties of other mechanical types of pulp. This is why this semi-finished product without bleaching may be used only to a limited degree for the production of printing paper.

CMP yield may be even lower than 90 %, which is why there is a high content in the wastewater of both organic compounds and the chemicals used for a deeper processing of the wood.
Sometimes CMP is produced as a commercial product. In those cases it is dried in a special dryer up to a dryness of 90 %.
The characteristics of the main milling equipment of the CMP/CTMP processes are shown in table 2.20.

Table 2.20 The characteristics of the main milling equipment of the CMP/CTMP processes

Parameter	Type of mill						
	RGP 60	RGP 65	RGP 68	RGP 70 CD	RGP 76 CD	RGP 82 CD	RGP 86 CD
Disk diameter, mm (inches)	1500 (60)	1650 (65)	1730 (68)	1870 (70)	1930 (76)	2082 (82)	2135 (8)
Capacity t/day if:							
A TMP a one-stage line at a SEC = 1800 kWh/t and 2000 kWh/t and with waste milling	130	130	150	210	280	315	530
A one-stage milling CTMP line at a SEC = 1400 kWh/t	140 … 170	140 … 170	170 … 200	240 … 270	290 … 350	340 … 416	-
Pressure (design), kPa	700	700	900	900	700	900	800
Temperature, (design) °C	180	180	180	180	180	180	180

Parameter	Type of mill						
	RGP 60	RGP 65	RGP 68	RGP 70 CD	RGP 76 CD	RGP 82 CD	RGP 86 CD
Electrical engine: Power, MW	8 … 10	10 … 12	12… 16	15… 17	19 … 23	22 … 26	25 … 32
Frequency of shaft rotation	1500 – 1800	1500 – 1800	1500 – 1800	1500 – 1800	1500 – 1800	1500 – 1800	1500 – 1800
Mass, t	18	22	22	32	25	27	27

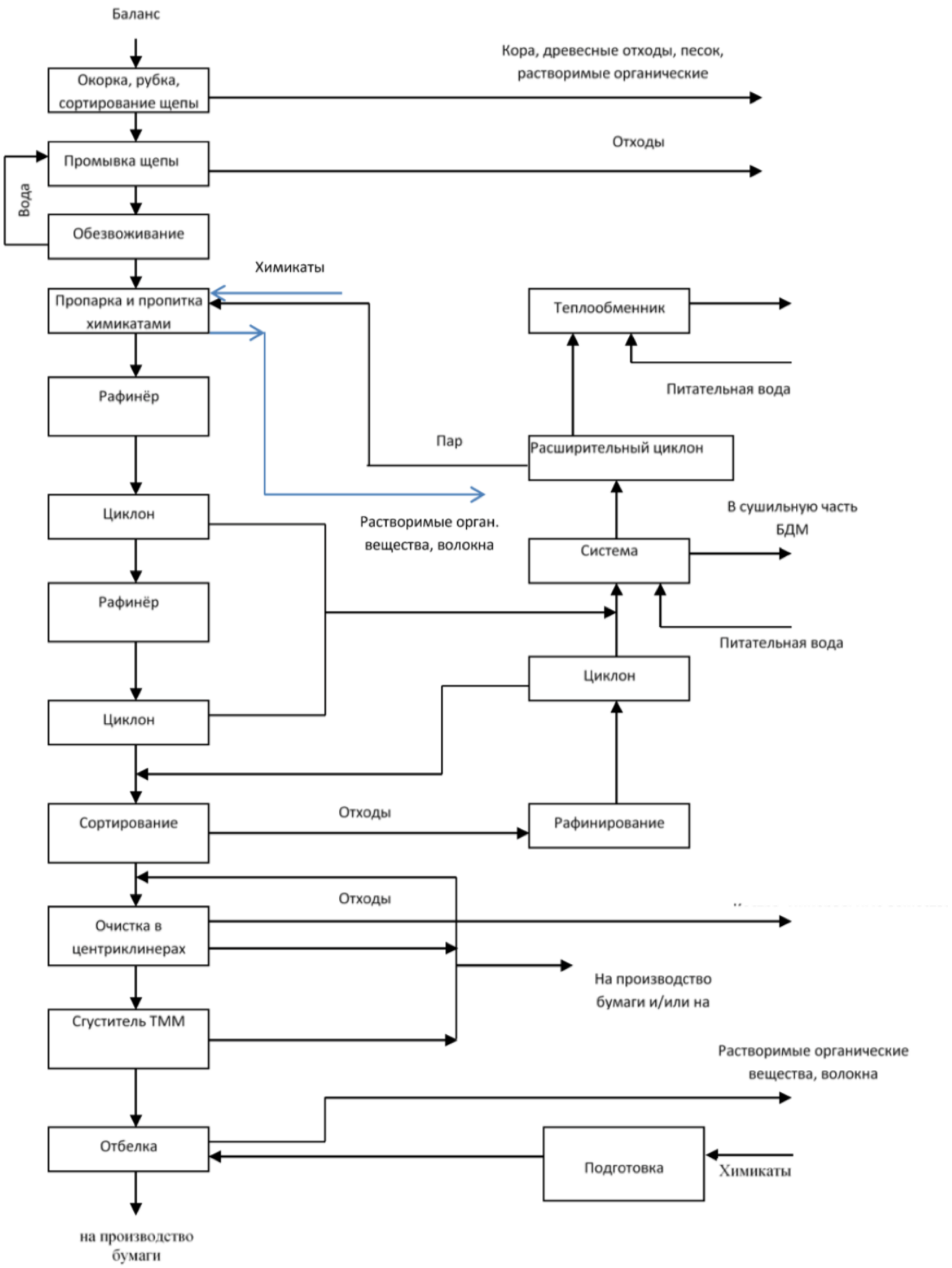

Figure 2.16 Scheme of the CTMP production process

2.5.3 Bleaching of Mechanical Pulp

Since the demand for paper and board with an elevated brightness grows, bleaching of mechanical and chemi-mechanical pulp is becoming more and more frequent. This bleaching process is different from the process of bleaching chemical pulp, since its general principle involves the keeping of lignin, instead of removing it as would be done when bleaching cellulose pulp. The bleaching of groundwood pulp is carried out thorough the transfer or the chromophore groups of the lignin into a colourless form. IN this way, while increasing the brightness, the fiber yield is only slightly diminished. The result from such bleaching is not constant and the paper turns yellow (the reversal of the bleaching process occurs). Since it is possible to attain a stable brightness during the bleaching of such intermediates, it is preferred to use this kind of fiber for the production of newsprint or magazine paper and not for the production of books or archive documents. The bleaching process with the retention of lignin is carried out in one or two stages, depending of which level of brightness of the pulp is needed. The bleaching processes are different from each other on account of the reagent used.

2.5.3.1 Reductive Bleaching Using Sodium Dithionite ($Na_2S_2O_4$)

When using dithionate (hydrosulphite: shorthand: S) for bleaching purposes, the organic constituent of the wood is, in fact, not diluted. Usually 8 – 12 kg dithionate per ton of air-dry pulp is used. This allows for the achievement of minimal losses in product yield, whereas the brightness may be increased by 12 units from the original level – from 58 - 70 % ISO to 70 – 76 % ISO. When using this kind of bleaching the pH of the process ranges between 5,6 and 6,5, and the temperature may reach 70 °C. The decomposition of the residual dithionite in the pulp may lead to corrosion of the metallic details of the equipment used in the subsequent production stages. In order to avoid this, at a majority of the companies chelates are used (for instance, ethylenediamine tetraacetate or pentaacetate sodium salts, EDTA or DTPA), preventing the decomposition of dithionate. The concentration of the pulp during ordinary hydrosulphate bleaching ranges between 3 and 5 %. However the emergence of intermediate concentration pumps (MS), with the capacity to transfer pulp with a concentration of 10 – 12 %, has allowed for the performance at this concentration of the hydrosulphite bleaching, which has led to the increase of its efficiency.

2.5.3.2 Oxidative Bleaching Using Hydrogen Peroxide (H_2O_2)

The lowering of the product yield when bleaching with peroxide (shorthand: P) is about 2 %. This happens mainly because of the alkaline environment entertained during the bleaching process and leading to the build-up of the amount of soluble organic wood matter, which leads to the increased load on the treatment plants.
Peroxide bleaching effects the pulp properties – apart from the higher brightness its strength is increased, while the amount of extractables is decreased and the water balance is improved. When using the maximum allowed from an economical viewpoint amount of peroxide, it is possible to raise brightness by 20 units – up to 78 – 84 % ISO. If heavy metal ions are present in the system, the bleaching is ended with a lower brightness and a higher consumption of peroxide is needed on account of its partial decomposition. This is why chelates (for instance EDTA or DTPA) are added before the bleaching in order for stable complexes with the heavy metals to form (Fe, Mn, Cu, Cr). This provides the possibility to avoid a lowered brightness of the pulp and the destruction of the peroxide. EDTA and DTPA contain nitrogen, which, contained in them, turns up in the wastewater. The use of a washing stage of the unbleached pulp before the bleaching is an efficient method of lowering of the content in it of the said metals and, thus, permits the lowering of the consumption of expensive chelates. The bleached pulp subsequently acidified by sulphuric acid or sulphur dioxide to a pH of 5 – 6. The modern bleaching process using peroxide is performed at a pulp concentration of 25 -35 %.
Two bleaching process may be combined. A higher final brightness is reached by peroxide bleaching then by using dithionate, however the opacity of the pulp in the latter case is lower. The final brightness of the intermediate product depends on the brightness of the unbleached pump, which, in turn, depends on the raw material and the type of bleaching used. The wood species and the milling degree of the pulp also affect the brightness of the end product.

2.6 The Paper and Board Production Process

At the Russian pulp and paper works a wide range of paper and board are produced [4,5].
The main raw material for the production of various types of paper and board are the primary fiber intermediate products, product from the plant raw material (pulp, semi-chemical pulp and various types of mechanical pulp) as well as secondary,

recovered from scrap paper. At present, the composition of paper and cardboard is defined by, more now than ever, by the cost of the separate constituents. The composition of the raw material used for the production of paper affects substantially the general production costs, the quality of the products and the environment.
In spite of the wide variety of the produced types of paper and board, and also the production schemes, they all include the following sup-processes:

- Preparation of the pulp
- Short circulation system
- Paper/board production machine including:
    - Stuff box, providing the even feeding of pulp onto the cloth, the homogeneity of the concentration over sheet profile as well as the continuity of the feed over the breadth of the machine.
    - The cloth, upon which the formation of the paper sheet is performed, as well as its drying up to 20 % dryness.
    - The press for the removal of waster from the sheet by the compacting under pressure until a dryness of about 50 % is reached.
    - The dryer, performing the dewatering of the paper sheet by heating. The dryness of the sheet after the dryer is 93 – 96 %
    - The wind stand performing the reeling up of the paper into a roll.

Depending on the types of paper/board, additional technology equipment may be used, as, for instance: creping and microcreping facilities, gluing press, coating machine, calender machines, etc.

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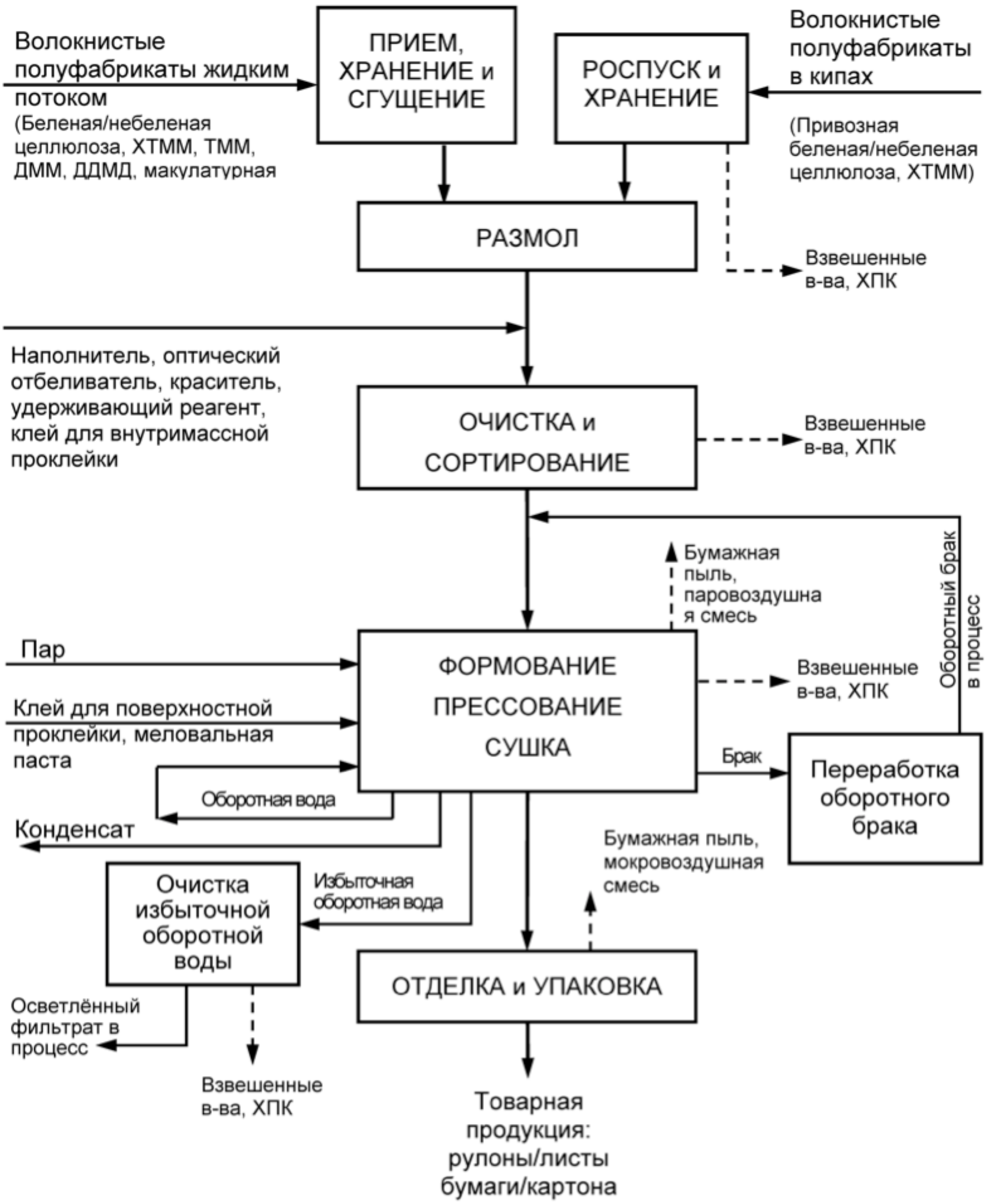

Figure 2.17 Block scheme of the paper and board production process

Table 2.21 A description of the paper and board production process

Input	**Stage of the process**	**Output**	**Main process equipment**	**Emissions**
1	2	3	4	5
fiber intermediate products in a liquid flow: Bleached pulp Unbleached pulp CTMP BCTMP TMP SGW PGW Scrap paper stock Recirculated water Electric energy	Reception, storage, thickening	Thickened fiber intermediate product Recirculated water	Accumulation tank Thickening tank	

Input	Stage of the process	Output	Main process equipment	Emissions
1	2	3	4	5
Bleached pulp from foreign sources (bales) Unbleached pulp from foreign sources (bales) CTMP (bales) Recirculated water Electrical energy	Break-up and storage	fiber intermediate product	Accumulation tank Hydropulper	Discharge to the production wastewater system (suspended particles, COD, BOD)
fiber intermediate product Electrical energy	Milling	fiber intermediate product	Disk/cone mills	
Paper stock: fiber intermediate products, recycled scrap, filling, sizing agent, absorbing agent, plasticizing agent, optical bleaching agent, dye Recycled water Electric energy	Washing and screening	Paper stock Waste from treatment and screening Recycled water	Washers Screens Deairator	Discharge to the production wastewater system (suspended particles, COD, BOD)

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Input	**Stage of the process**	**Output**	**Main process equipment**	**Emissions**
1	2	3	4	5
Paper stock Glue for surface gluing Coating paste Circulated water Steam Gas Electrical energy	Forming Pressing drying	Paper/board Scrap (trimmings, failures) Recirculated water Condensate	Paper/board machine Stuff box Forming machine Press Dryer Gluing press/coating machine Microcreping machine Stack Reel section Vacuum pumps Heat recuperation equipment	Discharge to the production wastewater system (suspended particles, COD, BOD) Emissions to air: (steam/air mix, paper dust)

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Input	Stage of the process	Output	Main process equipment	Emissions
1	2	3	4	5
Paper/board Electrical energy	Finishing and packaging	Commercial product: Rolls/sheets of paper/board Paper scrap	Longitudinal cutting machine Roll packing machine Sheet cutting machine Baling press for scrap Air filter	Emissions to air: (paper dust)
Recycled water Electrical energy	Treatment of surplus recycled water	Recycled water (cloudy/clear filtrate) Trapped fiber	Disk filter Flotation trap	Discharge to the production wastewater system (suspended particles, COD, BOD)
Wet scrap Dry scrap Recycled water Electrical energy	Processing of scrap	Fibrous intermediate product	Scrap Hydropulper Scrap deflocculator Scrap thickener Screening and treatment of scrap	

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2.6.1 Reception, Storage and Drying

At integrated works the fiber intermediate product enters into the paper/board-making machine in a liquid flow from the pulp plant.
The fiber intermediate e fed into the thickener, where the surplus water is separated out, whereas the thickened fibrous intermediate is fed to the milling stage.
When using foreign intermediate products, arriving to the company in bales, the beginning stage of preparation of the paper stock is the dissolution in hydropulpers of various construction.

2.6.2 Milling

The aim of the milling process is to give the fiber a certain structure, length and thickness, to make the fibers elastic and plastic through the exterior and interior fibrillation of the fiber. Depending of the type of produced wares and the condition of the initial raw material, various equipment and modes of milling are used.
At present, the most widespread are the disk mills – single or double disk. However at a number of companies modified conic mills are used.
When using the various types of intermediate products, generally, the dissolution and the milling are done separately. When establishing the composition of the paper grade stock recycled scrap is added, and – if needed – filling, dye, glue substances and auxiliary chemical compounds.
The milling process is extremely energy consuming – the energy consumption ranges between 100 and 500 kWh/h for the majority of types of paper and board.

2.6.3 Cleaning and Screening

The finished paper grade stock is further diluted by water to the needed concentration and screened to remove unwanted inclusions, which are removed from the pulp in the course of the cleaning and screening.
In the centrifuge cleaners, the removal of fiber inclusions from the pulp is performed under the action of centrifugal forces. One distinguishes cleaners for heavy and light particles. The centrifugal cleaners are usually installed in a number of stages (up to 6 stages).

After the vortex cleaners the pulp is fed into the deairator, where air is removed from the pulp. Thereafter the deaired pulp enters the screen either with slit or round openings.
The quality of the produces paper and the functioning of the paper/board machines depend on the level of cleaning of the paper stock: pollution is one of the reasons for breaks of the paper sheet.

2.6.4 Paper/board machine. Forming, Pressing, drying

In the paper/board machine, sheet formation and the creation of most of the properties of the paper or board.
In the stuff box the pulp takes on the form of a flat stream, which is the base for the shaping of the sheet. From the stuff box the pulp ends up on the cloth, onto which the fibers from the diluted pulp settle and a paper/board sheet is formed. Lately double-cloth machines are used for the formation of the sheet, which is an example of the modern way of paper production equipment. In double-cloth formers the fibrous suspension passes between the two cloths, whereas the water is removed from both sides. There is a combination of a long-cloth and a double-cloth machine (hybrid formers).
Hereafter the sheet is subjected to compression. In the pressing process, water is removed from the sheet on account of it being compressed as a result of external pressure. The press part of the machine usually consists of a number of different presses, through which the paper sheet travels sequentially. After the press, the dryness of the paper is usually 28 – 40 %.
The further dewatering until the final dryness (92 – 95 %) is reached proceeds in the dryer part of the paper machine by evaporation of moisture from the sheet.
The main drying methods are the contact method (used for the drying paper and board) and the air method (used for the drying of board).
The dryer is usually the most expensive part of the machine, and it accounts for about 65 % of the energy expenditure, used in paper production.
The dryer is covered with a hood in order to lower the heat losses and the increase in the efficiency of the process, and, furthermore the dryer is furnished with a mechanism for heat recovery, to which the hot and humid air from the hood is directed. The air temperature is

usually 80 – 85 °C, the moisture – 140 – 160 g H_2O/kg dry air. Part of the moisture (approximately 1 – 1,5 m^3/t paper) is emitted to air. For reasons of economic viability all paper plants are equipped with heat regeneration systems.

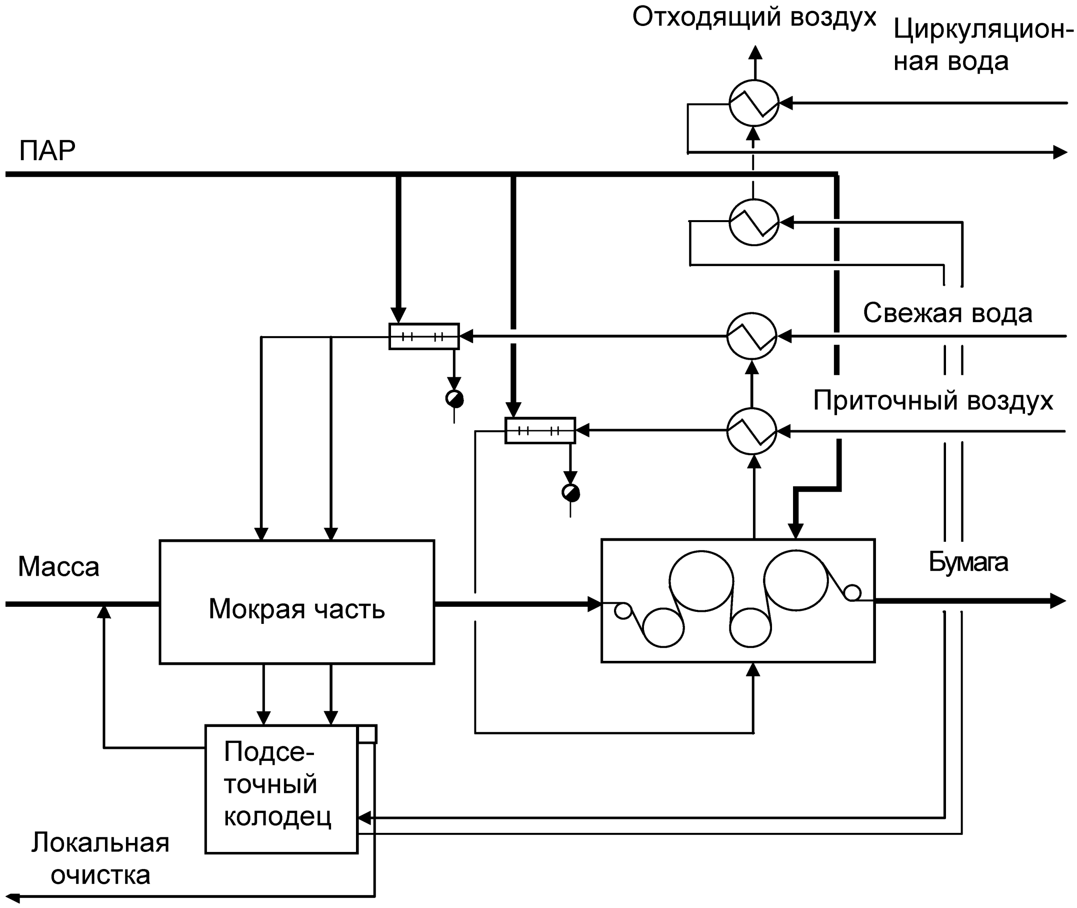

Figure 2.18 Heat recovery system

In most cases, the paper machine/board machines contain various units, which are necessary for the rendering of certain qualities to the paper. For instance, in the dryer, a sizing press is installed for vat sizing, a coating machine, and creping and microcreping machines. The mixtures for the surface processing is applied onto the paper surface with the aid of shafts, a blade, etc. after which the sheet is fed into the short end dryer to dry.
In order to enhance the gloss and the shine of the paper and to give the paper an even thickness over the full width after the dryer a calender (stack) is mounted.
The reeling-in of the paper into rolls is made onto a reeling-up stand.
In order to produce a commercial product, the finished paper/board is cut into reels in a score cutter.
The paper/board rolls are packed and as rolls it is transferred to the warehouse.

In order to produce sheet products the rolls of paper/board are sent to the sheet-cutting machine, where it is cut into the needed formats, it is sorted, stacked or baled and packaged. The finished sheet products are transferred to a warehouse.

2.6.5 Treatment of Surplus Recycling Water

During the process of paper/board production, continuous removal of water is conducted.
In order to reduce fiber and fresh water consumption, the water, removed in the process of shaping the sheet is used as recycled water in the production process.
Depending of the place of formation and the content of suspended and dissolved matter; the recycling water is divided into the flows (cycles).
The first flow is formed by the register water from the paper sheet formation zone of the cloth section, which is enhanced by fiber and filler. This water, without being cleared is directed to be diluted in the pulp preparation shot and to the flow of the paper/board machine.
The water of the second flow (from the suction box, the couch roll, the press, the cloth washer) contains from two to three times less suspended particles, than the register water. This water is transferred to the local (shop) cleaning unit, after which the cleared water is used in the production process instead of fresh water.
The trapped fibers from the local treatment are returned to the flow.
The water from the third flow contains the surplus recycled water from the secondary cycle (from the cleaners, screens, etc.). Because of the high level of pollution it is dispatched as wastewater to the chemi-mechanical and (or) biological treatment at the wastewater treatment plant of the company.

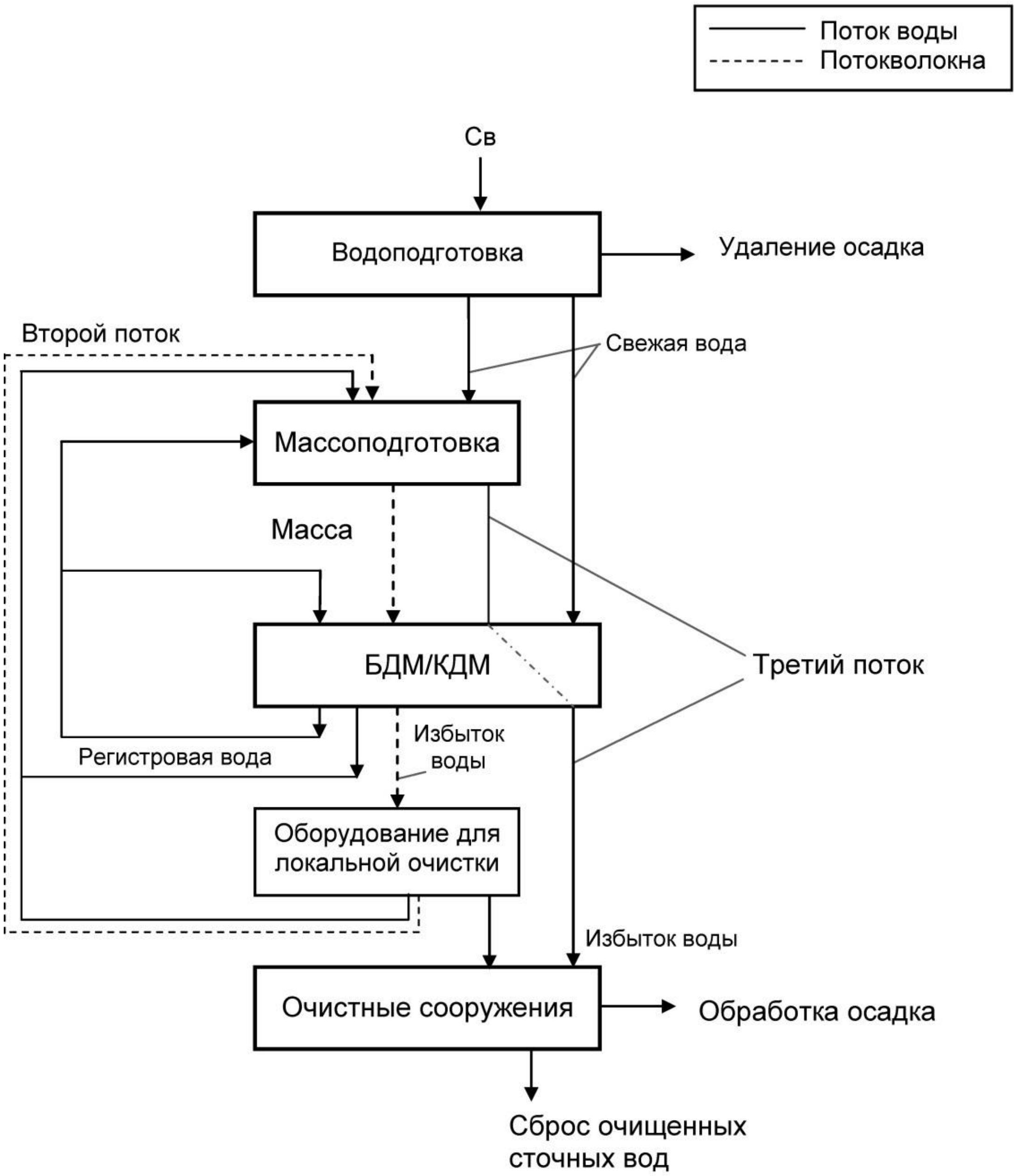

Figure 2.19 Simplified scheme of water and pulp flows of a paper production plant

2.6.6 Sizing

In the course of producing mass quantities of paper (printing/letter, including paper used in office appliances) and board, the sizing process plays an important role. There are two types of sizing of paper and board – sizing in the stock and surface sizing.

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When sizing, the sizing substances are added directly into the paper stock. At present, various sizing substances – as well as mehtods – are used: acid, neutral and pseudoneutral. In Russia, all three versions of sizing in the stock are used.
When applying the acid sizing method as hydrophobization substance (glue) gum and tall resin products or their modifications of various degrees of saponification, while as precipitator aluminium sulphate is used. Sizing proceeds in an acid environment at a pH of 4,3 – 5,5. In order to raise the pH of the sizing sodium aluminate is used as a precipitator. The sizing pH at this point is 5,5 – 6,0.
When using high-mole disperse resin sizes (for instance, of the brand *Sakotsep*), the sizing proceeds at a pH value, close to neutral (6,0 – 6,5). This kind of sizing is called pseudoneutral sizing. The precipitator of the size in this case is also aluminium sulphate or aluminium polyoxyfluoride. The pseudoneutral sizing allows for the minimization of the aluminium sulphate consumption from the range 25-40 kg/t to 7-21 kg/t as well as the resin size from 9-25 kg/t to 6-16 kg/t.
In the course of the past few decades, sizing in an environment close to neutral (pH 6,5–8,5) - neutral sizing - has become the most widespread technique. As sizing agent water dispersions of reactive synthetic substances based on alkyl ketene dimers of fatty acids or alkyl succinic anhydride or their modifications are used. The active groups of these substances are interacting with the hydroxyl groups of the cellulose fibers, whereas their hydrophobic radicals bock the surface of the fibers, thus rendering the paper hydrophobic. In order to enforce the sizing agent on the surface of the fiber and to speed up the reaction of the interaction, cat ion additives are used (starches, polyamide dichloride hydrin resins, polyacrylic amide (PAA), polyethyleneimin (PEI), polyelectrolytes, etc.).
The use of sizing in a neutral environment offers a number of advantages. The production process becomes more ecologically clean, as there is no wastewater formed with an acid environment. The paper quality is raised and the production costs are lowered. The mechanical strength properties of the paper are enhanced, as well as its brightness, its preservation during long-term storage as well as its resistance to thermal exposure. When neutral sizing is used, a high effect of the sizing at a low consumption of the sizing agent is achieved (from 0,8 to 1,5 kg/t dry weight), as well as resistance to both acid and alkaline environments.

When producing print grade type of paper, surface sizing plays an important role, supplying the needed level of absorptive capacity towards printing dies, lowering the scuffing and fluffing level when applying print, improving the structural-mechanical properties of the paper, increases the resistance of the paper to deformation in a moist state. The most frequent surface-sizing agent of print-type of paper is starch, modified by chemical or physicochemical methods. The oxidized version accounts for approximately 60 % of the total volume of applied modified types of starch. There are various schemes of the process of production of oxidized starch. When oxidizing starch, highly dispersed colloid solutions with a reduced viscosity having high adhesion characteristics are formed. These solutions penetrate deeper into the pores of the paper, more efficiently glue the fibers and produce a film with higher mechanical strength. This is why oxidized starch is frequently uses as the main binding agent during surface sizing of paper.

During the surface sizing the paper sheet is passed between the shafts of the sizing press, mounted before the last group of drying drums of the dryer part of the paper machine. Between the rolls of the sizing press the sizing solution is applied to the paper from one or two sides. The amount of applied sizing solution depends upon the concentration of the sizing solution as well as the linear pressure between the rolls of the sizing press. Usually the amount of applied sizing agent is 0,3 – 0,5 g/m^2.

The use of a sophisticated construction of the sizing press for the surface sizing of paper – the film-forming sizing press provides significant advantages as compared with the traditional press construction, where the sheet is moisturized abundantly between the two rolls, which gave rise to certain problems with the even application of the sizing agent over the full width of the paper sheet. The construction of the sizing press of the film application type provides the possibility of application of a controlled amount of sizing agents as well as the even distribution over the full width of the paper sheet. The film-applying press technology of application of the sizing solution onto the paper differs in a principal way from the traditional method, since, when using this method, the sizing solution, initially is applied onto the application roll, creating an even-thickness film layer, which subsequently is transferred to the paper sheet. The water contained in the sizing solution is removed when the wet paper sheet goes through the last group of drying drums of the paper machine.

When exclusively using the surface type of sizing of the paper sheet technology for the production of letter and print grades of paper the costs of treating the companies' wastewater are considerably reduced.

2.6.7 Coating

The technology of producing high-quality types of book- and journal paper as well as board, coated for the manufacturing of folding boxes with multicolour printing, involves the special treatment of the surface of the paper or boxboard, the so-called co coating process (the application of coating paste onto the surface of the paper or board), which may be referred to one of the types of surface sizing, providing the improved printing properties of the surface of the paper and board.

Coating paste is a water suspension containing white pigments, binding material as well as various auxiliary compounds. As pigments, kaolin, talc or calcium carbonate are used. The composition of the coating paste depends on the requirements to the quality of the surface of the paper, defined by the used printing method. The preparation of the coating past is med in the so-called kitchen – the paste preparation shop, where the preparation and blending according to a certain formula is performed. Before being fed to the coating machine, the coating paste is filtered.

There are single-type or repeated coating of the paper with coting paste. The double coating is usually done in two stages: first one layer of the coating paste is applied onto the paper in a coating mechanism built into the paper machine, and, then, subsequently, paste is applied in a separately mounted coating machine. The weight of the first layer, applied on-line, directly in the paper machine varies between 4 and 6 g/m^2. The weight of the second layer, applied in the isolated coating device varies between 20 ad 25 g/m^2 (occasionally up to 40 g/m^2.)

The inclusion of coating machines into the paper machine set-up became possible after the development of the film-type roll mechanism, with the aid of which the coating colour is applied simultaneously on both sides of the paper sheet while the contour profile of the paper is preserved. New coating unit designs are provided with two shafts, to both of which the dosing roller, revolving with a speed, different than the speed of the applier shaft is adhered, thanks to which in the film of the coating formula shearing forces arise, providing stability to the film at high speed.

There are paper machine constructions, which allow for the performing of double covering of the paper with coating paste in one single technological process. When this is done, a second layer may be applied onto the dried first layer (the wet-on-dry method) or directly onto the wet layer (the wet-on-wet method). The paper, after the coating has a matte surface, which after calendering becomes glossy.
Coating is subdivided into light, full and cast coating. Using these various types of processing, there is a variation not only as to the quantity of applied coating paste, but there is also en change in the paste's penetration into the structure of the paper sheet. The depth of penetration may be considerable as well as insignificant. Among the methods of paper coating, the most promising is the curtain coating. The device for curtain coating lacks the mechanical elements for the evening out of the paste over the sheet surface. The paste is pressed out through a narrow slit of the head chamber and by action of gravity falls onto the sheet as a curtain. In the point of contact with the sheet, the curtain changes direction of movement and is stretched out and forms a thin film on top of the paper sheet. This film dries up by air. The disadvantage of the curtain method is the fact that the coating is applied only to one side of the sheet.
The group of separately placed coating machines encompasses the equipment used for the unwinding of the paper reel, the coating unit or units, the dryer (infrared drying, hot air drying and heated cylinders) and reel-in. Various systems for management and control are used for the management of the plant operation.
In the coating section, during the process of operation, circulation of the coating formula and its filtration is carried out in order to filtrate it to remove fibers and other inclusions, which provides the stability of the coating paste properties. The filters are cleaned regularly, at which stage there is a formation of a stream of concentrated waste.

2.6.8 Dying

Paper dying is carried out in order to give it a certain colour of varied intensity. One distinguishes between paper, imbued with colour and tinted paper. Paper may be coloured in the stock and on the surface. The most widespread way of colouring is the direct colouring of the paper stock. In order to do this the dye solution is introduced into the paper stock in the process of it being prepared. In the process the dyestuff is adsorbed onto the pulp fiber. Paper, dyed using this method is dyed through its full depth. In order to raise the dyestuff retention in the paper stock, special additives are injected. The efficiency of the dying of paper stock depends on a number of factors, including: the level of size reduction and the type of the fiber used, the sizing agent, mineral fillings and alum cake content, the pH of the environment and the temperature of the dying process, the temperature of the paper drying process, the calendering, etc. Surface drying of paper is done in the paper machine coating press in the supercalender or in other special devices where the dyestuff is mixed with the gluing mixture. When this technique is used the inner layers of the paper remain undyed. The advantages of such a method of dying are the significantly reduced dye consumption (up to 30 %), the considerably lower quantity of dyed coloured wastewater, as well as the possibility to dye small batches of paper. The surface of the paper may be coloured in the process of coating, if an additive of organic or inorganic pigment is injected into the composition of the coating paste.

The most widespread dyes for paper dying are the organic synthesized dyes, divided into water-soluble and water non-soluble pigments. The water-soluble dyes are used to dye paper in the stock, whereas the non-soluble pigments are used to dye paper on the surface.

The water-soluble organic dyes are divided into basic, acidic and direct dyestuffs. The most popular dyes to dye paper are the direct dyestuffs, having a direct similarity to cellulose, which offers the possibility of retaining the dyestuff on the fiber without the introduction of any special additional chemical substances. The direct dyes are mainly used for the dying of cleaned delignified pulp, uncoated paper stock without any mechanical pulp content. There are techniques developed for the joint dying of paper stock, for instance, by direct and basic dyestuffs as well as by basic and acidic dyes.

Out of the pigment dyestuffs the most popular for the dying of paper and board are the vat dyes (anthraquineon), phtalocyanide and azo dyes as well as technical carbon.

2.6.9 Technique Associated with the Use of Additional Chemical Compounds when Producing Paper and Board.

The efficient use of additional chemical compounds in the production of paper and board provides the possibility, at minimal capital expenditure, to lower the cost of the production and to raise of environmentally safety of the said sub-industry of the pulp and paper production. As pointed out above, additional chemical compounds are used in various stages of the technological processes of the production of paper and board. We will concentrate our attention on the most relevant processes of the production of

the dominant types of paper and board production, i.e. the retention of the components of the paper stock, the coating and strengthening.
In order to retain the components of paper pulp during formation of the paper sheet, on the wire frame of the paper machine a combination of cationic starch and silica sol or anionic bentonite.
The use of a combination of cation starch and silica sol, the so-called Compozil system, involves the processing of the paper stock by the successive introduction into it by cationic starch and silica sol. This system, in Russia, is mainly introduced by the specialists of the company Eka-Nobel.
The combination technique: *cationic starch* – bentonite involves the successive introduction into the paper stock of a starch solution, and, thereafter – a bentonite suspension. This system offers an obvious advantage over the Compozil system: at the plant, bentonite is delivered in the form of a dry powder, as distinct from the water dispersions of silica sol, which significantly widens the possibilities of its application. In order to prepare the solution of cationic starch, a jet-cooker is used, whereas the bentonite suspension calls for the use of a special automatic set-up. The use of the abovementioned technique allows for a 82 % retention of the cationic starch. This technique is used at the *OAO Mondi SLPK*.
The technology of strengthening of the dominating paper types and board involves mainly, the introduction into the paper stock of a paste of cationic starches of various manufacture, where average and higher gamma number starches are preferred. The consumption is 4 – 12 kg/t. IN order to prepare the starch solutions at major works (for instance at the Segezha PPP), automatic jet cookers are used of various manufacturers. The use of jet cookers offers the possibility to carry out the cooking of starch in an automatic mode in the temperature range 110 - 165 °C. The capacity of the gear is 1 – 2 t/h, which provides for the continuous operation of the paper machine with a capacity of 200-300 t/h. The automatic jet cooker occupies no more than 20 m^2. A highly important advantages of the cooking of the starch in the jet cooker are: the practically full absence of dust, the minimal starch losses (less than 0,5 %), and the extremely ease of handling and control. Apart from this, there is no need to have a larger tank for the storage of an operational amount of starch solution, nor is there any need for special operators.

2.6.10 Calendering

The overwhelming majority of the products produced at paper and board machines are subjected to the process of automated calendering, which to a high degree determines the quality criteria, important for a number of dominant types of paper and board,

such as the density, the smoothness and thickness uniformity. The cited parameters, being important for a number of dominating types of paper and board, are provided for by controlling the parameters of calendering. The calendering process parameters are generally affected by the temperature between the rolls, the number of operations, the duration of the calendering, the temperature and wetness of the processed sheet. These parameters may be looked upon as the controllable parameters of the process. A most important parameter of the calendering process is the linear pressure and its distribution over the width of the contact area between the drums and the paper.
During the machine calendering, the paper or board sheet passes between the drums under a certain linear pressure, usually under the effect of heat and moisturization.
A calender machine consists of two or more cast iron drums with a very smooth surface, which are placed one after the other, as shown in figure 2.20.

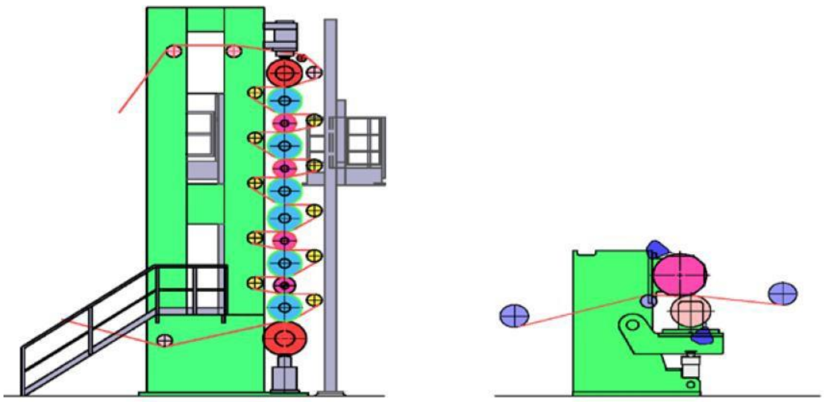

Figure 2.20 Machine calender and supercalender

The paper sheet is passed through the interspace between the rolls (strict tolerance). Modern calenders are equipped with heated cast iron rolls in combination with a roll with a soft rubber coating (soft calender). Two or more of them are arranged one after the other. The calender rolls are heated on the inside by hot water, steam or oil.
The paper sheet, produced in the paper machine or the coating line is often subjected to further processing, which is called supercalendering. When the sheet passes through the supercalender its surface attains a very high

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smoothness. Supercalenders are mounted separately from the paper machine. The processing in them enables the enhancement of the surface gloss. The supercalendering increases gloss and the printing properties up to the requirements, raised towards art paper. Before the supercalendering the reel is subject to rewinding, during which possible defects are remedied and the edges are trimmed. The system of supercalendering involves equipment for rewinding (unwinding), a supercalender and reel-in equipment.

Environmental impact of the process of (super-) calendering mainly involves consumption of the energy needed for the operation of the equipment and the heating of the rolls.

2.6.11 Paper Moisturizing, Winding, Cutting and Packaging

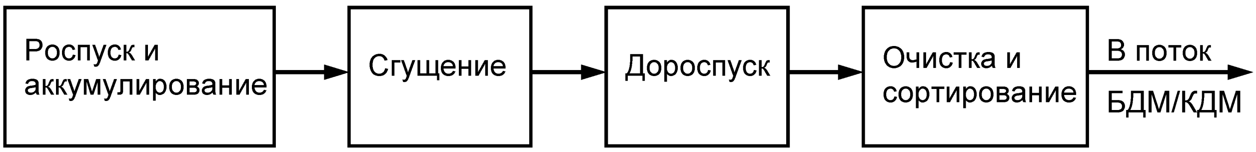
Some types of paper, with high requirements as to its smoothness and glossiness, are subjected to additional processing in supercalenders. Paper, passing into the supercalender is moisturized, usually in the reel section of the paper machine when it is being wound-up on a drum. The moisturizing degree varies and depends on the needed properties of the paper, its composition and the weight of one square meter of paper. The operating principle of the moisturizing machines, arranged between the machine calender and the paper machine reel section, is based on the dispersal of water by a jet nozzle, a brush or compressed air. The moisturized side of the paper, when being reeled onto the reel stand touches the unmoisturized side and the moist is evenly distributed on both sides of the paper. Some special high-end types of paper are moisturized in separate moisturizers, combining this operation with a controlled rewinding of the paper. There are various types of moisturizers in use: with a brush distribution of moisture, with compressed air water sprinkling, with the transfer of moisture to the paper using rollers or with humid air moisturizing of the paper. After the moisturization of the paper in the paper machine or in separate moisturizing lines, the paper is transferred to the supercalender.

The finished paper in the reel-up section is wound onto a drum to form reels. Based on the type of reeling, there are various kinds of reel sections, as, for instance axial winding (friction reel-up), as well as drum-type winding (peripheral reel-ups). The friction reeling is used at low-speed machines with a paper and board production with a high weight per square meter. At present, in most paper machines, peripheral reeling is used, which provides the tight reeling of paper. The rotation of paper in the reeling roll is accomplished by the rolling friction of this roll against the carrying drum, revolving by means of the drive with a constant angular rotation.

Depending on the requirements as to the format of the delivered paper, to be further processed, the paper, on drums, is transferred to the winding and longitudinal cutting machine, where the paper is cut into reels of the needed format.
The reels or stacks are packaged at packaging machines in accordance with the requirements and the concrete type of production.
The environmental impact from the aforementioned operations is relatively insignificant, but there is a possibility that dust will be formed while cutting the paper.
The mentioned processes do not consume large amounts of energy. The waste formed is the paper trimmings, which are usually transferred back to the production process.

2.6.12 Broke Processing

The main purpose of the scrap processing system is the preparation of broke to be used again in the composition of the paper.
The quantity of formed waste in the process of paper and board production usually ranges between 5 and 20 % of the machine capacity.
The waste is formed in various places of the paper/board machine. Wet paper broke is formed under normal conditions of the paper/board machine operation as trimmings in the vat section. Dry broke is formed during the paper finishing, and also as broke and trimmings.
From the paper/board machine, broke is transferred to broke hydrobeaters under the machine after which they are transferred to the broke tank. The recycled broke is thickened in a water extractor until it reaches a concentration of 4 – 5 %, after which the pulp is transferred to a multi-step cleaner, which allows for the reduction of the non-recoverable losses. Hereafter the recycled scrap is added to the composition of the paper/board at a certain ratio.



Defibration and accumulation ->thickening->further defibration->cleaning/screening->back to the paper/board machine flow

Figure 2.21 The principal scheme of scrap processing

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Description of the used production equipment

Table 2.22 Characteristics of the main paper/board production equipment

Equipment unit name	Equipment purpose	Technological characteristics[1)]
1	2	3
Mills	Milling of fibrous intermediates	Type: conical, disk Capacity: up to 480 t/day Concentration: 2,0 – 6,5 % Input beating and freeness: 10 – 18 ° Schopper/Riegler Output beating and freeness: 15 – 50 ° Schopper/Riegler
Screens	Screening of the paper stock	Type: multi-step vortex type conical cleaners Capacity: up to 110 000 l/min Number of steps: up to 6 Input concentration: up to 2 % Quantity of good stock: 84 – 99,5 % Quantity of waste: 0,5 – 16 %
Cleaners	Trapping and removal of heavy and light inclusions	Type: vertical/horizontal force-fed slit type Capacity: up to 800 t/day Size of the openings/slits of the sieve: 0,35 – 2 mm Output concentration: up to 4 %
Paper/board machines, including:	Production of paper/board	Product range: letter/print types of paper, box cardboard, package cardboard and others Capacity: up to 1 250 t/day Trimming width: 3 160, 4 200, 6 300, 8 550 mm Driving gear speed: up to 1 250 m/min

Equipment unit name	Equipment purpose	Technological characteristics[1)]
1	**2**	**3**
Stuff box	Feed of the paper pulp to formation	Type: closed Capacity: up to 120 000 l/min Input concentration: up to 1,2 % Maximum opening of the slits: up to 76 mm Degree of recirculation: 10 %
Former	Forming of the paper/board sheet	Type: single/multicloth cantilever type with dewatering elements Output dryness: up to 25%
Defrosting conveyer	Flushing and defrosting of timber in wintertime	Capacity, dense timber cubic meter/hour: 250-390 Water temperature: 40-60°C
Former	Forming of the paper/board sheet	Type: single/multicloth cantilever type with dewatering elements Capacity: dense timber cubic meter/hour: 120-390 Length, 25,0-42,0 m Diameter, 4,0-5,2 m Rotation velocity, 4-9 rpm
Press	Pressing of the paper/board sheet	Type: pickup, conventional, straight, suction, flattening, with a broadened press zone, etc. Input dryness: up to 25 % Output dryness: 31 – 48 %
Dryer	Drying of the sheet to final wetness	Type: cylindrical, type "flekt", Yankee-cylinder Input dryness: 31 – 48 % Output dryness: 92 – 98 % Diameter of the drying cylinders: 1 500 mm Quantity of drying cylinders: up to 106 Percentage of condensate return: up to 95 %
Sizing press/coating machine	Surface sizing, coating	Type of equipment: Quantity of sizing layer: 2.2 – 4 g/m^2

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Equipment unit name	Equipment purpose	Technological characteristics[1)]
1	**2**	**3**
Calender	Surface calendering of the sheet in order to raise the smoothness of the paper, the improvement of printing properties of the paper, the elevated density and evening out of the thickness of the paper	Type: double stack Number of calenders: 1 Smoothness of the sheet on exit: 30 – 200 sec
Reel section	Winding-on of the sheet of paper/board on a drum	Type: peripheral Diameter of the spool: 900 – 2 800 mm
Vacuum pumps	Creation of vacuum for the dewatering system of the formation and press sections	Type. Water-wheel vacuum pumps Number of units: 5 - 10
Heat recuperation equipment	A system for the recuperation of heat during the production of paper and board	The unit consists of: air-to-air heat exchangers, air, water, fans and a scrubber
Longitudinal cutting unit	Cutting of the reels into consumers' formats	Number of units in the flow: 1 – 2 Capacity: up to 800 t/day Speed: up to 2 300
Reel packaging unit	Packing of reels of paper/board	Capacity: up to 60 reels/h

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Table 2.23 – Environmental protection equipment for paper/board production

Equipment unit name	Equipment purpose	Technological characteristics[1)]
1	2	3
Thickener	Thickening of the intermediate products	Type: single or double-drum Capacity: 60 – 380 t/day Filtration surface: 17,5 – 70 m^2 Input concentration: 1 – 4 % Output concentration: 8 – 30 % Drum diameter: 3,5 – 5, 8/1,5 m. Power of the main electrical engine: 15-30/110 kW
Hydrobeater (pulper)	Defibering of sheet intermediate products	Type: vertical Capacity: 50 – 250 t/day Volume: 16 – 80 m^3 Concentration: 2,5 – 5 % Power of the agitator electrical engine: 90 - 270 kW
Disc filter	Treatment of the surplus recirculation water	Type: segment/flotation Number of discs: 10 – 16 Disk diameter: 3 660 – 3 800 mm Concentration of the cloudy filtrate: 3 000 – 4 000 mg/l Concentration of the clear filtrate: 10 – 50 mg/l Concentration of the superclear filtrate: up to 5 mg/l
Scrap hydrobeater (pulper)	Defibering of recycled scrap	A scrap treatment unit under the machine: the couch-pit, the press part of the hydrobeater for scrap cooking Concentration: 2,5 - 4 %

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Equipment unit name	**Equipment purpose**	**Technological characteristics[1)]**
1	**2**	**3**
Environmental protection equipment for paper/board production		
Broke thickener	Thickening of recycled broke	Type: thickener with/without doctor (couch roll) Capacity: 15 – 240 t/day Filtration surface: 14 – 50 m^2 Input concentration: 1 – 2,5 % Output concentration: 4 – 4,5 %
Scrap screen	Recycled scrap screening	Type: vertical force-fed slit screen Sieve aperture/slit: 0,2 – 4 mm Concentration: 2 – 4 %
Scrap cleaner	Recycled scrap cleaning	Type: vortex conical cleaners Input concentration up to 1 %
Edge and dust removal from the longitudinal cutting unit	Removal of edges and dust	Unit consisting of: a fan-shredder and a separator
Dust removal from the sheet in the sheet cutting machine	Removal of dust from the surface of the sheet	Unit consisting of: suction boxes in the zone of transverse and longitudinal cutting over the whole width of the sheet, a fan and a dust separator
[1)]the technological characteristics depend on the type of wood, and the needed capacity of the production line		

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2.6.13 Techniques and Main Equipment in the Production of the Dominating Types of Paper

The dominating types of produced paper are various types of bank and print type paper. The main requirements towards the bank and print type of paper are: minimal fluctuation over the full breadth of the sheet of the density per square meter, as well as of the thickness, smoothness, absence of unevenness of shade, and flaking as well as a sufficient level of surface strength. The efficient providing of the said number of qualities depends upon the used techniques and the possibilities of the used main production equipment.

At present, for the forming of various dominating types of produced paper, are paper machines with double sheet formers. The sheet formers guarantee the fast dewatering of the stock, the even structure of the paper sheet, a high-quality forming at any speed of the machine, a high retention of filler and pulp, ease of control, low operating costs as well as the dewatering of the paper fiber. The use of up-to-date forming technique allows for the production of both print paper containing mechanical pulp and pulp without any mechanical pulp content. The used former should preferably be used in high-speed paper machines (above 1 200 m/min), as well as when carrying out reconstruction work on a Fourdrinier former, providing the possibility of a further use of many components of the flat grid. The paper stock, fed onto the forming unit through the stuff box, is evenly distributed over the full width of the cloth. The dewatering of the paper stock begins on the forming roller. Thereafter follows the bent forming shoe with vertically arranged elastic forming plates, the so-called D-part. With the aid of vacuum, it is possible to control the structure of the sheet in the Z direction. The Forming plates are softly squeezed to the shoe by a pneumatic system.

The press of modern paper machines for the production of bank type paper is equipped with presses with an extended pressing zone (with three or four zones) and cooking guiding of the sheet. The use of one or the other construction of the press is determined by the requirements towards the produced type of paper, as well as the operational speed of the paper machine. For instance, when producing high-end types of paper without any content of mechanical pulp (coating base paper and paper for deep printing) a press with three pressing zones is used. During this process

in the last pressing nip, the upper side of the paper sheet is squeezed towards the smooth roll, which offers the possibility of regulating the two-sidedness of the sheet surface.
The efficient drying of the print-grade of paper types, the production of which is carried out on high-speed paper machines (1 200 – 2 000 m/min), is achieved by using a drying unit construction with a single-row upper configuration of the drying cylinders.
In order to finish the paper sheet while production print grade paper types the calendering process is used, for instance, using a soft calender, composed by two rolls, an upper floating roll with a soft cover, and a second, driving roll.
In order to reel in the paper on the drum in a high-speed paper machine one uses, for instance, a reel section produced by a company which uses a reeling process that can be controlled by a modern system for the control of winding density.
Table 2.24 shows the main types of paper machines.

Table 2.24 The main types of paper machines, used for the production of dominating paper types

Name of equipment unit	**Application of the equipment unit**	**Technical and technological features**
1	**2**	**3**
1. Paper machine	Production of light coated paper	1. Head box MasterJet with a system for the control of the stock profiled ModuleJet 2. Twin wire forming unit DuoFormer TQ_w 3. Tandem press NipcoFlex. 4. Drying unit TopDuoRan. 5. Sizing press SpeedSizerAT 6. Soft Calender EcoCal 7. Integrated coating 8. Width, mm: 8 100 – 10 600 9. Speed, m/min: 2 000

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Table 2.24, cont. The main types of paper machines, used for the production of dominating paper types		
Name of equipment unit	**Application of the equipment unit**	**Technical and technological features**
1	**2**	**3**
2. Paper machine	Production of print paper	1. Head box OptiFloll. 2. Forming unit OopriFormer 3. Press OptiPress 4. Sizing press SymSizer 5. Soft Calender OptiSoft 7. Reeling unit OptiReel 8. Width, mm: 10 200 9. Speed, m/min: 2 000 (design)

2.6.14 Technique and Equipment for the Production of Light-weight Coated Paper (LWC)

LWC is used for the production of illustrated journals, leaflets, and advertising catalogues with colour printing. A distinguishing property of LWC is the low weight of the paper per square meter (50 – 80 g/m^2), which defines the properties of the technology for the production of it. As fiber components in LWC mechanical pulp is used (SGW, TMP, CTMP) as well as recycled paper at a rate of 60 – 70 % and 30 – 40 % of either sulphate of bisulphate softwood pulp.

The design capacity of the LWC producing paper machines reach 350 – 500 thousand tons per year at a width of 9-10 m and an operating speed of 1 500 – 2 000 m/min. At present a compact system of the wet part of the paper machine, (BDM-ROM) that can react swiftly on changes in the production parameters and that supports the stability of the paper machine. The use of ROM (??) raises the paper machine efficiency with 3 to 10 %. The control of the paper sheet stock per square meter on the paper machine wire is carried out with the aid of a step diffuser of the hydraulic stuff box.

The construction of the wet part of modern high-speed paper machines is based on a twin wire gap former, guaranteeing the efficient dewatering of the pulp on the wire and the high quality of the forming of the paper sheet.

The increased speed of the paper machine gives rise to the need to remove the free stretches of transfer of the paper sheet to the press part of the machine. In order to accomplish this, wide-span shoe presses are used, increasing the surface of the drainage. The dryness of the pulp attains 50 – 52 %, whereas the steam consumption for drying purposes is lowered by 20 – 25 %.

The impulse drying technology is a new development in the advance of pressing processes and currently it is in the stage of introduction. It differs from the conventional-type pressing by the fact, that one of the press rolls is heated by gas or electricity to a high temperature (400 °C), which is why the dryness of the paper sheet is raised to 60 % within 20 – 100 ms. The use of this method allows for the economy of energy expenditure, the improvement of the mechanical strength properties of the paper, as well as the optimization of its composition.
The introduction of coating units into the paper machine became possible after the development of sizing presses with a film-type roll unit, which apply the coating paste simultaneously on both sides of the paper sheet, while retaining the contour outline of the paper. The new construction of the coating unit have two rolls, towards both of which a dosing roller is connected and rotating with a different speed than the applicator roll, thanks to which in the film of the applied coating compound there arise transverse forces, providing stability at a high speed.
The use of SpeedCoater when producing LWC gives considerable advantages as compared to the traditional two-blade coating system. It involves a considerable lowering of capital investment expenditure and the reduction of needed area for the set-up. Another advantage of the Speed Coater is the higher production capacity of the paper machine.

2.6.15 Technology and the Basic Equipment, used in the Production of Sanitary and Hygienic Paper

Modern sanitary and hygienic paper production technologies are mainly determined by the properties of the used fibrous intermediate products and the additional chemical compounds as well as by the technical level of the main production equipment (paper machines).
In modern paper machines, depending on the construction, one may produce one-, two- and three-layered crepe paper or – non-creped sanitary and hygienic paper, white or coloured, with stamping or without.
The manufacturers of paper machine for the production of sanitary and hygienic paper are various foreign companies.
The main parameters of modern paper machines for the production of sanitary and hygienic paper are:

- Wire width: 1 800 – 5 600 mm
- Operating speed: 1 800 – 2 500 m/min
- Capacity: 24 – 110 thousand t/year

- Diameter of the Yankee cylinder: 3 660 – 5 500 mm
- Weight per square meter: 11 – 45 g
- Creping degree: 10 – 30 %

Modern paper machines for the production of sanitary and hygienic paper, usually, include:

- a hydraulic stuff box with baffle plates for the production of multi-layered paper and an automatic weight per m^2 profile control system through the dilution of the recirculated water over the stuff box zones, supplying the even turbulence when transferring the stock to the wire.
- a compact former, providing a high-quality forming, the reduction of the number of failures and the increase in paper machine speed.
- A special construction press with a bent shoe, and a protracted pressing zone, the use of which in the paper machine construction guarantee the high quality of the sanitary and hygienic paper and the reduction of the relative energy consumption
- A perforated drying cylinder for the drying of paper with blowing hot air jets or a drying Yankee cylinder with a fast drying hood, the advantage of which is the possibility to reduce about two-fold the energy consumption as compared to a paper machine equipped with a perforated drying cylinder with blowing hot air jet drying. Modern paper machines may or may not be equipped with a creping unit. In order to intensify paper drying, a natural gas heat centre unit may be fitted.
- A soft calender (for multi-layered uncreped paper after hot air jet drying) and a stamping press
- Reel section with automatic control of the tightening of the paper sheet and the winding density of the paper drums
- A paper dust removal system at the stretch beginning at the creping blade and ending at the reel section, supplying a dust concentration of the air not exceeding 1 mg/m^3.

Modern paper machines are equipped with an automated paper moisture control system in the machine and transverse directions.

A paper plant control system includes the control and regulation of the grinding of the stock as well as its preparation, control of the composition of the stock, the change in composition based on the paper production target, the regulation of the weight of 1 m^2, moisture and the creping level of the paper.

As fiber intermediate products for the production of high-quality sanitary and hygiene paper, sulphate, bleached softwood or hardwood pulp, bleached CTMP (predominantly softwood) and bleached secondary fiber. In some types of sanitary and hygiene paper, for instance, for the production of table-cloths and towels, chemical fibers are used with a length of 5 – 9 mm (polyether, viscose, etc.). The main types of paper machines, used for the production of sanitary and hygiene paper are shown in table 2.25.

Table 2.25: main types of paper machines use for the production of sanitary and hygiene paper

Name of equipment unit	**Application of the equipment unit**	**Technical and technological features**
1	**2**	**3**
1. Paper machine, PrimLine concept	Production of sanitary and hygiene paper	1. A hydrodynamic stuff box with 1,2 and 3-layer forming of the paper stock 2. Crescent Former forming unit 3. Shoe press TissueFlex. 4. Drying unit PrimeTAD. 5. Creping blade 6. Horizontal reeling unit 7. Speed, m/min: 1 000 – 2 200 8. Wire width, mm: 2 000 – 5 600 9. Air temperature in the fast drying hood: 300 – 700 °C
1. Paper machine, Advantage concept	Production of sanitary and hygiene paper	1. Stuff box Optiflo 11 2. Crescent Former forming unit 3. Shoe press ViscoNip 4. Yankee cylinder and fast drying hood AdvantageAirCap 5. Creping blade 6. Horizontal reeling unit 7. Speed, m/min: 1 600 – 2 000 8. Wire width, mm: 2 800

In order to enhance the quality of sanitary and hygiene paper in modern production reinforcing additives, softeners, agents for creping improvement, as well as cation dyestuffs of various colours and shades are added, the latter providing the even colouring of the paper with a minimal pollution of the recycled water.

One element of the production chain when production sanitary and hygiene paper is the longitudinal cutting machines, with a cutting speed of 2 200 m/min, allowing for the cutting of paper reels into the width needed for the continued processing. Modern longitudinal cutting machines, having in their unreeling stand up to four reels, are equipped with a special cutter drum allowing for an individual drive for each knife. When using such longitudinal cutting machines the adjustment of the format of the paper cutting is made by the operator practically without flow interruption.

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2.7 Boilers for the Incineration of Wood and Bark Waste and Treatment Plant Sludge

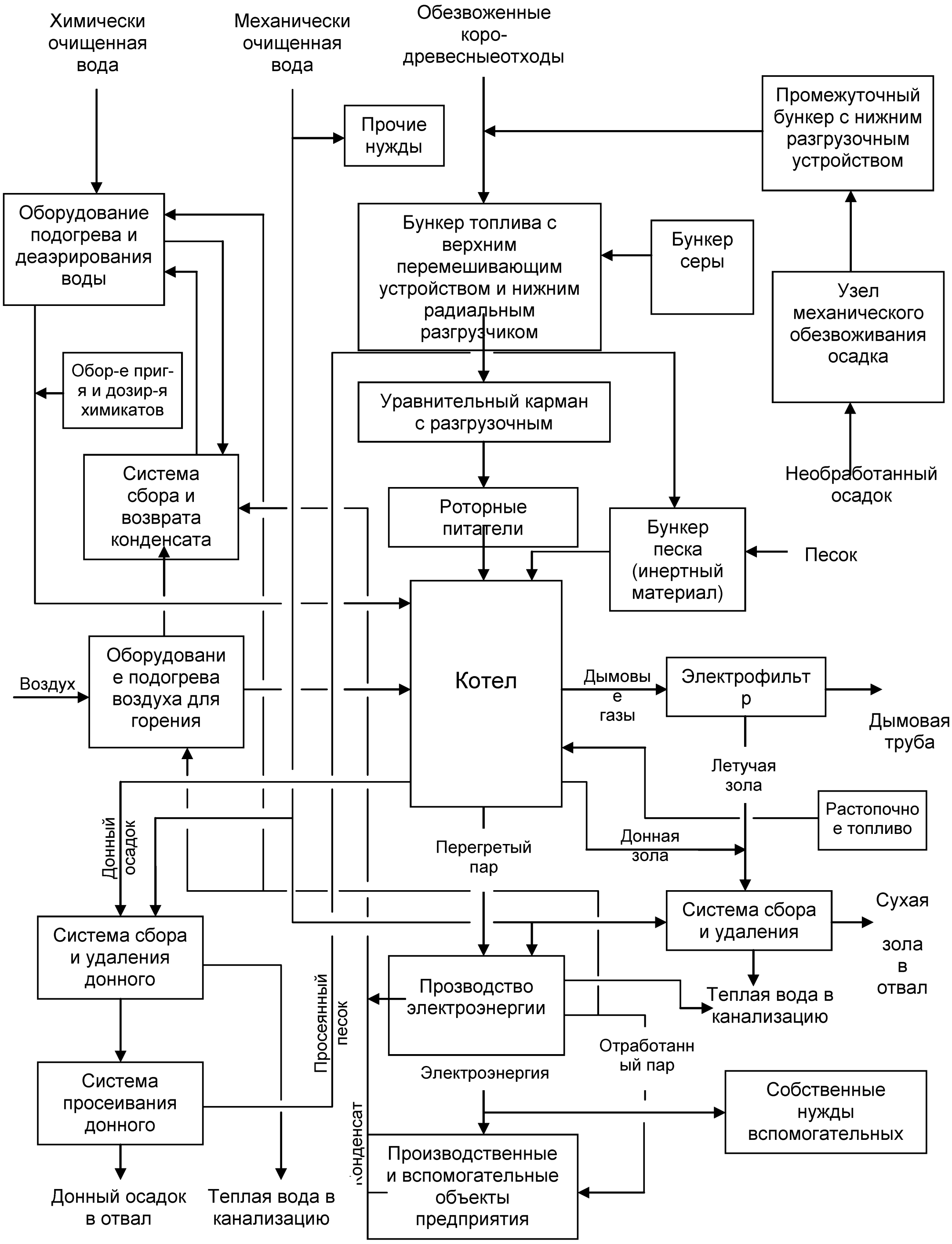

Figure 2.22: The general technological Scheme of the process for the incineration of bark and wood waste and wastewater sludge of the plant.
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1.7.1 A Description of the Technological Process of the Incineration of Bark and Wood Waste and Wastewater Sludge

The process of the incineration of the production waste and wastewater sludge involves the following sub-processes:

- The preparation of the fuel mix and the feed into the boiler
- The preparation of feed water and the feed into the boiler
- The preparation of incineration air and feed into the boiler
- The incineration of the fuel in a specialized hearth (reactor)
- The collection and removal of ash and bottom sludge
- The settling of the bottom precipitation

Information on the specified sub-processes is shown in table 2.26.

Table 2.26 Description of the technological process of incineration of bark and wood waste from the production and from the wastewater sludge

Input	Stage of the process	Output	Main process equipment	Emissions
1	2	3	4	5
Undewatered wastewater precipitation Dewatered bark and wood waste Sulphur Electrical energy	13.1.1 Preparation of the fuel mix and feed into the boiler	The fuel mix of the needed quality	Belt presses Intermediate sludge pit with a bottom discharge gear	Gaseous emissions to air Water from the dewatering of the bark and wood waste and the wastewater sludge (to the drain)

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Input	Stage of the process	Output	Main process equipment	Emissions
1	2	3	4	5
Chemically cleaned water Condensate Steam Electrical energy Chemicals	13.1.2 Preparation of feed water and feed into the boiler	Boiler water of the needed quality	Deairators Preparing and chemicals proportioning unit	Noise from the operation of the equipment Warm water from the pump seals to the drain Condensate to be recycled
Air Steam Electrical energy	13.1.3 Preparation of air for the incineration and feed into the boiler	Heated air	Steam heaters Blow-down fans	Noise from the operation of the equipment Warm water from the pump seals to the drain Condensate to be recycled
Fuel mix Air Start-up fuel Boiler water Sand Electrical energy	13.1.4 Burning of the fuel in a special hearth (reactor)	Overheated steam	Water cooled perforated grid	Flue gases (including sand grains) of to the treatment system Blow-down water to the blow-down separator Bottom ash and sludge to the collection and removal system Noise from the operation of the equipment

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Input	Stage of the process	Output	Main process equipment	Emissions
1	2	3	4	5
Ash (fly ash and bottom ash after the convective shaft) Bottom sediment Electrical energy Mechanically cleaned water	13.1.5 Collection and removal of ash and bottom sediment	Ash and bottom sediment	Scraper type conveyer system	Noise from the operation of the equipment Warm water to the drain Ash and refuse Bottom sediment to settling/clearing
Bottom sediment Electrical energy	13.1.6 Settling of the bottom sediment	Settled sand for reuse	Scraper type conveyer system	Noise from the operation of the equipment Warm water to the drain Ash and refuse Bottom sediment to settling/clearing
Flue gases	13.1.7 Flue gases treatment	Flue gasses with acceptable content of fly ash and other suspended particles	Electrical filter Suction boxes	Treated flue gases to air through the smokestack Fly ash to the collection and removal system

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A description of the main equipment is presented in table 2.27

Table 2. 27 A description of the main equipment for the process of burning of bark and wood production waste and wastewater sludge

Name of equipment unit	**Application of the equipment unit**	**Technical and technological features** [1)]
1	**2**	**3**
Intermediate pit for sludge storage with a bottom discharge mechanism	Regulation of the even feed of sludge into the mixture of bark and wood waste in the needed proportions	Useful design volume of the pit: 50 m^3 Moisture content of the material: 75%
Fuel pit with a top agitator and bottom radial discharge mechanism	The even agitation of the sludge and bark/wood waste The even feed of the fuel mixture into the burning hearth and feed regulation. The creation of a supply of fuel mix needed for the specified time	Useful design volume of the pit: 100 m^3 Moisture content of the material: 61,67 % Size of the fuel mix particles: 3,1 – 90 mm Bulk specific gravity: 0,7 t/m^3
Equalizing pocket with a discharge mechanism	Regulation of the fuel mix feed based on the specified steam generation capacity of the boiler	
Sulphur pit	Serves for the feed of sulphur and fuel mix in order to bind chlorine in the dewatered sludge and, as a consequence, the reduction of corrosion of the heating surfaces of the boiler	Useful design volume of the pit: 2,0 m^3

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Name of equipment unit	**Application of the equipment unit**	**Technical and technological features** [1)]
1	**2**	**3**
Deairators	The thermal deaeration of water in order to remove the dissolved aggressive gases (oxygen and carbon dioxide). The creation of a supply of deaerated water for the specified time	Capacity: 5 – 300 t/h Volume of the deaerated water tank: 2 – 75 m^3
Chemicals production and batching	The correctional processing in order to lower the carbon dioxide corrosion and the reduction of iron oxide	-
High and low pressure heaters	The heating of water to the needed temperature before the deaerators – and after them – in order to reach the design parameters of the deaerator and boiler operation	Operating pressure of the heating steam: 1,5 MPa Operating temperature of the heating steam: 300 °C Input and exit temperature of the water, °C
Fuel pit with a top agitator and bottom radial discharge mechanism	The even agitation of the sludge and bark/wood waste The even feed of the fuel mixture into the burning hearth and feed regulation. The creation of a supply of fuel mix needed for the specified time	Useful design volume of the pit: 100 m^3 Moisture content of the material: 61,67 % Size of the fuel mix particles: 3,1 – 90 mm Bulk specific gravity: 0,7 t/m^3
Feeding electrical pumps	Boiler water feed into the boiler drum	Capacity: 275 t/h Developed head: 120 bar Needed cavitation supply 90 bar
Equalizing pocket with a discharge mechanism	Regulation of the fuel mix feed based on the specified steam generation capacity of the boiler	
Sulphur pit	Serves for the feed of sulphur and fuel mix in order to bind chlorine in the dewatered sludge and, as a consequence, the reduction of corrosion of the heating surfaces of the boiler	Useful design volume of the pit: 2,0 m^3 Coefficient of efficiency: 79 % Consumption of electrical power: 1 250 kW Revolution frequency: 3 000 rev/min

Name of equipment unit	**Application of the equipment unit**	**Technical and technological features [1)]**
1	**2**	**3**
Steam heaters for the primary/secondary air	Heating of the air to the needed temperature in order to reach the design parameters for the burning of the fuel mix	Operating pressure of the heating steam: 1,2 MPa Operating temperature of the heating steam: 270 °C Input/exit temperature of the air 35/80°C – 120 °C Heating Power: 1 350/2 400 kW
Primary/secondary air blow-down fans	Intake and feed of the water into the boiler hearth	Capacity: 17,4/17,5 nm^3/s Total pressure difference 17,92/6,0 kPa Input air temperature: 40 °C Revolution frequency: 1 000 rev/min
Water cooled perforated plate (tray)	The creation of a fluidized bed, functioning as a heat accumulator supporting the burning process and evening out the fluctuations brought on by the properties of various types of fuel The removal of the coarse fraction of the fluidized bed (sintered sand, scruff	Humidity of the fuel mixture: 60 – 64 % Inferior calorific value of the fuel mix per operative weight 1,4 kcal/kg Adiabatic temperature: 1 188 °C Inert material particle size: 0,5 – 1,5 mm
Scrape-type conveyer system	Transport of the material within the confines of the shop	Capacity: 6,0 sat. m^3/h

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Name of equipment unit	**Application of the equipment unit**	**Technical and technological features 1)**
1	**2**	**3**
Screen filter (sizing screen)	Settling of the bottom precipitation in order to separate out the sand fraction, suitable for recovery	Capacity: 6,0 m^3/h Revolution frequency: 20 rev/min Reduction gear power: 1,5 kW
Flue-gas fans	Overcoming of the resistance of the gas tract against the removal of flue gases	Capacity: 48,7 nm^3/s Total pressure difference 4,66 kPa Input air temperature: 180 °C Revolution frequency: 1 000 rev/min
1) the production features depend upon the capacity of the production line		

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Table 2.28 – The environmental protection equipment for the process of incineration of bark and wood production waste and wastewater sludge

Equipment unit name	Equipment purpose	Technological characteristics[1)]
1	2	3
Electrical filter	Trapping of solid matter (dust, fly-ash) with the aid of an electrostatic field, created between coronating and precipitation electrodes.	Volume flow of the (moist) flue gases: 43,4 nm^3/s Mass flow of (moist) gases: 53,2 kg/s Normal temperature of the flue gases: 165 °C Maximum constant working temperature: 185 °C. Design temperature: 230 °C Change in pressure over the set-up: 350 Pa Coefficient of efficiency: 95 – 99,75 %

2.8 Production of Pulp Stock from Recycled Paper. The Use of Recycled Paper for the Production of Paper and Board

Secondary fiber has become an irreplaceable raw material for the paper industry. It accounts for about one third of all fiber material by virtue of the low cost of the regenerated fibers as compared to the corresponding types of commercial pulp and also due to the fact that the recycling of waste paper more and more becomes the general practice in many European countries. It should be considered, though, that the maintenance of a production cycle with a presence in the composition of secondary fiber calls for the use some quantity of primary pulp fiber as well, in order to provide the mechanical strength and other properties of the produced paper [4, 5].

IN order to achieve an efficient use of secondary fiber, one needs to collect, sort and classify it according to its quality. This is why, after the collection of waste paper, it is sorted. The unwanted inclusions, as, for instance, plastic, laminated paper and the like, are removed as carefully as possible before the packaging of wastepaper into bales. The sorted waste paper is usually compressed in special packaging presses. The used paper, received in large quantities from industrial sources, is usually sent to a paper production plant to the waste paper processing shop.

2.8.1 Processes and Techniques Applied

Waste paper processing systems vary depending on the kind of paper or board produced on its basis. Usually the recovered fiber production process is divided into two main categories:

- Processes, in the course of which, exclusively mechanical treatment is uses, without the removal of typographical dye, in order to produce such products as testliner, fluted board, box or package board
- Processed involving the use of mechanical treatment as well as the removal of ink and typographic dye in order to produce such merchandize as newsprint, thin sanitary and hygienic paper, printing paper and paper for copying equipment, journal paper (supercalendered/coated), coated board and package board or commercial recycled stock without any typographic dye content.

Various systems for the processing of waste paper are used at paper plants. All the processes of the system are there for the dissociation of fibers of the processes waste paper, the deflocculation (the dissociation of fiber bundles – floccules) as well as the removal of various inclusions. The schemes of the units for the production of recycled pulp have similar blocks, which are use for the creation of the defined production scheme. The typical scheme of the process of the production of waste paper pulp consists of the following elements (blocks)

- Waste paper storage
- Production of pulp stock our of the dry waste paper
- Removal of mechanical inclusions
- Removal of ink (dyes) with the use of flotation
- Treatment of the process water
- Recovery of sludge and waste

2.8.1.1 Waste Paper Storage

The waste paper is brought to the paper works in bales. At some companies the waste paper is also received in bulk, in containers, or is brought in dump trucks. At the paper works, the waste paper is stored in special areas.

2.8.1.2 Production of Pulp Stock from Dry Waste paper

Waste paper is fed into the hydropulper together with heat and recirculated water and, in the hydrobeater, the waste paper stock is formed in the process of mechanical and hydraulic dissociation into fibers of the paper and board sheets. After the hydrobeater the waste paper has the needed concentration for further processing. Often some chemicals are used, for instance reagents for the removal of typographic dyes and NaOH. Usually the removal of typographic dye is begun already when the pulp is received. For various types of raw material and produced merchandise, various process reagents are used.

There are three types of hydrobeaters for pulp; the ones working under conditions of a low pulp concentration (4 – 6 %), or medium concentration (7 – 15 %) and high concentration (15 – 20 %). They are divided into batch and constant working processes. In order for the pollutants not to end up in the pulp fraction and not to accumulate in the hydrobeater, they are constantly being removed curing the course of the operation of the hydrobeater, for instance through a perforated sieve, and are fed to the waste conveyer.

The water used for the dissociation of the waste paper is recycled as recovery water.

2.8.1.3 Removal of Mechanical Inclusions

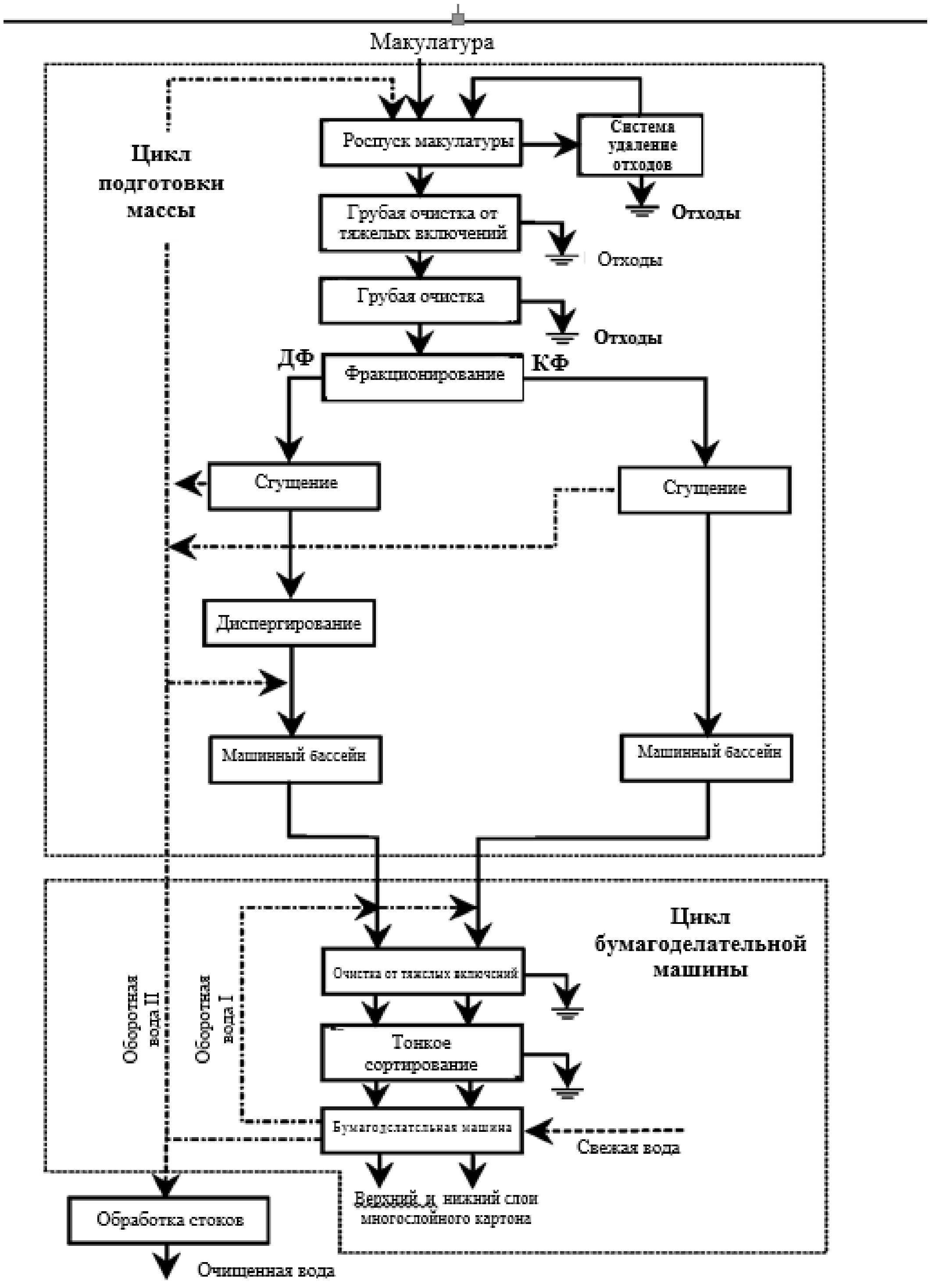
In order to remove mechanical inclusions a sieve with various diameters of the openings (or slits) is used as well as various types of hydrocyclones (cleaners for high-concentration stock, centricleaners, etc.).

Waste, separated out from the stock in these machines and from the hydrobeater, is removed to a waste deposit. The next stage of the process is the screening. The choice of the type of screening depends on the end product and the quality of the produced fiber pulp. A coarse screening (concentration 3 – 4 %) for the removal of large inclusions in the process of the preparation of the pulp may be different from the fine screening, carried out when the concentration of the pulp is about 1 % in the sorting scheme before the paper machine. The used equipment in principle works according to the same principle, however, having different possibilities of separation the various fiber fractions. Usually the screening at low concentrations

proceeds more efficiently, however calling for a larger quantity of apparatuses and uses more energy. The waste is put on a landfill or is subjected to further processing. Depending on the composition of the paper stock, the machine for the preparation of the waste paper pulp must have additional equipment, such as fractionators, dispergers or refiners. The fractionator divides the pulp into two fractions, which provides the possibility of the processing of the short and the long fibers by different methods. The disperger process, calling for a large energy consumption, may be used in order to achieve the highest possible bond forming between the fibers in order to guarantee high mechanical strength properties of the paper produces as well as to reduce the size of dirt particles.
A typical scheme of the mechanical treatment of waste paper in order to produce package material (testliner) is shown in figure 2.23. It is necessary to mention the fact that in practice, every piece of machinery has its individual equipment from one or several manufacturers depending on the used type of waste paper, the quality requirements towards the end product, capacity and technical properties of the paper machine and the local environmental requirements.

2.8.1.4 Removal of Ink (Dyes) with the Use of Flotation (for High-End Products)

The removal of ink (printing dyes) is necessary at plants producing paper types, for which brightness is important; newsprint, of the covering layer of board based on waste paper. The main reasons why dyes are removed are the increased brightness and whiteness, as well as the reduction of the content binding materials.



ДФ: long fiber fraction; КФ: short fiber fraction

Figure 2. 23 Production scheme of the production of secondary stock for the production of the flat layers of fluted board.

The full set-up for the removal of printing dyes includes also the abovementioned main equipment with the processes of waste paper dissolution, screening in order to remove non-fiber inclusions. In addition to the mechanical treatment for

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composition cleaning, chemical processing of the stock is applied as well as the subsequent removal of dyes by flotation.
The chemicals used for the removal of dyes, such as NaOH, sodium silicate, hydrogen peroxide, soap or fatty acids as well as chelating agents are added during the procedure of pulp production. The dispersed particles of the dyes are subsequently removed from the fiber pulp, using the method of multi-stage flotation. The process of dye removal by flotation lies in the following: water in the form of small bubbles is introduced into the paper stock while the dye particles first separated from the fibers is sorbed by the bubbles and, subsequently, the surfaces pollutants are removed.
The dye-containing stock and waste are dewatered separately in a centrifuge or with the aid of a press until 50 % dryness is reached. The precipitation formed during the process of dye removal is incinerated or is disposed to a landfill. After the removal of the dyes the stock is thickened, washed with the aid of belt filter presses, disc filters, screw extrusion machines as well as other washing equipment.
In some processes the remnant unremoved dyes, wax and binding agents contained, for instance in the glues, etc., are dispersed in dispergers at a concentration of 25 – 30 % and a temperature of approximately 95 °C.
The order of the operations may differ depending on the company's decision, and some of the stages may be repeated.
Figure 2.25 shows the scheme of the set-up for the removal of dyes but the flotation method during the preparation of the pulp for the production of newsprint.

2.8.1.5 Process Water Treatment

After the paper waste processing stages, the water may be cleaned by aid of microflotation devices. The process waster is then repeatedly used in the production process. In the microflotation installation a precipitation is formed, which is thickened and either disposed to a landfill or incinerated. In the process of dye removal, the total water consumption is reduced through the recycling of cleaning water. A special flotation unit removes the suspended matter from the filtrate.

2.8.1.6 Sludge and Waste Recycling

When processing waste paper, various types of waste and sludge need to be recycled. They are passed to the system for the processing of precipitation and waste.

2.8.2 Waste Paper Processing Systems

Various properties of the products call for various levels of whiteness and brightness of the recycled pulp, and therefore, the applied processes also differ. For instance, the removal of dyes is not needed for many grades of board. And, on the contrary, a very efficient multi-stage process is needed for the high-speed paper machines for the production of thin paper or types of paper, for which brightness is important. The level of complexity the production scheme depends on the used composition and the type of the produced paper.

Below, a more detailed list of examples of the main systems of waste paper processing is shown:

- The production of recycled pulp for the production of packaging paper and some cardboard types (testliner and fluting paper)
- The production of recycled pulp for the production of newsprint and simple print and writing paper
- The production of recycled pulp for the production of coated, supercalendered, high-end print and writing-type paper
- The production of recycled pulp for the production sanitary and hygienic paper as well as commercial recycled pulp

The system for processing of waste paper may differ from each other by differing composition and the fact that they have different environmental impact because of the differing consumption of energy and fresh waster, the amount of wastewater formed as well as the amount of sludge formed.

2.8.2.1 Packaging Paper and Board

In order to produce packaging paper or board from recycled pulp, i.e. for the production of testliner and the middle layers of fluted board, only mechanical treatment is used, i.e. there is no need to remove dyes. For these grades of paper mixed waste paper or supermarket waste paper is used. Figure 2.24 shows a typical system for the preparation of the raw material for the production of testliner from waste paper. IN order to produce testliner and paper for fluting, some companies have fully closed circuit systems for water use. The closed-circuit water circulation systems operate quite well in conditions a well-managed companies, producing high-quality products, if approximately 3 – 4 m^3 of the process water per ton of finished pulp is cleaned at biological treatment plants.

2.8.2.2 Newsprint and Writing and Printing Paper

Figure 2.25 shows a block scheme of the process of production of recycled pulp for the production of newsprint. As raw material common decolorized waste paper, after the removal of the printing dye, including the 50:50 mix of paper and journal paper. A characteristic feature of this system is the two-stage flotation as well as the bleaching in combination with an intermediate fragmentation. In order to produce newsprint grades with enhanced properties and whiteness, processing with hydrosulphite is used after the pulp thickening stage. In order to produce print paper from waste paper it is especially important to organise the recycling water system as well as the treatment of the recycling water.
The internal plant water treatment after the thickening phase involves the flotation by dispersed air, in order to lower the load from colloids and anion compounds, contained in the process water, in order to maintain the needed level of ash content of the paper. The recovered stock from the production line is thickened in the waste processing system.
As raw material a constant 50:50 proportion of paper and journal paper is used.

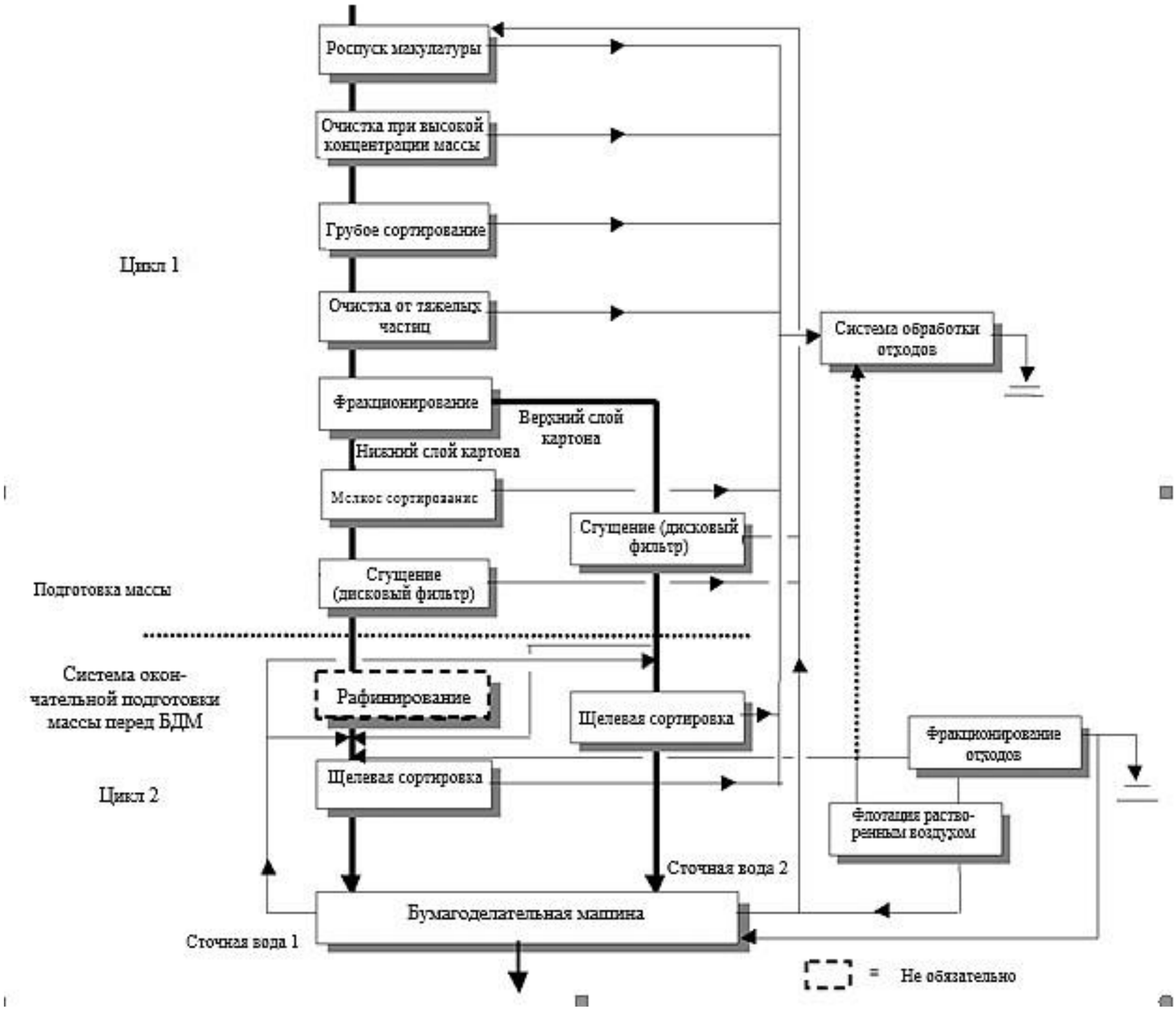

Figure 2.24: A principal scheme of the preparation of recycled stock for the production of testliner (2-stage system)

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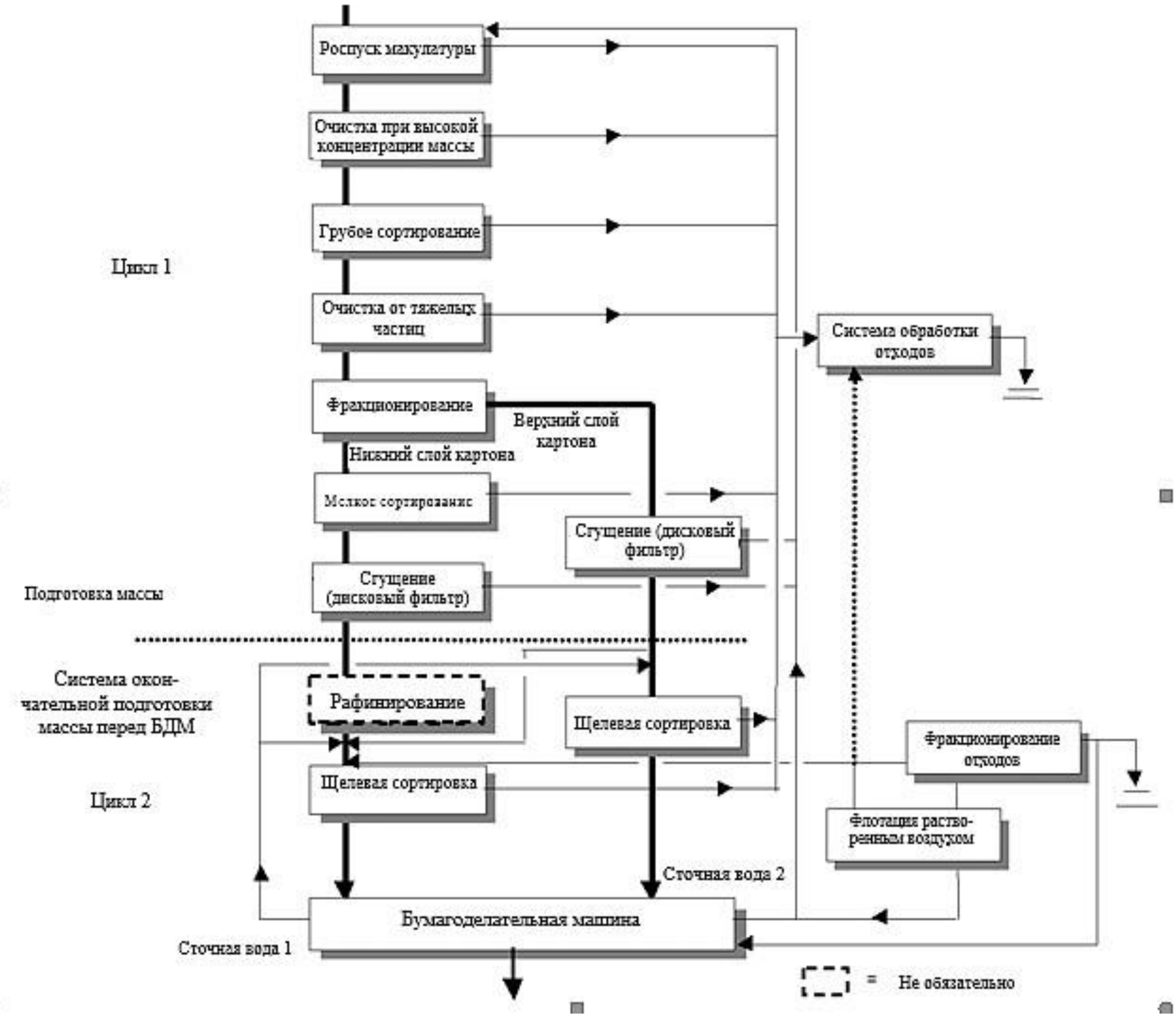

Figure 2.25 A principal scheme of the production of newsprint from recycled pulp.

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2.8.2.3 Coated and Supercalendered Paper

When processing household waste paper into refined pulp for the production of high-end types of paper, containing mechanical pulp such as supercalendered and light coated types of paper, it is necessary to observe special requirements. One of these is the necessity to reach a low level of unwanted inclusions, and the achievement of a high-quality surface (a glossy surface) and the elevated requirements towards the optical properties (brightness, whiteness) of the end product.

Based on the high optical requirements, to which brightness and whiteness is referred, it is necessary to involve two-stage flotation and the bleaching of the waste paper.

A general scheme of the production is analogous to the one shown in figure 2. 25. When applying this version of pulp preparation, the problem with unwanted inclusions (colloidal pollution, anions), which may disturb the sensitive mechanism of the retention of particles during sheet formation in the paper machine, is solved through the corresponding process scheme of the recirculated waster and its treatment in the stock preparation stage.

If the ash content of the finished pulp is higher than 8 – 10 %, then there is no need to use any equipment for the washing of the waste paper.

2.8.2.4 Sanitary and Hygienic Paper and Commercial Recycled Pulp

If waste paper is used for the production of high quality hygienic types of paper or commercial refined recycled pulp, it is necessary to process it in such a way, as to remove not only the large fractions of pollutants, but also the printing dye, the glue particles, the very short fibers as well as the filler.

The main distinctive feature of the discussed types of paper from newsprint is the necessity of ash removal from the waste paper (the removal of fine inclusions and filler particles) as well as the achievement of softness and high ink holdout of the end product.

For the major part of the products, for instance, towels of toilet paper, one may use the same raw material, as in the production of newsprint, i.e. the mixture of paper and journal paper or in an accumulated form waste paper from paper of intermediate and high quality. For the basic formula, one might use also waste paper without mechanical wood pulp (recycled pulp from copy paper).

Figure 2.26 shows the scheme of an installation for the production of pulp from waste paper with the following properties: a hydrobeater for high concentration recycled pulp with a waste removal system. The waste is subjected to screening in a perforated drum and dewatering in a screw extrusion machine.
The main flow of the pulp is processed in high-concentration washers and is subsequently transferred to low-concentration washers, where mainly metallic inclusions, such as staples, etc. Thereafter the stock is processed in a multi-stage screening and treatment system.
The low concentration pulp washing involves the efficient use of recycles washing water. The printing dye and other suspended particles need to be removed from the recycled water in the process of flotation by dissolved air or any other efficient technique for water treatment. The 1st washing stage serves for the removal of ash elements, as well as very short fibers and small dye particles. After this, the stock is transferred to the press to be dewatered down to the concentration of 30 %. The filtrate from the washing stage is cleaned by flotation and the use of cation flocculants. The ash elements and the very short fibers are removed, whereas the water is returned to the system. The stock is heated in the screw and is processed in the disperger, which leads to the removal of the printing dye, which remains on the fibers. During this process, the simultaneous of mixing the stock with bleaching chemicals proceeds.
In the flotation stage the dye particles that were separated out during the dispersion are removed, as well as the dark, fine inclusions and sizing compound particles. The secondary bleaching may be used after the second washing stage. Thereafter the stock is fed either to the storage tower, or to the final screening and treatment that takes place already in the paper machine stock feed system.

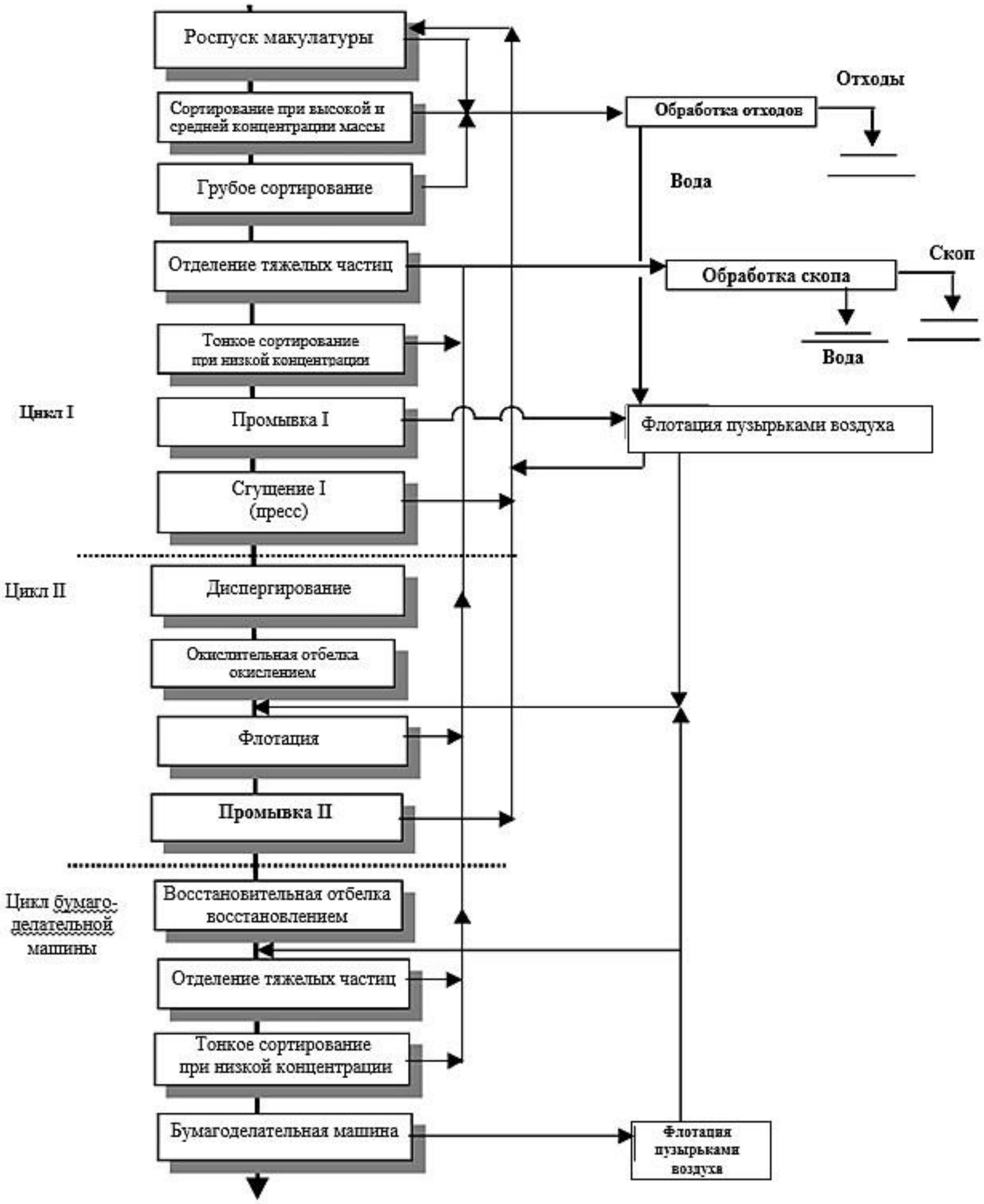

Figure 2.26 Production of recycled pulp for the production of sanitary and hygienic paper.

2.9 Production Wastewater Treatment

The production process at pulp and paper production companies is connected to the formation of a large quantity of wastewater, polluted by suspended and dissolved organic substances [7,8,9].

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At the companies referred to the quantity of wastewater is between 64 and 167 m^3 per ton of produced merchandize (commercial pulp).
Because of the specific relations of the technologies used at pulp and paper works, the wastewater is a multi-component water system, containing the following main groups of compounds:

- Suspended substances
- Dissolved inorganic components
- Dissolved organic components

In the list of controlled wastewater quality parameters of pulp and paper production works, one may highlight the marker substances. To the first group one may refer the marker (integral) parameters, which in accordance with the analytical determination methods used, are characterized by the content in the water by a number of various compounds. In the list of such parameters are included, among others, the chemical oxygen demand (COD), the Biochemical oxygen demand ($BOD_{20}/BOD_{5/7}$), Suspended matter SM, the solid residue, the colour and mineralization.
The main sources of pollution of the effluents when producing pulp are the cooking, washing and bleaching shops.
According to the character of the contained pollutants, the wastewater from a pulp and paper plant is divided into the following groups:

- Alkaline containing
- Acid and alkaline-containing
- fiber containing
- Bark-containing
- Foul-smelling

Based on a statistic analysis of the information on the composition of the wastewater from pulp and paper works if the Ural division of the Russian Academy of Science (UrO RAN) [7] it has been stated, that under the presence of a quite heterogeneous composition of the waste water after the biological treatment for all of the plants, the general representative parameter is the COD.
The chemical oxygen demand is a measure of the total level of pollution of the water by the organic and inorganic reduction agents reacting with a strong oxidizing agent contained in it. It is usually expressed in milligrams of oxygen equivalent per litre of investigated water. This method is recommended when analysing wastewater, the oxidizability of which exceeds 100 mg O_2/l, especially when investigating pulp and paper plant wastewater.

In international recommendations, as an indicator of COD is proposed the effluent pollution standard for the wastewater from pulp and paper plants expressed as the loss of alkaline and organic substances. In Russia, the COD parameter was included in the state statistic reporting form in 1999.
According to the international standard ISO, and the methods of PNDF (The Federal Environmental Regulatory Document), when appraising the quality of waste water, the COD parameter corresponds to the total amount of oxygen, equal to the amount of potassium bichromate, which is reduced through the oxidation of the components of mixed chemical nature and aggregate condition, i.e. not only the dissolved, but also the suspended components.
In order to confirm the integral nature of the parameter ”chemical oxygen demand), a complex analysis was performed of the COD as applied to the technology environments of the companies within the chemical and forestry complex as well as to the evaluation of the efficiency of its use for environmental analytic control.
The experimental method of analysis was build upon a certain input of individual compounds and groups of organic components into the marker parameter COD through the measuring of the value of chemical oxygen demand of the initial water, the water after the removal of undissolved suspended compounds, the dissolved mineral compounds, the discharge of organic fractions as well as the determination of the COD parameter of every individual substance fraction, present in the analysed water.
The input of the suspended matter into the COD value of waste water from various spots of the production process varies and may be above 2 % of the total COD value (see table 2.29). One should add, that this fact depends upon a whole range of factors (the technique of the process, the efficiency of the operation of the equipment, the concentration of SM, etc.)

Table 2.29 The input of suspended matter into the total value of COD for various types of pulp and paper plant wastewater.

Production/type of wastewater	**Input of suspended matter in % of the total COD value**
Integrated pulp and paper works, producing fiber intermediate products as well as finished products (paper, board): - mixing chamber of the biological treatment plant	7-8
1st stage of the biological treatment	40 -43

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Production/type of wastewater	**Input of suspended matter in % of the total COD value**
After the biological treatment	3-24
Local wastewater flows of a sulphate pulp plant: Production of unbleached pulp Production of bleached pulp Oxygen-alkaline processing stage Bleaching stage D0	 29-49 2-10 7-11 2-4
Companies producing paper from recycled paper: Before biological treatment After biological treatment	 35-40 0,5-5,0
Local wastewater flows from CTMP production	33-34

The input of the ion-molecular content of the inorganic components into the value of the COD parameter of the wastewater is determined bye den separation of the organic and the inorganic components of the wastewater by ionic chromatography. After the ionic chromatography a lowering of the COD parameter takes place as compared to the initial water through the extraction of the main part of the mineral component from the wastewater. The residual content of mineral components may be regarded as a background level, which impacts the size of the bichromatic oxidizability, comparable to the tolerance of the determination of COD by the standards method (10 – 15 %). For wastewater from pulp and paper plants, the input from dissolved mineral substances may account for up to 80 % of the total COD value (see table 2.30).

Table 2.30 The input of dissolved mineral compounds into the total value of COD for various types of pulp and paper plant wastewater.

Production/type of wastewater	**Input of suspended matter in % of the total COD value**
Integrated pulp and paper works, producing fiber intermediate products as well as finished products (paper, board): - mixing chamber of the biological treatment plant - after biological treatment	 49- 82 53 - 82

Production/type of wastewater	**Input of suspended matter in % of the total COD value**
Local wastewater flows of a sulphate pulp plant: Production of unbleached pulp Production of bleached pulp Oxygen-alkaline processing stage Bleaching stage D0	 15- 60 55 - 84 30 39
Companies producing paper from recycled paper: Before biological treatment After biological treatment	 27 – 50 65
Local wastewater flows from CTMP production	34 – 38

The difference between the total value of the COD parameter and the input from the suspended matter and the dissolved mineral compounds is the input to the COD by dissolved organic substances (see table 2.31).

Table 2.31 The input of dissolved organic compounds into the total value of COD for various types of pulp and paper plant wastewater.

Production/type of wastewater	**Input of suspended matter in % of the total COD value**
Integrated pulp and paper works, producing fiber intermediate products as well as finished products (paper, board): - mixing chamber of the biological treatment plant - after biological treatment	 20,4 - 44 20 - 32
Local wastewater flows of a sulphate pulp plant: Production of unbleached pulp Production of bleached pulp Oxygen-alkaline processing stage Bleaching stage D0	 6,8 – 11,4 9,0 – 15,1 above 50 above 50

Production/type of wastewater	Input of suspended matter in % of the total COD value
Companies producing paper from recycled paper: Before biological treatment After biological treatment	 8,3 – 15,5 17 - 24
Local wastewater flows from CTMP production	27,6 – 31,9

The composition of the organic component of the pulp and paper production wastewater is of great importance. By using the elaborated scheme of fraction formation the representative fractions of the main groups of organic components were separated from the local and total wastewater flows from pulp and paper plants, and their input into the marker parameter of COD was determined. In order to determine the COD of lignin substances, neutral substances, non-volatile phenols, resin and fatty acids (RFA), calibration COD dependencies of the concentration of the substance were created. The coefficient R2 ranged from 0,94 to 0,99.

The largest input into the organic component of the COD balance is made by the fractions of lignin compounds, volatile organic compounds – volatile with phenol vapours, methanol, turpentine, formaldehyde, non-volatile, phenols, extractive substances, etc. (figure 2.27).

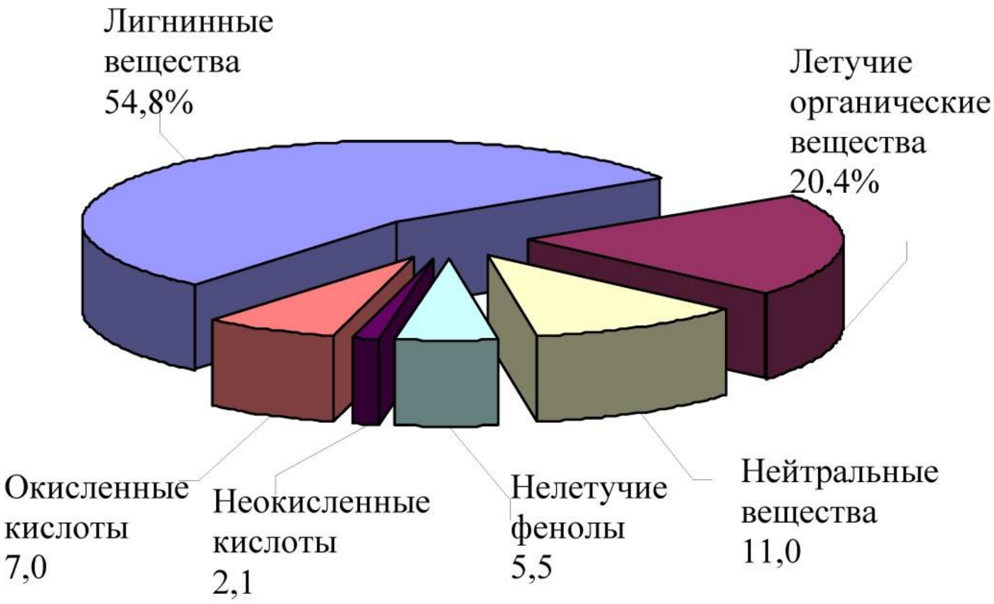
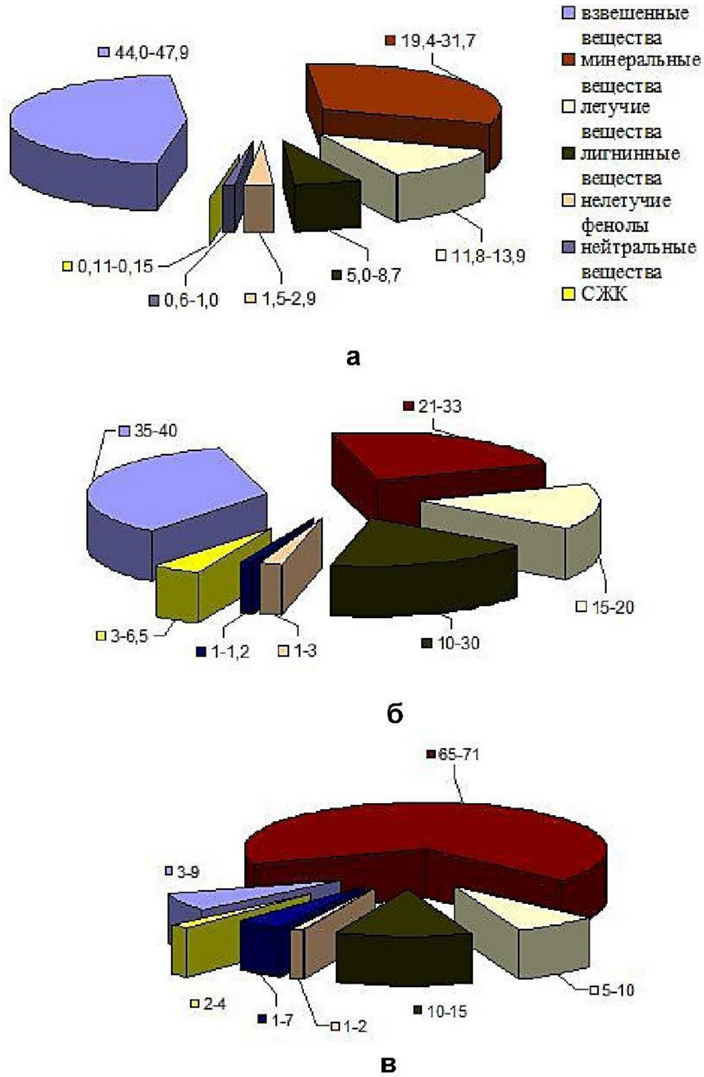


Figure 2.27 Balance of organic components of the COD value of biologically treated wastewater for one of the pulp and paper plants

Blue: Lignin substances, Orange: Oxidized acids, Brown: Unoxidized acids, Light blue: Non-volatile phenols, Yellow: Neutral compounds: Wine-red: Volatile organic compounds.

The consolidated balance of the COD parameter is presented in figure 2.28, showing the results of two integrated works, using similar technologies and producing a similar range of products.
When implementing same-type technique processes, however with different technological parameters, type of raw material, chemicals, the used main production equipment, the wastewater quality is characterised by COD numbers close to each other. However, the analysis of the composition of the wastewater indicates that there are differences both as to the quantitative content of the individual components and groups of organic compounds, and as to their chemical and functional nature.
Apparently, as for the untreated production wastewater, the largest input to the total COD parameter is made by the suspended matter, the efficient removal of which at the stage of mechanical treatment allows for a COD reduction in the wastewater by approximately 30 – 40 %.
The volatile substances fraction and the lignin components exercise the maximum input to the COD balance of untreated wastewater (19 – 33 % and 12 – 20 % accordingly). After the passage of the biological treatment stage, the input from the volatile substances fraction is reduced down to 5 – 10 %, whereas the lignin compounds are reduced approximately twofold.
Out of the rest of the groups of components, the input from the non-volatile phenol substances is about 1 – 3, and the extractives – 0,7 – 7,7 %.
The total ”organic” COD when passing through the biological treatment stage is reduced about 5 times, whereas the volatile compounds COD – more then 10 times.
However not all of the organic components, contained in the wastewater are subjected to bio-oxidation. The biological treatment technology allows for the efficient execution of assimilation of the groups of volatile and low-molecular weight phenol components, while at the same time allowing for the transit through the system of high molecular weight components of the fraction of lignin components and extractives, representing the component of the COD not being prone to oxidation.
Special attention should be directed towards the dissolved mineral component of the industrial wastewater from pulp and paper production. As shown in the table above, 2.31 as well as in the 2.28 figure, the input of inorganic compounds into the COD parameter is about 30 %, while at the same time after the biological treatment phase when ”recycling” the organic component there is a redistribution of the input of pollutants and a growth of the mineral component up to 70 %, i.e. the mineral substances are also passing by transit to the recipient.

Thus, the shown results give testimony to the fact, that the COD parameter really is a marker (integral) value, i.e. a function of the concentration of the content in the wastewater of pollutants of various chemical nature. However, even if two plants are using the same type of technology and if they have a similar product range, it is not correct to just transfer the qualitative and quantitative evaluation of the priority environmental toxicants and their input into the COD from one plant to another. The introduction of changes in the production process (reconstruction of the production, replacement of the chemicals uses, etc.) brings on a quality change of the effluents.



а: Company 1: mill effluents
б: Company 2: mill effluents
в: Company 2: wastewater at the release point to the recipient
Light blue: suspended matter; Whine red: mineral compounds, Beige: volatile compounds; Black: lignin compounds; Brown: non-volatile phenols; Dark blue: neutral compounds; Yellow: RFA (resin- and fatty acids)

Figure 2.28: The input into the marker index COD, % share, of pollutants of chemicals of various chemical nature from pulp and paper production

The major aggregate indices of pollutants transferred with the process wastewater to external treatment plants are presented in table 2.32.

Table 2.32 The aggregate indices of pollutants transferred wit the process wastewater to external treatment plants

Comp no.	Index	Measurement unit	Index value
1	2	3	4
1	Suspended solids	Kg/ADt	8, 5 - 10
2	BOD_p	Kg/ADt	10,5 – 3,5
3	COD	Kg/ADt	50,1 – 155,5

2.9.1 A General Scheme of the Process of Plant Wastewater Treatment

The general principal scheme of the process of pulp and paper plant wastewater treatment is presented in figure 2.29.

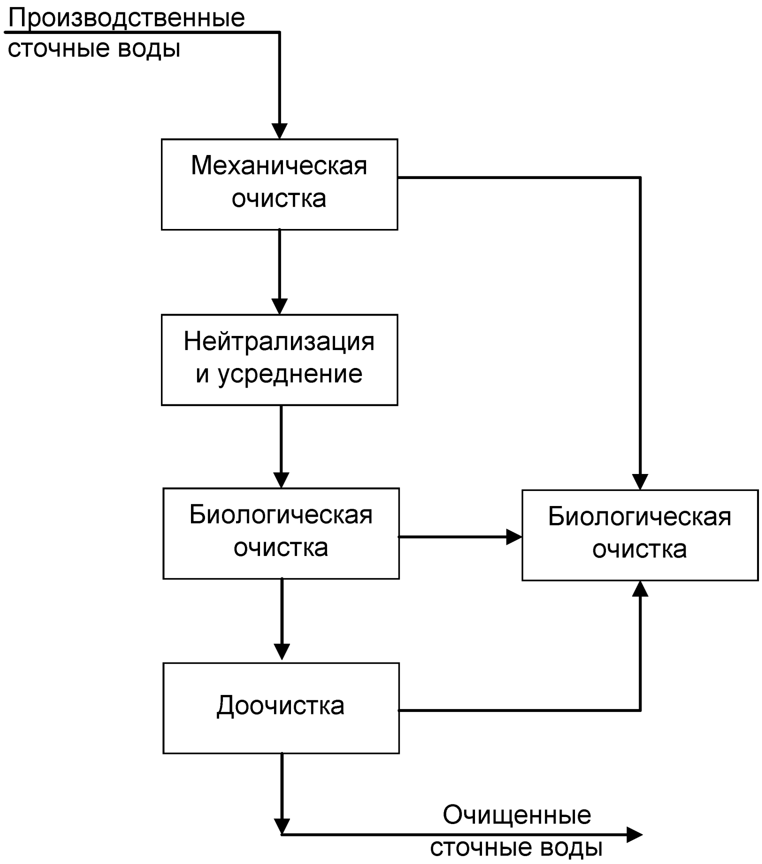


Figure 2.29 A general principal scheme of the process of plant wastewater treatment
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The pulp and paper plant wastewater treatment process at an off-site treatment plant includes the following stages:
- preliminary wastewater treatment – mechanical cleaning
- neutralization and homogenization
- secondary wastewater treatment – biological treatment
- tertiary wastewater treatment – final cleaning
- wastewater precipitation (sludge) processing

2.9.2 Mechanical Wastewater Treatment

Polluted process wastewater from various production subprocesses of a pulp and paper production plant before it is fed into an off-site treatment plant undergo preliminary treatment at the internal workshop treatment plant.
The intradepartmental treatment provides the possibility to guarantee a residual content of suspended particles in the wastewater entering the off-site treatment plant not exceeding 200 – 250 mg/l[1].
The primary or the mechanical treatment of the process wastewater at off-site treatment plants involves:
- mechanical removal of large suspended matter in screens
- mechanical removal of fine dispersed suspended matter in primary settling tanks

Large inclusions (bark, undercooked pulp, knots, etc.) are trapped in the screens, are removed into a container and, thereafter, are transported on trucks to authorized waste storage sites.
The fine suspended matter (pulp fiber, wood particles, sludge, etc.) with the aid of the gravitation force is settled on the bottom of the primary settlers and is transferred by pumps to sludge thickener tanks. The moisture content in the primary tanks is 97 – 98 %.
The clarified wastewater is fed to the biological stage of the treatment process.

[1] A description of the applied at present workshop internal treatment plant is given in 2.1, 2.2 – 2.5.

The effect of the primary treatment depends on the properties and quality of the wastewater fed into the treatment plant. The efficiency of suspended matter removal may range between 50 and 70 %.
If there is a need of deeper mechanical treatment (with an efficiency exceeding 70 %) it is possible to use physical and chemical methods of wastewater treatment.

2.9.3 Neutralization and Homogenization of Wastewater

Before the biological treatment stage the wastewater is subjected to neutralization, the beneficiation by biogenic elements as well as homogenization.
These actions may be implemented directly before the biological treatment, as well as before the feed of the wastewater to the primary settling tanks.
The neutralization is there in order to ensure that the reaction that takes place in the wastewater is as favourable as possible for the development of oxidizing microorganisms. The most favourable environment for the activated sludge is a neutral environment, corresponding to a hydrogen concentration index of pH 6,5 – 7,8.
The neutralization is carried out by the introduction into the wastewater of the needed reagents – alkaline or acid, depending on the wastewater environment - before the feed of the wastewater into the equalizing reservoir.
Also in the mixing tank of the equalizing reservoir there is a feed biogenic elements – phosphor and nitrogen. In order to guarantee normal vital functions of the microorganisms the biogenic element content before the biological treatment needs to be no less than 5 mg/l of nitrogen (N) and 1 mg/l of phosphor (P) per every 100 mg/l COD_{tot}, i.e. COD : N : P = 100 : 5 : 1.
The necessity to homogenization of the wastewater before it is fed to the biological treatment stage is determined by the irregularity of its feed from the production shops, both as to the flow and as to the pollutants content. The mixing and homogenization of the wastewater is taken care of in special homogenization facilities.

2.9.4 Biological Wastewater Treatment

The aim of the secondary or biological treatment of wastewater is the removal of organic elements. For the secondary treatment, the main alternatives are the aerobic and anaerobic biological treatment systems. The most widespread at Russian pulp and paper plants is the aerobic treatment methods with the use of activated sludge and in the presence of dissolved oxygen.

The activated sludge is an artificially cultivated biocenosis consisting of aerated polluted water and inhabited by bacteria, protozoans and multicellular organisms. Treatment plants with activated sludge consist of two main blocks: aerotanks and secondary settlers.
In the aerotank the process of biochemical oxidation of organic matter by aerobic microorganisms is proceeding. IN order to oxidize the organic matter, the breathing of the microorganisms and the maintenance of the activated sludge in a suspended state, air is blown into the biological treatment system. The settling and separation of the activated sludge from the treated water is carried on in the secondary settling tanks. The cleared water, after the secondary settlers, is either discharged into a recipient, or transferred to tertiary treatment – to final treatment installations.
The circulating activated sludge is returned to the aerotanks in order to maintain the high sludge concentration. The surplus activated sludge is transferred to installations for sludge processing. The efficiency of removal of organic pollutants according to BOD when applying biological treatment of production wastewater from pulp and paper plants may range between 70 – 98 %. The level of treated wastewater according to the BOD_5 index ranges between 10 and 25 mg/l. The proportion COD/BOD ranges between 4 and10.

2.9.5 Advanced Wastewater Treatment

At some of the Russian pulp and paper production plants, in order to separate out the thinly dispersed substances, tertiary treatment - or advanced treatment – is applied. The equipment used in advanced treatment comprises flotofilters, filters with sand beds as well as aerated ponds. The physical and chemical treatment allows for the attainment of a lower content of organic substances (BOD and COD) as well as the substantial reduction of the quantity of suspended matter, nitrogen and phosphorus. Flotation sludge is formed from the water used for the washing of the floaters. The flotation sludge is transferred to the precipitation processing installation. The main aggregate pollutant parameters of treated wastewater of Russian pulp and paper companies are presented in table 2.33.

Table 2.33 Aggregate parameters of pollutants in wastewater.

Comp. No	Parameter	Measurement unit	Parameter value[1]
1.	Suspended matter	Kg/ADt	0,19 - 2,9
2.	BOD_{tot}	Kg/ADt	0,16 – 2,71
3.	COD	Kg/ADt	13 - 50

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[1] The minimal parameters correspond to companies with a tertiary (aftertreatment) wastewater scheme of treatment

1.9.6 Wastewater Sludge Treatment

A large quantity of sludge is formed at the plant wastewater treatment installations:

- primary settler sludge
- surplus activated sludge
- flotation mud from the treatment of flotation filter flush water

The treatment of all types sludge is usually carried out jointly, since the biological (surplus sludge) and chemical (flotation sludge) treatment sludge is insufficiently dewatered and in order to improve the dewatering properties it is necessary to mix it with fibrous sludge.

The sludge treatment process involves the following technological operations:

- compacting (thickening) of the sludge
- dewatering of the sludge
- recycling of the dewatered sludge

The purpose of the sludge-thickening unit is the mixing of the initial sludge before the mechanical dewatering process and the raise of the concentration. The thickening of the sludge is accomplished in sludge thickeners.

In order to dewater the thickened sludge, various constructions of filter presses are used. In order to raise the level of water return before the dewatering it is usually treated with a flocculant (polymer solution). The dewatering of the sludge provides the reduction of its volume 20-fold. The filtrate formed is returned to the biological treatment plant. The dewatered sludge is transferred either to be burned or to disposal in landfills or other authorized sludge storage sites. The average total amount of sludge from off-site treatment plants of the companies studied is 20 – 40 kg per ton commercial pulp. The general scheme of the process of production wastewater treatment at paper and pulp production companies is shown in figure 2. 30.

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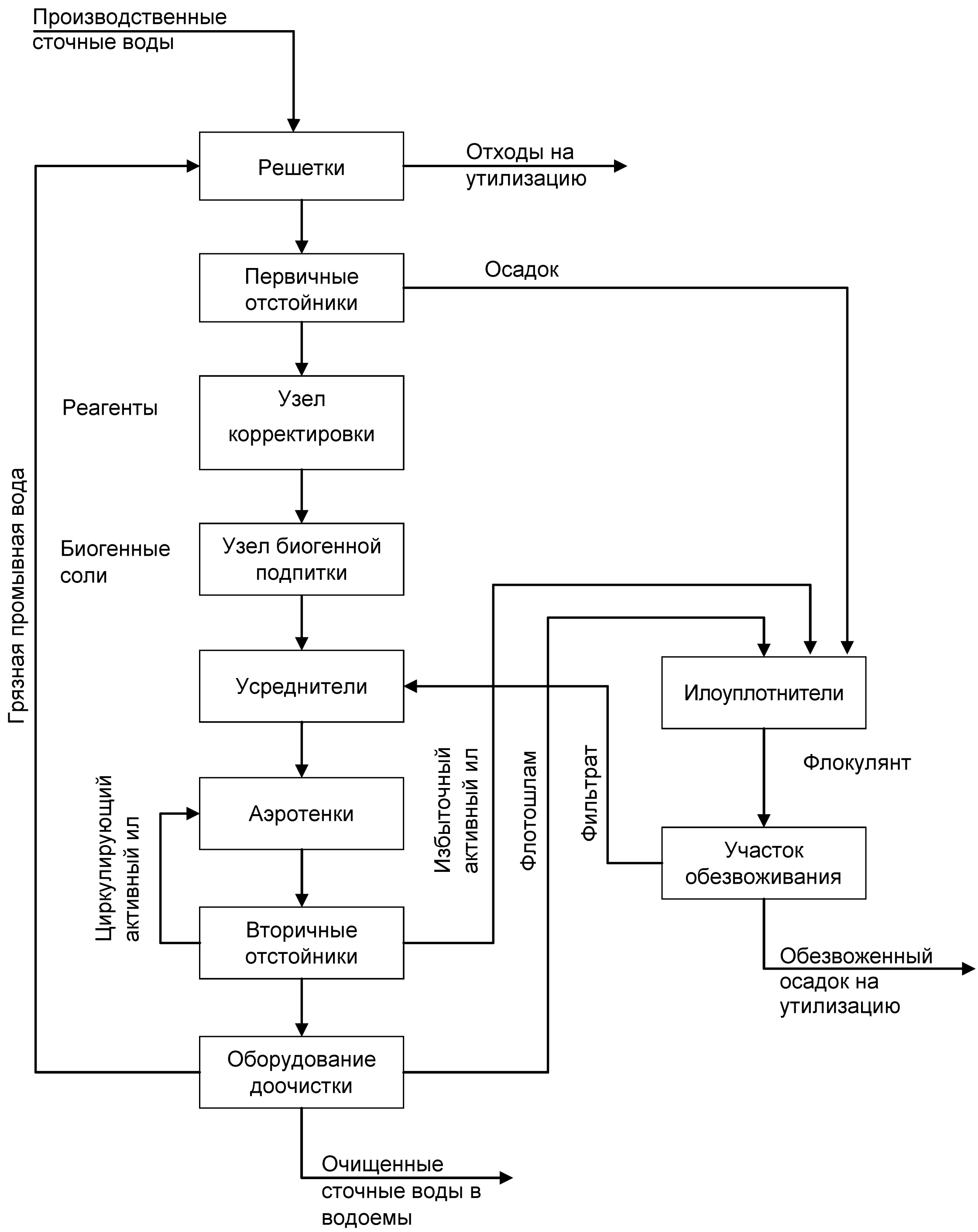

Figure 2. 30 A general scheme of the production wastewater treatment process

The main information on the process of production wastewater treatment, used at present in Russian pulp and paper production companies is presented in table 2.34.

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Table 2. 34 Main information on the process of production wastewater treatment

Input	Stage of the process (sub-process)	Output	Main process equipment
1	2	3	4
Polluted production wastewater	Mechanical treatment of wastewater	Clarification of wastewater Waste from screens Sludge	Screens Sand traps Primary settlers
Clarification of wastewater Biogenic salts Reagents (acids and bases)	Neutralization and equalization of wastewater	Clarification of wastewater	Equalization tanks
Clarified wastewater	Biological treatment of wastewater	Biologically treated wastewater Activated sludge	Aerotanks Bioreactors Secondary sedimentation tanks
Biologically cleaned wastewater	Aftertreatment of wastewater	Treated wastewater Sludge	Sand filters Flotation filters Aerator ponds
Sludge Surplus activated sludge	Wastewaters sludge treatment	Dewatering of sludge	Sludge concentrators Thickeners Filter presses Centrifuges

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A description of the process equipment used in the process of production wastewater treatment is shown in table 2.35.

Table 2.35 A description of the process equipment

Equipment unit name	**Equipment purpose**	**Technological characteristics[1)]**
1	**2**	**3**
Screens	Removal of large inclusions	Quantity Capacity based on hydraulic calculations
Primary settling tanks	The removal of finely dispersed suspended matter	Quantity Volume The size based on hydraulic calculations
Equalizing tank	Neutralization, equalization and enriching by biogenic elements	Quantity Volume The size based on hydraulic calculations
Aerotanks	The oxidizing of organic substances by aerobic microorganisms	Quantity Volume The size based on hydraulic calculations
Secondary settling tanks	The separation of the activated sludge and the clarified water	Quantity Volume The size based on hydraulic calculations
Flotation filter	The removal of finely dispersed substances	Quantity Volume The size based on hydraulic calculations
Filter with a sand bed	Removal of finely dispersed substances	Quantity Volume The size based on hydraulic calculations

Equipment unit name	Equipment purpose	Technological characteristics[1)]
1	2	3
Aeration tanks	Removal of finely dispersed substances	Quantity Volume
Sludge concentrator	Concentration of the sludge	Quantity Volume Size
Thickeners	Thickening of the sludge	Quantity Volume
Belt press filters	Dewatering of the sludge	Quantity Capacity
Decanters	Dewatering of the sludge	Quantity Capacity
Filter presses	Removal of large inclusions	Quantity Capacity
Sludge platforms	Dewatering and storage of sludge	Quantity Volume

Section 3. Current Levels of Emissions to the Environment

3.1 Material and Energy Balance

3.1.1 Wood Preparation

General information on the consumption of raw material, supplies and energy resources is presented in tables 3.1 and 3.2 [8].

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Table 3.1 Consumption of raw material, supplies and energy resources

Raw material, supplies and energy resources			
Name	Measurement unit	Consumption per 1 ton product	
		Minimal	maximal
1	2	3	4
Consumption of pulpwood per solid 1 m^3 chips	m^3/solid m^3	1,09	1,12
Chips for cooking for 1 ADt	m^3/ADt	3,50	5,45
Steam per 1 solid m^3 pulpwood	Gcal/solid m^3	0,002	0,008
Fresh water per 1 solid m^3 pulpwood	m^3/solid m^3	0,56	6,50
Electrical energy per 1 solid m^3 pulpwood	kWh/solid m^3	7,30	33,50

Table 3.2 Yield of main and by-products

Products, intermediate products and energy resources			
Name of the main product and by-product	Measurement unit	Yield per 1 ton product	
		Minimal	maximal
1	2	3	4
Chips made from pulpwood	m^3/solid m^3	0,89	0,93
Bark	m^3/t	0,36	,077

3.1.2 The Process of Production of Neutral Sulphite, Sulphite Pulp as well as SGW, TMP, CTMP and CMP

Table 3.3 Consumption of raw material, supplies and energy resources for the production of Neutral Sulphite, Sulphite Pulp as well as SGW, TMP, CTMP and CMP

Raw material, supplies and energy resources			
Item	Measurement unit	Consumption per 1 ton product	
		Minimal	maximal
Production of sulphate pulp			
Unbleached pulp			

Raw material, supplies and energy resources			
Item	Measurement unit	Consumption per 1 ton product	
		Minimal	maximal
		Per 1 ton ADt by cooking	
Chips, active caustic Na_2O	Solid m^3/t	3,50	5,45
White liquor,	kg/t	230	418
Froth destroyer	kg/t	0,21	0,50
Chemical additives (dispersion agent and others)	kg/t	0,29	0,40
Anthraquinone	kg/t	1,23	1,23
Oxygen-alkaline delignification chemicals:			
Magnesium sulphate	*kg/t*	*1,70*	*2,00*
Oxygen	*kg/t*	*19,00*	*24.00*
Sodium hydroxide, caustic NaOH	*kg/t*	*24.00*	*36,00*
Thermal energy:			
Cooking department	*KWh/t*	*0,49*	*1,79*
Oxygen-alkaline delignification	*KWh/t*	*0,81*	*0,81*
Fresh water	*M^3/t*	*2,54*	*12,70*
Bleached pulp, per air dry commercial pulp			
Bleaching chemicals:			
Magnesium sulphate	*kg/t*	*0,80*	*1,20*
Chlorine	*kg/t*	*4,80*	*55,00*
Chlorine dioxide	*kg/t*	*5,90*	*11,70*
Sodium hydroxide	*kg/t*	*12.00*	*53,30*
Oxygen	*kg/t*	*4,80*	*24,00*
Sulphuric acid	*kg/t*	*0,00*	*12,80*
Sulphur dioxide	*kg/t*	*0,80*	*3,00*
Sodium hypochlorite	*kg/t*	*9,07*	*19,84*
Hydrogen peroxide	*kg/t*	*7,80*	*8,20*
Thermal Energy	Gcal/t	0,20	1,33
Electrical energy	kWh/t	62.00	236,00

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Raw material, supplies and energy resources			
Item	Measurement unit	Consumption per 1 ton product	
		Minimal	maximal
Fresh water	m^3/t	8,12	46,00
Production of chlorine dioxide by the Metison method		**Per ton of chlorine dioxide**	
Sodium chlorate	*t/t*	*1,80*	
Sulphuric acid and sulphur dioxide	*t/t*	*1,40*	
Methanol	*t/t*	*0,80*	
Electric energy	*kWh/t*	*80,00*	
Production of chlorine dioxide by the HP-A method		**Per ton of chlorine dioxide**	
Sodium chlorate	*t/t*	*1,65*	
Sulphuric acid and sulphur dioxide	*t/t*	*2,10*	
Hydrogen peroxide	*t/t*	*0,29*	
Electric energy	*kWh/t*	*80,00*	
Production of chlorine dioxide by the integrated Chemetics method		**Per ton of chlorine dioxide**	
Elemental chlorine	*t/t*	*0,73*	
Steam	*t/t*	*8,00*	
Electric energy	*kWh/t*	*8 900,00*	
Production of neutral sulphite pulp			
		Per ton of air-dry semi-chemical pulp	
Chips	*Solid m^3 t/t*	*2,40*	*2,60*
Calcined soda	*kg/t*	*93,26*	*120,50*
Sodium monosulphite	*kg/t*	*530,00*	*716,00*
Fresh water		*5,00*	*6,10*
Steam	*Gcal/t*	*0,43*	*0,55*
Electric energy	*kWh/t*	*189,00*	*335,00*
Production of sulphite pulp			
Unbleached pulp			
Chips	*Solid m^3 t/t*	*4,20*	*4,700*
Calcined soda	*kg/t*	*120,00*	*153.00*

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Raw material, supplies and energy resources			
Item	Measurement unit	Consumption per 1 ton product	
Sulphur	*kg/t*	*85,00*	*138,00*
Sodium monosulphite	*kg/t*		
Fresh water	*m³/t*	*36,00*	*51,00*
Steam	*Gcal/t*	*1,00*	*1,500*
Electric energy	*kWh/t*	*237,00*	*318,00*
Unbleached pulp; see the sulphate pulp section			
Commercial pulp; see the sulphate pulp section			
Production of mechanical pulp			
Groundwood pulp (defibred wood pulp)			
Timber, spruce, not determined	*Solid m³ t/t*	*2,56*	*2,78*
Fresh water	*m³/t*	*15,00*	*20,00*
Steam	*Gcal/t*	*-*	*-*
Electric energy	*kWh/t*	*1441,41*	*1961,56*
Bleaching agents: if the SGW brightness is lower than 58 %	*kg/t*		
Caustic soda NaOH	*kg/t*	*0,08*	*2,76*
Chelates (EDTA and DTPA)	*kg/t*	*0,04*	*1,26*
Sodium bisulphite	*kg/t*	*6,54*	*15,34*
Bleaching reagents if SGW brightness is lower than 58 %	*kg/t*	*0*	*0*
Thermomechanical pulp			
Timber, spruce, not determined	*Solid m³ t/t*	*2,78*	*2,88*
Fresh water	*m³/t*	*2,51*	*7,76*
Steam	*Gcal/t*	*0,15*	*0,40*
Electric energy	*kWh/t*	*2 328*	*2 509*
Impregnation and bleaching reagents	*kg/t*		
Caustic soda NaOH	*kg/t*	*0,19*	*1,433*
Chelates (EDTA and DTPA)	*kg/t*	*0,04*	*1,08*
Sodium bisulphite	*kg/t*	*15.00*	*17,00*

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Raw material, supplies and energy resources			
Item	Measurement unit	Consumption per 1 ton product	
Sodium hydrosulphite	*kg/t*	*3,57*	*8,72*
Chemi-thermomechanical pulp, CTMP, (softwood)			
Timber, spruce, not determined	*Solid m³ t/t*	*2,88*	*2,90*
Fresh water	*m³/t*	*2,51*	*7,76*
Steam	*Gcal/t*	*0,15*	*0,40*
Electric energy	*kWh/t*	*2 328*	*2 509*
Impregnation and bleaching reagents	*kg/t*		
Caustic soda NaOH	*kg/t*	*0,19*	*1,433*
Chelates (EDTA and DTPA)	*kg/t*	*0,04*	*1,08*
Sodium bisulphite	*kg/t*	*15.00*	*17,00*
Sodium hydrosulphite	*kg/t*	*3,57*	*8,72*
Chemimechanical pulp, CMP (aspen)			
Timber, spruce, not determined	*Solid m³ t/t*	*3,00*	*3,10*
Fresh water	*m³/t*	*12,00*	*13,00*
Steam	*Gcal/t*	*0,30*	*0,40*
Electric energy	*kWh/t*	*1 200,00*	*1 400,00*
Impregnation and bleaching reagents	*kg/t*		
Caustic soda NaOH	*kg/t*	*25,00*	*30,00*
Sodium silicate	*kg/t*	*6,00*	*8,00*
Sodium sulphite	*kg/t*	*15.00*	*20,00*
Hydrogen peroxide	*kg/t*	*20,00*	*30,00*

Yield of Main and By-Products, Semi-finished Products and Energy Resources when Producing Sulphate and Neutral Sulphite Pulp

The basic information about the yield of main and by-products, intermediate products and energy resources is presented in table 3.4.

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Table 3.3 Yield of main and by-products, intermediate products and energy resources during the production of sulphate, neutral sulphite and sulphite pulp

Raw material, supplies and energy resources			
Item	Measurement unit	Consumption per 1 ton product	
		Minimal	maximal
Production of sulphate pulp			
		Per ton air dry pulp based on cooking	
Pulp from cooking	%	100,00	100,00
Weak black liquor	m^3/t	7,90	11,70
Sulphate soap	t/t	0,10	0,15
Crude turpentine	t/t	0,005	0,009
		Per ton air dry bleached pulp	
Bleached pulp	%	78,00	93,00
Production of chlorine dioxide by the Metison method		**Per ton of chlorine dioxide**	
Sodium sulphate	*t/t*	*1,20*	
Sulphuric acid	*t/t*	*1,50*	
Production of chlorine dioxide by the HP-A method		**Per ton of chlorine dioxide**	
Sodium chlorate	*t/t*	*1,10*	
Sulphuric acid	*t/t*	*1,30*	
Oxygen	*t/t*	*0,26*	
Production of chlorine dioxide by the integrated Chemetics method		**Per ton of chlorine dioxide**	
Chlorine	*t/t*	*0,18*	*0,24*
Production of neutral sulphite semichemical pulp			
Semichemical pulp	*%*	*100,00*	*100,00*
Red liquor	*kg Dry solids/t*	*240,00*	*260,00*
Production of sulphite pulp			
Pulp	*%*	*100,00*	*100,00*
Lignin sulphonates (dry)	*kg/t*	*436,00*	*500,00*
Cleaned condensate	*m^3*	*2,06*	*2,45*

3.1.4 Chemicals Recovery

The basic information as to the consumption of raw material, supplies and energy resources is presented in table 3.4

Table 3.4 Yield of main and by-products, intermediate products and energy resources when producing sulphate, neutral sulphite and sulphite pulp

Products, intermediate products, by-products and energy resources			
Name of the main product and by-product	Measurement unit	Yield per 1 ton product	
		Minimal	maximal
Production of sulphate pulp			
		Per air dry ton of pulp after cooking	
Pulp after cooking	%	100,00	100,00
Weak black liquor	m^3/t	7,90	11,70
Sulphate soap	t/t	0,10	0,15
Crude turpentine	t/t	0,005	0,009
Production of sulphate pulp			
		Per air dry ton bleached pulp	
Bleached pulp	%	78,00	93,00
Production of chlorine dioxide by the Metison method		**Per ton of chlorine dioxide**	
Sodium sulphate	*t/t*	*1,20*	
Sulphuric acid	*t/t*	*1,50*	
Production of chlorine dioxide by the HP-A method		**Per ton of chlorine dioxide**	
Sodium sulphate	*t/t*	*1,10*	
Sulphuric acid	*t/t*	*1,30*	
Oxygen	*t/t*	*0,26*	
Production of chlorine dioxide by the integrated Chemetics method		**Per ton of chlorine dioxide**	
Chlorine	*t/t*	*0,18*	*0,24*
Production of neutral sulphite semichemical pulp			
Semichemical pulp	*%*	*100,00*	*100,00*
Red liquor	*kg Dry solids/t*	*240,00*	*260,00*
Production of sulphite pulp			
Pulp	*%*	*100,00*	*100,00*
Lignin sulphonates (dry)	*kg/t*	*436,00*	*500,00*
Cleaned condensate	*m^3*	*2,06*	*2,45*

3.1.4 Chemicals Recovery

Basic information on the consumption of raw material, supplies and energy resources is presented in tables 3.5 and 3.6.

Table 3.5 Consumption of raw material, supplies and energy recourses of the evaporation department

Raw material, supplies and energy resources			
Item	Measurement unit	Consumption per 1 ton product	
		Minimal	maximal
1	2	3	4
Weak black liquor	m^3/t	8,00	12,00
Electric energy	kWh/t	24,00	85,00
Steam	Gcal/t	1,30	2.10
Water	m^3/t	30,00	60,00

Table 3.6 Consumption of raw material, supplies and energy resources of the caustization and lime-reburning department

Raw material, supplies and energy resources			
Item	Measurement unit	Consumption per 1 ton product (1 t of recovered lime)	
		Minimal	maximal
1	2	3	4
Caustic soda	kg/t	12,00	23,00
Limestone	kg/t	30,00	50,00
Lime	kg/t	300,00	400,00
Fuel for lime burning	kg fuel equiv./t	200,00	300,00
Fresh water	m^3/t	19.00	25.00
Steam	Gcal/t	0,12	0,35
Electric energy	kWh/t	130,00	160,00

3.1.5 Paper and Board Production

Basic information on the consumption of raw material, supplies and energy resources can be found in table 3.7 and 3.8.

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Table 3.7 Consumption of raw material, supplies and energy resources when producing paper

Raw material, supplies and energy resources			
Item	Measurement unit	Consumption per 1 ton product	
		Minimal	maximal
1	2	3	4
fiber intermediate products	kg/t	752,00	1 050,0
Filler	kg/t	0,00	237,00
Sizing agent	kg/t	0,00	47,00
Retention material	kg/t	1,00	28,00
Optical bleaching agent	m^3/t	0,00	15,00
Dyes	kg/t	0,00	0,14
Fresh water	m^3/t	11,00	35,00
Steam	t/t	1,50	3,50
Electric energy	kWh/t	400,00	1 000,00

Table 3.8 Consumption of raw material, supplies and energy resources when producing board

Raw material, supplies and energy resources			
Item	Measurement unit	Consumption per 1 ton product	
		Minimal	maximal
1	2	3	4
fiber intermediate products	kg/t	921,00	1 080,00
Filler	kg/t	0,00	68,00
Sizing agent	kg/t	2,00	58,20
Retention material	kg/t	1,50	31,00
Optical bleaching agent	m^3/t	0,00	4,00
Dyes	kg/t	0,00	2,82
Fresh water	m^3/t	10,00	30,00
Steam	t/t	2,00	3,00
Electric energy	kWh/t	435,00	650,00

3.1.6 Process Wastewater Treatment

Basic information on the consumption of raw material, supplies and energy resources can be found in table 3.9

Table 3.9 Consumption of raw material, supplies and energy resources for purposes of wastewater treatment

Raw material, supplies and energy resources			
Item	Measurement unit	Consumption per 1 ton product (1 000 m³ of wastewater)	
		minimal	maximal
Fresh water	m^3/t	7,00	11,00
Electric energy	kWh/t	350,00	980,00
Biogenic salts (nitrogen)	kg	1,00	16,00
Biogenic salts (phosphorus)	kg	0,20	10,50
Flocculants	kg	0,60	10,00
Neutralization chemicals (acid)	kg	0,20	6,30
Neutralization chemicals (base)	kg	14.00	20,00

3.2 Current Levels of Emissions, Discharges and Consumption

Since the majority of complaints from the public is about the smell from sulphate pulp producing companies, it is necessary to introduce the marker parameter ”total sulphur”, in order to appraise the level of emissions of sulphur-containing gases, instead of controlling such individual pollutants, as hydrogen sulphide, methylmercaptan, dimethyl sulphide, dimethyldisulphide, etc. When choosing the BAT for emissions it is necessary to use the total relative emission of sulphur-containing gases.

Table 3,10 Emissions of pollutants to air

Item	Measurement unit	Volume and (or) mass of the emission of pollutants before treatment per ton		Emission sources	Environmental protection equipment, treatment method, reuse	Volume and (or) mass of the emission of pollutants after treatment per ton	
		Range	Average			Range	Average
1	2	3	4	5	6	7	8
Mehtylmercaptan	Kg/t	0,003 – 0,020	0,011	Installations for cooking, washing, screening of unbleached pulp	Gas treatment scrubber. Gas treatment adsorber	0,25 – 1,20	0,73
Hydrogen sulphide	Kg/t	0,045 – 0,063	0,054				
Dimethyl sulphide	Kg/t	0,22 – 2,50	1,36				
Dimethyl disulphide	Kg/t	0,40 – 1,90	1,15				
Sulphur dioxide	Kg/t	-	-	Kiln for the burning of NCG:s, limekiln, recovery boiler	Gas treatment scrubber	1,10 – 1,20	1,12
Nitrogen oxides	Kg/t	-	-			0,003 – 0,004	0,004
Chemicals recovery							
Sulphur dioxide	Kg/t	0,50 – 1,25	0,88	Recovery boiler	Scrubber	0,20 – 0,50	0,35
Nitrogen oxides	Kg/t	0,20 – 3,00	1,70			0,20 – 1,50	0,85

Item	Measurement unit	Volume and (or) mass of the emission of pollutants before treatment per ton		Emission sources	Environmental protection equipment, treatment method, reuse	Volume and (or) mass of the emission of pollutants after treatment per ton	
		Range	Average			Range	Average
1	2	3	4	5	6	7	8
Dust from the soda recovery process	Kg/t	118,50 – 131,00	124,80		Scrubber	0,13 – 2,44	1,29
Sulphur dioxide	Kg/t	0,0025 – 0,025	0,014	Lime recovery kiln	Scrubber	0,001 – 0,01	0,006
Hydrogen sulphide	Kg/t	0,22 – 2,50	1,36		Scrubber	0,03 – 0,10	0,065
Nitrogen oxides	Kg/t	0,40 – 1,90	1,15		Scrubber	0,0044 – 0,373	0,189
Dust from the lime recovery process	Kg/t	2,70 – 6,10	4,40		Electrofilter	0,01 – 0,79	0,40
Thermal energy production							
Sulphur dioxide	Kg/t	0,0017 – 0,0020	0,0018	Bark boiler	Electric filter	0,01 – 1,06	0,54
					Cyclone		
Nitrogen oxides	Kg/t	0,19 – 0,26	0,23		Electric filter	0,20 – 0,70	0,45
					Cyclone		
Ash	Kg/t	4,10 – 4,70	4,40		Electric filter	0,17 – 0,56	0,37
					Cyclone	0,10 – 1,60	0,85

Table 3.11 Production and consumption waste

Waste item	Hazard class	Measurement unit[1]	Mass of waste formation per ton		Formation sources	Treatment method, reuse. Recycling	Weight of the waste per ton of product	
			Range	Average			Range	Average
1	2	3	4	5	6	7	8	9
Receiving, storing and preparation of the wood raw material								
Waste formed during wood processing; including:			246,00 – 683,00	464,50		Scrubber	0,13 – 2,44	1,29
Bark	IV	Kg/t	219,00 – 627,00	423,00	Debarking (preparation of the wood before processing)	Recycling in bark boilers	0,001 – 0,01	0,006
Bark with soil inclusions	IV	Kg/t	12,00 – 26,00	19,00	Wood storage (preparation of the wood before processing)	Disposal at waste disposal sites in order to produce a compost	12,00 – 26,00	19,00
Sawdust and shavings from natural clean unsorted wood	V	Kg/t	15,00 – 30,00	22,50	Debarking (cutting and shaping of the wood)	Recycling in bark boilers	15,00 – 30,00	22,50

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[1] Process moisture content means the actual moisture content of the waste as a result of its formation in various production processes

Waste item	Hazard class	Measurement unit[1]	Mass of waste formation per ton		Formation sources	Treatment method, reuse. Recycling	Weight of the waste per ton of product	
			Range	Average			Range	Average
1	2	3	4	5	6	7	8	9
Production of commercial bleached/unbleached pulp								
Wood waste from pulp screening	IV	kg/t	3,90 – 13,60	8,80	Cooking, screening of pulp (pulp screening)	Recycling in bark boilers	3,90 – 13,60	8,80
Mineral waste from the screening process	IV	Kg/t	0,60 – 4,00	2,30	Screening to remove mineral inclusions	Disposal at waste disposal sites	0,60 – 4,00	2,30
Waste from the process of preparation and recovery of chemical reagents, including sludge from the cleaning of equipment	IV	Kg/t	2,00 – 22,40	12,20	Preparation and recovery of chemical reagents and cleaning of equipment during pulp production	Disposal at waste disposal sites	2,00 – 22,20	12,10

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[1] Process moisture content means the actual moisture content of the waste as a result of its formation in various production processes

Waste item	Hazard class	Measurement unit[1]	Mass of waste formation per ton		Formation sources	Treatment method, reuse. Recycling	Weight of the waste per ton of product	
			Range	Average			Range	Average
1	2	3	4	5	6	7	8	9
Production of commercial bleached/unbleached pulp (cont'd)								
Sludge and sedimentation from the biological treatment plants for household and mixed effluents	IV, V	kg/t	19,00 – 50,00	35,00	Biological treatment of household and mixed effluents	Disposal at waste disposal sites in order to produce a compost	19,00 – 50,00	35,00

Table 3.12 Wastewater

Name of the pollutant	Measurement unit	Volume and (or) mass of the emission of pollutants before treatment per ton of produced merchandise		Recipient	Volume and (or) mass of the emission of pollutants after treatment, per ton produced merchandize	
		Minimum	Maximum		Minimum	Maximum
1	2	3	4	5	6	7
Wastewater	m^3	64,00	167,00	Water body	64,00	167,00
Suspended solids (ss)	Kg/t	8,50	10,00	Water body	0,19	2,90
Biological oxygen demand $BOD_{tot(?)}$	Kg/t	10,50	31,50	Water body	0,16	2,71
Chemical oxygen demand (COD)	Kg/t	50,10	155,50	Water body	13,00	50,00
Total nitrogen (N_{tot})	Kg/t	0,20	0,35	Water body	0,02	0,30

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[1] Process moisture content means the actual moisture content of the waste as a result of its formation in various production processes

Name of the pollutant	Measurement unit	Volume and (or) mass of the emission of pollutants before treatment per ton of produced merchandise		Recipient	Volume and (or) mass of the emission of pollutants after treatment, per ton produced merchandize	
		Minimum	Maximum		Minimum	Maximum
1	2	3	4	5	6	7
Total phosphorus (P_{tot})	kg/t	0,09	0,10	Water body	0,02	0,09
Adsorbed organically bonded halogens	kg/t			Water body	0,01	3,00

The emission and consumption levels corresponding to best available techniques (BAT) according to BREF (EU), 2015 are shown in Attachment Б.

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Section 4. The Determination of Best Available Techniques

The definition of a certain technique as BAT is regulated by the order of the Ministry of Industry and Trade of the Russian Federation of the 31 March 2015 no. 665 *On the Confirmation of the Method Recommendations for the Determination of a Technique as Beast Available Technique* (hereinafter: the Method Recommendations).
The determination of a certain technique as BAT is made by the members of the technical working groups (TWG) in the process of development and updating of the information technology BAT reference documents.
In accordance wit the Method Recommendations, the definition of the applied techniques as BAT will be made based upon the criteria:

- the lowest possible negative impact on the environment represented as a number per time unit or volume of produces merchandize or any other parameter value expressing environmental impact, as treated by Russian Federation's international agreements.
- The economic efficiency of introduction and operation
- The introduction period
- The industrial introduction of technological processes, equipment, technical methods at two or more Russian Federations plants, having a negative environmental impact

First and foremost are considered the criteria of industrial introductions of processes, equipment and technical mehtods at 2 or more Russian Federation plants, after which the rest of the criteria are considered.
The TWG members, when defining a technique as BAT, in addition to the Method Recommendations may use international information technology BAT handbooks, the corresponding scientific literature, statistic digests, results from scientific work as well as other sources.

4.1 Techniques, Considered when Defining BAT, in the Field of Sulphate Pulp Production

Techniques, defined as BAT [10], when producing sulphate pulp, allowing for the economy of raw material, water, and energy as well as the reduction of emissions to the environment and the formation of waste, are shown in table 4.1.

Table 4.1: List of techniques regarded as BAT in the field of sulphate pulp production

Technique	Description	Applicability
1	2	3
Dry wood debarking	4.1.1	Generally applicable
Prolonged modified cooking	4.1.2	Generally applicable
Closed circuit screening system and the efficient washing of unbleached pulp	4.1.3	Applied at new and existing plants
Oxygen-alkaline delignification	4.1.4	The majority of bleached pulp production plants in Europe, America and Russia have oxygen delignification facilities
ECF bleaching and the production of chemicals needed for this purpose	4.1.5	The majority of sulphate pulp production plants in Europe and in the world use the ECF bleaching technology
Stripping and recycling of polluted condensate after treatment in the stripping column	4.1.6	Generally applicable
Partly closed circuit system of the water circulation of the bleach plant	4.1.7	Södra Cell at Mönsterås, Mörrum and Värö, Celtejo (Portugal), Merer Stendal Rosentahl (Germany) and other plants. This method may be limited by the formation of deposits on the equipment
Partial or full reuse of clean cooling water	4.1.8	Generally applicable
Recuperation of heat when producing pulp, paper and board	4.1.9	Generally applicable

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Technique	Description	Applicability
1	2	3
Buffer tank for the collection of leakages	4.1.10	Generally applicable
Closed circuit chemicals recovery for cooking	4.1.11	Generally applicable
Collection and decomposition of sulphate soap	4.1.12	Generally applicable
Separation and collection of turpentine	4.1.13	Generally applicable
Collection of weak and strong gases and the subsequent burning in special kilns, the lime recovery kiln, recovery boiler, etc.	4.1.14	Generally applicable
Incineration of black liquor at concentrations above 72 %	4.1.15	Generally applicable
The improved flushing of sludge from chemicals recovery	4.1.16	Generally applicable
Dewatering of waste from the chemicals recovery cycle	4.1.17	Generally applicable
Electrical filters after the RB, LK as well as after the boiler for the burning of bark and treatment plant sludge	4.1.18	Generally applicable
Boilers for the incineration of bark and sludge from the treatment plant, undercooked pulp and the fuel preparation for the abovementioned boilers	4.1.19	Generally applicable
Biological treatment of wastewater	4.1.20	Generally applicable
Dewatering of the sludge from the treatment plant	4.1.21	Generally applicable
Improvement of the system for scrap processing (paper and board machines)	4.1.22	Generally applicable
Trapping system for fibers from the surplus (waste) water from the paper/board machines	4.1.23	Generally applicable
VOC before the treatment plant	4.1.24	Generally applicable
Introduction of an ACDS system	4.1.25	Generally applicable
Combined production of thermal and electrical energy	4.1.26	Generally applicable

4.1.1 Dry Debarking

Description of the technique
In new or reconstructed wood preparation workshops the dry type of debarking is practically always used.
Water is only used for the washing of the pulpwood, after which it is recirculated with a minimal formation of wastewater or water pollution. The department there is equipment for the local treatment of bark-containing water.
The internal water circuit may reach 70 %. The water used during wet and semi-dry debarking, having passed through the debarking drum, contains solid waste, the removal of which involves the use of water separation drums and drainage containers. After the primary treatment, the water is passed to the sludge separators or mesh filters, where fine bark particles and mechanical inclusions are trapped.
When passing to the dry debarking, the solid wood waste ends up in the water only during the flushing of the pulpwood, which is why there is no need to install filters or sludge separators. After the primary treatment in the drainage conveyers, the waster is collected in a pond. The settled solid matter in the form of sand is transferred to a container by a scrape conveyor and is subsequently deposited on a landfill. The clarified water is pumped back to the process and, partly to the treatment plant of the company to be further processed. In order to maintain the necessary quantity of waster the water circuit system is replenished with fresh water.
In northern regions, before the feed of the timber to the debarking section, it is subjected to thawing with the use of hot water or steam, which are feed directly into the debarking drum or to the thawing conveyor.
After the debarking drum, the bark is fed into a fragmenting machine and, if it is moist, to the press of the subsequent burning in special boilers.
As a result of the dry debarking, the bark has a lower moist content, which leads to a raised energy efficiency when it is burned.

The environmental effect achieved
When transferring to the dry wood debarking method the water consumption is decreased drastically.
Table 4.2 shows the pollution parameters for wastewater depending on the wood debarking method before it is transferred to the biological treatment facility.

Table 4.2: Pollution in wastewater depending on the wood debarking method before the timber is fed to the biological treatment.

Debarking technique	Wastewater volume		BOD_5		COD		Tot P
	m^3/solid m^3	m^3/ADt	m^3/solid m^3	kg/ADt	kg/solid m^3	kg/ADt	g/ADt
1	2	3	4	5	6	7	8
Semi-dry debarking and pressing	0,6 – 2	3 – 10	0,9 – 2,6	5 – 15	4 – 6	20 - 30	25 - 35
Dry debarking and pressing	0,1 – 0,5	0,5 – 2,8	0,1 – 0,4	1 – 10	0,2 – 2	1 – 10	10 20

<u>Environmental impact</u>
When applying dry debarking, the volume of the wastewater from wood preparation usually ranges between 0,5 and 2,8 m^3/ADt. The reduction in volume of the wastewater is achieved by the increase in the water volume involved in the closed water circuit. The transition from semi-dry to dry debarking reduces the amount of wastewater by 5 – 10 m^3/ADt.
<u>Operational information</u>
During dry debarking the total COD level may be reduced down to 10 % as compared to the value of this parameter when applying dry debarking.
<u>Field of application</u>
Dry debarking may by used both in new and existing production units (softwood and hardwood), as well as for the production of all types of intermediate products (pulp, mechanical pulp, etc.) The debarking drums when applying the dry debarking method, at present, is the dominating method of the industry, while the use of the semi-dry method is phased out.
<u>Implementation factors</u>
The dry debarking reduces the volumes of suspended particle content in the wastewater, as well as the COD and BOD, and, furthermore, it promotes the reduction of the amount of organic compounds, such as resin acids and fatty acids, which are leached out of the bark and transferred to the wastewater flows.
<u>Reference literature</u>: [3]; [8].

4.1.2 Prolonged Modified Cooking

Technique description

The pre-bleaching delignification of the pulp is performed in the course of the cooking process. The oxygen delignification process is also applied in order to achieve this at many plants.
Since the selectivity in the process of oxygen delignification is much higher than when cooking, there is a need to establish a balance between the lowering of the Kappa number in the pulp process and the oxygen delignification.
The selectivity is the amount of dissolved carbohydrates per unit of dissolved lignin.
For the plant, it is important to define the optimal relationship between the pulp yield parameters and the mechanical strength characteristics and the content of residual lignin.
In order to reduce the lignin content (the Kappa number) in the pulp fed into the bleaching stage, and to reduce the consumption of bleaching reagents a few modifications of the processes of continuous and batch sulphate cooking have been developed and introduced into operation.
The purpose of various modified processes is the increase in the selectivity of the cooking process (the increased yield and viscosity)
For the selective delignification of wood without any noticeable degradation of the pulp it is necessary to:

- Maintain a lower concentration of effective liquor in the initial stages of the cooking process, as well as to – in the cooking process - maintain the constant concentration of liquor over the full height of the boiler;
- Provide for the maximum possible concentration of hydrosulphide ions in the beginning of the stages of the main delignification of the cooking process, meaning that the sulphidity of the liquors must not be increased as compared to the traditional type of cooking technology;
- Lower the content of dissolved fractions of lignin in the cooking liquor, especially in the end of the continuous process.

4.1.2.1 Continuous cooking

The best modern methods of continuous cooking are Lo-Solids and Compact Cooking G2

One of the features of these types of cooking is the application of lowered temperatures in the cooking zone, as well as the radial distribution of temperature and liquor concentration and the evening out of the liquor profile over the full height of the boiler. The basis of the Compact Cooking G2 method is the increased selectivity of the delignification through the steaming at atmospheric pressure and the low-temperature impregnation of the chips at a high water consumption of the cooking, practically in the black liquor environment, which is collected from the highest zone of the cooking and has a quite high liquor concentration.
The method Lo-Solids, as when using any type of modified cooking, the liquor profile is regulated over the height of the boiler through the distributed feed of white liquor. Furthermore, this involves the collection of black liquor from the highest cooking zone and its replacement by filtrate, which eventually reduces the concentration of dissolved lignin in the end of the cooking process and increases the speed of the diffused processes while the lignin is dissolved.

4.1.2.2 Batch cooking

The modern processes of batch cooking (RDH and Superbatch K) are based upon energy economy techniques of displacement of the impregnation and boiling liquors in order to reduce the heat consumption for cooking purposes.
The storage of liquor of various density and temperature is performed in accumulator tanks. In order to maintain constant temperature and concentration, fresh chemicals and steam are added to these tanks.
The classic cooking facilities have a Kappa value of the pulp after pumping of 30 – 32 for softwood and 18 – 20 for hardwood pulp without any quality loss.
Through the use of modified cooking processes, the Kappa value of the pulp may be reduced to the level of 18 – 22 for softwood and 14 -16 for hardwood pulp.
For reasons of wood economy, beginning in the 1990s, when producing sulphate pulp, an increase in the Kappa value (and yield) of the pulp after cooking is practiced, with the subsequent lowering of it in the stage of oxygen delignification.
<u>The environmental effect accomplished</u>

A higher level of delignification with the conservation of the pulp yield, the low waste content, a lower cooking temperature, a considerable economy of energy as well as the increase of the bleaching properties of the pulp.
The low consumption of bleaching chemicals as well as the reduction of the discharge of pollutants with the wastewater.

Environmental impact
Through the lowering of the lignin content of the pulp before the bleaching, the volume of the discharge of pollutants with the wastewater from the bleaching facility is reduced, as are the quantities of organic substances, dispatched to be incinerated in the RB.
When the hardness of the pulp is lowered before the bleaching per 1 unit of Kappa value, the discharge of COD from the bleaching facility will be reduced approximately by 2kg/ADt
Operational data
The lowering of the Kappa value by 6 – 7 units or softwood and 4 – 5 units for hardwood.
Field of application
A great number of European, North American and Russian plants have been modernized or reconstructed in order to be able to apply a modified type of cooking
Implementation factors
Through the transfer to the modified continuous or batch cooking method, the capacity of the digesters may be reduced. The introduction of new cooking plants involves large volume boilers.
Reference literature. [3].

4.1.3 Closed Circuit System for the Screening and Efficient Washing of Unbleached Pulp

Description of the technique
The screening of unbleached pulp is done along a multi-step scheme at pressure screens with profile screens with slit perforation.
When applying modern process of chips production and boiling, there are less than 0,5 % waste in the pulp after cooking, in the form of knots and shives, which are separated from the process of pulp production for bleaching.
The multi-stage countercurrent washing of the unbleached pulp before and after the oxygen delignification using efficient washing equipment, guaranteeing a minimum loss of organic matter of the black liquor to the bleaching facility, and, correspondingly, the reduction of the consumption of chemicals for bleaching purposes, the lowering of the discharge of pollutants with the wastewater from the bleaching unit.
The installing of screening equipment in the system of countercurrent washing of unbleached promotes the closing of the water consumption system,

resulting in a limited volume of polluted wastewater from the washing and screening of the unbleached pulp that will be transferred to be evaporated and burned in the recovery boiler together with the black liquor (a more detailed description can be found in section 2.2).

Achieved environmental benefits

The reduction of the organic substance content of the wastewater, and the reduction or total removal of the discharge of wastewater to the treatment plant from the washing and screening units.

Operational data

The purchase of screening equipment, working in conditions of elevated concentrations, 3 – 4 % for softwood and up to 5 % for hardwood, provides the possibility to lower the size of investments in new equipment and reduce the electrical energy consumption for screening.

Field of application

This technique has been implemented at a majority of the European, North American and Russian plants

It is applied at new and already existing companies

Implementation factors

The increase of the steam consumption for the evaporation of the black liquor

Reference literature: [3].

4.1.4 Oxygen Alkaline Delignification before Bleaching

Description of the technique

When the cooking is run to achieve high Kappa numbers, the reduction of the lignin content of the pulp before the bleaching unit is achieved through the oxygen delignification of unbleached pulp.

In the process of oxygen delignification, lignin is removed through the processing by oxygen of the unbleached pulp in an alkaline environment at an elevated temperature under superatmospheric pressure in one- or two-stage reactors.

The level of delignification ranges between 40 and 70 % (a more detailed description is given in section 2.2).

Achieved environmental benefits

Through the reduction in rigidity of the pulp that is transferred to be bleached, a reduction of the chemicals consumption is achieved as well as a reduction of the pollutants from the bleaching unit to the treatment plant.

Operational data
Additional steam in order to evaporate the black liquor: 4 – 10 % (as a result of the feed of water steam, white liquor and a magnesium sulphate solution into the oxygen-alkaline process)
The additional load to the recovery boiler is about 45 – 70 kg bone-dry substance/air-dry ton pulp.
The additional load to the caustization of green liquor and the lime recovery kiln (LK) ranges between 4 and 6 %.
Field of application
The majority of bleached pulp production plants in Europe, North America and Russia are equipped with oxygen delignification installations.
Modern bleached pulp production plants are designed to include a modified cooking process and oxygen delignification.
Implementation factors
When organising the oxygen delignification step at an already existing plant, one needs to take into account the increased load on the chemicals recovery system.
Reference literature: [3].

4.1.5 ECF Bleaching and the Associated Production of Chemicals

Description of the technique
The main bleaching reagent for ECF bleaching (without any use of molecular chlorine) is chlorine dioxide.
In order to minimize the consumption of chlorine dioxide, in modern ECF schemes there is the combination of alternative oxygen containing chemicals (oxygen, hydrogen peroxide, peracetic acid, ozone, etc.) as well as the introduction into the bleaching process scheme of such steps as oxygen processing, hot acid hydrolysis (Ahot) for hardwood, and the ozone processing at moderate or high concentrations, hydrogen peroxide processing at atmospheric pressure (P) oar under pressure, as well as the hot chlorine dioxide processing (Dhot).
ECF bleaching reduces the negative impact on the environment (a low volume of wastewater as well as low AOX emissions) and provides the possibility of a partial closing of the filtrate flow of the bleaching units (a more detailed description can be fount in section 2.2).
The possible ECF bleaching schemes and the use of various chemicals or their combinations are shown in table 4.3.

Table 4.3: Modern ECF bleaching Schemes

Bleaching Schemes		
1	2	3
O/ODEDP	O/OADED	O(OPDQ(PO))
O/ODED	O/OZEDD	OQ(PO)(DQ)(PO)
O/ODEDD	O/OADtZP	LQXOP/ODEPDPaa
O/OADEDP	O/OZDP	O/O(Q)OPDPO

Note:
The used terms:
O or O/O: one- or two-step oxygen delignification before bleaching
A: Acidic washing for the removal of metals from the pulp
D: Bleaching using chlorine dioxide
E: Alkaline extraction by sodium hydroxide
EO: alkaline extraction using hydrogen peroxide
EOP: Alkaline extraction using oxygen and hydrogen peroxide
mP: Modified hydrogen peroxide treatment
O: Oxygen treatment
P: hydrogen peroxide treatment
PO: hydrogen peroxide and oxygen treatment
Paa: Peracetic acid treatment
Q: Chelating agents treatment
X: Xylanase treatment
Z: Ozone treatment
ZD: Consecutive one-stage ozone and chlorine dioxide treatment

Achieved environmental benefits

The main reason why ECF is used is the reduction of AOX discharges.
When applying ECF bleaching it is possible to attain a AOX content of less than 0,2 kg/BD

Environmental impact:

The formation of 2,3,7,8- TCDD and 2,3,7,8-TCDF is reduced down to a non-detectable level
The formation of chlorophenols and chloroform is prevented and the formation of chlorine-containing organic compounds (AOX) is reduced down to a level of 0,2 – 1,0 kg/ADt (before treatment at an off-site treatment plant).

Operational data:
When applying ECF bleaching the cost of the bleaching chemicals grows and the energy consumption grows for the production of chlorine dioxide, oxygen and hydrogen peroxide.
Field of application:
ECF bleaching should be considered at new sulphate pulp production plants, and maybe should the introduced at already existing plants.
Introduction factors:
The concept of bleaching technology depends on the priorities of bleached sulphate pulp as to the cost of chemicals, operational costs the yield of pulp as well as to the specific limits of the process.
The transition of an already existing company to ECF bleaching often calls for a modernization of the fiber production line as well as the installations for the production of chlorine dioxide.
Reference literature: [3].

5.1.6 The Stripping and Recycling of Polluted Condensates after the Treatment in the Stripping Column

Description of the technique:
The stripping of contaminated condensates is done with the aim to lower the consumption of fresh water in the production, as also for the lowering of the load of organic substances on the treatment plant as well as for the reduction of the total reduced sulphur. The steam stripping and the recycling of the condensates may lead to a considerable reduction of the COD load on the treatment plant.
About 8 – 10 m^3 tons ADt of the total amount of condensates are formed with a COD and BOD_5 load, respectively of about 20 – 30 and 7 – 10 kg/t. Usually, about 1 m^3/ ADt is heavily polluted, where as 4 m^3/ ADt are moderately polluted and 4 m^3/ ADt minimally polluted.
A considerable share of the COD is accounted for by methanol (5 – 10 kg/ ADt) whereas the remaining part is accounted for by ethanol, a number of sulphur-containing compounds (1 – 2 kg/ ADt), turpentine (1 – 2 kg/t) as well as inorganic nitrogen compounds.
1 m^3 of the condensate has a COD value of 10 – 20 kg/m^3. This parameter is higher in condensates from hardwood pulp production.

these polluted condensates are usually treated in a stripping column, where the efficiency of removal of the majority of the compounds is 90 % (depending of the pH value). In blowing-off systems the non-condensable gases are usually removed (total reduced sulphur), as well as other compounds, having and influence on the COD of the condensate. After the distilling off, the cleaned condensates may contain 1 – 1,5 kg COD/m^3 of condensate.

There is no metal content in the treated condensates, and, thus, they are especially suitable for the use in the bleach plant is the aim is to close the circuit of this part of the process. They also may be reused in the process of washing of the unbleached pulp, in the caustization workshop (the washing and dilution of the sludge, as a fluid for the washing of the gases from the limekiln that contain the total reduced sulphur or as waster for the production of white liquor. This means, that some of the condensates may be used in the closed circuit part of the process and will not end up in the wastewater.

The best method of recycling of the condensates if the washing of the pulp with the feed of the condensate to the last step of the washing procedure oar to the thickener if there is a closed circuit of the treatment department water supply system.

<u>Achieved environmental benefits</u>

Reduction of the COD of the treatment plant; the reduction of the consumption of energy for aeration purposes as well as the energy consumption and chemicals for the processing of the surplus activated sludge, the removal of the smell of dirty condensates, the reduction of fresh water consumption and the waste gases from the stripping column may replace the fuel, thus cut down expensed for fuel oil or natural gas.

<u>Environmental impact:</u>

The reduction of the total reduced sulphur (TRS) and methanol as well as the emissions to air.

The recycling of the condensates in the presence of a closed-circuit system of water use of the treatment department provides for the reduction of the water need for the washing of the pulp. The usual waster need for pulp washing is 10 – 13 m^3/ADt. The amount of the condensates, arriving from the evaporation and cooking processes and suitable for recycling may be 6 – 9 m^3/ADt. This number represents the amount of water that can be saved.

The Blow-down of the heavily polluted condensates leads to the reduction of the total reduced sulphur and amounts to about 97 %, whereas methanol accounts for 92 %.

Operational data:
For many years, at modern companies, the distillation of polluted condensates has been used. When using stripping columns, the condensate arriving from them is fairly clean an may be recycled at the plant, for instance for the washing of unbleached pulp.
The main aim of the installation has to be the minimization of the flow to the stripping system and the division of the condensates in order to reduce the costs:

- in the evaporation unit, the condensate both from the last steps of the evaporation and from the surface condenser are divided into two fractions:
- the relief from the batch digester may be condensed in two steps. The secondary steam of the evaporation station may be used as the main source of heat for the stripping column.

The operational costs for the stripping of condensates consist main of the costs for the steam used in the process as well as the maintenance of the assembly. If the stripping column is operated separately from the evaporation station, then the operational costs are considerably higher because of the need for fresh steam. The costs amount to about 0,6 – 0,7 M Euro/year. If the stripping column is connected to the evaporation station, then the operational costs are lower and amount to 0,3 – 0,4 M Euro/year.
Field of application:
It may be used at both new and already operating plants.
The stripping columns for condensate processing may consist of a separate installation or it may be built into the evaporation station. In the first case, there might be a need of live steam, whereas in the latter case one may use secondary steam from any evaporation apparatus. However, there has to be a thermal oxidation of the gases, arriving from the stripping column. In order to achieve this one may use the lime recovery kiln as well as thermal energy boilers or special kilns.
Introduction factors:
The reduction of the COD load on the treatment plant and the economy of fresh waster during the production of pulp.
Reference literature: [3]

4.1.7 The Partial Closing of the Water Circuit of the Bleaching Plant

The full closing of the water circulation of the bleaching plant (where the surplus water from the pulp drying machine is fed to the pulp washing after the last step of the bleaching and, successively going through all the washing steps of the bleaching plant, is dispatched to the washing of unbleached pulp and thereafter to the chemicals recovery system) may not be defined as a category of BAT. A necessary condition of the water use in the bleaching plant must be the full separation of acid and alkaline filtrates.

The surplus acid and alkaline filtrates are sent to the treatment plants, and, in some cases, the alkaline filtrate is used for the washing of the pulp after the oxygen delignification (which is possible only when there is a tight control of the chlorine content parameters of the alkaline filtrate).

The problems that are connected with the high concentration of organic and inorganic (non-process elements) compounds of a partially closed water circulation system is a major obstacle for the further water use reduction of bleaching plants:

- the increased Cl^- and K^+ ion content of the smelt from the RB, which leads to clogging-up and corrosion of the equipment.
- The increase of the inert inclusions in the lime recovery circuit as a result of the accumulation of phosphorus.
- The increased deposit on the bleaching installations as a result of the increased concentrations of Ca^{2+}, Ba^{2+}, $C_2O_4^{2-}$, and SO_4^{2-} in the pulp and in the filters
- The increased consumption of bleaching chemicals as a result of the transport of organic compounds to the subsequent steps of the bleaching process
- The reduction of the selectiveness of certain oxidising agents as a result of the increased concentration of mixed valence metals
- The decrease of the quality of the pulp as a result of resin deposits, etc.

<u>Achieved environmental benefits</u>

Modern schemes of ECF bleaching with a countercurrent washing system with a partial closing of the circuit of filtrates, the flow of wastewater amounts to about 15 – 20 m^3/ADt (depending on the type of used washing equipment).

Environmental impact
The reduced quantity of wastewater and the COD load on the treatment plant.

Operational data
There is a required capacity and an extra steam consumption needed for the evaporation in the cases where the dissolved organic substances are fed to the evaporation station and further to the RB with the effluents from the bleaching plant.
Field of application
It may be used both in new plants and in already existing plants.

Introduction factors:
The level of closure depends on the type of wood, the quality of the water the scheme of the bleaching procedure, the type of washing equipment as well as the general design of the process.
As for the safety of the evaporation of wastewater from the bleaching plant, it is more adapted for the TCF technology bleaching than for the ECF bleaching, where there is risk of corrosion of the RB equipment based on the chloride exposure.
The further reduction of water use depends on the presence of efficient industrially introduced methods of cleaning the system from calcium, oxalated as well as non-process elements.
Reference literature: [3].

4.1.8 The Partial or Total Recycling of Clean Cooling Water

At pulp and paper, a large quantity of unpolluted and thermally polluted water, heated in heat-producing equipment units. The partial or full recycling of this water provides the opportunity to reach a minimal fresh water consumption level, to reduce the amount of wastewater discharged to the recipient, and, by doing this, lower the environmental impact.
Part of the used warm water from the evaporation, bleaching, cooking and drying plants as well as from some accessory production units is used in the production process. Part of the warm water is cooled in heat exchangers or in cooling towers as is returned to the consumers. In the process, there is a need of 10 – 15 % fresh water in order to compensate for the losses.
Nowadays, the separation of the cooling water into a independent flow and the return of it after it has been cooled are applied widely.

The separation and the repeated use of the clean cooling waster may be applied at newly started companies, as well as already existing companies.
If the clean cooling water is discharged into the sewerage system, then, in order to lower the hydraulic pressure on the off-site treatment plant, it should not be mixed with polluted production wastewater. If such a precaution is taken, it will lead to a greater efficiency of the wastewater treatment process and it would also reduce the treatment costs.

4.1.9 Hear Recovery wen Producing Pulp, Paper and Board

The recycling of the heat contained in the used steam-air mixture in the drying part of the drying machine of the paper or board machines is one of the most important fields of secondary energy resources use in order to increase the coefficient of efficiency of the dryer and the economy of fuel and energy resources. The choice of the type of heat recycling equipment system determines the choice of hood system of the dryer.
The principal heat recovery system is shown on 2.5 (see figure item 2.11).
The description if presented in the item 4.2.2: *Heat Recovery during the Production of Paper and Board.*

4.1.10 Buffering Tanks for the Collection of Leakage

<u>Description of the technique</u>
In order to avoid an excessive load on the off-site treatment plant and periodic disturbances of the wastewater treatment process, there is a need for tanks for cooking and recovery fluids, as well as for polluted condensates. These tanks need to have a capacity exceeding the normal operational volumes, at least by 30 %. The clean flows are diverted from potential leakage and overtop areas in order to prevent them from ending up in the production fluid flows.
The condition and level of filling of the tanks for weak and strong liquors of both sulphite and sulphate production need to be controlled regularly, especially during start-up of a plant or when the plant is under outage of during periods of disturbances of the normal operation of the plant. The main requirement towards the buffer tanks is defined by the concentration of the liquor, as defined by the content of dry matter. For instance, in old sulphate pulp plants the concentration of the weak and strong black liquor, correspondingly may be 8 and 60 %, which may be compared to the analogous parameters of a modern plant, where these numbers would be 16 and 75 %, correspondingly.

The necessary additional volume, apart from what is required during normal conditions of operation need to be based upon the peak flow load, possibly arising because of event of technological malfunctions in the course of a few hours of operation. The additional volume need to secure the storage of a sufficient quantity of weak liquor, in order for the evaporation station might function in a normal way, despite of short operational halts (shutdowns in order to fix malfunctions) of cooking and washing processes, as well as for the multi- or single flow evaporation station to be shut down for short-term repair. The volumes of the tanks for strong liquor need to be sufficient to hold such a volume as for the short-term stops of the recovery boiler not to lead to a reduction of the production evaporation, or in order to allow for the shutoff of the evaporation station to enable minor repair work.
Operating plants, considering the issue of introducing oxygen delignification must appraise the capacity of the tanks for weak and strong liquor as well as the capacity of the evaporation station, taking into account the fact that this production stage leads to the increase in the volume of water that needs to be evaporated.
The liquor produced from the smelt formed in the RB and transformed into fresh cooking (white) liquor, do not contain organic compounds, but then have a very high pH. The reservoirs to hold this liquor need to have a backup volume in order to relieve the short-term peak loads or for the event of malfunctions of the production equipment, for instance the liquor filters. If there, due to a bad organisation of the control, these liquors are transferred to the treatment plant, then they would cause a pH leap, which would lead to disturbances in the functioning of the off-site treatment plant.

The environmental effect achieved
If there is a quality management of the process and if the installations for the location of accidental overflows and leakages of the needed design, and also if there is a regeneration system and a 5 – 10 % excess capacity of the evaporation station, it is possible to lower the COD load to the treatment plant.

Environmental impact
The lowering of the COD load on the treatment plant of 3 – 8 kg/ADt. The overflows and leakages may be less than 2 kg COD/5 ADt.

Operational data
In order to determine and evaluate the overflows and leakage of liquor one may use electrical conductivity gauges, since in many cases it is possible to establish the correlation between the electrical conductivity and the liquor concentration for any flow. In the flows with a low concentration with a variable pH, the pH gauge, working on-line is a usual standard instrument.
The hot flows calling for a special control, may easily be controlled by temperature gauges, working on-line.
In order to resolve the issue of prevention of overflows and leakages as well as the creation of the needed strategy for the control of chemicals movement at the plant, there are a multitude of methods.
Obstacles for the efficient introduction of these measures are the various production problems that are at hand in the processes of washing and screening of the pulp as well as the evaporation of the liquors.

Field of application
This method may be used both at new and already existing plants.
The installation of buffer tanks as well as the system for the collection of accidental flow-overs and leakages should be carried out based on economic profitability as well as wit the aim to perfect the process, especially at the stages of washing and treatment of the pulp, as well as the evaporation and filtration of the liquor. The efficient containment of process leakages as well as overflows is an extremely important parameters of the operation of the production equipment, and influences to a high degree the environmental characteristics of the plant.

Introduction factors
Any measures taken in order to introduce this technique should be carried out taking into account environmental and production safety factors.

Reference literature: [3].

4.1.11 Closed Circuit for the Recovery of Cooking Chemicals

Technology description
The recovery system at a sulphate pulp producing plant fulfils three functions:
- The regeneration of inorganic cooking chemicals

- When burning black liquor, heat is produced which can be used for the production of production steam
- The recycling of valuable organic by-products (for instance tallic oil).

The heat content of the evaporated black liquor is usually sufficiently high as to provide a sulphate pulp producing plant with all the heat and electricity supply it may need. As to the organic by-products, they, at a majority of sulphate pulp producing plants play a limited economic role.

In the black liquor produced after the cooking, the dry matter content usually ranges between 14 and 18 %. This concentration needs to be substantially increased in order for the liquor to be efficiently incinerated in the RB. The liquor is concentrated in an evaporation plant until it reaches a concentration of 65 – 75 % dry matter. However, if the concentration of dry matter is higher than 75 %, then its viscosity increases dramatically, which may become the cause of problems when it is transferred. Because of this, under atmospheric pressure, the upper limit of dry matter content needs to be set at approximately 72 – 74 %. There are two methods used in order to overcome the problem with the lowering of the viscosity:

- Raising the pressure in the concentrated liquor storage tanks
- Raising the operating temperature of the evaporation apparatuses used for liquor evaporation.

The liquor may be concentrated down to a dry matter concentration of 80 % and more through the application of thermal processing of already concentrated black liquor and the subsequent evaporation under pressure. During thermal depolymerisation of the liquor, some of the volatile substances are separated out as non-condensable gases, which contain total reduced sulphur (TRS). These gases are collected and incinerated together with the other foul-smelling gases.

The condensates from the evaporation apparatuses are processed in the stripping column, which then allows for the secondary utilisation of them for the washing of unbleached pulp, the green liquor sludge as well as the caustization sludge.

The increased content of dry residue of the black liquor from 65 to 70 % to 80 – 85 % changes the material and energy balance, as well as the conditions of incineration in the recovery boiler. The volume of the fuel gas is reduced with the reduced quantity of water entering the kiln. The temperature of the combustion is increased wit the increase of the content of dry matter in the liquor. While this is happening, a large quantity of sodium is sublimated, which thereafter reacts with the sulphur, in doing so reducing the amount of emissions of sulphur compounds from the recovery boiler.

The smelt from the RB, consisting mainly of sodium carbonate and sodium sulphide, is dissolved in the weak white liquor in order to produce green liquor.

The green liquor is cleaned from suspended matter (green liquor sludge). The clarified green liquor reacts with the lime, forming white liquor and lime sludge.
The white liquor is separated out from the lime sludge and is transferred to the digester.
The lime sludge is washed and subjected to roasting in the lime recovery kiln. The roasting process is a high-temperature endothermic reaction, requiring the addition of heat from outside. As the result of the roasting, unslaked lime is formed (CaO), which is transferred to the caustization plant, as well as CO_2.
The concentrated non-condensable gases are collected and burnt, usually in the RB, or in a separate furnace, or, again, in the limekiln. The last option is the least convenient, since it may disturb the operation of the limekiln. The flue gases are cleaned in a scrubber, while the reflux water from the scrubber is transferred back to the chemicals recovery system.
At sulphate plants there is a collection and burning of the weak non-condensable gases as well as there thermal treatment. These gases, with a low concentration of foul-smelling and harmful substances are separated out in the process of preliminary steaming of the chips, washing and screening of the pulp, from the smelt solvent and from the liquor containers.

4.1.12 The Collection and Decomposition of Sulphate Soap

Reference literature

In order to avoid the strong formation of froth as well as the formation of deposit on the surface of the evaporation apparatuses, it is necessary, in the process of evaporation, to remove the soap (sodium salts of resin and fatty acids) from the black liquor.
The removal of soap from the liquor is achieved through sedimentation or separation. The necessary concentration of liquor in the clarification tanks is achieved though the partial return of the thickened liquor. The point of feed of the black liquor into the separator is of key importance. The distance that the soap particles have to cover in order to reach the surface needs to be minimal.
Tallol is produced from the sulphate soap by its dissociation by sulphuric acid, using a continuous process and using separators to separate out the tall oil.
The yield of the sulphate soap at various companies varies between 40,5 and 79,1 % of the mass of the extractives received with the timber. The loss of extractive matter with the liquor transferred to be incinerated ranges between 11 and 26 kg/t of pulp.
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Achieved environmental benefits:
The reduction in idle-time of the evaporation station in order to wash and limit the fresh steam for the evaporation of the liquor. The limitation of hydrogen sulphide from the production of crude tall oil.

Environmental impact:
The reduces consumption of sulphuric acid in order to decompose the soap. The decreased emissions of hydrogen sulphide.

Field of application:
Applicable at both new and already existing plants

Introduction factors:
Any measures aiming at the introduction of this technique have to be carried out based on environmental protection considerations as well as operational safety considerations.

Reference literature: [3].

4.1.13 Separation and Collection of Turpentine

Description of the technique:
In the process of steaming and cooking volatile compounds (terpene hydrocarbons) are produced. They are removed when the chips is being steamed before the continuous cooking and during the turpentine blowdown from the boiler during batch digestion. During the condensation of the vapours and the settling of the turpentine-containing condensate in the Florentine separator there is production of sulphate turpentine. The composition of the produced turpentine varies depending on the used wood species. The highest terpene content is found in fresh pinewood. In spruce wood the content is substantially lower. The crude sulphate turpentine is polluted by a considerable amount of foul-smelling sulphur compounds and has a very foul smell and a dark colour. The yield may vary in the range of 0,5 – 15 kg per ton of pulp.

Achieved environmental effect
A lowered discharge of turpentines

Field of application:
May be applied on both new and already existing plants.

Introduction factors:
Any measures aiming at the introduction of this technique have to be carried out based on environmental protection considerations as well as operational safety considerations.

Reference literature: [3].

4.1.14 Collection of Weak and Strong Gases and the Subsequent Burning in Specialized Kilns, a Limekiln or a RB.

Description of the technique:
Volatile sulphur compounds (non-condensable gases) are formed mainly during the digestion of pulp and the evaporation of liquors.
High concentration non-condensable gases (strong NCGs) are formed in the system of collection of turpentine from the blow-down of turpentine, during the condensation of vapours from the boilers during continuous and batch-wise cooking, in the cisterns for the storage of polluted condensate as non-condensed gases, which are removed from the evaporation plant. The sulphur content is about 4 kg/ADt.
The main sources of low concentration non-condensable gases is the washing and screening of unbleached pulp equipment, certain tanks and containers with pastes of alkaline solutions in the washing and screening of the pulp, the tanks for the storage of black liquor and the evaporation plant as well as the tank for the storage of white liquor in the caustization and lime regeneration plant. The sulphur content is about 0,5 kg/ADt.
The usual quantity of low concentration non-condensable at a company with the capacity of 1 000 t/day is about 50 000 – 100 000 m^3/h. The quantity of gases depends on the specific situation at the plant; if there is continuous cooking and pulp washing in the diffusor, the volumes are less than if batch digestion is used and pressure filter washing.
The main method used for the treatment of NCGs is burning. An alternative to burning may be an alkaline or oxidizing scrubber.
The incineration of concentrated foul-smelling gases in the recovery boiler is one of the treatment methods. In Europe there are a number of plants, and worldwide there are 41 plants, which burn strong foul-smelling gases in recover boilers.
The collected low concentration non-condensable gases may be burned as a constituent of secondary or tertiary air in the RB. At concentrations of dry matter in

the black liquor fed to be burnt in the RB above 72 %, sulphur dioxide usually is sorbed by the alkaline dust particles in the RB, and subsequently there is no need for any additional chemical treatment of the flue gases.
The incineration of concentrated non-condensable gases may by conducted in the limekiln or in a special kiln for the burning of non-condensable gases, equipped wit an SO_2 scrubber. The concentrated non-condensable gases account for more than 90 % of all compounds of the total reduced sulphur (TRS), produced during the cooking.
One advantage of burning non-condensable gases in the limekiln is the fact that there is no necessity of erecting a new special kiln. Apart from this fact, the sulphur containing gases may react with the lime, which lowers the emissions of sulphur dioxide. The limited amount sulphur compounds in the limekiln may react with gaseous sodium, producing sodium sulphate.
An average of 10 – 15 % of the fuel used in the limekiln may be replaced by the burning of concentrated foul-smelling gases. The condensation of methanol after the stripping column may minimized the problem, caused by the gas quality variations, which calls for further investments.
The burning of foul-smelling gases may also be conducted in a special kiln (furnace) for the burning of non-condensable gases, equipped with a scrubber for the absorption of SO_2. The gases are used as a fuel for the additional production of steam or hot water.

<u>The environmental effect achieved</u>
The limitation of the total emissions of gaseous compounds of reduced sulphur and the reduction of smell from organic sulphur compounds (OSC)

<u>Environmental impact</u>
The total emission of reduced sulphur in the form of non-condensable gases may be reduced by more than 99 % only through the collection and burning of concentrated non-condensable gases. The collection with the subsequent burning of foul-smelling gases brings on a considerable impact as is improves the air quality.

<u>Operational data:</u>

The indicated measures are used widely.
In modern limekilns there might arise operation problems because of a lack of oxygen.

At many old plants the pulp washing equipment is of the open type, which means that the collection and processing of flue gases from these sources call for a very large volume of air, which is technically and economically complicated.

Field of application.
The recycling of non-condensable gases measures are applicable both at new and already existing companies.
At already existing plants, it is quite complicated to organise the collection and processing of weak non-condensable gases.

Introduction factors
Reduction of the emissions of foul-smelling gases

Reference literature: [3].

4.1.15 Burning of Black Liquor with a Concentration above 72 %

One of the methods by which a reduction of the emissions of SO_2 can be achieved when burning black liquor is the transition to evaporation of the black liquor to a concentration of 75 – 80 %. When the concentration is raised to a level above 80 % the vapour production is increased and the thermal coefficient of efficiency of the boiler is raised. The effect of the raised black liquor concentration has been demonstrated and proved by the work of tens of new and reconstructed RBs in various countries of the world.
The elevated content of dry residue in the black liquor from 65 – 70 % to 80 – 85 % changes the material and energy balance, as well as the conditions of combustion in the recovery boiler. The volume of fuel gas is lowered with the reduced quantity of water being fed into the kiln. The raised content of dry matter may increase the capacity of the RB.

Achieved environmental benefits:

If the concentration is raised of the liquor transferred to the RB to be burned, then the sulphur emissions are lowered by as much as 80 %.

Environmental impact:
The sulphur emissions from the recovery boiler range between 5 and 50 mg S/nm^3 of kiln gas or 0,1 – 0,3 kg/ADt, and – sometimes – they may fall almost down to zero in view of the fact that a large quantity of the sodium is evaporated and reacts with the sulphur.

Operational data
This measure has been tested at a number of pulp production plants in Russia. The operational costs of the development of the system of the strengthening of the liquor are insignificant thanks to the increased energy economy (in this case it ranges between 1 and 7 %) and the increased capacity of the recovery kiln. The increased content of dry matter in the recovery boiler may lead even to some net economic saving.

Field of application
Measures for the strengthening of the liquor after the evaporation make economic sense both at new and at already existing sulphate pulp production plants.
However, the maximum dry matter (DM) content is limited by the increased viscosity and the tendency of the concentrated black liquor to stratify. This is dependent on the wood species and the temperature.

Introduction factors
Sulphate pulp production companies may encounter problems having to do with sulphur dioxide emissions, which may be reduced by the burning in the liquor recovery boiler under conditions of an elevated dry matter content. The increased capacity of the recovery boiler by 4 – 7 % is also a heavy argument for the company.

Reference literature: [3]

4.1.16 Advanced Washing of the Sludge formed in Chemicals Recovery

Description of the technique
Lime (CaO) is used for the caustization of green liquor ($Na_2S + Na_2CO_3$). After the caustization lime sludge ($CaCO_3$ is formed). The lime sludge is burned in the lime recovery kiln, as a result of which calcium carbonate is decomposed during the formation of lime. Before the lime sludge arrives at the lime recovery kiln it needs to be washed in order to remove the residual sodium hydroxide, sodium sulphide as well as other sodium salts, and – subsequently – to be dewatered. The equipment used for the washing of the lime sludge usually consists of clarifying tanks (settlers) or filters of various constructions. Earlier, for this purpose, two-stage washing apparatuses were widely used, however the modern one-stage washing procedure of the sludge

in a block settler with an integrated tank or in pressure filters or disc filter are becoming the dominating techniques
The sophisticated washing of the lime sludge may lower the suspended matter content of the white liquor from 100 mg/dm^3 down to 0 – 30 mg/dm^3 when using modern filters. The dryness of the lime sludge may also be raised from 50 – 60 % to 70 – 80 %. A more efficient washing process lowers the residual sodium content (0,1 % … 0,2 % by units of Na_2O of the sludge mass) of the lime sludge, in this way lowering the amount of hydrogen sulphide in the limekiln in the process of sludge roasting.
If the washing process is conducted down to a too low sodium content, then the emissions of reduced sulphur-containing compounds with the flue gases may grow, apparently as a result of the lowering of their interaction with the sludge, in which it reacts primarily with sodium salts, as well as with sodium partly at a high roasting temperature (1 100 – 1 250 °C) in the gaseous phase.
It is necessary to control the residual sodium in order to prevent the deposit of sintered sludge onto the walls of the limekilns.

Achieved environmental benefits
The lowering of the Na_2S in the lime sludge as well as the lowering of the amount of formed H_{2S} of the lime recovery kiln in the process of sludge roasting.

Environmental impact
The lowering of the hydrogen sulphide content as well as the content of foul-smelling organic sulphur compounds of the gases of the limekiln.

Operational data
The improved washing process of the lime sludge is applied at European pulp production plants for more than 20 years. The control of the residual sodium is necessary in order to prevent the deposit of sintered sludge onto the walls of the limekilns.

Fields of application
The methods is applicable both at new and already existing plants

Application methods
The lowering of the H_2S content as well as the content of the foul-smelling organic reduced sulphur compounds (RSC), and, as a result of this, of the smell from the flue gases of the limekiln.

Reference literature: [3]

4.1.17 Dewatering of the Waste from the Chemicals Recovery Cycle

Description of the technique
Then recovering the chemicals used during sulphate production various fractions of solid waste are formed: green liquor sludge and lime sludge.
The green liquor sludge and the lime sludge are often mixed, and it is hard to show any separate numbers. The total sum varies between (approximately) 10 and 60 kg/t pulp, and – as an average – about 30 kg/t pulp. The composition of such mixed waste varies and is divided into two groups: one almost without lime sludge (less than 2 %) and other with a large part of lime sludge (about 75 % as an average). The green liquor sludge is often dried in drum filters with a sub-layer of lime sludge (dry matter content between 30 and 70 %). If centrifuges are used, the content of dry mater in the sludge is about 8 – 20 %.

The environmental effect achieved
The lowering of the volume of sludge, transferred to landfills.

Environmental impact
The lowering of the losses of chemicals in the recovery cycle.

Operational data
The control of the dryness of the sludge and the water consumption for the washing of the sludge.

Field of application
Applicable both at new and already existing plants

Introduction factors
The reduction of the volumes of deposited waste

Reference literature: [3].

4.1.18 Electrical Filters after the RB, LK, the Bark and Treatment Plant Sludge Burning Furnace

Description of the technique
The main part of the emission from the wood waste burning kilns (bark burning kilns) consists of solid particles (dust). Usually the bark kilns are equipped with cyclones

for dust collection (85 % efficiency). However, at present, it is becoming more and more popular to used electrical filters with an efficiency rate of above 95 %.
The application of various types of fuels also effects the dust emissions. When running the incineration in a limekiln in order to minimize the amount of CaO, Na_2SO_4 and Na_2CO_3 particles in the flue gases it is possible to install an electrical filter An electrical filter is considerably more efficient than a scrubber when it comes to dust collection. If there is a gas washing equipment, the electrical filter is installed before the scrubber.
The main environmental protection results when treating the kiln gases of the bark boilers is the reduction of the concentration of solid particles from a level of 250 – 500 mg/Nm^3 down to 100 – 150 mg/Nm^3 if cyclones are used. The main part of the dust is CaO. Generally, CaO is produced starting from the loading part of the kiln. The quantity of dust, entering from the hot end of the kiln is considerably lower. The main components of the emissions of dust from the smokestack are small particles of Na_2SO_4 and Na_2CO_3, since the CaO particles are efficiently trapped in the flue gas treatment system.

Achieved environmental effect
The reduction of the emissions of dust to air

Environmental impact
The reduction of the concentration of solid particles in the kiln gases from the bark kilns using an electrofilter, down to 20 – 40 mg/m^3 (at 10 % O_2 in dry gas) at a treatment efficiency of above 95 %.

Operational data
Applicable at both new and already existing plants

Introduction factors
The reduction of the emission of dust to air

Reference literature; [3].

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4.1.19 Furnaces for the Incineration of Bark and Sludge from Treatment Plants, Undercooked Pulp as well as the Respective Fuel Preparation Processes

Description of the Technique

At present, the best method for the burning of waste from the production and the sludge from the treatment plants is the use of the technology called *Fluidized Bed*. This technique has become widely used at a majority of pulp and paper production companies in Russia

The experience received over many years of operation of kilns with such a technology as well as the results received from process flow and load balance tests made by specialised organizations have provided the opportunity to the producers to develop furnaces with quite high efficiency coefficient.

The Furnaces my operate within a wide range of proportions of the fuel: softwood bark, hardwood bark, sludge (unprocessed mud) from the biological wastewater treatment plant, sawdust, undercooked pulp, etc.

If there is an efficient system for the preparation of the fuel (a description of such a system can be found in section 2.6), modern constructions of kilns permit the maintenance of a stable heat production mode with the possibility of the further use of it to produce electrical energy.

Achieved environmental effect:

- A reduction of the extraction volume of fossil fuel
- A reduction in the use of purchased electrical energy and heat
- A reduced territory used as landfills and heaps for production waste
- The possibility of further use of the trapped ash and bottom sediment for construction and construction material production purposes
- A reduction of the emissions of greenhouse gases

Environmental impact

- Harmful emissions with the flue gases including: nitrogen oxides (NO_2), sulphur oxides (SO_2), carbon monoxide (CO), suspended solids;
- The relative indices of harmful substances: nitrogen oxides: (NO_2): less than 250 mg/Nm^3, sulphur oxides (SO_2): less than 500 mg/Nm^3, carbon monoxide (CO): less than 250 mg/Nm^3, suspended solids: less than 100 mg/Nm^3
- The use of extra sand to replace the losses
- Consumption of water for cooling and losses replacement purposes

- Noise from the operation of the equipment (less than 80 dBA at distance of 1 m)

Operational data

The twenty four – seven instrumental registration of the consumption of water and electrical energy

Registration of the added sand consumption

The obligatory performance of process flow tests of the kilns after any disturbances in the operational process and the introduction of changes in the set parameters.

The performance of periodic control measures of the air control activity of the boiler room by representatives of the internal environmental control service (at least once a year) or by state environmental control personnel (not more often than once per three years).

The evaluation of objective factors, affecting the results of the calculations of the emissions from the boiler room, not dependent on the operational personnel, is to be carried out for the following parameters: the kiln load, the fuel consumption, the quality of the fuel (the content of sulphur, nitrogen, ash as well as the heat of combustion) as well as the hardware configuration.

The measurement of the concentration of pollutants of the flue gasses is done during the actual workload of the kilns and ash trap equipment within the control performance period.

Field of application

Limited application – when there is a presence of sodium sulphate and a high pH of the fuel mixture

Introduction factors

The dependence of the production of purchased electrical energy and heat.

The lowering of the production cost of the produced merchandise.

4.1.20 Biological Treatment of Wastewater

Description of the technique

The biological (secondary) treatment of wastewater involves the treatment with the aid of active sludge by adsorption, chemi-sorption, bio-sorption, coagulation and bio-oxidation. This involves the oxidation of most of the pollutants present in the wastewater. Bacteria may feed on organic compounds as well as mineral components, i.e. iron, cupper, petroleum products and even heavy metals. An additional advantage of this method is its autoregulation. In the activated sludge, there is a presence of quite an impressive diversity of biological species. Depending on the composition of the

wastewater one type of colony thrives while others decline. In this way their symbiosis supports the natural balance. Before secondary treatment there is usually a number of stages of primary processing: the removal of suspended solids, neutralization, cooling and homogenization of the flows.
In the majority of cases a pulp and paper plant wastewater is treated by aerobic methods. The anaerobic treatment does not provide the opportunity to achieve in the wastewater the concentrations of BOD and COD that would be allowed to discharge into the recipient. This is why in anaerobic treatment at a pulp and paper plant may be used only in combination with an aerobic stage.

4.1.20.1 The Activated Sludge Process

Description of the technique

Activated sludge treatment plants are composed by two main stages: The aeration tank (aerotank) and the secondary sedimentation tank (settler). In the aerotanks the wastewater is processed by activated sludge, while in the secondary settlers there is a sedimentation and separation of the sludge from the clarified waster. The major part of the activated sludge is returned to the aerotanks in order to maintain a high sludge concentration. A smaller part of the activated sludge is removed from the system as surplus activated sludge.
In order to oxidize the organic components, in order to allow for the respiration of the microorganisms as well as the maintenance of the suspended state of the sludge, air is fed into the biological treatment system. There are various types of aerators; surface aerators, submersible turbine aerators, small bubble as well as jet aerators.
The designs of the already existing treatment plants are characterized by the number of stages, the construction of the aerotanks, the aerators of the secondary settlers as well as the equipment for the processing of the surplus activated sludge.
The activated sludge process is the most widespread process in the branch of pulp and paper production and is used in 60 – 70 %, of all biological treatment plants.

Achieved environmental benefits

Common values of the level of lowering of the BOD parameter value are 85 – 98 %, the lowering of COD – 60 – 85 % whereas the reduction in AOX content is 40 – 65 %.

Environmental impact

The reduction of discharges into recipients, the lowering of the level of pollution of the environment.

<u>Operational data</u>
During the treatment of wastewater, surplus sludge is formed, which, after being dewatered, may be burned in a recycling kiln, giving an extra heat production.
<u>Field of application</u>
Activated sludge has been used successfully during a period of many years at various sulphate pulp production plants.
<u>Introduction factors</u>
Biological treatment with the use of activated sludge is most preferential in cases, where a high or very high efficiency of the treatment is needed.

4.1.20.2 Aerated Ponds

<u>Description of the technique</u>
An aerated pond is a holding basin for the accumulation of a large volume for a long period of time (3 – 20 days) of wastewater. Microorganisms are cultivated in a suspension in a large quantity of liquid, attaining the concentration in the pond of 100 – 300 mg/l. The presence of oxygen for the growth of the microorganisms is provided for by mechanical aerators. The aeration equipment also guarantees the agitation necessary for the maintenance of the suspended state of the solid matter as well as the enforces microbe action. The biological process does not involve the recirculation of the biomass of the reservoir. The sedimented sludge is rarely removed, once in 1 -10 years.
The typical level of efficiency of the treatment is 40 – 85 % of BOD, 30 – 60 % of COD and 20 – 45 % of AOX.
<u>Achieved environmental benefits</u>
At present, the use of aerated ponds has become less widespread. The main reason for this is the lower efficiency of removal of pollutants as compared to the use of activated sludge, the large areas needed for their construction, the high energy expenditures for the aeration, as well as problems with froth formation and wastewater smell.
<u>Environmental impact</u>
The reduction of the discharge into recipients as well as the reduction of the pollution of the environment.

<u>Operational data</u>
Quite large areas are needed for the construction of an aerated pond. Such areas are neither always present in the neighbourhood of the company nor on-site.
During the treatment process in an aerated tank, less mud is formed than when using activated sludge. The recycling of the sludge by burning usually calls for more dewatering chemicals and additional fuel in relation to the dry weight of the sludge as compared to the activated sludge process.
<u>Field of application</u>
Aerated ponds have been used for a long period of time at many pulp and paper production plants in order to attain an intermediate level of pollutant removal from wastewater. At present, many existing ponds have been closed or have been modified into high-efficiency activated sludge installations or into water reservoirs for the additional treatment of wastewater.
<u>Introduction factors</u>
An aerated pond may be used in cases, when it is satisfactory to achieve a not especially high degree of reduction of the content of organic matter of the wastewater.

4.1.20.3 Membrane Bioreactor

<u>Description of the technique</u>
Membrane bioreactors (MR) techniques for wastewater treatment are in a state of development and represent a combination of biological treatment with activated sludge with mechanical membrane filtration.
The main feature of the membrane bioreactor, differentiating it from traditional biological treatment systems in aerotanks is the presence of a membrane module, used to divide the sludge mixture and it is an alternative to the widely used method of sedimentation of the activated sludge in secondary settlers.
Depending on the interaction between the reactor and the membrane module, there are two MBR configurations:

- A submersible membrane bioreactor (the membrane module is immersed directly in the aerotank, and the filtration is carried on under influence of a vacuum);
- An exterior membrane bioreactor with a recirculation cycle (the membrane module is located outside of the aerotank and combines two functions as both a secondary settler and a final, additional treatment plant).

The high activated sludge concentration (up to 10 – 20 g/l) allows for the operation of the bioreactor in the low load mode, which creates a reserve oxidizing ability, increases the sustainability of the biotic community of the activated sludge towards the fluctuations of the composition of the wastewater as well as the peak loads, while also guaranteeing a stable treatment quality and a multiple increase of the oxidizing capacity of the plant. Apart from this, the high sludge doses provide the opportunity to reduce the time the wastewaters spends in the works. The area occupied by a membrane bioreactor is 2 – 4 times smaller than the area occupied by traditional biological treatment plants.

Achieved environmental benefits

The reduction of the discharge of organic matter, phosphorus and AOX.

Environmental impact

The reduction of discharges into the recipients as well as the reduction in environmental pollution.

Operational data

This wastewater treatment method ensures a stable treatment quality and limits the duration of stay of the wastewater in the plant while also reduces the area that the works occupy.

Field of application

This technique may be applied both at new and old pulp and paper production plants

Introduction factors

The advantage of the MBR to the classical technology is manifested most clearly in cases where there is the presence in the wastewater of pollutants, resistant to oxidation or high quality requirements to the treated water in the lack of free areas.

4.1.20.4 Moving Bed Bioreactor

Description of the technique

The method is based upon the use of a special plastic non-oxidizable packing, which is under the constant conditions of intense turbulence during the full process. The wastewater fill up the moving bed biofilm reactor (MBBR) and flakes of activated sludge are established onto the mobile vehicles, freely floating over the full volume of the reservoir, thereby forming a film on the surface of these filling units, thereby lowering the quantity of organic pollutants in the wastewater.

Achieved environmental effect:

The reduction of the discharge of organic matter, phosphorus, nitrogen as well as AOX.

Environmental impact

The reduction of the discharge into recipients as well as the reduction of the environmental pollution.

Operational data

This wastewater treatment method permits the treatment of wastewater with high concentration pollution, while also reducing the residence time of the wastewater in the plant, as well as the reduction of the area occupied by the plant. This technique does not call for constant maintenance.

Field of application

It may be used in old, as well as new pulp and paper production companies.

Introduction Factors

This technique is still quite expensive and is introduces mainly in order to treat concentrated production wastewater when there is a limited territory on which to build a unit and when there are high requirements as to the quality of the treatment.

4.1.20.5 Combined Anaerobic and Aerobic Treatment

A description of the method

The method is based on the fact that wastewater is subjected to the action of anaerobic as well as aerobic microorganisms. This method is cost-efficient if the COD concentration in the production wastewater before the first stage – the anaerobic treatment – is above 1 000 – 2 000 mg/l. In addition, the content of suspended matter needs nod to exceed 200 – 500 mg/l.

Note: the description of the aerobic method of biological treatment is presented also under item 2.7.

Achieved environmental benefits

The reduction of polluted wastewater into the recipient

Environmental impact

The reduction of discharge into recipients as well as the reduction of the environmental pollution.

Operational facts
This wastewater treatment method allows for the treatment of high concentration wastewater.
Field of application
It may be applied both at old and new pulp and paper production plants
Introduction factors
At already operating companies it is expedient to introduce an anaerobic treatment stage in the case that the aerobic stage has reach the maximum of its potential or if it is congested.

4.1.21 Dewatering of the Wastewater Treatment Plant Sediment

Description of the technique
At pulp and paper production plant wastewater treatment plants there is a large amount of sediment formed in the primary treatment stage as well as surplus activated sludge if biological treatment is used and mud if polishing treatment is applied. The treatment of all types of sediments is carried out, as a rule, jointly, since the biological and chemical treatment sediments do not readily dewater and - in order to raise the dewatering capacity - it is necessary to mix with the fibrous sediment.
The reason why dewatering is practiced is the removal of as much water as possible from the sediment in order to facilitate its final recycling. The sludge from the biological as well as from the chemical stages of the treatment are – as a rule – thickened before the dewatering in gravitational thickeners. During this process, the content of dry matter is raised from 1 – 2 % to 3 – 4 %. Before the dewatering, the sediment, as a rule, is processed with the aid of chemicals (a polymer solution).
At present, in order to achieve dewatering, belt presses are used, as well as screw extruders, centrifuge-decanters and chamber filter presses.
The most popular are the belt presses, which work reliably and allows for the quite high dry matter content: 40 – 50 % for fibrous sediment and 25 – 40 % for mixtures of fibrous, biological and chemical sludges. Screw extrusion machines are also widely applied, providing the possibility to reach even higher levels of dry matter content. The use of screw extruders allows for the increase of dry matter content by 10 %.

As for deposits with a very low ability to be dewatered (clean precipitation with biological or chemical treatment), centrifuge-decanters are used.
The dewatering of the sludge gives the opportunity to reduce its volume approximately 20-fold. The sludge, after being dewatered, may be burned giving additional thermal energy.
Achieved environmental effect
The reduction of the amount of waste to be deposited of recycled.
Environmental impact
The reduction of subsoil water contamination.
Operational facts
The reduction of the volume of the sludge approximately 20-fold, as well as the facilitation of the final recycling of the sludge.
Field of application
The dewatering of the sludge may by used at old, as well as new pulp and paper plants
Introduction factors
The need to increase the dry matter content in order to facilitate the transfer and the final recycling of the sludge.

4.1.22 Development of the Scrap Processing System (Paper/Board Machines)

The system for the collection and processing of scrap involves the accumulation of the scrap from all production limits in the accumulation tank, which provides the stable function of flow of the machine, as well as the scrap batching into the paper/board composition. The accumulation of the scrap is an important factor during production outages and reduces the discharge of fiber into the sewerage system.
The system for the preparation of the scrap, including, thickening, repulping, cleaning, as well as the screening in multi-stage slot screens, guarantees the optimal quality of the secondary fiber to be used in the paper/board composition.

4.1.23 The System for the Trapping of fibers from the Surplus (waste-) Water from the Paper and Board Machines

In the technological process of board and paper production there is an installation for the internal shop cleaning of the surplus recirculated waster in order to use the clarified filtrate instead of fresh water as well as the returning of the trapped fiber to the production flow.
The treatment of the surplus recirculated water may be carried out in disc filters or in flotation save-alls.
The principal scheme is shown under item 2.6.5 (see figure 2.19).

4.1.24 VOC before the Treatment Plant

The local water treatment systems at the workshops are discussed under item 2.6.5.

4.1.25 The Introduction of an Automated dispatch Control System

Modern pulp and paper production companies, applying modern techniques and equipment practically lack permanent operating personnel present at the production workshop or section. The operative control of the production process is carried out by the operators of the production workshops or sections by use of an automated dispatch control system (ADCS).
A automated dispatch control system (ADCS) is intended for the control and management of the production processes, the increased efficiency and safety of the plant operation as well as the minimization of the human factor.
The introduction of ADCS provides the opportunity to carry out:

- The operative control of parameters and modes of the technological and production processes
- The keeping track of the condition of the process equipment
- The monitoring of the volume and quality of the produced goods
- The coordination of the work in accordance with the regulatory requirements, contract obligations, calendar schedules as well as the shift and daily tasks;
- The control of contingencies, taking of measures in order to avoid and remedy disturbances.
- Logging of events and the keeping of archive information

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4.1.26 The Combined Production of Thermal and Electric Energy

The process of paper and board production is energy intensive. At a relatively stable relative consumption of steam the electricity consumption have a tendency to escalate. This is related to the increased speed of the paper machines and the development of the systems for the preparation of fibrous intermediate products for sheet formation.
Usually, paper and board plant include a thermal and energy TPP (thermal power plant), involving standards energy boilers and turbines. The fuels are waste from the production in the form of recovered paper, paper scrap as well as organic types of fuel – gas or fuel oil.
The coefficient of efficiency of such a TPP is approximately 50 – 60 %. The losses during the production of heat and electric energy may be limited by the combined production of heat and electrical energy (co-production). Energy installations using the co-production principle have a coefficient of efficiency of 80 % and more as compared to conventional energy installations, by the token of which the fuel consumption as well as the CO_2 emissions to air may be lowered.
At paper and board production plants various schemes of combined energy installations are used. The most widespread and the most energy efficient of them is the steam-gas plant. Under conditions of constant stem production this installation allows for the production of a greater volume of electricity, than what is possible in conventional installations. As is the case in an ordinary gas turbine, the air is suctioned in from the atmosphere and is compressed. In the combustion chamber the fuel and the air from the gas turbine compressor is mixed and combustion takes place. The gas formed during the combustion process expands in the turbine, casing its rotors, placed on the same shaft as the turbine, to revolve. In co-production installations, the heat energy contained in the gases exiting from the turbine, is used in order to produce steam in the steam generator, which, in turn, is used in order to produce electric energy in the steam turbine. This principle allows for the achievement of the 80+ % of energy efficiency.
The combined production of heat and electrical energy is a well-known and well-proven technology at paper and board plants around the world.
The environmental effect achieved, the environmental impact, the operational facts, and the field of application as well as introduction factors are covered under item 4.1.19.

4.2 Techniques, Considered when Determining BAT for Sulphate Pulp Production

A list of best available technologies for the production of sulphite pulp is shown in table 4.4.

Some of the techniques used for the reduction and prevention of emissions, and eligible for sulphate plants, may also be used at sulphite pulp production plants. In order to avoid repetition, links are given to the suctions where analogous techniques are discussed.

Table 4.4 A list of best available technologies for the production of sulphate pulp

Technique	**Description**	**Applicability**
1	**2**	**3**
Dry debarking	4.1.1	Widely used
Extended or continuous cooking	4.1.2	Used at both new and already existing plants
Closed screen system and an efficient washing of unbleached pulp	4.1.3	Used at both new and already existing plants
The repeated use of condensates from pulp production and the separate cleaning of it	4.1.8	Widely used
The collection of gases with a high concentration of sulphur dioxide and its subsequent use in the production of cooking solutions	4.2.1	Widely used
Heat recovery during pulp production	4.2.2	Widely used
Buffer tanks for the collection of surplus liquor and recirculated waster	4.1.10	Widely used
Boilers for the combustion of wood and bark waste as well as sludge from the treatment plants as well as the fuel production from them	4.1.19	Widely used
Electrical filters of the boilers for the burning of wood and bark waste as well as waste from the treatment plant.	4.1.18	Widely used

Cont'd: Table 4.4 A list of best available technologies for the production of sulphate pulp		
Technique	**Description**	**Applicability**
1	**2**	**3**
Biological treatment of wastewater	4.1.20	Widely used
Dewatering of treatment plant sludge	4.1.21	Widely used
The development of the system for the processing of scrap (paper and board machines)	4.1.22	Widely used
Systems for the collection of fibers from the recirculated and (or) wastewater of the paper and board machines	4.1.23	Widely used
The introduction of an Automated dispatch Control System (ADCS)	4.2.25	Widely used

4.2.1 The Collection of Gases with a high Sulphur Dioxide Concentration and their further use in Cooking Solution Preparation

<u>Description of the technique</u>

Sulphur dioxide is present in the gaseous emissions from the production of cooking solutions, pulp cooking as well as from the formed liquids as well as their burning.
The absorption system of the acid shop, where the raw acid (the raw bisulphite solution) is produced, guarantees a high level of trapping of sulphur dioxide (99,8 – 99,9 % and even higher) at a residual content in the flue gases not exceeding 0,01%. This being the case it is often used also for the treatment of gaseous emissions of sulphur dioxide from other sources. Usually it contains (as a rule added in the residual gas column) gases with a high concentration of sulphur dioxide, having a relatively large volume. A relatively large volume of the gases contained may effect the stability of the operation of the acid shop as well as the reduction of its productivity. Apart from this, there may arise problems with the transfer of the gases because of the isolated location of the sourced of emissions.
If this is the case it is instrumental to use the gas treatment apparatuses with an integral spraying circuit, isolated from the absorption system of the acid shop. The surplus quantity of the absorbing solution containing the trapped sulphur dioxide is transferred to the acid shop to be used in the production of raw acid.

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When the sulphur dioxide is trapped there is also a recycling of the heat of the gaseous emissions.
When burning the evaporated liquors, whereby all the sulphur of the liquor is transformed into sulphur dioxide, the absorption system has a gas throughput capacity higher by 10 – 15 times. This is why it has the capacity to receive practically all the sulphur dioxide containing gaseous emissions, including high-volume-low-concentration emissions. The level of trapping of sulphur dioxide in it is 99,5 – 99,9 %. At that, the highest concentration gases with a low volume may be transferred to the absorption system of the magnesium recovery boiler. Lower concentration gases with a high volume may be used as a part of the air, necessary for the burning of the liquors. The specific organic compounds of the gas emissions are burned with the development of an additional amount of heat.
The choice of the collection of gaseous emissions, containing sulphur dioxide depends on the concrete conditions of the pulp production.
Achieved environmental benefits
The reduction of the total emissions of sulphur dioxide.
Environmental impact
Through the collection and recycling of the gaseous emissions, the total emissions of sulphur dioxide may be lowered by 99 % and more, this having a substantial influence on the improvement of air quality.
Operational data:
The abovementioned measures are used widely.
At many old plants the equipment for the washing of pulp from the digesters and its washing of the open type, the acid and liquor tanks have a connection with the atmosphere, and the sources of emissions are separated from each other by a large distance. This is why the collection and recycling of the flue gases from these sources call for large investment expenses.
Field of application
Measures, directed towards the recycling of sulphur dioxide from the gaseous emissions are used both at new and already existing plants. At already existing plants these measures are more complicated for the abovementioned reasons.
Introduction factors
The reduction of smell and the summary emissions of sulphur dioxide as well as the consumption of sulphur in the cooking process.

4.2.2 Heat Recovery during Pulp Production

Description of the technique

While producing sulphite (bisulphite) pulp there is a relief of the surplus steam-gas from the digester. These blow-down gases have a high heat and moist content. By this token, there is also a considerable content of sulphur dioxide in them. In order to recycle the heat and the sulphur dioxide, there is a recovery system, consisting of several recovery tanks, in which the steam gas blow-down gases are led through a countercurrent flow of raw acid (raw bisulphite solution). At this, the water steam is condensed, transferring its heat to the raw acid, heating it from 20 – 80 °C to 70 – 80 °C and more, whereas the sulphur dioxide is absorbed by the raw acid, forming the cooking acid with an elevated strength. The unabsorbed gases are transferred to systems of additional absorption of sulphur dioxide and the absorption of the acid shop and (or) to gas treatment apparatuses.

There exist a number of versions of recovery schemes, including versions with a cooling system for the blowdown steam-gas-mixture in the raw acid-water heat exchangers. Every system has its pros and cons and are used depending on the conditions of the concrete companies.

For classic sulphite digestion, the recovery from the blowdown is 0,2 – 03 Gcal/t – whereas the number for bisulphite is up to 0,4 – 0,56 Gcal/t

Furthermore, when tapping the liquor from the digester, after the cooking the liquor boils with the formation of a large quantity of steam gas mixer with a high heat content. The liquors are forwarded to heat exchangers, where the water steam is condensed, thereby heating the water used for the whishing of the pulp. The uncondensed gases are transferred to the sulphur dioxide recycling shop.

At that, about the same amount of heat is recovered, as is the case with the blowdown.

Achieved environmental benefits.

The cost savings on the heat energy for the cooking and, consequently the reduction of the emissions from the burning of fuel. The reduced heat pollution and emissions of sulphur dioxide.

Environmental impact

It lowers the heat and environmental load to the atmosphere

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Operational information

Various designs of the abovementioned measures are widely used.

The operation of the equipment working under unfavourable (aggressive) conditions calls for considerable investment expenditure.

Field of application

The measures for heat and sulphur dioxide recovery are applicable both at new and already existing plants.

Introduction factors

The reduction of heat and sulphur for purposes of cooking as well as the reduction of sulphur dioxide emissions.

4.3 Techniques, Considered when Determining BAT during the Production of Mechanical Pulp

In this section, in figure 4.5 all the techniques are listed, which at present are used for the prevention or the limitation of the formation of emissions and waste, and which are meant to save energy and raw material at already existing production plants as well as in newly introduced production plants. This list of techniques is not exhausting and it may be continued. These techniques include measures taken in the production process as well as separate techniques, offering the possibility to perfect the process and the prevention of pollution formation as well as pollution control.

Table 4.5 A list of best available technologies for the production of mechanical pulp

Technique	Description	Applicability
1	**2**	**3**
The production of stone groundwood from spruce-fir pulpwood in chain grinders, equipped with a thermo grinding system SGW	4.3.1	Widely used
The production of stone groundwood from spruce-fir pulpwood in chain grinders, equipped with a pressurised grinding system PGW	4.3.2	Widely used

Table 4.5 (cont'd) A list of best available technologies for the production of mechanical pulp

Technique	Description	Applicability
1	2	3
RTS method production of thermomechanical pulp	4.3.3	Widely used
APMP method production of chemi-thermomechanical pulp	4.3.4	Widely used
Partial or full recycling of clean cooling water	4.1.8	Widely used

4.3.1 The Production of Stone Groundwood from Spruce-Fir Pulpwood in Chain Grinders, Equipped with a Thermo Grinding System (SGW)

Description of the technique

The thermo grinding process is carried out in modernized chain grinders, equipped with an automated pulp temperature and recycled water control and regulation system (in the recycled water bath and line) as well the creation of a certain level of elevation of the fluid above the grinding zone (200 – 500 mm) through the equipment of the grinder with additional units for the sealing of the shaft by the grinding stone. A water layer condenses the vapours formed in the grinding process, thereby lowering the surplus heat losses. The automatic regulation system maintains a temperature of 100 °C in the end of the grinding zone. The use of automatic control increases the intervals of grinding stone sharpening and increases the pulp quality.

4.3.2 The production of stone groundwood from spruce-fir pulpwood in chain grinders, equipped with a pressurised grinding system PGW

Description of the technique

Pressurised Groundwood (PGW) is produced in pocket grinders equipped with grinder seal assemblies for the charging of the pulpwood into the digester bath, allowing for the increased pressure in the grinder above atmospheric pressure, as well as for the elevated temperature in the grinder bath. From the grinder bath the stock is transferred to the wood chips shredder, and blown out under pressure to the cyclone, where the steam is separated from the stock. Out of the cyclone the pulp is transferred to the thickener, where the recycling water is separated out of it. This water is used in a closed circuit for the grinding process.

After this point the processed of screening, cleaning, bleaching, waste milling and thickening of the finished stock is analogous the traditional process of groundwood production.

4.3.3 The RTS method production of thermomechanical pulp

Description of the technique

One of the thermomechanical pulp techniques, that has won the most widespread distribution lately, and that fully conforms to the BAT group is the RTS technology, where the R corresponds to *Residence time* (the duration of stay under high pressure of the steam), *T – to Temperature* (the elevated temperature of the chips during the hydrothermal processing) and *S – Speed* (A considerably much higher speed of the disc revolution of the grinder at the first milling stag). These three factors were changes in this technology as compared to the traditional technique of TMP production, which provided the opportunity of a lowered specific energy consumption, approximately from a level of 15 % to a level of 22 – 24 %. However, the change of the value of one or even two of the mentioned factors does not allow for the abovementioned effect without the worsening of other parameters of the process of water quality. It is when all three parameters are optimized that you may reach the abovementioned lowering of the specific energy consumption as well as the improvement of some other pulp quality parameters.

The duration of stay of the chips in a heated state in the process of steaming using traditional techniques is about 2 minutes. When using RTS it is limited down to 10 – 20 s. However this substantial decrease of the duration of the thermal exposure of the chips is compensated by the simultaneous considerable temperature increase of the process. If, during the traditional process the chips, before the first stage of the milling, are heated to a temperature of 120 °C to 130 °C (corresponding to the surplus pressure of the saturated steam – 0,1 – 0,2 MPa), which is below the temperature of the vitrification of lignin (approximately 140 °C), then, when applying RTS the temperature of the chips is raised to approximately 160 °C, which corresponds to the pressure of the saturated steam, used in the steaming process – 00,5 – 0,6 MPa. The same pressure is maintained in the first stage grinder. Apart from the change in parameter values of the hydrolytic processing, when using the RTS technique, the size, packing and moisture content of the chips are controlled. Any changes of the abovementioned parameters of the process are accompanied by a considerable increase in the speed of the rotation of the grinder discs – from a level of 1 500 – 1 800 rev/min during the usual CMP process up to 2 500 – 3 000 rev/min when applying RTS.

The raised temperature of the chips during the milling with the simultaneous reduction of the duration of the hydrothermal processing provides the opportunity to optimize the level of maceration of the lignin. An even higher plasticity, elasticity of the fibers achieved when using the TRS technique, reduces the (as compared to the traditional TMP technique) damage to the cell walls of the fibers during milling. Apart from this, as a result of the mentioned preliminary chip processing technology changes as well as the reduction of the duration of the milling process, the formation of chromophore groups and structures of the lignin is decreased, which reduces the level of loss of brightness of the mechanical pulp and facilitates the subsequent bleaching process and decreases the content in it of unwanted extractives (resins) during the pressing of the chips in the impressafiner after the steaming process. A considerable increase of the rotation speed of the discs leads to the increased intensity of the pulverization process. When applying the traditional TMP technique, an increase of the milling intensity leads to and increased shortening of the fibers as well as a damage to the cell wall, thereby lowering tearing resistance and other resistance parameters and increasing the number of fiber fragments.
When applying the RTS method, the correctly chosen combination of the values of the abovementioned variables of the processing at a high milling intensity promotes the optimization of the full process with an increase of the level of fiber fibrillation during the refining process (40 – 45 % as compared to 25 – 30 % when using conventional technology) higher than their surface, i.e. a well-processed pulp, with a relatively low content of coarse fibers or shives. During paper or board sheet formation this leads to the increased mechanical resistance properties of the product, especially concerning tear resistance at an equal breaking length.
At present, a few various of the RTS techniques have been elaborated, depending on the needs of the concrete plant. For instance, the version involving the achievement of high optical properties of the pulp is accompanied by a lowering of the specific energy consumption by approximately 15 % (from 2 200 to 1 900 kWh/t air dry fiber); whereas the version connected with the achievement of increased resistance qualities of the pulp (the coefficients of depression, tear and tension are higher by 6 – 11 %) calls for the same specific energy consumption as the conventional TMP production method.

4.3.4 APMP Method of Production of Chemi-Thermomechanical Pulp

Description of the technique

APMP is deciphered as "alkaline peroxide mechanical pulp". It is distinguished from the traditional CTMP technique by the fact that after the screening and washing of the chips, they are subjected to

deep permeation in 1 – 3 (most often 2) stages by a hydrogen peroxide solution in special apparatuses – impressafiners – which are used also when applying the abovementioned RTS technology. The high level of chip compression (4:1) in the impressafiner provides the subsequent deep permeation, which in turn leads to the removal of air and water from the chips, as well as their partial splitting along the fiber, which facilitates the division of the chips into fibers during milling. Into the alkaline hydrogen peroxide solution of the first permeation step a complexing agent is added, binding metals of mixed valence found in the wood, water as well as in the technical sodium hydroxide, which are capable of catalysing the decomposition of the peroxide. In the second and third stages of soaking, in order to stabilize the peroxide, sodium silicate and magnesium sulphate is usually added. Before every step of chip permeation, the chips is transferred to a special steam heated chip hopper, out of which it is transferred to the impressafiner and – subsequently – through the permeation screw and hopper before the next permeation step (or, having gone through all the permeation steps – to the hopper before the 1st step refiner). APMP refiners usually work under atmospheric pressure. However, in some modifications of this method the refiners of the first step work under elevated pressure. Between the milling stages there is usually a washing press, whereas after the last milling step there is a tank for the removal of latency, as in the traditional TMP production technique. Bleaching when APMP technology is applied goes on in the process of moving the chips along the production flow, i.e. in this case, as distinguished from the traditional way of CTMP, there is no need for special bleaching towers.
APMP technology calls for an increased consumption of hydrogen peroxide and alkali. However, this flaw is compensated by increased mechanical strength properties of the CTMP. The increased alkali consumption promotes a higher plasticisation of the wood material, which provides – during the milling – the conservation of a share of the long fibers as well as a lowering of the number of short fibers. The fibers swell and interlace better. As a result of this, the number of contacts points between them grows as well as the area of these contacts and – as a result of this – the increased mechanical strength qualities of the pulp and the continuity of the paper machine operation. The alkaline consumption as well as the consumption of hydrogen peroxide need to be optimised based on the type of paper/board product that any given pulp is used to produce.
The APMP process allows for the successful production of CTMP not only from hardwood (mainly aspen wood), but also from softwood type of raw material. The list of the types of paper, for which APMP may be used is as long for

CTMP, produced by the traditional methods: newsprint, letter paper and printing paper, journal and special types of paper, covering layers of boxboard, etc.
The advantages of APMP:

- The absence of sulphur-containing compounds (hydrosulphite, sodium sulphite), which to a considerable degree simplifies wastewater treatment, thereby making the production process more environmental-friendly.
- The absence of bleaching towers as well as the equipment accompanying them, since the bleaching is carried out during the processing of the chips.
- The relatively low energy consumption for the milling process (the specific energy consumption is 30 % lower than during traditional CTMP production).
- The investment expenditures for the construction of facilities for the equipment of a APMP installation is 25 % lower than when producing CTMP according to the traditional technique
- The versatility of the process, providing the option of a varied consumption of sodium hydroxide and hydrogen peroxide, the production of pulp from hardwood, as well as from softwood of various species, to be used for the production of a wide range of paper and board products.
- Lower operational costs as a result of a reduced quantity of equipment.

Of course, as is the case with any efficient technique, this method, in parallel to its introduction in the industry, it is constantly being developed. There are e few modifications proposed, out of which the most promising is regarded the method that combines the preliminary preparation of the chips and its chemical processing including the bleaching process, with the processing into the refiner, intended for not only the milling of chips, but also for the enhanced distribution and mixing of the chemicals in the stock. This APMP modification involves the partial introduction of an alkaline hydrogen peroxide solution into the chips during the permeation before the refining , whereas another part of it is fed directly into the 1st step refiner, which increases the efficiency of energy and chemicals use. An additional point is that after the refiner of the first stager, there is the introduction of yet another tank for the high-concentration pulp, in which there is a fuller bleaching reaction, and, as a result of this, a slight increase in brightness. After a relatively deep chemical processing of the pulp, the energy consumption of the size reduction process is reduced dramatically. At present, the APMP method is developed continuously, especially concerning the second stage where the refining is carried out at a low pulp concentration. The transfer to a low-concentration pulp at this stage of size reduction has made it possible to reduce the

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shives content more than two-fold (from 2,2 % to 1 %), to decrease the content of fiber bundles and, at the same time lower by more than 30 % the total specific energy consumption (from 940 to 710 kWh/t air-dry pulp). At that all the pulp parameters stayed unchanged, apart from a somewhat lowered tear resistance (by 10 %).

<u>RTS and APMP characteristic properties</u>

The main property of the RTS technology, as compared to the traditional TMP production technique is the shorter duration of the hydrochemical processing of the chips, however at a higher temperature, exceeding the temperature of lignin vitrification, as well as a 1,7 – 2-fold increase in the speed of the rotation of the refiner discs of the first milling stage.

The APMP technology for bleached CTMP production with the use of peroxide bleaching in an alkaline environment is distinguished by the presence of 1 – 3 stages of intense chip permeation by an alkaline solution of hydrogen peroxide through the preparatory replacement of the air and water contained in them through the intensive mechanical compression in the specialized apparatuses of the impressafiners. The size reduction in two stets is carried out at atmospheric or above-atmospheric pressure at the first stage involving also the washing of the pulp between the milling stages. The bleaching is accomplished during the movement of the pulp along the production flow in the absence of bleaching towers. Sometimes part of the bleaching chemicals is introduced into the refiner of the first stage, as a result of which the efficiency of the use energy and chemicals is raised. At that, after the first stage refiner a high concentration pulp tank is installed in order to achieve a fuller accomplishment of the bleaching process.

<u>Achieved environmental benefits</u>

The high yield of the end product from one cubic meter of original raw material provides the opportunity to save forest resources. Per ton of fiber, as compared to pulp production, there is a need of 1,5 – 1,8 times less wood.

<u>Environmental impact</u>

The reduction of the waste formation leads to less losses of fibers with the wastewater, as well as to the lowering of its COD. The use of only oxidizing bleaching using peroxide excludes by 100 % the presence in the wastewater of sulphur compounds. The reduction of the electrical energy consumption immediately leads to the burning of less quantities of fuel while producing electricity, which in turn leads to the reduced emissions to air of carbon dioxide, NOX as well as ash and the reduced amount of solid waste formed. In practically all publications on the above described BAT for the production of TMP and CTMP, it is mentioned that they are cost-efficient. Mainly, this is achieved through the reduction of the consumption of electrical energy for milling purposes by 15 – 20 %, as well as the reduction of investment and operational expenditure (when applying APMP by 25 %, mainly because of the absence of bleaching towers).

Operational information

The production of TMP, CTMP, APMP, as well as CMP is applied at the leading pulp and paper production companies.

All the abovementioned techniques are quite widely applied approximately since the mid-1990-ies. The countries where plants for the production of RTS and APMP include Sweden, Norway, Finland, USA, Canada, Germany, France, Great Britain, China, Chile, Iran, Australia and other countries.

Field of application

Both new and already existing plants.

Introduction factors

The widening of the raw material base for the production of fiber intermediate products – the use of various wood species as well as annual plants

The automation of the production process.

The main motivation for the introduction of these techniques is the reduction of the energy consumption, the reduction of the capital and operational expenditure, the improvement of the pulp quality, the increase of the yield of fiber from one cubic metre of wood as well as the improved environmental parameters of the wastewater.

Reference literature. [3]

4.3.5 The Minimization of the Consumption of Electrical Energy, Environmental Footprint as well as the Technical Maintenance during the Screening of Mechanical Pulp

Description of the technique

An essential part of traditional screening schemes for the achievement of high-quality pulp was the combination of centrifugal screens and centricleaners, since these two types of machinery, based on different principles of action, made possible the division of the pulp into three main fractions: The good pulp (the main flow), insufficiently divided into fibers products of the milling process (coarse fibers, fiber bundles as well as coarse shives), which by additional refining could be transferred into quality pulp and the final waste (sand, foreign fine inclusions, small shives, so called shavings, i.e. minor short fiber cuttings)

This kind of fractions formation is achieved based on the fact that the traditional construction screens enables the separation of pulp based on length, width and elasticity of the fibers, whereas the centricleaners would depend on the specific area, the volume and the mass of the screened particles. The traditional screening schemes of mechanical pulp with the use of a likewise traditional screen construction is discussed under item 5.1.3.
The considerable successes becoming available in the 1990-ies in the field of creating new types of sieves as well as new sieve production technique (slotted sieves, appearing in the beginning of the last decade of the last century) as well as new screen constructions, using this new kind of sieves, not only allowed for the transition to a high concentration pulp screening (at 3 – 4,5 % as compared to the former 0,8 % - 1,5 %), but actually, but also actually gave the opportunity to abandon the sieves used earlier with round holes, and, most important, to abandon the use of centricleaners which were installed in no less than three-four stages. This mainly promoted the considerable reduction of electric energy consumption used for the transfer of pulp, since the treatment of pulp in the centricleaners is carried out at concentrations of 0,4 – 0,6 % (and, apart from this, calls for a pressure of 0,3 – 0,4 MPa). The lowering of the electric energy consumption also facilitated the improved hydrodynamics of the flows in the new construction screens as well as the reduction of their hydraulic resistance.

Modern schemes of mechanical pulp screening using new construction equipment have retained some of the basic elements of traditional schemes. Mainly this is about the two- or three-stage screening, during which the good pulp from all levels of screening is united into one main flow of good pulp, which is transferred further on according to the production scheme. The presence of a step-wise screening is needed in order to reach a higher degree of separation all good fiber from the pulp arriving to be screened, and in order to minimize its loss along with the waste. The waste from the next level of screening is thickened and ground in the refiner with the subsequent (usually) one-step screening. At that, the good pulp from the screening of the milled waste is unified with the main flow, whereas the waste, usually, is returned to be ground again.

At all stages of screening slot screens are used, usually with variable characteristics of the sieves (the slot width, the profile thickness, its configuration, etc.) of every stage. The type of wood and the character of the fiber. Apart from this, the character of the sieves is usually chosen based on the type of mechanical pulp (SGW, TMP, CTMP, etc.), the wood species as well as the fiber, produces as a result of the grinding process, i.e. essentially the individual choice of every equipment producing company.

When all these conditions are observed, it is hardly possible to optimize the screening process from the viewpoint of minimization of energy consumption or as to the quality of the pulp. This notwithstanding, one should mention some of the pressure characteristics of the slot screens, used in the sorting process of mechanical pulp. For instance, when screening TMP used for the production of newsprint, the pulp screens of the main flow are equipped with sieves with a slot width of 0,15 mm, whereas in respect to the waste flow – 0,20 mm, at a fineness of about 60° SR. At this, the content of mini-knots in the screened pulp is only 0,09 %.

Above, one of the typical modern schemes of mechanical pulp screening is discussed. Naturally, the type of mechanical pulp present at a certain company, the used screening equipment, etc. does not allow for any rigorous unification of the screening and treatment schemes, however, in any schemes, the main principles of modern screening must be observed.

The capacity of narrow-width (as well as other parameter) slot sieve screens to trap the same type of unwanted inclusions as centricleaners would do, has made it possible, as already pointed out, to refrain from the use of the latter. In particular, in the traditional schemes, sometimes the whole main pulp flow, after the centrifugal screens, only the good pulp from the last stage screening was subjected to processing (the waste was transferred to be ground), before it was merged with the good pulp from the main flow. The pulp, after the screening of ground waste was usually also subjected to processing in the centricleaners.

There is an important tendency in modern screening that, step-by-step, is beginning to dominate at new companies – the carrying out of 2-4 steps of the screening process in the same machinery unit. Such combined screens are produced by practically all pulp producing companies. The main advantages of such screens are: the applicability to all types of pulp on account of the shiftable rotors, screening basket as well as the choice of sieves; the simplicity of management of the whole screening system; the shortening of the length of the tube system and the considerable lowering of the quantity of the number of components of the screening system, i.e. tanks, mixers, pumps, electrical engines, the lower cost of technical maintenance, etc.

Achieved environmental benefits
A reduction by 7 – 10 % of the energy consumption and the amount of fibrous waste through a more thorough screening

The level of shives removal is increased from 75 % when using the older types of screens with round holes to a level of 95 – 98 %.

Environmental impact
This measure is used at a number of companies
A more then two-fold reduction of the installed power requirements, as well as the capital expenditure; the reduction of the cost of technical maintenance, control and measurement devices (CMD) as well as the management of the screening process.

Field of application
This technique is applied at practically all European companies, the screening shops of which were constructed or modernized after the year of 1995.

Introduction factors
The motivation for the introduction of this technique is the improved quality and purity of the pulp and – as a consequence of this – the reduction of the quantity of web breaks, the reduced electric energy consumption, the quantity of equipment units as well as the footprint area, etc.
Reference literature: [3]

4.3.6 The Efficient Washing and Process Regulation

This technique is mainly connected to the production of chemi-thermomechanical pulp (CTMP).
Description of the technique
The washing process when producing CTMP is mainly the same, as when producing chemical pulp, however usually with considerably lower efficiency requirements. Then main aim is the separation from the fibers of the dissolved organic material extracted during the grinding.

At every company, a specific washing technique is used, and there are various versions of equipment application.
The process of CTMP washing is somewhat more complicated than chemical pulp washing, calling for higher capacity equipment. In practice, this means that there is a need for a larger filtration surface area per ton of produced pulp washed in the drum filters. The efficiency of the washing process usually ranges between 65 and 70 % calculated based on the dissolved organic content of the entering pulp. This usually based on a one-step-washing procedure, which usually is performed in drum filters, double-sieve presses as well as screw extrusion machines.
When using sequential 2-3 stage washing it is possible to attain a 75 – 80 % efficiency. Usually the same equipment is used as in the first step of the washing process.

<u>The environmental effect achieved</u>
When modernizing the washing process the possibility arises to produce a higher concentration of organic matter in the wastewater and, by doing this, to reduce the transfer of polluting matter onto the paper or board machine. This may be a positive factor under the condition that this wastewater subsequently are processed separately from the wastewater from paper or board machines, for instance in the process of an anaerobic treatment process.

<u>Environmental impact</u>
The reduction of the organic compound content in the wastewater as well as the reduction or the full elimination of wastewater discharge from the washing and screening processes in the treatment plants.

<u>Operation facts.</u>
The application of washing equipment, working under conditions of higher concentrations provides the opportunity to lower the size of investments to purchase new equipment as well as to reduce the electrical energy consumption. Usually the capital investment for washing purposes is between 3 and 5 million Euro for newly launched production plants and 2 – 3 million Euro at already existing production plants with a production capacity of 700 t air dry pulp per day. There are no considerable additional operational costs.
<u>Field of application</u>
This technique is introduced at a majority of European and North American plants
It is used at new as well as already existing companies.

Introduction factors

An incentive for the introduction of this technology is the fact that a modernized washing process may create better conditions for the anaerobic treatment of wastewater from CTMP production. This technology may also facilitate the improved quality of the paper and board produced using the CTMP process.

Reference literature: [3].

4.3.7 Treatment of Wastewater from Companies, Production CTMP within an Integrated Plant. The Closing of the Circuit through the Evaporation and Burning of Concentrates.

Description of the technique

There exist a number of methods of treatment of wastewater from CTMP producing plants.

The internal shop physical and chemical processing of the recirculated water at the first stage of waste water treatment with the use of the additional biological treatment using activated sludge. There is one CTMP producing company that processes this recirculated with chemicals, and thereafter removes the extractive substances and the fine fiber content in the floatation stage. At this there is an observation of a COD reduction by 40 – 50 %. The flaw of this method is the relatively high costs of chemical reagents.

The evaporation of the full volume of wastewater and the burning of the concentrate in the recovery boiler, allows for the diminishing of the discharge of wastewater down to zero. The company *Millar Western, Pulp (Meadow Lake) Ltd.* in Saskatchewan, Canada with a capacity of 240 000 tons per year, from 1992 and onward produces bleached CTMP without any discharge of wastewater. This company processes aspen wood, using the *APP – alkaline peroxide cooking* – method for the production of pulp using alkali and hydrogen peroxide. It produces high quality sanitary and hygienic as well as letter paper. The water circuit system with evaporation at the Meadow Lake company, producing CTMP is shown in figure 4.1.

The evaporation technique is used in order to create a closed circuit water system as well as a zero wastewater discharge [Evans, 1992].

Figure 4.2 shows a zero discharge wastewater process including the various treatment stages.

All the technical waster is transferred by pumps to the primary treatment step, where suspended solids are removed. They are dewatered and burned. The clarified water

may be stored in tanks, which allows for the possibility to have a water reserve at the stage between the mechanical pulp production shop and the evaporator plant.
The clarified waster enters the mechanical recompression evaporator plant (3rd stage), where the concentration of dry matter is increased from 2,5 to 35 %. The condensate from the evaporation plants is divided into various fractions, in order to eliminate the pollution of the clean condensate, which accounts for 85 % of its volume.

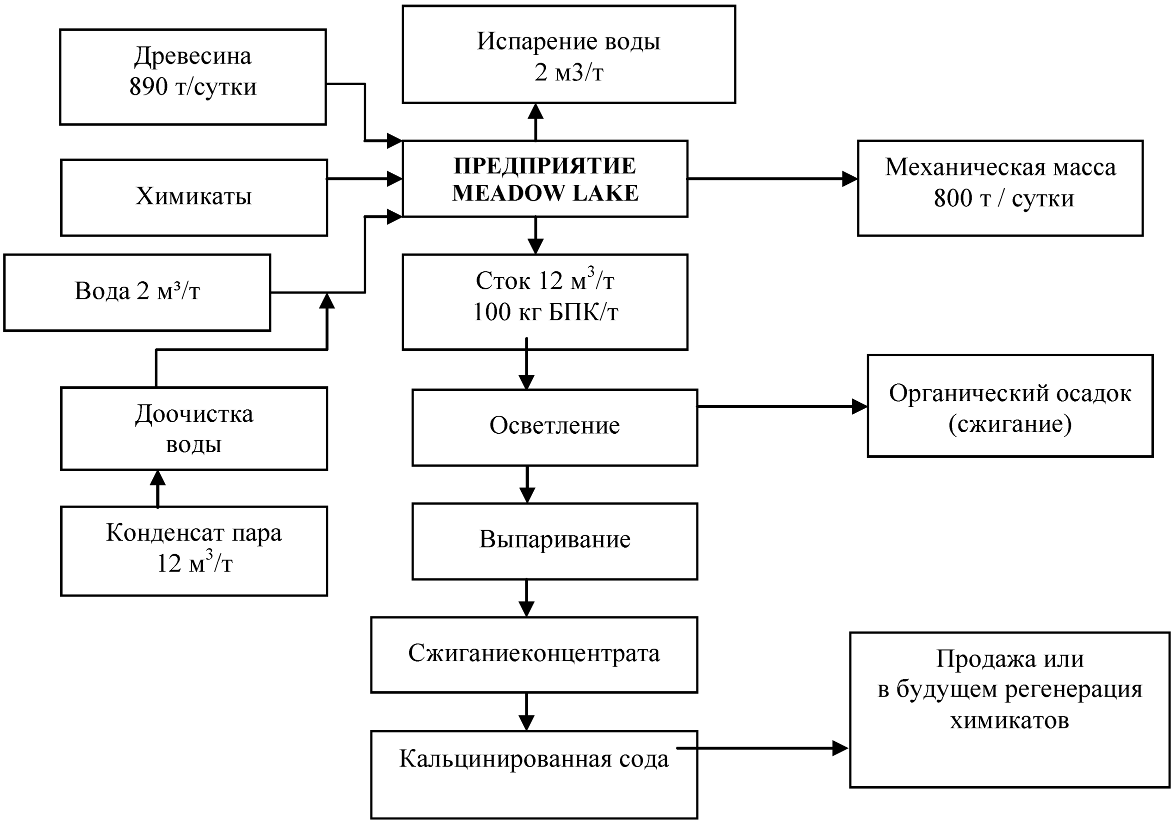

Figure 4.1 – The water circuit system at Meadow Lake, producing CTMP.

The fraction of the water condensate that is most polluted by volatile organic compounds is removed by distillation in the stripper (stripping column), where its main part is evaporated and subsequently burned in the recovery boiler. The main part of the distillate from the evaporators may be used directly in the production of mechanical pulp at a temperature of 65 °C. However, there is a need of a certain quantity of water with a temperature of 20 – 30 °C. In order to produce water with this temperature, part of the condensate, containing a residual quantity of volatile organic substances, is cooled, and these organic compounds are removed in a special tank by biological treatment.

The content of dry matter in the evaporated wastewater, transferred from the evaporation plant to the two-stage concentrator, is increased to 70 % under the influence of steam, and, subsequently, this concentrate is burned in the recovery boiler. The melt from the recovery boiler furnace is cooled, whereas the produced soda is transferred to a hopper by a conveyer.

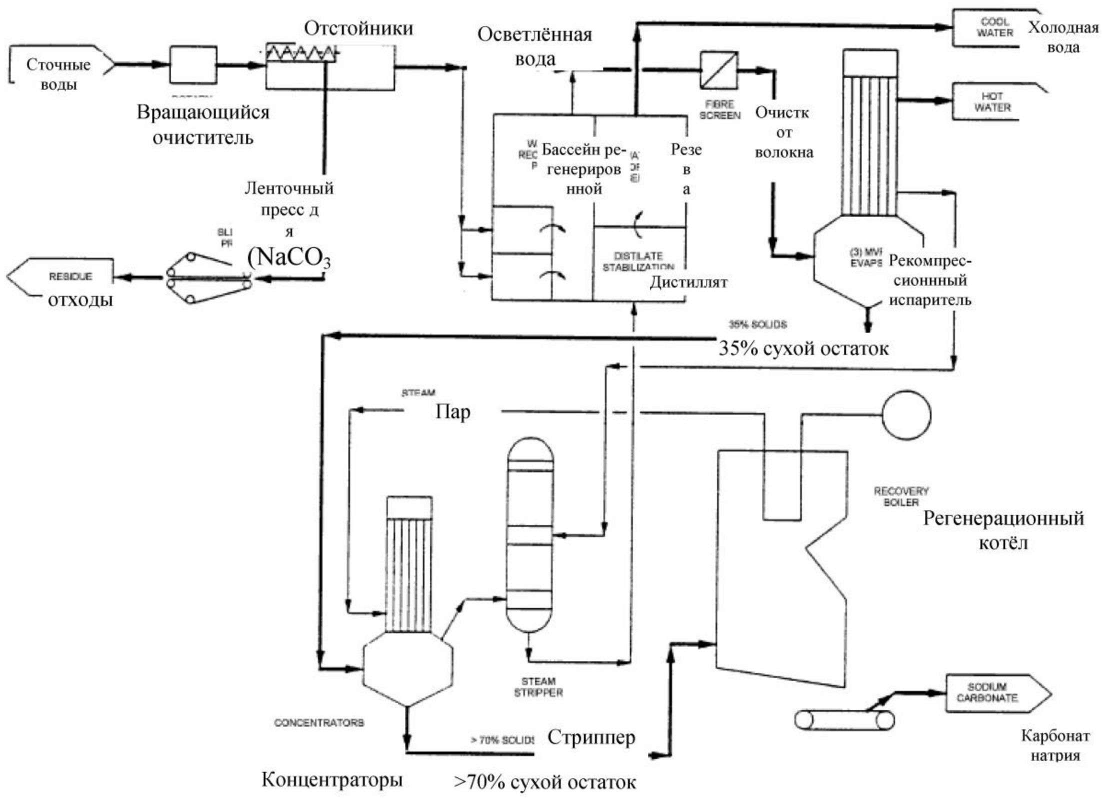

Figure 4.2 The zero wastewater discharge process

<u>The specific features when applying this technique</u>

The closed circuit may be applied both at new plants and at already existing plants. One limiting factor is the high capital costs for the evaporation and the construction of a recovery shop (as in Meadow Lake). The described technique has been used at a freestanding plant, and in order to implement it there is a need form large areas, which many already existing plants do not dispose of. A solution of the problem will depend on the concrete conditions and is often different, if you compare the production of commercial CTMP and the integrated production of CTMP. If evaporation towers are used, then the CTMP bleaching process needs to be modified, since it is not possible to use sodium silicates, which would lead to the formation of a deposit on surfaces.

Achieved environmental benefits
The 80 % reduction of fresh water use.
Environmental impact
No wastewater discharge.
Operational facts
At a company with a zero discharge, monitoring of the process and equipment is paramount. There are various programmes used, as well as the dynamic monitoring of pollutants and corrosion and quality management system according to ISO 9002.
Together with these measures, laboratory analyses are used, in order to achieve a full-fledged control system. For instance, the metal content monitoring programme, aimed at the monitoring of the ions in the system as well as the taking of preventing measures for corrosion, pollution and sediment formation control.
The use of a closed water circuit system does not lead to losses in the production of pulp and does not negatively affect its quality.
The new system has operational costs, comparable to the costs for the maintenance of the wastewater treatment system and the secondary processing of the sludge from the production of conventional bleached CTMP.
Field of application
The technique may be applied at new, de novo constructed companies.
Introduction factors
The popularity of the zero wastewater discharge technology is supported by the possibility to recover chemicals and energy, which promotes the reduced operation and depreciation costs.
The motivation for the introduction of this technique is limited water resources.
Reference literature: [3].

4.4 Technologies Considered when Determining BAT During the Production of Paper and Board

The best available technology during the production of paper and board, allowing for the reduction of consumption of raw material, water and energy wile also reducing the emissions to the environment and waste formation, are shown in table 4.6.

Table 4.6: List of techniques regarded as BAT of the production of paper and board

Technique	Description	Applicability
1	2	3
Closed water circuit of the screening, treatment and washing of the pulp	4.4.1	Generally applicable
Heat recovery during the production of paper and board	4.4.2	Generally applicable
Biological treatment of wastewater	4.4.3	Generally applicable
Dewatering of the sludge from the treatment plant	4.4.4	Generally applicable
Development of the system for scrap paper processing (paper and board machines	4.4.5	Generally applicable
A system for the trapping of fibers from the recirculated water during paper and board production	4.4.6	Generally applicable
	4.4.7	Generally applicable
Partial or full reuse of clean cooling water	4.1.8	Generally applicable

4.4.1 Closed Water Circuit of Pulp Screening, Cleaning and Washing

Description of the technique:

During the technological processes of screening, cleaning and washing of the pulp, recycled water from the paper/pulp production machine is used:

- for the repulping of intermediate products
- for the dilution of the pulp before the screening stations
- for concentration regulation

After the preparation system (screening, cleaning and washing) the pulp, together with the water is fed to the paper or board machine. During the process of sheet formation water is removed from the pulp and is transferred to the recycled water collection station of the paper or board machine. Part of the recycled water is used repeatedly in the production flow of the paper/board machine, whereas the surplus recycled water is transferred to the local workshop cleaning station.
The recirculated water with the waste from the last step of screening are transferred to the wastewater system of the plant.

Achieved environmental benefits
The reduction of the content of organic compounds in the wastewater as well as the reduction or the total absence of wastewater from the washing and screening stations to the treatment plant.
Environmental impact
A closed water circulation system provides the reduction of the recipient pollution load, which lowers the environmental impact.
Operational facts
The set-up of a multi-stage screen using a slog screen at 3-4 % concentration allows for the increased energy efficiency of the process through the reduction of the electric energy consumption, as well as the reduced formation of waste and effluent formation.
Field of application
This technique has been introduced at a majority of European, North American as well as Russian Plants. It is used in new as well as already existing plants.

Introduction factors
The total of the abovementioned measures brings about a positive effect: a reduced fiber and filling loss, a lowered effluent formation and, accordingly, reduced costs for wastewater treatment as well as the reduces electrical energy consumption.
Reference literature: [3].

4.4.2 Heat Recovery during the Production of Paper and Board

Description of the technique
The dryer of a paper/board machine for the drying of paper/board uses almost all the heat energy used for the production of paper and board. The drying installations of paper and board machines are equipped with thermally insulated caps as well as a system for the removal from the space under the caps of the steam-air mixture and its further feed to the heat recovery system. The heat efficiency of the drying installation is to a large extent defined by the intensity of the ventilation as well as the removal of air from the space under the hood of the machine, as well as the use of secondary energy resources. The heat energy recovery provides the reduction of the consumption of fuel and energy resources through the use of secondary energy resources. The recovered heat is used for the heating of the

dryer air, for the heating of the ceiling, for the heating of the recirculated water, the pit water, and the process water used for the paper/board showers.
One important factor for the drying and heat recovery systems is the optimization of the dewatering system as well as the increased dryness of the paper sheet before the drying process. The higher the dryness of the paper sheet after the press section, the lower the heat energy needed to for the final drying of the paper. The increased dryness of the sheet at the entrance of the dryer of 1 % results in a 4 % saving of heat energy. The intensification of the process of dewatering of the fibers before drying is provided by the installation of a press with a wide pressing zone (a shoe press). During this process the dryness press installation is raised by as much as 52 %. The installation of a press with a wide pressing zone (shoe press) allows for an increased sheet dryness after the pressing station, which means a saving of energy of the drying process in the range of 20 – 30 %.
<u>Achieved environmental benefits</u>
The raised energy efficiency of the drying process through the lowering of the consumption of steam for the drying of paper/board.
<u>Environmental impact</u>
The reduction of the consumption of fresh steam for the drying of paper/board provides a lower production of steam at the plant, which lowers the environmental impact.
The set-up of a hood (cap) in the drying installation, equipped with an automation system. The economy of energy through the recovery of heat and an alarm system lowers the risk of accidents.
The heat recovery system of the dryer provides the possibility to lower the steam/air emissions to air.
<u>Operational facts</u>
The installation of a drying cap in the system for the use of recovered heat provides the maximum humidity uniformity over the whole sheet, which leads to a higher product quality.
An up to 10 % energy economy through the heat recovery.
<u>Field of application</u>
In the dryer installation of paper/board machines for the production of a majority of paper/board types.

Introduction factors
The main factors for the introduction of this technique are: energy economy, the reduction of condensation and drop formation as well as mist, while improving the climate labour conditions as well as the quality of the product.
Reference literature: [3].

4.4.3 Biological Treatment of Wastewater.

Description of the technique
The biological (secondary) treatment of wastewater is the treatment with the aid of active sludge through absorption, chemical sorption, biological sorption, coagulation as well as biological oxidation. In this system, the majority of the pollutants present in the wastewater are oxidised.
For the secondary treatment, the main alternatives are aerobic and anaerobic systems of biological treatment. However, the possibilities to use anaerobic treatment are limited to the treatment of high COD concentration (≈200 mg/l) wastewater, which is why hitch technique mainly is applied at companies using secondary fiber.
As aerobic treatment various approached are used: biological treatment with the use of activated sludge, aerobic submersible biological filters, biological filters as well as biologic reactors.
An overview of widespread systems of aerobic biological treatment is shown in table 4.7.

4.7 An overview of widespread systems of aerobic biological treatment

System	Field of application (entrance BOD), mg/l	Advantage	Disadvantage	Efficiency of reduction of load	
				BOD	COD
1	2	3	4		
One-stage treatment with the use of activated sludge	100 – 1 000	A traditional process, thus a broad application experience	High energy consumption; a larges quantity of surplus sludge; problems with sludge swelling or floating	85 – 96 %	60 – 85 %

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System	Field of application (entrance BOD), mg/l	Advantage	Disadvantage	Efficiency of reduction of load	
				BOD	COD
1	2	3	4		
Two-stage treatment with the use of activated sludge (with a high sludge load stage)	600 – 1 200	Improved activated sludge properties	High energy use; a large amount of surplus sludge	85 – 98 %	75 – 90 %
One-stage treatment with aerobic submersible biological filters	20 – 100	The safe process; fixed biomass	Sensitive to elevated concentrations of suspended matter	60 – 65 %	50 – 55 %
Two-stage aerobic submersible biological filters	100 – 300	The safe process; fixed biomass	Sensitive to high suspended matter concentration	60 – 70 %	50 – 60 %
Low capacity biological filters	<100	The simple design; the low energy consumption; cooled water	Clogging risk; smell	60 – 65 %	50 – 55 %

System	Field of application (entrance BOD), mg/l	Advantage	Disadvantage	Efficiency of reduction of load	
				BOD	COD
1	2	3	4		
High capacity biological filters	200 – 800	Simple design, low energy consumption; cooling of the water	Risk of clogging; smell	60 – 70 %	50 – 60 %
Moving bed biofilm reactor (MBBR)	300 – 1 500	Fixed biomass; no circulating sludge; smaller volume of the reactor	The large quantity of surplus sludge	85 – 95 %	80 – 90 %

The process of biological treatment. The chemical precipitation of wastewater in paper/board production industry may be complemented by the process of chemical precipitation, which is used either before, or after the biological treatment. In some cases the chemical precipitation may be an alternative to biological treatment of wastewater. This technology is especially advantageous for small business. The chemical precipitation is especially worthwhile when it is necessary to attain a lower content of organic compounds (measured as COD and BOD), to remove nitrogen, phosphorus and suspended matter. Chemical precipitation presupposes the adding of chemicals in order to change the physical condition of the dissolved of suspended matter and their subsequent removal through sedimentation or flotation. As sedimentation chemical usually aluminium salts, iron chloride, ferric sulphate and lime are used. Tin order to optimize the flocculation, polyelectrolytes are used.

The efficiency of chemical precipitation rangers between 97 and 99 % as far as suspended particles goes, and – as for COD – 70 %. One of the disadvantages of the method is the increased aluminium or iron ion content of the treated wastewater.
In the paper industry, the recirculated water and wastewater constitute an environment where the majority of the substances – added to the paper grade pulp in the various stages of its preparation – are found.
Any measures taken in order to decrease the discharge of wastewater with added chemicals are gathered in a general approach during the operation of the technological process.
Apart from this general approach to the reduction of the discharge of chemical additives. The biodegradable, non-toxic and biologically non-accumulative chemicals must be used in all cases, where this is possible.
A description is also given under the item 4.1.20 Biological Treatment of Wastewater
<u>Achieved environmental effect</u>
The lowering of the load on the recipient in relation to the type of produced paper/board, their properties, the consumption of water per ton of produced products, used chemical additives as well as to the design and operation mode of the treatment plant.
<u>Environmental impact</u>
The reduction of the discharge to the recipient as well as the reduction of the environmental pollution.
<u>Operational facts</u>
The aerobic biological treatment of wastewater is successfully applied for more than 20 years. The efficiency of the load reduction for various systems of biological treatment ranges from (BOD) from 60 to 98 % and (COD) from 50 to 90 %.
<u>Field of application</u>
The biological treatment of wastewater may be applied both at old and new PPP companies.
<u>Introduction factors</u>
The ensuring of the reduction of the criteria for wastewater discharge (quantity, pollution) through the installation in the system of modern equipment for biological treatment as well as the provision of technical maintenance.
<u>Reference literature:</u> [3]

4.4.4 Dewatering of Treatment Plant Sludge

Description of the technique

At pulp and paper company installations, a large quantity of settled sludge is formed at the primary treatment stage as well as surplus activated sludge during the biological treatment and residue during the aftertreatment. The treatment of all types of sludge is usually carried out jointly, since the sludge from the biological and chemical treatment operation are poorly dewatered and – in order to improve its dewaterability – it needs to be mixed with the fibrous sludge.

The aim of the dewatering is the maximum removal of water from the sludge in order to facilitate its final recovery.

A description is shown under item 4.1.21: Dewatering of the Sludge from Treatment Plants

Achieved environmental benefits

The reduction of the amount of waste transferred to landfills

Environmental impact

The reduction of the pollution of groundwater

Operational facts

The reduction of the amount of sludge by roughly 20 times as well as the simplification of sludge recycling.

Field of application

Dewatering of sludge may be used both at old and new pulp and paper plants.

Introduction factors

The need to increase the dry matter content in order simplify the transfer and final recovery of the sludge.

4.4.5 The Improved Scrap Processing System (Paper and Board Machines)

Description of the technique

The system for the collection and processing of scrap involves the accumulation of the scrap from all process stages in the accumulator tank, which provides the stability of the work in the machine flow as well as the proportioning of the scrap in the composition of the paper or board.

The accumulation of the scrap is an important factor during shutdowns and reduced discharge of fiber into the drain.
The scrap preparation, including thickening, repulping, cleaning and the screening in multi-stage slot screens provides the optimal quality of the secondary fiber for its subsequent use in the paper/board composition.
The waste processing in the flows of paper and board machines essentially involves the following:

- the processing of the screening waste during the preparation of paper grade pulp
- the trapping of fibers of the wet part
- the processing of the humid and dry scrap

Achieved environmental effect
The reduction of the consumption of primary intermediate products
Environmental impact
Cost reduction through the recovery of the recycled scrap.
Operation facts
The use of recycled scrap in the paper/boards composition up to 20 %
Field of application
At pulp and paper plants during the production of various types of paper and board.
Introduction factors
The main introduction factors are the use of secondary fiber as well s the reduction of the formation of waste of the plant.
Reference literature: [3].

4.4.6 A System for the Trapping the fibers of Recycled and (or) Wastewater from Paper and Board Plant Production

Description of the technique
Before the biological treatment step, the wastewater from a paper production plant is subjected to primary mechanical cleaning, neutralization, and enrichment by biogenic elements as well as equalization.
The primary or mechanical cleaning of process wastewater involves:

- rough cleaning from coarse inclusions
- mechanical cleaning from fine suspended particles by the use of gravitation forces.

At some pulp and paper production plants flotation or filtration mehtods are used for the primary cleaning process.

The efficiency of suspended matter removal at the primary cleaning stage may reach 60 – 90 %. The level of removal of easily precipitated solid matter is usually higher: 90 – 95 %. The content of suspended matter after the primary cleaning may be in the realm of 30 - 200 mg/l.

In order to equalize the fluctuations of the consumption and pollutant concentration of the wastewater an equalization step is involved. The exposure time in the equalizing tanks is about 4 h.

The typical scheme of a local preliminary treatment involves the collection of wastewater, filtration, and a chemical precipitation step as well as the settling of suspended particles in the settling tank. The wastewater, after being cleaned in the local system, is transferred to the general process water treatment system.

In the process, in order to treat the recirculated water/wastewater, also membrane filtration is applied. Membrane technologies, depending on the membrane pore size (which approximately corresponds to the ”molecular weight” of the removed organic compounds) as well as the pressure of the filtration, are theoretically able to remove almost 100 % of the organic compounds without the use of unwanted compounds in the water environment.

Depending on the pore size it is possible to define various different membrane processes:

- microfiltration, which is applied at a pressure, higher than 1 bar with the use of membranes with a pore size of 0,1 – 0,2 µm<.
- ultrafiltration, carried out with a pressure drop of 1 – 2 bar.
- nanofiltration (nf) or reversed osmosis (ro) is carries out at a pressure of 15 – 25 bar.

The requirements to the measures for the prevention of the negative effects from the creation of closed circuit water systems:

- in order to prevent the clogging-up or wear of the equipment, the cooling water, the sealing water and the cleared water used for the paper/board spraying undergoes treatment in filters.
- the recirculated sealing water from the vacuum pump system is cooled in a heat exchanger or through the dilution of it by fresh water until the desired temperature is reached.
- the determination of the requirements to the quality of the water, including its content of suspended matter, hardness, pH and temperature in order to be able to use it if needed for various process stages and equipment.
- the choice of certain types of chemicals for the production of paper and boards at conditions of maximum closed water circuit in order to lower the accumulation of

chemicals in the recirculated water through the special properties of each chemical under conditions of their use in a wet environment – as well as the automation of the monitoring system as well as the laboratory control of the flows of recirculated water.
<u>Achieved environmental effect</u>
The optimization of the efficiency of the treatment of recirculated water and wastewater. The level of solid matter particle removal up to 90 – 95 %.
<u>Environmental impact</u>
The reduction of the quantity of discharged wastewater as well as the pollutants contained in it.
<u>Operational facts</u>
The economy of primary intermediate products as well as a reduction of losses of fiber up to 2 %.
<u>Field of application</u>
At various pulp and paper production plants.
<u>Introduction factors</u>
The main factors for the introduction of this technique are: the reduction of the content of pollutants in process wastewater, the reduction of the consumption of fibrous intermediate products as well as the reduction of the consumption of fresh water.
<u>Reference literature: [3].</u>

4.4.7 The Introduction of an, Automated dispatch Control System (ADCS)

Modern pulp and paper companies practically do not have any permanent operating personnel, being present in the production workshop or at the production sector. The operative management of the production process is carried out by operators of the production workshops of sections with the aid of automated dispatch control systems (ADCS).
Listed below are the general sections, where during the production of paper and board measurements as well as automation increase quality and productivity and also improve the environmental parameters:

- equipment for the treatment of surplus recirculated water
- a technological section for the process of determination of the composition of the paper grade pulp
- a section for the grinding of the fibrous intermediates
- the wet part of the paper/board machine.

A description is given under item 4.1.25 Introduction of a ADCS System

Table 4.8 A Short Summary of the BAT Technology List, for Integrated Works with Sulphate Cooking

No.	Name of the BAT	Effects in terms of levels of consumption and emissions (side effects)					Influence on the production process, i.e. the energy balance and yield
		Chemicals consumption	**Energy consumption**	**Discharges**	**Emissions**	**Solid waste**	
1	Dry debarking	NE	↑ debarking in drums ↓ modern mechanical debarking	↑ COD ↑ BOD ↑ Volume of wastewater	NE	NE	↑ Generation of energy in the bark boilers
2	Extended modified cooking, continuous (c) or batch (b)	↑ during cooking, need for chemicals ↓ during bleaching	↑ during cooking (c) ↓ during cooking (b) (↑) evaporation (↑) limekiln	↓ COD ↓ AOX	NE	NE	↑ energy generation ↑ final pulp yield

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No.	Name of the BAT	Effects in terms of levels of consumption and emissions (side effects)					Influence on the production process, i.e. the energy balance and yield
		Chemicals consumption	Energy consumption	Discharges	Emissions	Solid waste	
3	A screening, cleaning and washing system with a closed water circuit	↓	↑↓	↓ COD ↓ SS ↓ wastewater volume	NE	NE	↑ pulp quality
4	Oxygen-alkaline delignification	↑ at the O_2 step ↓ needed chemicals for bleaching purposes	↓ at the O_2 step ↓ oxidation of white liquor ↓during the caustization and in the limekiln	↓ COD ↓ AOX	NE	↑ sludge	↑ energy generation

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(mistake of pagination of the Russian original (299))

No.	Name of the BAT	Effects in terms of levels of consumption and emissions (side effects)					Influence on the production process, i.e. the energy balance and yield
		Chemicals consumption	**Energy consumption**	**Discharges**	**Emissions**	**Solid waste**	
5	ECF bleaching and the production of chemicals needed for it (as compared to bleaching with elemental chlorine)	↑/↓	↑/↓	↓ AOX	↓ AOX	NE	NE
6	Stripping and the repeated use of condensates after treatment in the stripping column	NE	↑ steam	↓ COD	↓ S_{tot}	NE	↑ water consumption
7	Partially closed water circuit of the bleach plant + increased boil-off	↑ bleaching	↑ evaporation	↓ COD	NE	NE	↑ water consumption
8	Partial or full re-use of clean cooling water	NE	↑	↓ COD ↓ BB ↓ wastewater volume	NE	↑NE	

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No.	Name of the BAT	Effects in terms of levels of consumption and emissions (side effects)					Influence on the production process, i.e. the energy balance and yield
		Chemicals consumption	**Energy consumption**	**Discharges**	**Emissions**	**Solid waste**	
9	Buffer tanks for the collection of leakage liquor	NE	↑ (evaporation)	↓ COD	NE	NE	NE
10	Heat recovery during the production of pulp, paper and board	NE	↓	NE	↓ from energy generation, including GHG	NE	NE
11	Closed circuit of the	↓ chemicals use	↑	↓ COD	↓ GHG	NE	NE
12	Collection and decomposition of sulphate soap	↑	↑	↓ COD	NE	NE	↑ energy generation, production of talloil
13	Separation or collection of turpentine	NE	↑	↓ COD	↓ S_{tot}	NE	The production o a by-product in the form of crude turpentine

No.	Name of the BAT	Effects in terms of levels of consumption and emissions (side effects)					Influence on the production process, i.e. the energy balance and yield
		Chemicals consumption	Energy consumption	Discharges	Emissions	Solid waste	
14	Collection of weak and strong gases and the subsequent burning in special kilns as well as in the LK and RB	↓ need to compensate S/↑ surplus S	↑ for the control system	NE	↓ S_{tot}	NE	↑ heat generation (burning with the return of heat)
15	Biological wastewater treatment	↑	↑	↓ COD ↓ AOX	↑	↑	
16	Dewatering of sludge from the treatment plant	↑	↑	NE	↑	↓	↑ energy generation through the burning of precipitation and sludge
17	Burning of black liquor at a concentration above 75 %	NE	↑ evaporation	NE	↓ S_{tot}, GHG	NE	↑ energy generation in the recovery boiler ↑ production capacity

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No.	**Name of the BAT**	**Effects in terms of levels of consumption and emissions (side effects)**					**Influence on the production process, i.e. the energy balance and yield**
		Chemicals consumption	**Energy consumption**	**Discharges**	**Emissions**	**Solid waste**	
18	Dewatering of the waste from the chemicals recovery cycle	NE	↑	↓ COD ↓ SS ↓ wastewater volume	NE	↓	NE
19	Improvement of the washing of the sludge from the chemicals recovery	↓	↑	↓ COD ↓ SS ↓ wastewater volume	↓ S_{tot}	↓	
20	Electrical filters after the RB, LK, bark kiln as well as the sludge from the treatment plant	↓ Sodium sulphate	↑	NE	↓ suspended solids	NE	NE

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No.	**Name of the BAT**	**Effects in terms of levels of consumption and emissions (side effects)**					**Influence on the production process, i.e. the energy balance and yield**
		Chemicals consumption	**Energy consumption**	**Discharges**	**Emissions**	**Solid waste**	
21	Kilns for the incineration of bark and sludge from the treatment plant, undercooked pulp and the fuel preparation for these kilns	NE	↑ for the control system	NE	↑ NO_x ↑ SO_2 ↑ Suspended solids ↓ GHG	↓	Energy generation
22	Improved systems for the processing of scrap (from paper and board machines)	↓	↑	NE	NE	↓	↑ Production yield
23	System for the trapping of fibers from the surplus (waste) water of the paper and board machines	↑	(↓↑)	↓ COD ↓ SS	NE	↓	↓ Water consumption
24	VOC before the treatment plant	↑	↑ electrical energy	↓ COD ↓ SS	NE	NE	NE
25	Introduction of a ADCS system	↓	↓	↓	↓	↓	↑

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No.	Name of the BAT	Effects in terms of levels of consumption and emissions (side effects)					Influence on the production process, i.e. the energy balance and yield
		Chemicals consumption	Energy consumption	Discharges	Emissions	Solid waste	
26	The combined production of heat and electric energy	NE	↓	↓	↓	↓	↑ increased energy production
Note: ↑ means an increase and ↓ a decrease; NE means «no effect» (or negligible); (↓↑) – there might be or might not be an effect (an inconspicuous influence depending on the conditions; 1)- it is assumed that there is an efficient treatment of wastewater; GHG – greenhouse gases							

Table 4.9 – a short summary of BAT techniques for integrated companies with sulphite cooking as well as production of mechanical pulp and paper/board.

No.	Name of the BAT	Effects in terms of levels of consumption and emissions (side effects)					Influence on the production process, i.e. the energy balance and yield
		Chemicals consumption	Energy consumption	Discharges	Emissions	Solid waste	
1	Dry debarking	NE	↑ debarking in drums ↓ modern mechanical debarking	↓ COD ↓ BOD ↓ Volume of wastewater	NE	NE	↑ Generation of energy in the bark boilers

No.	Name of the BAT	Effects in terms of levels of consumption and emissions (side effects)					Influence on the production process, i.e. the energy balance and yield
		Chemicals consumption	Energy consumption	Discharges	Emissions	Solid waste	
2	Extended or continuous (c) cooking	↑ during cooking, need for chemicals ↓ during bleaching	↑ during cooking (c) (↑) evaporation	↓ COD ↓ AOX	NE	NE	↑ energy generation ↑ final pulp yield
3	A pulp screening, cleaning and washing system with a closed water circuit	↓	↓	↓ COD ↓ SS ↓ wastewater volume	NE	NE	↑ pulp quality
4	Secondary use of condensates from the pulp production or their separate treatment	NE	↑ steam	↓ COD	↓ Sulphur-containing gases	NE	NE

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No.	Name of the BAT	Effects in terms of levels of consumption and emissions (side effects)					Influence on the production process, i.e. the energy balance and yield
		Chemicals consumption	Energy consumption	Discharges	Emissions	Solid waste	
5	Collection of gases with a high concentration of sulphur dioxide and their subsequent use in the process of production cooking solutions	↓ requirement of chemicals	(↑↓)	NE	↓ COD	↓ GHG	↑ energy generation
6	Heat recovery during the production of pulp, paper and board as well as thermomechanical pulp	NE	↓	NE	↓ from energy generation, including GHG	NE	NE
7	Buffer tanks for the collection of leakage liquor	NE	↑ (evaporation)	↓ COD	NE	NE	NE

No.	Name of the BAT	Effects in terms of levels of consumption and emissions (side effects)					Influence on the production process, i.e. the energy balance and yield
		Chemicals consumption	Energy consumption	Discharges	Emissions	Solid waste	
8	Kilns for the incineration of wood and bark waste and sludge from the treatment plant, undercooked pulp and the fuel preparation for these kilns	NE	↑ for the control system ↓ (if used to cover one's own needs)	NE	↑ NO_x ↑ SO_2 ↑ Suspended solids ↓ GHG	↓	↑ Energy generation
9	Electrical filters of the kilns for the incineration of wood and bark waste as well as sludge from the treatment plant	NE	↑	NE	↓ suspended solids	NE	NE
10	Biological wastewater treatment	↑	↑	↓ COD	↑	↑	
11	Dewatering of sludge from the treatment plant	↑	↑	NE	↑	↓	↑ energy generation through the burning of sediments and sludge

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No.	Name of the BAT	Effects in terms of levels of consumption and emissions (side effects)					Influence on the production process, i.e. the energy balance and yield
		Chemicals consumption	**Energy consumption**	**Discharges**	**Emissions**	**Solid waste**	
12	Improved systems for the processing of scrap (from paper and board machines)	↑/↓	↑	NE ↓	NE	↓	↑ return of fibers to the production
13	System for the trapping of fibers from the surplus (waste) water of the paper and board machines	↑	↓↑	↓ COD ↓ SS	NE	↓	↑ return of fibers to the production ↓ Water consumption
14	The introduction of a automated dispatch and Control (ADCS) System	↓	↓	↓	↓	↓	↑ production efficiency

Note: ↑ means an increase and ↓ a decrease; NE means «no effect» (or negligible); (↓↑) – there might be or might not be an effect (an inconspicuous influence depending on the conditions; [1)]- it is assumed that there is an efficient treatment of wastewater; GHG – greenhouse gases

Section 5. Best available techniques (BAT)

5.1 BAT Conclusions in Pulp and Paper Production

The BAT conclusions introduced in this section touch upon the production processes of integrated and non-integrated pulp and paper production plants, namely:

- The production of pulp from wood or other fiber materials
- The production of paper or board with a production capacity of above 20 tons per day

The presented conclusions comprise the following business processes when producing sulphate, neutral sulphite and sulphate pulp as well as fibrous intermediate products (SGW, TMP and CTMP), paper and pulp:

- The environmental management system
- The management of material resources as well as the appropriate production organization
- Water resource and wastewater management
- Management of the energy consumption and energy efficiency systems
- The management of the reduction of emissions to air
- The management of the system for the control of key parameters of the production process
- The management of the waste handling system

The BAT conclusions do not touch upon the following production processes/equipment:

- The production of pulp from non-wood fiber raw material (for instance, the production of pulp from annual plants)
- Stationary internal combustion engines
- Energy installations for the production of steam and electrical energy (through the combustion of fuel), except for recovery boilers
- The dryer part with an internal burner of a paper machine as well as of an offline coater

The techniques, listed and described in this section are neither prescriptive nor exhaustive. In actual practice other methods and techniques may be used, which provide

an equivalent level of environmental protection or even a higher level.
If not otherwise indicated, the BAT conclusions are generally applicable.
BAT-associated levels of discharges and emissions,
The BAT-associated levels of discharges and emissions are presented for an averaged period of time in various units of measurement (for instance concentrations and values of relative load – per ton of production). These ways of expressing BAT levels of discharges and emissions are dealt with as equivalent alternatives.
For the integrated pulp and paper companies, the BAT discharge and emission levels defined for separate processes of pulp production, paper or other production must be included proportionally to their part of the total discharges and emissions.
Information on BAT level discharges to water
If not otherwise indicated, when BAT is used, the daily (24h) or yearly average numbers are shown for discharges to water.
Normal conditions for emissions to air
The BAT levels of emissions are given for standard conditions, i.e. the temperature is 273,14 K and the pressure 101,3 kPa.
Information on BAT levels of emissions to air
If not otherwise indicated, when using BAT, daily (24h) or yearly average numbers are shown for emissions to air.
General BAT conclusions for the pulp and paper industry
The BAT conclusions, used in order to reduce the environmental impact for key parameters of impact are shown under items 5.1 – 5.12.

5.2 The Environmental Management System

BAT-1. The improvement of the general environmental parameters of the pulp, paper and board producing company through the introduction and maintenance of an environmental management system – (EMS).

BAT includes the following actions:

- The obligations of the environmental management, including senior management.
- Environmental policymaking including the constant improvement of management in this field
- Planning and introduction of the necessary procedures, goals and tasks in combination with the financial planning measures and investment projects.
- The introduction of procedures, especially emphasizing:
  - structure and responsibility
  - training, awareness and competence of the personnel;
  - contacts and communication
  - motivation of the personnel
  - document circulation system
  - efficient process control
  - programs for technical maintenance
  - preparedness for emergencies and emergency response
  - observation of environmental law
- control of the work and the taking of corrective measures, particularly paying attention to:
  - Monitoring and measuring the process parameters
  - Corrective and preventive measures
  - Record-keeping
- independent internal and external audit (where it is practiced) in order to determine whether or not the environmental management systems conform to the planned measures and whether or not they have gone through the implementation and maintenance as required;
- review of the environmental management system and its continuing applicability, sufficiency and efficiency by senior management.
- following the development of environmentally cleaner technologies
- consideration of the environmental impact of the possible decommissioning of an installation/a piece of equipment at the stage of design of a new plant as well as under the full period of its operation.
- the regular application of sectorial benchmarking

5.3 Management of Material Resources and the Appropriate Production Organisation

BAT-2. The optimal management of material resources and the appropriate organisation of the production in order to minimize the environmental impact of the production processes through the use of a combination of methods/equipment, shown in table 5.1.

Table 5.1 Methods/equipment used in order to optimize material resources management

	Method/equipment	**Applicability**
a	A careful selection and control of raw material, chemicals, supplies and additives	Generally Applicable
b	Input-output analysis of chemicals, including the control of the quality and the consumption norms	
c	The commitment to reduce of the level of chemicals use in accordance with the process regulations while maintaining the quality of the end product	
d	The minimization of the input of substances into the soil due to leakage, air deposition as well as the improper storage of raw materials, products or waste, also during contingency and (or) emergency situations.	
e	The preparation and implementation of programs for the management of discharges and emissions of pollutants as well as the production of solid waste.	

5.4 Management of Waster Resources and Wastewater

BAT-3. Management of the system for the prevention of pollution of wastewater from wood storage and preparation by the use of a combination of methods/equipment as shown in table 5.2.

Table 5.2 Methods/equipment for the prevention of pollution of wastewater from the storage and preparation of wood material.

	Method/equipment	**Applicability**
a	Dry debarking	Generally applicable
b	The paving of the wood yard area and, in particular, the surfaces used for the storage of chips	Applicability may be restricted due to the size of the wood yard and storage area
c	Control of the flow of sprinkling water and the minimization of the amount of surface run-off water from the wood yard	Generally applicable
d	Collection of polluted run-off water from the wood yard and the removal of polluted suspended and suspended solids from the wastewater prior to biological treatment	Applicability may be restricted due to the degree of contamination of the run-off water (low concentration) and (or) the size of the wastewater treatment plant (large volumes)

The BAT-associated effluent flow from dry debarking is 0,5 – 2,8 m^3/ADt.

BAT-4. The optimal control of the system of prevention of pollution of wastewater, the reduction of the fresh water consumption and wastewater generation in production of pulp, groundwood pulp, paper and board by a combination of mehtods shown in tables 5.3 and 5.4.

Table 5.3 Methods and equipment for the prevention of pollution of wastewater, the reduction of fresh water consumption and the generation of wastewater.

	Method/equipment	**Applicable**
a	Control and optimization of water use	Generally applicable
c	Monitoring of the level of closure of the system of water circuits and potential drawbacks; the use of additional equipment if necessary	
d	The removal of less polluted sealing water from the vacuum pumps and its repeated use	
e	The separation of the clean cooling water from the contaminated process water and its reuse	
f	Reuse of processing water to replace fresh water (water recirculation and water loops closing)	Applicable at new plants and after modernization. The applicability may be limited because of the water quality and (or) the requirements to the quality of the production or such things as the precipitation/incrustation in the water circulation system.
g	In-line (within workshop) treatment of the process water in order to improve quality and the possibility of recirculation or reuse.	Generally applicable

Table 5.4 BAT-associated waste water flow at the point of discharge after the production process

Name of production unit	**Unit of measurement**	**Yearly average level of wastewater formation[1)]**
Production of bleached sulphate pulp	M^3/ADt	25.00 – 50,00
Production of unbleached sulphate pulp	M^3/ADt	15,00 – 40,00
Production of bleached sulphite pulp for paper production	M^3/ADt	25,00 – 50,00
Production of unbleached sulphite pulp for paper production	M^3/ADt	20,00 – 45,00
Production of dissolving pulp	M^3/ADt	45,00 – 70,00
Production of neutral sulphite pulp	M^3/ADt	40,00 – 60,00
Production of mechanical pulp	M^3/ADt	11,00 – 20,00
Production of CTMP and TMP	M^3/ADt	9,00 – 16,00
Paper plants using primary fibers	M^3/t	15,00 – 27,00
Paper and board plants using secondary fibers	M^3/t	15,00 – 30,00 [2)]
Production of sanitary and hygienic types of paper using secondary fibers	M^3/t	15,00 – 25,00
[1)]the yearly average formation of wastewater is shown per 1 ton of market output from the indicated production process/production boundary [2)] a higher limit of the range is generally connected to the production of board for collapsible boxes.		

5.5 Management of the System for Energy Consumption and Energy Efficiency

BAT-5. The optimal management of the energy consumption and energy efficiency systems in order to reduce fuel and energy resources consumption as well as the reduction of the industrial environmental impact of the production processes and the CHP station through the use of the combination of methods/processes, shown below.

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Table 5.5 Methods and equipment for the reduction of the consumption of fuel and energy resources and the reduction of the industrial impact on the environment from the production processes and the CHP station

	Method/equipment	**Applicability**
	The implementation of the energy conservation and efficiency	
a	The use of an energy management system that includes the following features: I. Assessment of the total energy consumption and production II. Locating, , quantifying and optimizing the possibilities of energy use III. Control and maintenance of the optimal parameters of energy consumption.	Generally applicable
b	Measures for a considerable recovery of heat and a reduction of heat consumption: - a high content of black liquor and bark dry matter - a high efficiency coefficient of the steam boilers, one of the characteristics of which may – for instance – be a low temperature of the combustion gas - an efficient system for the use of secondary heat, e.g. hot water with a temperature of about 85°C - a maximum closure of the water system - a high pulp concentration - the use of secondary heat for the heating of the premises	

	Method/equipment	**Applicability**
c	Transition to the use of natural gas. Maximum energy generation by burning waste and residues from the production of pulp, paper and board that may not be used in the main production and that have a high content of organic matter and calorific value	Applicable only if it is impossible to process or recycle the waste and residues from the production of pulp, paper that may not be used in the main production and that have a high content of organic matter and high calorific value
d	Cover steam and power demand with the aid of cogeneration heat and power in the CHP station, the RB, the wood and bark furnaces, etc.	Applicable at all new plants as well as at modernized energy stations.
e	The use of excess heat to dry biomass and sludges of the treatment plant in order to heat the feed water of the energy producing boilers, the process water and for the heating of the premises.	The applicability of this method may be limited in cases where the sources of heat and the heat consumption plant are situated far from each other.
f	Insulation of the steam and condensate pipe fittings	Generally applicable
g	The use of efficient vacuum systems for the dewatering in the paper machine	
h	The use of high efficiency electrical motors, pumps and agitators	
i	The use of frequency inverters for the electric motors of pumps, compressors and ventilation equipment.	

5.6 Control of Reduced Emissions to Air

BAT 6 The prevention and reduction of gaseous emissions generated in the wastewater system by the use of a combination of methods shown in table 5.6.

Table 5.6 Methods and equipment for the prevention and reduction of the emission of gases formed in the wastewater system.

	Method/equipment	Applicability
	1. A maximum closure of the water system	
a	The design of the production processes of the paper plant, the tanks for the storage of pulp and water, pipes and chests shall be done in such a way, as to avoid any long-term retention, dead zones or sections with poor mixing and circulation of water in order to avoid uncontrolled deposits, decay and decomposition of organic and biological matter	Applicable if there is a maximum closed circuit system of water use.
b	The use of biocides, dispersants or oxidation agents (e.g. catalytic disinfection with hydrogen peroxide) in order to reduce odour and decaying bacteria growth.	
c	The installation of an internal treatment system (filters for internal cleaning) to reduce the concentration of organic matter and, consequently, possible odour problems of the white water system.	
	2. Wastewater treatment and sludge handling to avoid conditions, where wastewater or sludge turn anaerobic	Generally applicable
a	The implementation of closed sewer systems with controlled vents, using chemicals in some cases to reduce the formation of hydrogen sulphide or for its oxidation in the sewer systems	
c	Ensure sufficient aeration capacity and the appropriate mixing in the aeration tanks; the regular control of aeration systems	
d	Guarantee the proper operation of the secondary clarifier and sludge pumping	
e	Limitation of the retention time in sludge storages by sending the sludge continuously to the dewatering units	

	Method/equipment	Applicability
f	The elimination of possible failures and the prevention of contingencies	
g	The implementation of methods for the removal of gases from equipment where drying of sludge and mud is performed	
h	The use of plate heat exchangers. Avoid air cooling towers for untreated wastewater.	

5.7 Management of the System for Control of the Key Parameters of the Production Processes

5.7.1 Monitoring of Key Parameters of the Production Processes

BAT-7. The control of key parameters of the production process at companies (pressure, temperature, the amount of pollutants in the flue gases as well as other key indicators according the production regulations of the company).

BAT-8 The control and measurement of emissions to air (NO_x, SO_2, dust, etc.).

BAT-9. The control and measurement of discharges to recipients (COD, BOD, suspended matter, AOX, total phosphorus, total nitrogen, pH, electrical conductivity, etc.).

BAT-10. The regular control and assessment of the release of odorous gases from relevant sources.
The assessment of NCG release may be reduced [possible semantic error; translators comment (t.c.)] through the periodic measurement and assessment of emissions released from various sources (e.g. the pulp line, tanks, chip hoppers, etc.) through direct measurements.

5.8 Waste Management

BAT-11. Reduction of the level of waste generation, the collection for recycling and preparation for disposal on landfills through the employment of a combination of methods/processes, shown in table 5.7.

Table 5.7 Methods/equipment for a reduced waste generation , the collection for recycling and the preparation for disposal at landfills

	Method/equipment	**Applicability**
a	Separate collection of various types of waste (including the separation and classification of hazardous waste)	Generally applicable
b	The merging of suitable types (fractions) of waste in order to produce a mixture that can be better utilized.	Generally applicable
c	Pretreatment of waste before reuse or recycling	Generally applicable
d	Energy generation on-site or off-site from waste with a high content of combustible organic matter.	For off-site use the applicability depends on the availability of a third party
e	Pre-processing and preparation of waste before it is recycled or transported to a landfill	Generally applicable

The BAT-associated level of waste generation when producing sulphate/sulphite pulp and mechanical pulp at an integrated plant for already existing and new/modernized production are shown in tables 5.8 and 5.9.

Table 5.8 – the BAT level of waste generation. Already existing plants

Production parameter			Yearly average value for integrated works, which include the production of sulphate pulp for:		Yearly average value for integrated works, which include the production of sulphate pulp, for:	
			Unbleached pulp	Bleached pulp	Unbleached pulp	Bleached pulp
Waste from chemicals recovery to be disposed of		Kg/ADt	15.00 – 20,00	15,00 – 20.00	-	15,00 – 20,00
Biodegradable waste (expressed as DS, Dry solids)	Bard and wood waste from screening (shives, knots)	Kg/ADt, DS	400,00 – 550,00	400,00 – 550,00	400,00 – 550,00	400,00 – 550,00
	Waste from screening (undercooked pulp)	Kg/ADt	5,50 – 6,00	5,50 – 6,00	5,50 – 6,00	5,50 – 6,00
	Treatment plant sludge	Kg/t[1)]	45,00 – 50,00	45,00 – 50,00	50,00 – 80,00	50,00 – 80,00
[1)] Per ton of produced merchandise						

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Table 5.9 – the BAT level of waste formation. New or major refurbishment

Production parameter			Yearly average value for integrated works, which include the production of sulphate pulp, for purposes, including		Yearly average value for integrated works, which include the production of sulphate pulp, for purposes, including	
			Unbleached pulp	Bleached pulp	Unbleached pulp	Bleached pulp
Waste from chemicals recovery to be disposed of		Kg/ADt	≤15.00	≤15.00	-	≤15.00
Biodegradable waste (expressed as DS, Dry solids)	Bard and wood waste from screening (shives, knots)	Kg/ADt, DS	400,00 – 550,00	400,00 – 550,00	400,00 – 550,00	400,00 – 550,00
	Waste from screening (undercooked pulp)	Kg/ADt	≤5,50	≤5,50	≤5,50	≤5,50
	Treatment plant sludge	Kg/t[1)]	≤45,00	≤45,00	≤50,00	≤50,00
[1)] Per one ton of produced merchandise						

The BAT levels of waste generation in the production of sulphate and sulphite pulp as well as mechanical pulp at an integrated plant for already existing and new or major refurbishment plants are shown in Appendix E (Д) (tables E2 and E3 (Д2 and Д3)

5.8.1 BAT conclusions for sulphate pulp production

For integrated companies with the production of pulp, paper and/or board, in order to reduce the emissions of pollutants with the wastewater, BAT and the combination of the methods/processes listed below are implemented.

5.8.2 Wastewater and Pollution

BAT-12 The reduction of the discharge of pollutants to receiving waters from the whole plant through the use of a modernized ECF bleaching technique (without the use of elemental chlorine), are described in Section 4 and BAT ((items 4.1.3, 4.1.5, 4.1.7 and 4.1.10), in accordance with the methods described in table 5.10.

Table 5.10 Methods/equipment for the reduction of discharges of pollutants to recipients from the whole plant

	Method/equipment	**Applicability**
a	Modified cooking before bleaching	Generally applicable
b	Closed brown stock screening and efficient brown stock washing	
c	Partial process water recycling of the bleaching process	Water recycling may be limited due to incrustation in bleaching
d	The efficient control of leakages, spillages and pollution by a suitable recovery system	Applicable
e	The provision of a high-quality of black liquor evaporation and recovery boiler capacity to cope with peak loads.	Usually Applicable
f	The removal of contaminated condensates and their repeated use in the process	

The BAT associated discharges into the water recipient after the treatment plant

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BAT associated levels of discharges into the water recipient after passing the treatment plant are shown in tables 5.11 and 5.12 (not applicable for the production of dissolving sulphate pulp). The properties of wastewater of sulphated plants are shown in BAT-5.

Table 5.11 The BAT levels of discharge after the treatment plant during the production of bleached sulphate pulp. Active production plants.

Production parameter	**Measuring unit**	**Yearly average value**
Water consumption[1)]	m^3/t	100,00 – 150,00
Chemical Oxygen Demand (COD)	kg/t[2)]	8,00 – 30,00
Biological Oxygen Demand (BOD_{full})	kg/t	0,80 – 1,20
Total suspended solids (SS) content	kg/t	0,60 – 1,90
Total nitrogen (N_{tot})	kg/t	0,25 – 0,40
Total phosphorus (P_{tot})	kg/t	0,01 – 0,04
Adsorbable organically bound halogens (AOX)	kg/ADt[3)]	0,25 – 0,40
Toxicity	none	

[1)]Wastewater consumption (fresh water) is given for the full company taking into account the consumption for turbine cooling
[2)] The parameters are shown as compared to the production of market products for integrated plants, where the discharge from the paper production is included
[3)]The parameters are shown per ton of air-dry pulp.

Table 5.12 The BAT associated levels of discharge after the treatment plant during the production of bleached sulphate pulp. New and modernized plants.

Production parameter	**Measuring unit**	**Yearly average value**
Water consumption[1)]	m^3/t	≤100,00
Chemical Oxygen Demand (COD)	kg/t[2)]	≤8,00
Biological Oxygen Demand (BOD_{full})	kg/t	≤0,80
Total suspended solids (SS) content	kg/t	≤0,60
Total nitrogen (N_{tot})	kg/t	≤0,25
Total phosphorus (P_{tot})	kg/t	≤0,01
Adsorbed organically bound halogens (AOX)	kg/ADt[3)]	≤0,25
Toxicity	none	

[1)]Wastewater consumption (fresh water) is given for the full company taking into account the consumption for turbine cooling
[2)] The parameters are shown as compared to the production of market products for integrated plants, where the discharge from the paper production is included
[3)]The parameters are shown per ton of air-dry pulp.

Table 5.13 BAT-associated discharge levels after the treatment plant during the production of unbleached sulphate pulp. Active production plants.

Production parameter	**Measuring unit**	**Yearly average value**
Water consumption[1)]	m^3/t	50,00 – 70,00
Chemical Oxygen Demand (COD)	kg/t[2)]	5,00 – 12.00
Biological Oxygen Demand (BOD_{full})	kg/t	0,30 – 0,70
Total suspended solids (SS) content	kg/t	0,90 – 1,20
Total nitrogen (N_{tot})	kg/t	0,25 – 0,40
Total phosphorus (P_{tot})	kg/t	0,01 – 0,04
Toxicity	none	

[1)]Wastewater consumption (fresh water) is given for the full company taking into account the consumption for turbine cooling
[2)] The parameters are shown as compared to the production of market products for integrated plants, where the discharge from the paper production is included

Table 5.14 The BAT associated levels of discharge after the treatment plant during the production of unbleached sulphate pulp. New and modernized production plants.

Production parameter	**Measuring unit**	**Yearly average value**
Water consumption[1)]	m^3/t	≤50
Chemical Oxygen Demand (COD)	kg/t[2)]	≤5
Biological Oxygen Demand (BOD_{full})	kg/t	≤0,30
Total suspended solids (SS) content	kg/t	≤0,09
Total nitrogen (N_{tot})	kg/t	≤0,25
Total phosphorus (P_{tot})	kg/t	≤0,01
Toxicity	none	

[1)]Wastewater consumption (fresh water) is given for the full company taking into account the consumption for turbine cooling
[2)] The parameters are shown as compared to the production of market products for integrated plants, where the discharge from the paper production is included

5.8.3 Emissions to Air. The Reduction of Emissions of Strong and Weak Malodorous Gases

BAT-13 The reduction of odour and emissions of strong and weak odorous gases through the trapping of strong and weak odorous gases from all production processes. These BAT prevent the emissions through the capturing of all sulphur-containing exhaust gases, including all vents with sulphur-containing emissions, by applying the method shown in table 5.15.

Table 5.15 Methods/equipment for the prevention of emissions of strong and weak malodorous gases.

	Method/equipment	**Applicability**
a	Collection systems for strong and weak malodorous gases, comprising the following features: - covers, suction hoods and extraction system with sufficient capacity - leakage control and detection system - methods to guarantee the safe handling of the equipment	Generally applicable
b	The burning of strong and weak malodorous gases with the use of - recovery boiler - limekiln - a dedicated NCG kiln equipped with wet scrubbers for the removal of SO_x - power boilers In order to provide the constant availability for incineration for malodorous strong gases, back-up systems are installed. Limekilns may be such back-up installations for the recovery boilers; other back-up installations are flares and package boilers.	Applicable if the needed equipment is available

The BAT associated levels are: SO_2 content from the burning of sulphur-containing gases: 1,1-1,2 kg/ADt. The residue level of dispersed NCG shall be in the range 0,25 – 1,00 kg/ADt. (this is a marker substance for the production of sulphate pulp).

5.8.4 Reduction of Emissions from a Recovery boiler (RB)

5.8.4.1 Emissions of SO_2 and Total Reduced Sulphur (TRS)

BAT-14. The reduction of SO_2 and TRS from the recovery boiler is based on BAT (sections 4.1.11, 4.1.15) as well as on a combination of the methods shown in table 5.16.

Table 5.16 Methods/equipment for the reduction of SO_2 and TRS from the recovery boiler

	Method/equipment	**Applicability**
a	Increased dry solids content of the black liquor through evaporation before incineration	Generally applicable
b	Optimized firing (firing conditions may be enhanced, for instance, by intensified mixing of the air with the fuel, the control of the furnace load, etc.)	Applicable
c	Wet scrubber	Applicable

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Table 5.17 BAT-associated SO_2 and TRS levels from the RB[1]

Parameter		Daily average concentration[1, 2] mg/Nm³ at 6 % O_2	Yearly average concentration[1] mg/Nm³ at 6 % O_2	Yearly average concentration[1] Kg S/ADt
SO_2	DS < 75 %	10 – 70	5 – 50	-
	DS < 75-83 %[3)]	10 – 50	5 – 25	-
Total reduced sulphur (TRS)		1 – 10[4)]	1 – 5	-
Gaseous S (TRS-S + SO_2-S	DS < 75 %	-	-	0,03 – 0,17
	DS 75 - 83 %			0,03 – 0,13

1) The increased content of dry matter of the black liquor leads to the reduced emissions of SO_2 and the increases emissions of NO_x, which is why in a RB with a low level of SO_2 the level of emissions of NO_x may be higher and vice versa.
2)The value of the upper BAT level does not take into account the period, when the RB is heated and the concentration of dry matter in the liquor is substantially lower than during normal operation.
3)If black liquor is burned in the RB, DS > 83 %, then the level of SO_2 emissions and the gaseous S will have to be reconsidered in every concrete case.
4)The range is applicable without the burning of strong non-condensable gases,
Dry weight of fuel oil is equal to the concentration of dry matter in the black liquor.
The formula for the calculation of the concentration of the emissions at a reference level of oxygen is shown below:

$$E_R = \frac{21 - O_R}{21 - O_M} \times E_M$$

where:
E_R (mg/Nm³): the concentration level connected to the reference level of O_R
O_R (volume %): is the reference level of oxygen
E_M (mg/Nm³): is the measured concentration of emissions, connected to the measured level of oxygen O_M
O_M (Volume %): the measured level of oxygen.

[1]The information is given as a reference based on the Internet service of the EC, since in Russia, there is not yet any RBs burning DS in the range of 75 – 83 %.

5.8.4.2 Emissions of Nitrogen Oxides NO_x

BAT-15. The reduction of NO_x from the recovery boiler in accordance with BAT-associated methods (section 4.1.26) is shown in table 5.18. The BAT associated NO_x emission levels from the RB[1] are shown in table 5.19.

Table 5.18 BAT-associated methods/equipment for the reduction of NO_x from the recovery boiler

	Method/equipment	**Applicability**
a	Computerised combustion control	Applicable in new recovery boilers and in cases of modernization of regeneration boilers, since this method calls for considerable changes in the system for air feed into the furnace.
b	Efficient mixing of fuel with air	
c	Staged air feed systems, for instance with the use of various air throttles and air nozzles at various levels and points.	

Table 5.19 BAT-associated methods/equipment for the reduction of NO_x from the RB

Parameter		Yearly average value[1)]
NO_x	Softwood	DS[2)] < 75 %: 0,8 – 1,4 DS 75 – 83 % [3)]: 1,0 – 1,6
	Hardwood	DS < 75 %: 0,8 - 1,4 DS 75 – 83 %[4)]: 1,0 – 1,7

[1)] The raised content of dry solids (DS) of the black liquor leads to reduced emissions of SO_2 and raised emissions of NO_x, which is why a RB with a low level of SO_2 emissions may show a higher level of emissions of NO_x and vice versa.
[2)]The concentration of dry solids in the black liquor
[3)] The actual levels of emissions of SO_2 from a certain mill depend on the concentration of dry matter and the content of nitrogen in the black liquor, the amount and composition of the non-condensable gases as well as other nitrogen-containing flows, fed to be burnt (for instance, the ventilation gases from the dissolving tank, the methanol separated from the condensate, the biological sludge). The higher the content of dry matter and nitrogen in the black liquor as well as burnt odorous gases and other nitrogen-containing flows, the more the level of emissions will move towards the upper value of the range.
[4)]If a black liquor with a DS content above 83 % is incinerated in the RB, then the level of emissions shall have to be reconsidered on a case-by-case basis.

[1]The information is given as a reference based on the EU B BAT since in Russia, there is not yet any RBs burning DS in the range of 75 – 83 %.

5.8.5 Emission Reduction from the Limekiln (LK)

5.8.5.1 Total Reduced Sulphur (TRS) Emissions

BAT-16. The BAT reduction of TRS (a marker substance) emissions from the limekiln is founded upon one of the methods – or combination of methods – listed in table 5.20

Table 5.20 BAT-associated methods/equipment for the reduction of TRS (a marker substance) emissions from the limekiln

	Method/equipment	**Applicability**
a	Fuel selection/low-sulphur fuel	Generally applicable
b	Limit incineration of sulphur-containing odorous strong gases from the limekiln	
c	Control of the Na_2S content in the mud feed	
d	Control of surplus oxygen	
e	Alkaline scrubber	

Table 5.21 BAT- associated levels of total reduced sulphur emissions from the limekiln

Parameter	Yearly average value Mg SO_2/Nm^3 at 6 % O_2 2)	Yearly average value Kg S/ADt
SO_2 when strong NCG 1) are not burnt in the LK	5 – 70	–
SO_2 when strong NCG are burnt in the LK	55-120	–
Gaseous S (TRS-S + SO_2-S) when strong NCG are not burnt in the LK	–	0,055-0,12
1)Strong NCG including methanol and turpentine 2) As for the calculation of the oxygen level, see table 5.17		

Table 5.22 BAT associated emissions of total reduced sulphur from the LK

Parameter	Yearly average value Mg S/Nm^3 at 6 % O_2
Total reduced sulphur (TRS)	<1-10[1)]
[1)]When burning strong NCG (including methanol and turpentine) in the LK, the upper value may reach 40 mg/Nm^3	

5.8.5.2 NO_x Emissions

BAT-17. The BAT-associated reduction of NO_x (not a marker substance) emissions from the limekiln is based on a combination of methods accounted for in table 5.23.

Table 5.23 Methods/equipment for the reduction of NO_x (not a marker substance) emissions from the limekiln

	Method/equipment	**Applicability**
a	Burner/firing optimisation	Generally applicable
b	The efficient mixing of the fuel with the oxygen in the air	
c	Kilns with low NO_x emission burners	
d	The use of fuel with a low nitrogen content	

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table 5.24 BAT-associated levels of NO_x emissions from the LK

Parameter		Yearly average value[1] mg/Nm³ at 6 % O_2[3]	Yearly average Kg NO_x/ADt
NO_x	Liquid fuel	100 – 200[1]	0,1 – 0,2[1]
	Gaseous fuel	100 – 350[2]	0,1 – 0,2[2]

[1] When liquid fuel, produced from plant material (for instance, turpentine, methanol, tallic oil, etc.) is used, including fuel produced as a by-product of the cooking process, there might arise emission levels of up to 350 mg/Nm³ (corresponding to 0,35 kg NO_x ADt)
[2] When gaseous fuel, produced from plant material (for instance, non-condensable gases) is used, including fuel produced as a by-product of the cooking process, there might arise emission levels of up to 450 mg/Nm³ (corresponding to 0,45 kg NO_x/ ADt)
[3] As for the oxygen level calculation, see table 5.17

5.8.6 Reduction of Emission from High-Concentration Odorous Gases Kilns

BAT-18. The reduction of emissions of SO_2 when burning strong odorous gases in specialised kilns (see Section 4.1.14). BAT are based on the use of an alkaline scrubber for the separation of SO_2.

Table 5.25 BAT- associated levels of SO_2 and total reduced sulphur when burning strong odorous gases in a specialised kiln

Parameter	Yearly average value mg SO_2/Nm³ at 9 % O_2[2]	Yearly average value Kg S/ADt
SO_2	20,00 – 120,00	–
Total reduced sulphur (TRS)	1,00 – 5,00	–
Gaseous S (TRS-S + SO_2-S)	–	0,002 – 0,05[1]

[1] BAT is the highest level for gas flow in the range 100,00 – 200,00 Nm³/ADt

BAT-19. The reduction of emissions of NO_x when burning strong odorous gases in specialised kilns. BAT (see Section 4.1.14) is applied as well as one of the methods or combination of methods cited in table 5.26.

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Table 5.26 BAT-associated methods/equipment for the lowering of NO_x emissions when burning strong odorous gases in special kilns

	Method/equipment	Applicability
a	Burner/firing process optimization and control	Generally applicable
b	Staged incineration	Generally applicable for new and major refurbishments.

The BAT-associated levels of NO_x emissions, formed during the burning of strong non-condensable gases in a dedicated kiln are shown in table 5.27

Table 5.27 BAT-associated levels of NO_x emissions, formed during the burning of strong non-condensable gases in a dedicated kiln

Parameter	Yearly average value mg SO_2/Nm^3 at 9 % O_2 1)	Yearly average value kg S/ADt
NO_x	50,00 – 400,00 2)	0,01 – 0,10 1)

1) As for the calculation of the oxygen level see table 5.17
2) When, at existing plants, it is impossible to carry out the transition into staged incineration, the emission level reaches 1 000 mg/Nm^3 (corresponds to 0,2 kg/ADt).

5,8.7 Reduction of Dust Emissions

BAT 20. The reduction of dust emissions from the RB as well as the LK when using electrostatic precipitators (filters) (ESP) or the combination of an ESP with a wet scrubber.

Table 5.28 BAT-associated levels of dust emissions from the RB,

Parameter	Dust removal system	Yearly average concentration mg /Nm^3 at 6 % O_2 1)	Yearly average value kg dust/ADt
Dust	New or major refurbishment	40,00 – 50,00	0,08 – 0,40 1)
	Already existing	50,00 – 100,00 1)	0,40 – 0,80 2)

1) As for the calculation of the oxygen level see table 5.17
2) The upper boundary of the level of emissions for existing RB equipped with an ESP with a long time of operation may reach 150,00 mg/Nm^3 (which corresponds to 1,20 kg/ADt)

Table 5.29 BAT-associated levels of dust emissions from the LK

Parameter	Dust removal system	Yearly average concentration mg /Nm³ at 6 % O_2 1)	Yearly average value kg dust/ADt
Dust	New or major refurbishment	40,00 – 50,00	0,02 – 0,04
	Already existing	50,00 – 80,00 2)	0,015 – 0,07 2)

1) As for the calculation of the oxygen level see table 5.17
2) For existing LK equipped with an electric filter with a long time of operation the level may reach 100,00 mg/Nm³ (which corresponds to 0,10 kg/ADt)

Table 5.30 BAT-associated levels of dust (ash from the burning of bark/wood waste) emissions from bark boilers

Parameter	Dust removal system 1)	Yearly average concentration mg /Nm³ at 6 % O_2 2)	Yearly average value kg dust/ADt
Dust	New or major refurbishment	40 – 50	0,4 – 0,5
	Already existing	50 – 80 3)	0,5 – 0,8 3)

1) Not taking into account the sludge from the treatment plant
2) As for the calculation of the oxygen level see table 5.17
3) For existing bark boiler equipped with an electric filter with a long time of operation may reach 150 mg/Nm³ (which corresponds to 1,5 kg/ADt)

5.8.8 Energy Consumption and Efficiency

BAT-21 Reduction of the consumption of thermal energy (steam) and electrical energy: BAT is based on a combination of methods, listed in table 5.31.

Table 5.31 BAT-associated methods/equipment for the reduction of thermal energy (steam) and electrical energy consumption

	Method/equipment	**Applicability**
a	High dry solids content of bark through the use of efficient bark presses or dryers	Generally applicable
b	High efficiency steam boilers, for instance through the lowering of the temperature of the exhaust gases	
c	Efficient secondary heating systems	
d	Closing water systems, including bleach plant	
e	High pulp concentration (intermediate or high)	
f	High evaporator installation efficiency	
g	Recovery of heat from the tanks for solution preparation, for instance through the scrubber vent	
h	The appropriate use of the heat from the flow of the high-temperature effluents as well as the heat sources for the heating of premises, boiler feedwater and process water	
i	Appropriate use of secondary heat and secondary condensate	
j	Monitoring and control of processes and the use of advanced control systems	
k	Optimized integrated heat exchanger network	
l	Heat recovery from the flue-gas from the RB between the ESP and the fan	
m	Ensuring as high pulp concentration as possible, in screening	
n	Use of speed control of the of various large electrical motors	
o	The use of efficient vacuum pumps	
p	Proper sizing of pipes, pumps and fans	
q	Optimized tank levels	

BAT-22. The BAT-associated raised efficiency of electrical energy production based on a combination of methods, listed in table 5.32.

Table 5.32 The BAT-associated increased efficiency of electrical energy production

	Method/equipment	**Applicability**
a	A high dry solid content of the black liquor (increased efficiency of the boiler, steam production, and – as a consequence – the production of electrical energy.	Generally applicable if the appropriate equipment is available
b	High recovery boiler pressure and temperature (in new recovery boilers the pressure may be minimum 90 bar, and the temperature 510°C)	
c	The pressure of the exit steam from the turbine with counter pressure needs to be as low as technically possible.	
d	Condensing turbine for power production from excess steam	
e	A high efficiency coefficient of the turbine	
f	Preheating of the feedwater to a temperature close to the boiling temperature	
g	Preheating the combustion air and fuel charged to the boilers.	

5.9 BAT Conclusions for Sulphite Pulp Production

For integrated companies with pulp, paper and/or board production, BAT and the combination and the listed below methods/processes are used in order to reduce the discharges of pollutants the wastewater:

5.9.1 Wastewater and Discharges to Recipients

For integrated sulphite with board and paper production, BAT and the combination and the listed below methods/processes are used in order to reduce the discharges of pollutants the wastewater:

BAT-23. The BAT (4th section) associated reduction of discharges of pollutants in the wastewater is as well as the use of the following combination of methods/processes.

Table 5.33 The BAT-associated reduction of discharges of pollutants with wastewater:

	Method/equipment	**Applicability**
a	Dry debarking	Generally applicable
b	Extended modified cooking before bleaching	The applicability may be limited by the pulp quality requirements (where a high strength is needed)
c	High efficiency washing and screening of brown stock in a closed water cycle.	Generally applicable
d	The use of chlorine-free (TCF) bleaching. TCF bleaching with high pulp concentrations makes it possible to reach a high level of brightness with short bleaching schemes. However, if there at an already existing plant is a stage (or many) of chlorine dioxide bleaching and an installation to produce it, then, the most feasible implementation is, also in this case, ECF bleaching within a short scheme.	There is a limited applicability for plants producing commercial pulp for paper with high brightness, as well as for specialized types of paper for chemical applications.
e	Pre-treatment of wastewater	Generally Applicable
f	Anaerobic treatment of condensates from the evaporators	Generally applicable
g	Efficient spill and pollution monitoring and containment, also with chemicals and energy recovery systems	Generally applicable
h	Sufficiently large buffer tanks for the storage of process solutions and fibre pulp between the main production stages, and also for concentrated or hot liquids used for treatment before they are discharged into the recipients.	Generally applicable
i	The optimal division of the water systems of the pulp and paper production sections. The recirculation of the transfer and dilution water flows between the pulp and paper plants	Generally applicable

Table 5.34 BAT-associated levels of discharge after the treatment plant during the production of bleached sulphite pulp. Active production plants.

Production parameter	**Measuring unit**	**Yearly average value**
Wastewater formation (water consumption)1)	m^3/t	40,00 – 55,00
Chemical Oxygen Demand (COD)	kg/t2)	20,00 – 35.00
Biological Oxygen Demand (BOD_{tot})	kg/t	2,00 – 2,60
Total suspended solids (SS) content	kg/t	1,00 – 2,00
Total nitrogen (N_{tot})	kg/t	0,30 – 0,40
Total phosphorus (P_{tot})	kg/t	0,03 – 0,04
Absorbed organically bound halogens (AOX)	kg/ADt3)	0,25 – 0,4
Toxicity	none	
1)Wastewater flow (fresh water) is given for the whole mill taking into account the consumption for turbine cooling 2) The parameters are shown as compared to the production of market products for integrated plants, where the discharge from the paper production is included 3)Per ton of air-dry bleached pulp		

Table 5.35 The BAT-associated discharge levels after the treatment plant during the production of bleached sulphite pulp. New/modernized production plants.

Production parameter	**Measuring unit**	**Yearly average value**
Wastewater flow (water consumption)1)	m^3/t	≤40,00
Chemical Oxygen Demand (COD)	kg/t2)	≤20,00
Biological Oxygen Demand (BOD_{tot})	kg/t	≤2,00
Total suspended solids (SS) content	kg/t	≤1,00
Total nitrogen (N_{tot})	kg/t	≤0,30
Total phosphorus (P_{tot})	kg/t	≤0,03
Absorbed organically bound halogens (AOX)	kg/ADt3)	≤0,25
Toxicity	None	
1)Wastewater production (fresh water) is given for the whole company taking into account the consumption for turbine cooling 2) The parameters are shown as compared to the production of market products for integrated plants, where the discharge from the paper production is included 3)Per ton of air-dry pulp		

Table 5.36 BAT-associated discharge levels after the treatment plant during the production of unbleached sulphite pulp. Existing plants.

Production parameter	**Measuring unit**	**Yearly average value**
Wastewater formation (water consumption)[1)]	m^3/t	40,00 – 90,00
Chemical Oxygen Demand (COD)	kg/t[2)]	20,00 – 40.00
Biological Oxygen Demand (BOD_{tot})	kg/t	2,00 – 6,00
Total suspended solids (SS) content	kg/t	1,00 – 2,00
Total nitrogen (N_{tot})	kg/t	0,30 – 0,50
Total phosphorus (P_{tot})	kg/t	0,03 – 0,05
Toxicity	None	
[1)]Wastewater production (fresh water) is given for the whole mill taking into account the consumption for turbine cooling [2)] The parameters are shown as compared to the production of market products for integrated plants, where the discharge from the paper production is included		

Table 5.37 BAT-associated discharge levels after the treatment plant during the production of unbleached sulphite pulp. New and modernized plants.

Production parameter	**Measuring unit**	**Yearly average value**
Wastewater flow (water consumption)[1)]	m^3/t	≤40,00
Chemical Oxygen Demand (COD)	kg/t[2)]	≤20,00
Biological Oxygen Demand (BOD_{tot})	kg/t	≤2,00
Total suspended solids (SS) content	kg/t	≤1,00
Total nitrogen (N_{tot})	kg/t	≤0,30
Total phosphorus (P_{tot})	kg/t	≤0,03
Toxicity	None	
[1)]Wastewater formation (fresh water) is given for the full company taking into account the consumption for turbine cooling [2)] The parameters are shown as compared to the production of market products for integrated plants, where the discharge from the paper production is included		

5.9.2 Emissions to air from Magnesium-Based Sulphite Cooking

BAT-24. The prevention and reduction of SO_2 (marker substance) emissions.

BAT is the collection of all gas flows of high concentration SO_2 in connection with the preparation of cooking acid from boilers, washing vessels or blow tanks and the transfer of it to be recovered.

BAT-25. The prevention and reduction of sulphur dioxide from the processes of washing, screening and evaporation as shown in table 5.38

Table 5.38 The prevention and reduction of sulphur dioxide from the processes of washing, screening and evaporation:

	Method/equipment	**Applicability**
a	Strengthening of the cooking acid	Applicable
b	Wet scrubbers	Applicable

Table 5.39 Levels of SO_2 emissions from the magnesium recovery boiler

Parameter	Average value during the sampling period (mg/Nm^3 at 5 % O_2)[4)]		
	Daily average concentration[1, 2] mg/Nm^3 at 5 % O_2	Yearly average concentration[1] mg/Nm^3 at 5 % O_2	Yearly average concentration kg/ADt
SO_2	100 – 200 [1) 2) 3)]	50 - 250 [1) 2)]	2,00 – 3,00 -
NO_x	100 – 350	100 – 270	1,50 – 2,00

[1)] Due to the fact that the higher levels of BAT-associated specific emissions of SO_2 are not associated with the recovery boilers permanently working under "acid" conditions, i.e. using sulphite liquor as a washing liquid in the wet scrubbers, as a part of the sulphite recovery process.
[2)]For existing multi-stage Venturi scrubbers there might be higher emissions of SO_2, up to 350 mg/Nm^3, as a yearly average.
[3)]Not applicable under conditions of "acid functioning", i.e. during periods, during which the preventive cleaning and washing activities to remove deposits in the scrubber are performed. During such periods, the emissions may be up to 300 – 500 mg SO_2/Nm^3 (at 5 % O_2) if one scrubber is cleaned, and up to 1 200 mg SO_2/Nm^3 (value for half an hour at 5 % O_2) when the last washing unit is being cleaned.
[4)] The calculation of the oxygen level is shown in table 5.17

The BAT-associated Level of Environmental Efficiency, is the length of acidic process of about 240 hours per year for scrubbers and less than 24 hours per month for the last monosulphite scrubber.

5.9.3 Energy Consumption and Energy Efficiency

BAT-26. The BAT-associated reduction of thermal energy, and electrical energy consumption (steam) is based on a combination of methods, shown in table 5.40.

Table 5.40 BAT-associated methods and equipment for the reduction of thermal energy consumption (steam) and electrical energy

	Method/equipment	**Applicability**
a	High dry solids content of bark, by use of efficiently working presses and drying.	Applicable
b	High efficiency steam boilers, i.e. low exhaust gas temperatures	Applicable
c	Efficient secondary heating systems	Applicable
d	Closing water systems, including bleach plant	Applicable
e	High pulp concentration (middle or high consistency techniques)	Applicable
f	Appropriate use of secondary heat and secondary condensate	Applicable
g	Monitoring and control of processes and the use of advanced control systems	Applicable
h	Optimizing the integrated heat exchanger network	Applicable

5.10 BAT Conclusions for Production of Mechanical and Chemimechanical Pulping

5.10.1 Wastewater and Emissions to Recipients

BAT-27. The BAT-associated reduction of the consumption of fresh water, the amount of formed wastewater as well as the pollution load is based on the appropriate combination of methods that are described in the BAT (items 4.3.1, 4.2.2, 4.3.3 and 4.3.4), as well as the methods that are listed in table 5.41.

Table 5.41 BAT-associated reduction of the consumption of fresh water, the amount of formed wastewater as well as the pollution load

	Method/equipment	**Applicability**
a	Dry debarking	Generally applicable
b	Counter-current flow of process water and separation of water systems	
c	High consistency bleaching	
d	Pre-washing of the chips before refining as well as the use of chip pre-treatment	
e	Efficient division of water systems of the process of mechanical pulp production from the paper production through the use of thickeners. The dewatering of the mechanical pulp substantially reduces the content of pollutants that end up in the water system of the paper machine. The filtrate from the thickener is returned to the process of mechanical pulp production. This does not allow for the dissolved compounds of the wood to go through the full process of paper production.	
g	Pretreatment, secondary biological treatment and (or) wastewater treatment using chemical reagents with the aim to precipitate pollutants	Generally applicable
h	Substitution of NaOH with $Ca(OH)_2$ or $Mg(OH)_2$ as alkali in hydrogen peroxide bleaching	Applicability for high brightness may be limited

5.10.2 Energy Consumption and Energy Efficiency

BAT-28. The reduction of thermal and electrical energy consumption: BAT is based on a combination of methods, presented in table 5.42.

Table 5.42 The BAT-associated reduction of thermal and electrical energy consumption

	Method/equipment	**Applicability**
a	The introduction of a system for the control of energy consumption and production parameters	Applicable
b	Modernization of the equipment. Replacement of equipment by energy saving equipment with automatic process control instead of a conventional system.	Applicable
c	Use of energy efficient refiners	Applicable during replacement, reconstruction of modernization of the process equipment
d	Extensive recovery of secondary heat from TMP and CTMP refiners and reuse of recovered steam in the paper and pulp drying processes	Generally applicable
e	The minimization of fibre losses while also using a more efficient reject refining system (secondary refiners)	
g	The reduction of fresh water flow by internal process water treatment and recirculation systems	

5.11 Bat Conclusions for Processes, Accompanying the Production of Paper and Board

The BAT conclusions in the present section are applicable for board and paper production as part of an integrated paper and board producing plant.

5.11.1 Wastewater and Emissions to Recipients

BAT-29. The reduction of the production of wastewater: it is recommended to use BAT (sections 4.4.1, 4.4.3, 4.4.4, 4.4.6 and 4.4.7) as well as the combined methods listen in table 5.43.

Table 5.43 Methods/equipment for the reduction of the formation of wastewater with the use of BAT

	Method/equipment	**Applicability**
a	The minimal use of water for various types of paper through the increased recirculation of process water as well as measures for water resources control. Standard setting for water consumption as well as water quality for the various use as a basis for a high-quality water resources control.	Generally applicable
b	A well-balanced system for the use of recirculated water (clarified filtrate) as well as broke, the optimal organisation and construction of tanks and stuff boxes while also applying, to the extent possible, design solutions and equipment with a reduced water consumption	Applicable at new plants as well as at modernized already existing plants
c	The maximum retention in the formation part of the paper machine, of O-fibres and filler in order to reduce the amount of suspended substances in the pit water as well as the recovery of fibre and filler and the treatment of recirculated water.	Generally applicable
d	The increased circulation of recycling water	Generally applicable. Dissolved organic, mineral and colloidal substances may limit the repeated use of the paper in the forming zone.
e	The optimized spray jets of the paper and board machines	Generally applicable

BAT-30. The reduction of the consumption of fresh water and the discharge of pollutants as to water at companies producing special technical grades of paper: BAT is based on a combination of methods, mentioned in table 5.44.

Table 5.44 Methods/equipment for the reduction of the consumption of fresh water and the emission of pollutants to water at plants, producing special technical grades of paper with the use of BAT.

	Method/equipment	**Applicability**
a	The development of paper production planning system in order to optimise the production	Generally applicable
b	Control of circulating water as well as water circuits when transferring to production of a new type of paper, the use of new additives, dyes, etc.	
c	Local treatment plants compensating for the changes in the flow fluctuations, low concentrations as well as the various types and amounts of chemical additives	
d	Adjustment of the broke system as well as stuff box capacities	
e	The minimization of release of chemical additives (e.g. grease/water-proof agents) containing per- and polyfluorinated compounds or substances contributing to their formation.	Applicable only at plants producing grease- and water-repellent paper
f	The use of chemicals for the development of the production process, containing a low amount of AOX (e.g. strength - epichlorohydrine resin - agent replacement)	Applicable only for plants producing paper grades with a high wet strength

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BAT-31. The reduction of the pollution load from coating colours and binders, which may disturb the functioning of the biological wastewater treatment plant: BAT is based on the methods/processes, presented in table 5.45.

Table 5.45 BAT methods and equipment for the reduction of the load from the emissions of components of coating suspensions and binding compounds, which may disturb the functioning of the biological wastewater treatment station.

	Method/equipment	**Applicability**
a	Recovery of coating colours/recycling of pigments	In the case of ultrafiltration, the applicability may be limited, when: - effluent volumes are very small - coating effluents are generated in various stages of the production process - there are many changes in the coating process - different coating colour recipes are incompatible
b	Separate collection of wastewater from the coating units and the section for the preparation of coating mixtures (coating kitchen)	
c	Pretreatment of wastewater containing coating colours (for instance the flocculation method) in order to increase the efficiency of the subsequent biological treatment of the wastewater.	Generally applicable

BAT-32. The prevention and reduction of the pollution load of wastewater to receiving waters from the whole mill: BAT is based on the suitable combination of methods presented in the BAT (see items 4.4.1, 4.4.3, 4.4.4, and 4.4.6).

BAT associated levels of discharges

BAT associated discharges are shown in tables 5.49 and 5.47. At integrated pulp and paper works they are included in the total discharge after the treatment plant.

Table 5.46 BAT-associated discharge levels of pollution with wastewater to recipient from non-integrated paper and board plants. Already existing plants

Production parameter	**Yearly average value kg/t[1)]**	
	Fresh intermediate products	**Secondary fibre**
Chemical Oxygen Demand (COD)	1,80 – 5,00	4,00 – 5,00
Biological Oxygen Demand (BOD_{tot})	0,30 – 0,50	0,50 – 1,00
Total suspended solids (TSS) content	0,30 – 0,70	0,30 – 0,40
Total nitrogen (N_{tot})	0,20 – 0,30	0,02 – 0,03
Total phosphorus (P_{tot})	0,02 – 0,03	0,02 – 0,03
Adsorbable organically bound halogens (AOX)	0,005 – 0,007	0,005 – 0,007
Water consumption	15,00 – 27,00	12,00 – 16,00
[1)]The production parameters values are presented in the calculation per ton of market product		

Table 5.47 BAT-associated discharge levels of pollution with wastewater to recipient from the production of paper and board at non-integrated mills. New and modernized plants

Production parameter	**Yearly average value kg/t[1)]**	
	Fresh intermediate products	**Secondary fibre**
Chemical Oxygen Demand (COD)	≤1,80	≤4,00
Biological Oxygen Demand (BOD_{tot})	≤0,30	≤0,50
Total suspended solids (SS) content	≤0,30	≤0,30
Total nitrogen (N_{tot})	≤0,20	≤0,20
Total phosphorus (P_{tot})	≤0,20	≤0,02
[1)]The production parameters values are presented in the calculation per ton of market product		

5.11.2 Emissions to Air

BAT-33. The reduction of emissions from off-line or on-line coaters: BAT gives the opportunity to choose the composition of the coating suspension that reduces the level of emissions.

5.11.13 Waste Generation

BAT-34. The reduction of the amount of waste, disposed of in the environment. BAT prevents the generation of waste and involves processing operations and the employment of a combination of methods, presented in table 5.48.

Table 5.48 The BAT-associated reduction of the amount of waste, disposed of in the environment.

	Method/equipment	**Applicability**
a	Fibre and filler recovery and treatment of white water	Generally applicable
b	Broke recirculation system. Broke from various locations/stages of papermaking processes is collected, repulped and returned to the fibre feedstock.	Generally applicable
c	The recovery of coating colours/recycling of pigments	
d	Reuse of fibre sludge from primary wastewater treatment	The applicability may be limited by the requirements to the quality of the products produced.

5.11.4 Energy Consumption and Efficiency

BAT-35. The BAT for the reduction of the consumption of thermal and electrical energy is based on a combination of the methods, listed in table 5.49.

Table 5.48 The BAT-associated reduction of the consumption of heat and electrical energy.

	Method/equipment	**Applicability**
a	Energy saving screening techniques (the optimization of the design of the rotor, sieves, vortex cleaners, etc.) as well as the optimization of their operating mode.	Applicable at new and modernized plants
b	Heat recovery in refiners	
c	Optimised dewatering in the press stage of the paper machine/wide nip press	Not applicable for sanitary and hygiene paper as well as many types of special paper
d	The use of condensate and the efficient recycling of the heat of the recovery system	The applicability may be limited by the requirements to the quality of the products produced.
e	Optimisation of the operating mode of existing refiners (e.g. the reduction no load power requirements, the use of energy efficient decoiling equipment, etc.)	Generally applicable
f	The optimized pumping design, variable speed control of the rotation of the pump rotors, gearless drive, etc.)	
g	The use of steam boxes for the heating of the paper web in order to improve dewatering.	Not applicable for sanitary and hygienic and many special types of paper.
h	Optimised vacuum system (e.g. turbo fans instead of water ring pumps)	Generally applicable
i	Preheating of shower water, through the use of low-temperature heat sources of the recirculated water	
j	Use of waste heat for sludge drying or upgrading of dewatered biomass	
k	Heat recovery from the Yankee hoods of the paper and board machines	

5.12 Method Description

5.12.1 Description of techniques for the prevention and control of emissions to air

5.12.1.1 Emissions of Nitrogen Oxides NO_x

Table 5.50 Emissions of nitrogen oxides NO_x

Method	Description
Reduction of the air-fuel ratio	This method is mainly based on the following properties: - the careful control of the air used for combustion (low excess oxygen) - minimisation of air leakage into the furnace - modified design of the furnace combustion chamber

Method	Description
Optimized combustion and combustion control	This method is based the technique of control in order to achieve the best combustion conditions. The content and the emissions of NO_x may be reduced through the correction of the operational parameters, air distribution, the excess oxygen as well as flame shaping and the temperature profile.
Staged incineration	Staged incineration is based on the use of two burning zones with controlled air ratios and temperature in a first chamber. The first combustion zone operates under sub-stoichiometric conditions for the conversion of the ammonia compounds into elementary nitrogen at high temperature. In the second zone, additional air feed competes combustion at a lower temperature. After the two-stage incineration, the flue gas flows to a second chamber for the recovery of heat from the gases as well as the production of steam to the process.
Fuel selection/Low-N fuel	Fuel with a low content of nitrogen is applied in order to reduce the amount of emissions of nitrogen oxides from the oxidation of the nitrogen, contained in the fuel during the combustion process. The combustion of NCG or biomass-based fuel increase the NO_x emissions as compared to fuel oil and natural gas. Due to higher combustion temperatures, gas firing leads to higher levels of NO_x than oil firing.
Low-NO_x burner	Low-NO_x burners are based on the principle of reducing peak flame temperatures, delaying but completing the combustion and increasing the heat transfer (increased emissivity of the flame). This may be associated with the modified design of the furnace combustion chamber.

5.12.1.2 Prevention and Control of SO_2 and Total Reduced Sulphur

Table 5.51 Prevention and control of SO_2 and total reduced sulphur

Method	Description
High dry solid black liquor	With a higher dry solid content of the black liquor, the combustion temperature increases. This vaporises more sodium (Na), which can bind the SO_2 forming Na_2SO_4, thus reducing SO_2 emissions from the recovery boiler. A drawback to the higher temperature is that emissions of NO_x may increase
Fuel selection/low-S fuel	The use of low-sulphur fuel with a sulphur content around 0,2 – 0,5 mass % (e.g. forest biomass, bark, low-sulphur mineral oil, gas) reduces SO_2 emissions generated by the oxidation of sulphur in the fuel during combustion
Optimised firing	Techniques such as efficient firing rate control system (air-fuel, temperature, residence time), control of excess oxygen or good mixing of air and fuel.
Control of Na_2S content in lime mud feed	Efficient washing and filtration of the lime mud reduces the concentration of Na_2S, thus reducing the level of formation of hydrogen sulphide in the kiln during the reburning process.
Collection and recovery of SO_2 emissions	The collection of high concentration flows of SO_2 from acid liquor production, the digesters, diffusers or blow tanks. SO_2 is recovered in absorption tanks with different pressure levels, both for economic and for environmental reasons.

Method	Description
Incineration of odorous gases	Collected strong gases may be destroyed by burning them in the recovery boiler, in dedicated boilers or in the limekiln. Collected weak gases are suitable for burning in the recovery boiler, in the limekiln, in special kilns or in burners. Gas from the dissolving tank of the RB may be burnt in modern RBs
Collection and incineration of weak gases in a recovery boiler	Combustion of weak gases (large volume, low SO_2 concentrations) combined with a back-up system. Weak gases and other odorous components are collected simultaneously and burnt in the RB. As a back-up system scrubbers are used.
Wet scrubber	Gaseous compounds are dissolved in a suitable liquid (waster or alkaline solution). Simultaneous removal of solid and gaseous compounds may be achieved. Downstream of the wet scrubber the flue gases are saturated with water and a separation of droplets is required before the discharge of flue gases. The liquid thus formed must be treated as a wastewater treatment process, while the insoluble matter is collected by sedimentation or filtration

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Method	Description
ESP or multicyclones with multistage Venturi scrubbers or multistage double inlet downstream scrubbers	The separation of dust is accomplished in an electrostatic precipitator or in a multi-stage cyclone. In the case of a magnesium-based sulphite process, the dust retained in the ESP consists mainly of MgO, however also to a lesser degree of K, Na or Ca compounds. The recovered MgO ash exists in a suspended state in the water and is removed by washing or slaking in order to form $Mg(OH)_2$, which subsequently is used as an alkaline scrubbing solution in the multistage scrubbers in order to recover the sulphur components of the cooking chemicals. In the course of an ammonium-based sulphite process, ammonia is not restored. After the removal of the dust, the flue gas is cooled when going through the cooling scrubber after which it is transferred through three or more flue gas scrubbers, where the SO_2 emissions are removed by alkaline solutions.

5.12.1.3 Description of techniques for the reduction of the use of fresh water, the amount of wastewater and the reduction of the pollution load of wastewater.

5.12.1.3.1 Methods, integrated in the Production Process

Table 5.52 Methods, integrated in the production process

Method	Description
Dry debarking	Dry debarking of wood in dry tumbling drums (water is used exclusively for the washing of the logs after which it is returned to the process with only a minimal purge to the wastewater treatment plant.
ECF bleaching technique	Modern ECF bleaching minimizes the consumption of chlorine dioxide by using one or a combination of the following bleaching stages: oxygen, hot acid hydrolysis stage, ozone bleaching at medium and high consistency, stages using atmospheric pressure hydrogen peroxide and pressurised hydrogen peroxide.

Method	Description
Extended delignification	Extended delignification by: (a) modified cooking or (b) oxygen delignification enhances the level of delignification of pulp (lowering the Kappa number) before the bleaching, thereby reducing of the use of bleaching chemicals as well as the COD load of the wastewater. Lowering the Kappa number by one unit before the bleaching process can reduce the COD released in the bleach plant by approximately 2 kg COD/ADt. The removed lignin may be recovered and transferred to the chemicals and energy recovery system.
Extended modified cooking (a)	Extended cooking (batch or continuous systems) involves longer cooking periods under optimised conditions (e.g. alkali concentration in the cooking liquor is adjusted to be lower in the beginning and higher at the end of the cooking process), in order to extract the maximum amount of lignin before the bleaching process without any carbohydrate degradation or excessive loss of pulp strength. This, the use of chemicals in the subsequent bleaching stage and the organic load of the waste water from the bleach plant can be reduced.
Oxygen delignification (b)	Oxygen delignification is an option for the removal of a considerable fraction of the lignin remaining after cooking, in the case of digester must work with a higher Kappa number. The pulp reacts with the oxygen under alkaline conditions, as a result of which some of the residue lignin is removed.

Method	Description
Closed and efficient brown stock screening and washing	Brown stock screening is carried out with slotted pressure screens in a multistage closed circuit. Impurities and shives are thus removed at an early stage of the process. Brown stock washing separates the dissolved organic and inorganic chemicals from the pulp fibres. The brown stock pulp may first be washed in the digester, then in high efficiency washers before and after oxygen delignification, i.e. before bleaching. The level of pollution load of the wastewater is reduced through reduced losses and the use of chemicals for bleaching purposes. Additionally it allows for recovery of cooking chemicals from the washing water. Efficient washing is done by counter-current multi-stage washing using filters and presses. The water system in the brown stock screening plant is completely closed.
Partial process water recycling in the bleach plant	Acid and alkaline filtrates are recycled within the bleach plant counter-currently to the pulp flow. Water is purged either to the waste water treatment plant, or – in some cases – to post-oxygen washing. Efficient washers in the intermediate washing stages are a prerequisite for low emissions.

Method	Description
Effective spill monitoring and containment, also with chemical and energy recovery	Effective spill control, catchment and recovery systems that prevents accidental releases of high organic, and sometimes toxic loads or peak pH values (to the secondary wastewater treatment plant) comprises: - automated control of the electric conductivity or the control of the pH value at appropriate places in order to detect losses or spills. - The recovery of the spilled and collected alkali and fibres to the production process at the appropriate stages - The prevention of flooding of concentrated or harmful flows from the most important areas of the process (including tallic oil and turpentine) to the biological treatment of effluents.
Maintaining sufficient black liquor evaporation and recovery boiler capacity to cope with peak loads.	Sufficient capacity of the evaporation plant and the RB ensure that processing of the additional volume of alkali and dry substance through the collection of spills or effluents from the bleaching stage. This reduces the losses of weak black liquor, other concentrated effluents and washing water of the process as well as potential bleach plant filtrates. The evaporation plant concentrates the weak black liquor from the brown stock washing and – in some cases – also biosludge from the effluent treatment plant and (or) sodium sulphate from the chlorine dioxide (ClO_2) production plant. The additional capacity for evaporation guarantees the possibility to recycle the spillages and the processing of possible circulation filtrate flows from the bleach plant.

Method	Description
Stripping the most concentrated contaminated condensates and their reuse	The stripping of the polluted condensates and the repeated use of the condensates in the production process lowers the consumption of fresh water in the plant as well as the level of organic substances in the wastewater to the treatment plant. In the stripping column, steam is transferred countercurrently through the initially treated condensates, which contain a lowered amount of sulphur compounds, terpenes, methanol as well as other organic compounds. The volatile substances of the condensate are accumulated in the overhead vapours to the highest section of the column as non-condensable gases and methanol and are withdrawn from the system. The purified condensates may be used again in the production process, for instance for washing in the bleach plant, for washing of the brown stock, in the caustization area (mud washing and dilution, mud filter showers), as TRS scrubbing liquor for limekiln or as white liquor make-up water. The stripped non-condensable gases from the most concentrated condensates are fed onto the collection system for strong malodorous gases and are incinerated. Stripped gases from the low-contaminated condensates are collected into the high concentration gas system and are incinerated.
Increasing black liquor dry solids content.	The waste is first concentrated through evaporation, after which they are brunt as biofuel in the RB. The sodium carbonate, containing dust and smelt in the lower part of the kiln are dissolved for the recovery of a soda solution.

Method	Description
Recirculation of washing liquids from the pre-bleaching of the brown stock and evaporation in order to reduce pollution from the magnesium-based (MgO) pre-bleaching.	Prerequisites for the use of this method are a relatively low Kappa number after cooking (14 – 16), a sufficiently large volume of tanks, evaporators and recovery boiler to cope with additional flows, the possible removal of deposits from the washing equipment as well as an moderate brightness level of the pulp (>87 % ISO), since this method may lead to a slight loss of brightness in some cases. For producers of market pulp or other products that need to have a high level of brightness (>87 %) the application of magnesium based (MgO) bleaching may be associated with problems.
Counter-current flow of process water	In integrated mills, fresh water is introduces mainly to the paper machine showers, from which it is fed to the cooking workshop.
Separation of water systems	Water systems of different process units (e.g. pulping unit, the bleaching and paper machines) are separated by washing and the dewatering of the pulp (e.g. by wash presses). This separation prevents carry-over of pollutants subsequent process steps and promotes the removal of pollutants from smaller volumes.
High consistency hydrogen peroxide bleaching	For high consistency hydrogen peroxide bleaching the pulp is dewatered, e.g. by a twin wire or any other kind of press, before the bleaching chemicals are added. This provides the opportunity for a more efficient bleaching chemicals use as well as the production of a cleaner pulp, less carry-over of detrimental substances transferred with the to the paper machine and reduces COD. The remaining peroxide may be returned to the production process and reused.

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Method	Description
Fibre and filler recovery and treatment of white water	White water from the paper machine may be treated with the by the following methods: a) water circulation installations (usually a drum or disc filter, a flotator or the like) that separates solids (fibres and filler) from the process water. Dissolved air flotation in white water loops transforms the suspended solids, fines, and small-size colloidal materials into flocks that are then removed. The recovered fibres and the fillers are returned to the production process. Clear white water may be reused in showers with less stringent requirements for water quality. b) additional ultrafiltration of the pre-filtrated white water allows for the production of a filtrate with a high level of purification and a quality sufficient for the use as high pressure shower water, sealing water as well as for the dilution of chemical additives
Clarification of white water	The water clarifying systems mainly used in the paper industry are based on sedimentation, filtration (disc filter) and flotation. The most frequently used method is dissolved air flotation. Anionic trash and fines are agglomerated into physically treatable flocks with by using additives. High-molecular water-soluble polymers or inorganic electrolytes are used as flocculation agents. The generated agglomerates (flocs) are then floated off in the clarification basin. In dissolved air flotation the suspended solid material is attached to air bubbles.

Method	Description
Water recirculation	Clarified water is recirculated as process water within a unit or in integrated mills from the paper machine in the pulp mill and from the pulping to the debarking plant. Effluent is mainly discharged from points with the highest pollutant load (e.g. the cleaned filtrate of the disc filter in pulping or debarking)
The optimal design of tanks and chests (papermaking)	Holding tanks for stock and whit water storage are to be designed so that they can cope with the process fluctuations as well as with the varying flows also during start- ups and shut-downs.
Washing stage before refining of softwood mechanical pulp	Some mills pretreat softwood chips by combining the pressurized preheating, high compression and impregnation to improve pulp properties. A washing stage before refining and bleaching significantly reduces COD by removing of a small but highly concentrated effluent stream that can be processed separately.
Substitution of NaOH by $Ca(OH)_2$ or $Mg(OH)_2$ as alkali in peroxide bleaching	The use of $Ca(OH)_2$ as alkali results in in approximately 30 % lower COS emission loads while keeping brightness levels high. $Mg(OH)_2$ is also used as a replacement for NaOH
Closed-loop bleaching	In sulphite pulp mills using sodium as a cooking base, the bleach plant effluent may be treated e.g. with ultrafiltration, flotation and separation of resin and fatty acids, which enables closed-loop bleaching. The filtrates from bleaching and washing are reused in the first washing stage after the cooking and finally returned to the chemical recovery unit.

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Method	Description
pH adjustment of the weak liquor before/inside the evaporation plant	Neutralization is done before evaporation or after the first evaporation stage to keep organic acids dissolved in the concentrate, in order for them to be sent, together with the spent liquor to the recovery boiler/RB.
Anaerobic treatment of condensates from the evaporation units	See 4.1.20.5 (combined anaerobic-aerobic treatment)
Stripping and recovery of SO_2 from the condensates of evaporators	SO_2 is stripped from the condensates, while the concentrates are subjected to biological treatment and the SO_2 is transferred to be recovered as a cooking chemical.
Monitoring and continuous control of process water quality	The optimization of the entire "fibre-water-chemical additive-energy system" is necessary for advanced closed water systems. This requires a continuous monitoring of the water quality and staff motivation, knowledge and action related to the measures needed to ensure the required water quality
Prevention and elimination of biofilms by methods that minimize emissions of biocides	A continuous input of microorganisms by water and fibres leads to a specific microbiological equilibrium in each paper plant. To prevent growth of microorganisms and deposits of biomass or biological film in water circuits and equipment, biodispersants or biocides are often used. When using catalytic disinfection hydrogen peroxide the biofilms and free bacteria in the process water and the paper suspension are removed by methods, minimizing emissions of biocides.

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Method	Description
Removal of calcium from process water by controlled precipitation of calcium carbonate	Lowering the calcium concentration by controlled removal of calcium carbonate (e.g. in a dissolved air flotation cell) reduces the risk of undesired precipitation of calcium carbonate or scaling in water systems and equipment, e.g. in section rolls, wires, felts and shower nozzles, pipes or biological wastewater treatment plant.
Optimization of showers in papermachine	Optimising showers involves: a)the reuse of process water (e.g. clarified white water) to reduce fresh water use and b) the application of special design nozzles for the showers

5.12.1.3.2 Wastewater treatment

Table 5.53 Wastewater treatment

technique	Description
Primary treatment	Physico-chemical treatment, such as equalisation, neutralisation or sedimentation. Equalisation (e.g. in equalizing basins) is used to prevent large variations in flow rate, temperature and contaminant concentrations and thus to avoid overloading the waste water treatment system.
Secondary (biological) treatment	For the treatment of wastewater by means of microorganisms, the available processes are aerobic and anaerobic treatment. In a secondary clarification step, solids and biomass are separated from effluents by sedimentation, sometimes combined with flocculation.

technique	Description
a) Aerobic treatment	In aerobic biological wastewater treatment, biodegradable dissolved and colloidal material in the water is transformed by microorganisms in the presence of air, partly into solid substance (biomass), partly into carbon dioxide and water. The following processes are used: - one- or two-stage process activated sludge - biofilm reactor - a biofilm/activated sludge method (compact biological treatment plant). This method consists in combining moving bed carries with activated sludge. The generated biomass (excess sludge) is separated from the effluent before the water is discharged.
b) combined aerobic/anaerobic treatment	Anaerobic wastewater treatment converts the organic content of wastewater by means of microorganisms in the absence of air, into methane, carbon dioxide, sulphide, etc. The process in carried out in an airtight tank reactor. The microorganisms are retained in the tank as biomass (sludge). The biogas formed by this process consists of methane, carbon dioxide and other gases such as hydrogen and hydrogen sulphide, and is suitable for energy generation. Anaerobic treatment is to be seen as pretreatment before aerobic treatment due to the remaining COD loads. Anaerobic pretreatment reduces the amount of sludge generated from biological treatment.
Tertiary treatment	Advanced treatment comprises techniques such as filtration for further solids removal, nitrification and denitrification for nitrogen removal or the flocculation followed by filtration for phosphorus removal. Tertiary treatment is normally used in cases where primary and biological treatment are insufficient to achieve of a low content of TSS, nitrogen and phosphorus.

technique	Description
Properly designed and operated biological treatment plants	A properly designed and operated biological treatment plants includes the appropriate design and dimensioning of the treatment tanks/basins (e.g. sedimentation tanks) according to hydraulic loads and contaminant loads. Low TSS emissions are achieved by ensuring the good settling of the active biomass. The periodic control of the design, dimensioning and operation of the wastewater treatment station facilitate the achievement of such objectives.

5.12.1.4 Description of Techniques for Waste Generation Prevention and Waste Management.

Table 5.54 The description of the waste formation prevention and waste management.

Technique	Description
Waste assessment and waste management system	Waste assessment and waste management systems are used to identify feasible options for optimisation and prevention of the formation, reuse, recovery, recycling and final disposal of waste. Waste inventories allow for identifying and classifying type, characteristics, amount and origin of each waste fraction.
Separate collection of different waste fractions	The separate collection of various fractions of waste at the points of origin and – if appropriate – their intermediate storage enhance the options for reuse or recirculation. Separate collection also includes the separation and classification of hazardous waste fractions (e.g., oil and grease residues, hydraulic and transformer oils, waste batteries, scrap electrical equipment, etc.)
The merging of homogenous waste	The merging of suitable waste depending on the preferred options for reuse/recycling, further treatment and recovery.

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Technique	Description
Pretreatment of process residues before reuse or recycling	Pretreatment comprises techniques such as: – dewatering e.g. of sludge, bark or rejects and in some instances drying before recycling (e.g. to increase calorific value before incineration) – dewatering to reduce weight and volume for transport. For dewatering belt presses, screw presses, decanter centrifuges or chamber filter presses are used – crushing/shredding of rejects e.g. from RCF processes and removal of metallic parts to enhance combustion characteristics before incineration – biological stabilization before dewatering in case agricultural utilization is foreseen.
Material recovery and recycling of process residues on site	Processes for material recovery comprise techniques such as: – separation of fibre from water streams and recirculation into feedstock – recovery of chemical additives, coating pigments, etc. – Recovery of cooking chemicals by means of recovery boilers, caustization, etc.
Energy recovery of on- or off-site from wastes with high organic content	Residues from debarking, chipping, screening, etc. like bark and other organic residues, are mainly burned due to their high calorific value for energy recovery

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Technique	Description
Waste recycling	The use of waste from pulp and paper production may be carried out in other industrial sectors, for instance – firing in the kilns or mixing with feedstocks in cement, ceramics or bricks production (also includes energy recovery) – composting sludge from the treatment plant or the fertilization of soil by appropriate waste fractions for agricultural purposes – use of inorganic waste fractions (sand, stones, grits, ashes, lime) for construction purposes, for instance paving, road construction, protecting covering layers, etc. The suitability of waste fractions for off-site utilisation is determined by the composition of the waste (e.g. inorganic content), and the evidence that the foreseen recycling operation does not cause harm to the environment or health.
Pretreatment of waste before recovery	Pre-treatment of waste before recycling comprises measures (dewatering, drying, etc.) reducing the weight and volume for the transport or recovery.

The BAT list proposed above is not conclusive, which is why any other techniques or combination of techniques and methods, the industrial use of which allows for the same or better result, may also be considered as BAT, even though they are not described in this BREF.
The list of marker substances in pulp and paper production is shown in Attachment C, the BAT list in Attachment D, the list of technological indices in Attachment E, and the control methods in Attachment F.

Section 6. Economic Aspects of the Implementation of Best Available Techniques

6.1 Economic Aspects of the Sulphate Pulp Production BAT Implementation

Table 6 Economic parameters when implementing BAT when producing sulphate pulp

Technique	**Description**	**Economic parameters (capital and operational costs, effects)**
Dry debarking	4.1.1	The costs for the dry debarking drums do not in any substantial way differ from the costs of wet debarking drums. Standard investment costs for entirely new dry debarking systems from the log feed to the chips conveyer (including the chipping machine and the ancillary conveyers) is around 15 M Euro for a capacity of 1 300 ADt per day. The modernization of the existing drums for wet debarking for dry debarking costs 4 – 6 M Euro. This cost includes the equipment and its installation. In certain cases, there is a need for a new building at the site as well as special measures for the reduction of noise level as well as other measures, which are not included into the costs, however they might be the reason for higher future costs.
Extended modified cooking	4.1.2	A modified cooking process may be realized at new as well as already existing plants. The costs of the introduction of a modernized cooking process are estimated separately in every individual case.
A closed water circuit screening, cleaning and washing of the stock	4.1.3	The investments needed for the introduction of a closed circuit screening system are approximately 4 – 6 M Euro at new plants and 6 – 8 M Euro at already existing plants. The operational costs are 0,3 – 0,5 mil Euro/year for a plant with a capacity of 1 500 ADt/day

Technique	Description	Economic parameters (capital and operational costs, effects)
Oxygen-alkaline delignification	4.1.4	The investments for an oxygen delignification system with a capacity of 1 500 ADt/day is 35 – 40 M Euro: - Operational costs: 2.5 – 3 M Euro/year - Net effect from the introduction of oxygen delignification is the economy on the bleaching chemicals, which depend on the wood species.
ECF bleaching, and the production of the necessary ECF chemicals	4.1.5	- capital investment for an ECF system with a capacity of 1 500 ADt/day is 8 – 10 M Euro at new plants and 3 – 5 M Euro at already existing plants - the abovementioned capital investment costs take into account the possibility of using the equipment of the already existing bleaching installation, whereas the capital investment mainly involves the increased production of chlorine dioxide. - The operational costs are 10 – 12 mil Euro/year, including the extra costs, connected with the increased consumption of chlorine dioxide
Stripping and reuse of polluted condensates after treatment in the stripping column	4.1.6	- The investments for the installation of condensate stripping equipment when producing sulphate pulp is 2,0 – 3,5 M Euro. Additional investments may be required in order to increase the capacity of the evaporation plant, however the size of such investments depends to a large depend on the possibilities of an already existing evaporation installation. The costs for a modernization may vary from 1 to 4 mil Euro.

Technique	Description	Economic parameters (capital and operational costs, effects)
The partial closing of the water circuit of the bleaching plant	4.1.7	Considerable investments are needed for the reconstruction of the water distribution system of the bleaching equipment, including an additional tank for water storage. In some cases there is also a need for investments for the modernization of adaptation of the bleaching stages, the water control system as well as efficient washing apparatuses.
The partial or full repeated use of clean cooling water	4.1.8	At a company with a capacity of 1 500 tons ADt/day the capital investment for the installation of 2 storage tanks for production fluids, each with a volume of 3 000 m^3, including the necessary tubing, isolation, and pumps, the monitoring instrument, necessary for the production process and supplied with the needed electrical energy amount to approximately 0,8 – 1,0 M Euro
Heat recovery during pulp production	4.1.9	
Buffer tanks for the collection of leakage fluids	4.1.10	At a plant with the capacity of 1 500 tons ADt/day the investments for the installation of 2 tanks for the storage of production liquids with a volume of 3 000 m^3 each, including the needed for this purpose tubes, isolation and pumps, the monitoring instrument, necessary for the production process and supplied with the needed electrical energy amount to approximately 0,8 – 1,0 M Euro
A closed circuit of the chemicals recovery of the cooking	4.1.11	
Collection and decomposition of sulphate soap	4.1.12	
Separation or collection of turpentine	4.1.13	

Technique	Description	Economic parameters (capital and operational costs, effects)
The collection of strong and weak odorous gases with the subsequent burning in dedicated kilns, LK and RB.	4.1.14	The cost for the introduction of a collection and burning system for both low- and high-concentration non-condensable gases is 4 – 5 mil Euro at new plants and 5 – 8 M Euro at already existing plants with a capacity of 1 500 tons ADt/day. In the case of use of the burning heat of the burning of the produced methanol, there will be no increase of the operational costs. In the opposite case, the costs will be increased by 0,3 – 0,5 M Euro per year.
Burning of black liquor at a concentration above 72 %	4.1.15	The costs of the improvement of the evaporation and thickening of the concentrated black liquor at already existing plants are connected with the level of concentration achieved. At an already existing plant with a capacity of 1 500 tons ADt/day of sulphate pulp in order to increase the concentration of dry matter from 63 % and higher, the capital costs are: - A concentration of 63 to 70 % - 1,7 – 3,0 M Euro - The increase of concentration from 63% to 75 % - 3,5 – 4,0 M Euro - The increase in concentration from 63 % to 80 % - 8,0 – 9,0 M Euro
Improved washing of sludge from the chemicals recovery process	4.1.16	Typical investments would amount to 1 – 1,5 M Euro
Dewatering of waste from the chemicals recovery cycle	4.1.17	

Technique	**Description**	**Economic parameters (capital and operational costs, effects)**
Electrostatic filters after the RB, LK and the boiler for the burning of bark and sludge from the treatment plant	4.1.18	For a plant with a capacity of sulphate pulp production of 1 500 ADt/day, the investment when installing an electrical filter in the bark burning boiler is about 3 – 5 M Euro, whereas if it were installed in the limekiln – 5 – 6 M Euro. The operational costs would be increased by less than 0,3 M Euro/year in both cases.
Boilers for the incineration of bark and treatment plant sludge, undercooked pulp as well as the required fuel preparation	4.1.19	The capital investment would be 20 – 40 M Euro, depending on the steam generation capacity of the boiler. This would allow for refraining from buying electrical energy or heat.
Biological wastewater treatment	4.1.20	The process using activated sludge: The capital investment would be 19 - 24 M Euro. The operational costs would be 2,0–2,6 M Euro per year. The process using an aerated pond: the capital costs would be 16 – 20 M Euro. The operational costs: 1,3 – 1,7 M Euro per annum.
Dewatering of the treatment plant sludge	4.1.21	
Improvement of the scrap processing system (paper and board machines)	4.1.22	
A system for the trapping of fibre from the surplus (waste-) water of the paper and board machines.	4.1.23	
VOC before treatment plants	4.1.24	

Technique	**Description**	**Economic parameters (capital and operational costs, effects)**
ADCS introduction	4.1.25	
The combined production of heat and electrical energy	4.1.26	The specific costs for a steam-gas installation would be 1,5 – 2,0 thousand Euro/1kWh

6.2 Economic Aspects of the Introduction of Sulphite and Mechanical Pulp Production BAT

Table 6.2 Economic parameters of the introduction of sulphate and mechanical pulp production BAT

No	Technique	Description	Economic parameters (capital and operational costs, effects)
1	Dry debarking	4.1.1	The costs for the dry debarking drums do not in any substantial way differ from the costs of wet debarking drums. Standard investment costs for entirely new dry debarking systems from the log feed to the chips conveyer (including the chipping machine and the ancillary conveyers) is around 15 M Euro for a capacity of 1 300 ADt per day. The modernization of the existing drums for wet debarking for dry debarking costs 4 – 6 M Euro. This cost includes the equipment and its installation. In certain cases, there is a need for a new building at the site as well as special measures for the reduction of noise level as well as other measures, which are not included into the costs, however they might be the reason for higher future costs.
2	Extended or continuous cooking	4.1.2	Cooking may be conducted at new and already existing plants. The cost for the introduction is estimated for each concrete case individually

No	Technique	Description	Economic parameters (capital and operational costs, effects)
3	A closed water circuit screening, cleaning and washing of the stock	4.1.3	The investments needed for the introduction of a closed circuit screening system are approximately 4 – 6 M Euro at new plants and 6 – 8 M Euro at already existing plants. The operational costs are 0,3 – 0,5 mil Euro/year for a plant with a capacity of 1 500 ADt/day
4	The recycling of the condensates from pulp production and their separate cleaning	4.1.6	No information is presented
5	The collection of gases with a high content of Sulphur dioxide and their subsequent use in order to produce cooking liquors	4.2.1	
6	Heat recovery during pulp production	4.2.2	
7	Buffer tanks for the collection of leakage fluids	4.1.10	At a plant with the capacity of 1 500 tons ADt/day the investments for the installation of 2 tanks for the storage of production liquids with a volume of 3 000 m^3 each, including the needed for this purpose tubes, isolation and pumps, the monitoring instrument, necessary for the production process and supplied with the needed electrical energy amount to approximately 0,8 – 1,0 M Euro

No	Technique	Description	Economic parameters (capital and operational costs, effects)
8	Boilers for the incineration of bark and treatment plant sludge, undercooked pulp as well as the fuel preparation for them	4.1.19	The capital investment would be 20 – 40 M Euro, depending on the steam generation capacity of the boiler. This would allow for refraining from buying electrical energy or heat.
9	Electrostatic filters after the RB, LK and the boiler for the burning of bark and sludge from the treatment plant	4.1.18	For a plant with a capacity of sulphate pulp production of 1 500 ADt/day, the investment when installing an electrical filter in the bark burning boiler is about 3 – 5 M Euro, whereas if it were installed in the limekiln – 5 – 6 M Euro. The operational costs would be increased less than by 0,3 Euro/year in both cases.
10	Biological wastewater treatment	4.1.20	The process using activated sludge: The capital investment would be 19 - 24 M Euro. The operational costs would be 2,0 - 2,6 M Euro per year. The process using an aerated pond: the capital costs would be 16 – 20 M Euro. The operational costs: 1,3 – 1,7 M Euro per annum.
11	Dewatering of the treatment plant sludge	4.1.21	
12	Improvement of the broke processing system (paper and board machines)	4.1.22	
13	A system for the trapping of fibre in the whitewater or effluents of the paper and board machines.	4.1.23	

No	Technique	Description	Economic parameters (capital and operational costs, effects)
14	The introduction of an automated dispatch control system (ADCS)	4.1.25	

6.3 Economic Aspects of the Introduction of BAT for Paper and Board Production

Table 6.3 Economic parameters when introducing BAT in production of paper and board

Technique	Description	Economic parameters (capital and operational costs, effects)
A closed water system in screening and washing of the stock	4.1.3	The investments needed for the introduction of a closed circuit screening system are approximately 4 – 6 M Euro at new plants and 6 – 8 M Euro at already existing plants. The operational costs are 0,3 – 0,5 mil Euro/year for a plant with a capacity of 1 500 ADt/day
Heat recovery in production of paper and board	4.3.2	The decreased consumption of energy when producing paper and/or board through the use of recovered heat in the production process and in the ventilation system
Biological treatment of effluents	4.3.3	Investment costs are approximately: - A biological activated sludge treatment system– 300 – 600 Euro/kg COD per day; - Biofiltration: 500 Euro/kg COD per day The level of investment costs depends on the pollutant load

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Technique	**Description**	**Economic parameters (capital and operational costs, effects)**
Dewatering of treatment plant sludge	4.3.4	
Improvement of the broke processing system (paper and board machines)	4.3.5	The increased energy efficiency of the production process through the decreased consumption of energy for the processing of intermediate products
A system for the trapping of fibre from the whitewater and (or) wastewater of the production of paper and board.	4.3.6	- The use of the trapped fibre in the production process instead of part of the primary intermediate products - The decreased consumption of fresh water in production of paper/board down to 8- 10 m^3 through the use of clarified water.
The introduction of an automated system for production management	4.3.7	This would allow for the stabilization of the process, the lowering of the peak emission loads.
The partial or full recycling of clean cooling water	4.1.6	

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Section 7 Emerging Techniques

Section 7 describes the pulp and paper production techniques that are on the level of R & D as well as on the level of experimental industrial introduction, as well as foreign techniques that have not yet been large-scale introduced in the Russian Federation.
A list of emerging techniques is presented in Attachment H.

A Description of Emerging Techniques for Russian Sulphate Pulp Production Plants (ET-1)

ET-1.1 Ozone Bleaching

Ozone bleaching is associated with ECF and TCF bleaching techniques. One of the main objectives of the ozone application is to ensure a higher delignification susceptibility of the pulp at subsequent bleaching stages. The ozone activates the pulp based on the effect of hydrogen peroxide and chlorine peroxide. This facilitates the achievement of a higher level of brightness of the pulp as well as a lower peroxide consumption. This is why the ozone stage preferably should be located in the beginning of the bleaching scheme.
The main stage of the bleaching process is used at the plants of almost all major pulp and paper mills in the world. The industrial techniques of the ozone stage are implemented at an intermediate and high stock concentration. An example of one of the most efficient modes of carrying out ozone bleaching is the Ze Trac method, developed by Metso Paper and introduced at companies in Europe, North America, Japan, etc. This method is carried out not under pressure of the oxygen-ozone mixture as this is done usually, but under conditions of rarefying, which lowers the likelihood of the ozone ending up in the air due to leakages of the facilities or the fittings (ozone is highly toxic due to its high oxidizing activity).
Ozone is recovered by electric discharges in the flow of gaseous oxygen. Ozone (O_3) bleaching involves high capital investment due to the high cost of ozone generators and ancillary equipment for the formation of ozone, and also due to the high energy consumption at the ozone formation stage (10-15 kWh/kg ozone).

Status of development
This technology in the Russian Federation is on the R&D level and may by introduced both at new and already existing pulp and paper plants. Abroad, the ozone stage of the bleaching process has been used for 20 years already.

Achieved environmental advantages
The Ze Trac allows for the decreased consumption of chlorine dioxide from 35 down to 10 kg/ADt counted based on active chlorine at an ozone consumption of 6 kg/ton ADt and the total lowering of the bleaching consumption of 32 %. While this is achieved, the water used for bleaching purposes is reduced by 25 %, and, correspondingly, the quantity of wastewater; the COD and BOD parameters by 30 – 40 % the and the AOX content of the wastewater and the OX of the pulp by 2-4 times, whereas the water colour index is reduced by 60-65%.

Economic aspects of the introduction:

- The elimination of the use of SAAs in order to exclude problems concerned with resin.
- The elimination of the souring stage when bleaching pulp of all wood species apart from eucalyptus, where the presence of Ahot (hot souring at a temperature of 80-900°C) is seen as expedient.
- The exclusion from the schemes of light ECF bleaching (with ozone) of the chelation stage (when using TCF bleaching this stage is necessary),
- The use of ozone in the ECF bleaching technology allows for the achievement of the same paper formation properties of the pulp as when using schemes of ozone bleaching.
- At plants using TCF bleaching the use of ozone and other non-chlorine-containing bleaching chemicals reduces the complicated nature of the process of the closing of the circuits of filtrates from the washing stages.
- The investment for the construction of a bleaching installation with an ozone stage with a capacity of 1 500 tons ADt/day is 12 – 15 M Euro. The corresponding operational costs are 1,8, 2,1 M Euro/year.
  Reference material: *Zhurnal TsBK, 2015 no 7.*

ET-1.2 Chlorine-free Bleaching Technique (TCF)

Description of the technique

TCF bleaching is a type of pulp bleaching without the use of chemicals containing chlorine compounds. This process is under rapid development, although the use of it calls for, usually, more drastic changes of the production process. When using TCF bleaching it is quite common to use hydrogen peroxide, ozone (Z) or peracetic acid (Paa). In this case, if the pulp has a quite low Kappa number after the extended cooking process and the oxygen delignification and if the transition metals (e.g. Mn^{2+}) are removed to the necessary chelating stage (Q stage), then, in principle, there is a possibility to attain a quite high brightness of the pulp, satisfying the requirements of the market, with the use of hydrogen peroxide as the only bleaching chemical. The H_2O_2 consumption in this process is usually quite high. One of the possible options for the reduction of the H_2O_2 consumption is the introduction of ozonisation at the stage of peroxide processing (ZQP or ZChP). The downside of using ozone is the fact that at high quantities of ozone, the unsatisfactory mixing of the gas with the stock or at the inappropriate apparatus design and mode of production it has the tendency to have a destructive impact on the pulp fibres.
The use as a bleaching agent of peracetic acid at the stage before the bleaching with hydrogen peroxide allows for the successful replacement of ozone. The high brightness is possible to attain even in cases where the Kappa number of the unbleached pulp is not extremely low. The drawback of the use of peracetic acid is that it is quite expensive. Examples of the use of various TCF bleaching schemes are presented in table 7.1.

Table 7.1 – TCF bleaching schemes for sulphate pulp from softwood and hardwood timber

TCF bleaching of softwood	TCF bleaching of hardwood
Q(EP)(EP)(EP)	QPZP
Q(OP)(ZQ)(PO)	Q(OP)(ZQ)(PO)
Q(EOP)Q(PO)	Q(EOP)Q(PO)
Q(OP)ZQ(PO)	Q(OP)ZQ(PO)

TCF bleaching of softwood	TCF bleaching of hardwood
Note: Q is a weak acid stage, during which chelating agents ADTA and DTPA; EP is the stage of alkaline extraction during which sodium hydroxide (NAOH) is used with the addition of a H_2O_2 solution in order to enforce the process through oxidation; EOP is the alkaline extraction with the addition of oxygen and H_2O_2 in order to enforce the process through oxidation EO is the stage of extraction during which sodium hydroxide and gaseous oxygen are used as; P- the processing with H_2O_2 in an alkaline environment Z is the ozone stage, during which gaseous Ozone (O_3) is used in a mixture of O_2 and O_3 PO is H_2O_2 bleaching under oxygen pressure	

At present TCF bleaching is a mature technology. Many plants in Europe have flexible bleaching schemes, allowing for the production of either TCF or ECF-bleached produce. Some plants produce only ECF pulp, since, when using TCF bleaching, it is harder to reach a high brightness. The share of TCF pulp in the world during the past few years does not exceed 5-7% of all bleached pulp however in Scandinavia its share is around 25 %.

<u>Status of development</u>
This technique is – in Russia – the stage of R&D and may be introduced both at new and already existing pulp and paper plants.

In the transition from ECF to TCF bleaching it is necessary to have: a chelating stage, a new oxygen stage and additional washing equipment. In the case when there is a stage with hydrogen peroxide or ozone processing, it is necessary to have two new bleaching towers, as well as the modernization of the washing filters of the bleach plant. When using ozone for bleaching purposes it is necessary to have ozone generators and a reactor for the ozone bleaching of the stock. In order to bleach with peracetic acid there is an additional need for one bleaching tower.
<u>The environmental advantages</u>
When applying TCF bleaching there is no formation of AOX, dioxins or chlorophenols, there is a total exclusion of AOX in the bleach plant effluents.

Economic aspects of the introduction

The capital expenditure for the introduction of H_2O_2 bleaching at new plants with a production capacity of 1 500 tons ADt/day is 7 – 8 M Euro; at already existing plants – 2,5 M Euro, depending on the material from which the existing bleaching equipment is made. If the material is H_2O_2-resistant, then the expenditure will be 2-3 M Euro. The operational costs when using hydrogen peroxide is considerably higher, than when using ECF bleaching based on the higher costs, mainly of H_2O_2, attaining 1,8 – 2,1 M Euro/year.

ET-1.3 Partial and Full Closed-Loop Bleaching

Description of the technique

The main prerequisite for the closure of the water loop of the bleach plant is the reduction of the volume of the water flow running through the bleach plant. This may be achieved through the use when washing the pulp of a countercurrent method, when the fresh and excess water from the drying machine is fed to the pulp washing plant after the last bleaching stage, and, further, into the chemicals and heat recovery system. In order to raise the level of closure of the water loop of the bleach plant it is necessary to use an additional tank for the storage of bleaching filtrates, as well as to rebuild the water distribution system.

The partial closure of the water loop of the bleach plant ensures the reduction of the volume of wastewater, the consumption of fresh water and the content of effluent BOD and COD pollutants.

The dissolved organic compounds in the wastewater from the bleach plant are transferred to the recovery boiler through an evaporation plant, which increases the energy consumption.

There are a number of companies in Europe and North America that use a closed water loop of the bleach plant.

<u>Status of development</u>
The lowering of the fresh water consumption in the bleach plant may be achieved both at new and at already functioning plants. However, at already functioning plants the capital costs in order to serve for the recirculated water storage, the water transfer system as well as the organisation of a control and management system for the water flows of the plant are relatively high. Modern plants, usually, already work with lower quantities of water thanks to more efficient equipment. One condition for this is the sufficient capacity of the evaporation installations and the recovery boiler. One should note that the evaporation of bleach plant effluents is easier to achieve when using TCF bleaching. When using ECF bleaching, there is a higher risk of corrosion under the impact of chlorides in the recovery boiler.
Pulp mills working without off-site biological treatment plants were the first companies where it was tired to lower the amount of bleach plant effluents by the abovementioned measures.

<u>Achieved environmental benefits</u>
The reduction of the volume of wastewater down to 10 m^3/ton ADt, COD – 6 kg/ADt.

<u>Economic aspects of introduction</u>
In order to introduce this technology it is necessary to make quite substantial investments. There is a need to make a total redesign of the water supply system of the bleach plant, including additional tanks for the storage of recirculated water. It is necessary to develop a control method for the management of the water resources of the workshop as well as to field-test and introduce it. There is no knowledge of any reliable information of the costs of the abovementioned measures.

ET-1.4 Gasification of Black Liquor

<u>Description of the technique</u>
Gasification is a promising technique for pulp mills, for the generation of surplus electric power. The principle of gasification of black liquor lies in the pyrolysis of concentrated black liquor under the formation of inorganic and gaseous phases through the interaction of the liquor with oxygen (air) at high temperatures. Conceptually, the options of this process of gasification of the black liquor are divided into two types. The first type is the gasification at relatively low temperatures. While this is happening, the gasifier works at

a temperature lower than the melting temperature of inorganic salts (700-750°C). The second type of gasification process are processes which are carried out at temperatures above the melting point, and within which water is used for the dissolution of the melted sodium salts.
One of the most interesting possibilities, connected to the black liquor gasification process is the functioning of a gas turbine in combination with a steam turbine in a unified cycle. The problem that must be overcome is mainly associated with the level of purity of the gas that is necessary for the prevention of damage to the gas turbine.

<u>Status of development</u>
The first demonstrated facility for the gasification of black liquor with the use of the Chemrec principle was put into operation at the Frövifors plant in Sweden in 1991. A demonstrational gasifier working under pressure of a similar type was also in operation in Stockholm (Sweden). This process type has been used in industrial scale in USA. Integrated gasification combined cycle (IGCC) is being introduced in the pulp and paper industry step by step, in connection with, mainly, the depreciation life of the existing recovery boilers. Furthermore, the gasifiers will, to begin with, be built only at smaller-size plants and not at the major pulp mills. The integrated gasification may be interesting for some companies where the recovery boiler is the bottleneck for the development or modernization of the production, whereas the increased capacity of the recovery of chemicals may resolve these problems.

<u>Achieved environmental benefits</u>
The possible advantages of BLGs:

- The increased power generation through the use of a combined cycle (gas turbine plus steam turbine). Theoretical balance calculations show that the recycling of black liquor based on the IGCC technology may lead to an approximately 30 % higher energy efficiency based on the heat value of black liquor. This may be compared to the increase by 12-13 % of the efficiency of a conventional recovery boiler. However, at the same time the overall efficiency (power + steam) is decreased by 5 % to about 75 %. Thus, the production of process steam decreases. In a situation, where there is surplus steam, this appears to be and interesting option for and increased power production, e.g. for export

- low emissions to the atmosphere
- It enables pulp mills restricted in capacity, because of recovery boiler limitations, to increase production. This system is particularly beneficial in mills with cooking capacity that they don't use, as well as at plants where the quantity of dry matter is increased in the recovery system (for instance due to the introduction of cooking down to low Kappa numbers, oxygen delignification, the increased amount of dry matter sent to the recovery system with the effluents from the bleaching system).

<u>Economic aspects of the introduction</u>
A broadened sphere of application of alternative types of fuel.

<u>Reference material:</u>
Gasification of black liquor in sulphate production, textbook, Saint Petersburg, 2011.

ET-1.5 Enhanced Production of Electric Power based on Biomass Products and the Utilisation of Excess Heat

<u>Description of the technique</u>
There is a tendency in the world to increase the use of wood biomass (BM) in systems for district heating. District heating stations burning wood chips are built in order to replace stations working on fuel oil or coal, united with the existing heating networks, or as new stations and heating networks (so-called "urbanized" projects). Boilers for the burning of wood chips at district heating stations are designed for the production of heat within the power range from 1 to 10 MW with an average level of 3,5 MW.
At thermal stations of the condensation type often there is no need for any additional equipment for the treatment of the combustion products.
Boiler facilities burning wood BM may be used for the heating of separate houses or groups of houses, as well as - at industrial plants - fulfilling the function of producing heat and process steam. A typical boiler-room

for the incineration of wood chips is built around a solid-fuel boiler. The boiler systems are highly automated. For instance, the fuel feed from storage facilities to the grid is done with a computer-controlled crane.
All systems have the following main components:

- Storage facilities for wood biomass
- A transport-loader and batching equipment for the handling of BM
- A furnace and a boiler
- A flue gas treatment system
- A flue gas condensation system

Status of development
This technique is being introduced at a number of plants.

Achieved environmental benefits
The level of emission of pollutants when burning wood chips at European stations are: SO_2 – 60 mg/MJ, NO_2 – 90 mg/MJ, solid matter – 300 mg/Nm^3 – when using a system for the condensation of the combustion products, CO < 0,05 %
The CO and NO emission level is entertained within acceptable limits through the appropriate control of the combustion process. In order to achieve the admissible concentrations of particulate matter multicyclones are used in general, whereas in order to reach a higher level of cleaning – bag filters and electrostatic filters are used.
Economic aspects of the introduction
During the past few years the cost of fossil fuel has grown sharply, which to a high degree has influenced the level of use of BM for the production of heat. The price of wood waste on the European market depends on the quality and primarily from the humidity and ash content. The fuel cost is defined by the type o fuel in terms of combustion energy units.
The capital costs of thermal stations working on BM is about 320 $/kW, including the costs of buildings, the boiler and the systems for the condensation of the combustion products. Based on the costs of construction of the heating network the specific capital costs are around 530$/kW.
In order to operate a thermal station with a capacity of 1,5 – 5,0 MW 1 – 2 people are needed, whereas, for stations with a capacity of above 5,0 MW – 2-3 people.

ET-1.6 Borate Autocaustization

Description of the technique

The process of partial autocaustization is recommended when modernizing sulphate plants, when it is needed to increase the capacity of the caustization workshop as well as the limekiln without any additional capital investment.
The main principle of the method is the use of sodium tetraborate (in the form of $Na_2B_4O_75H_2O$) in order to compensate for the losses of soda (sodium hydroxide). In this process, in the existing RB, there is an interaction of the tetraborate with the main inorganic component, formed during the incineration of the black liquor – sodium carbonate, accompanied by the formation of Na_3BO_3, turning– during the dissolution of the melt – into sodium hydroxide and metaborate ($NaBO_2$).
In this process, at least partly, there is no longer any need to have to stages of the process of chemicals recovery – lime caustization and recovery. Sodium metaborate, together with the soda may successfully participate in the cooking process as the alkaline agent. The main reactions going on in this regeneration process may be presented as the following equilibriums:

$$Na_2B_4O_7 + 5Na_2CO_3 = 4Na_3BO_3 + 5CO_2 \quad (1)$$

$$NaBO_2 + Na_2CO_3 = Na_3BO_3 + CO_2 \quad (2)$$

$$Na_3BO_3 + H_2O = 2NaOH + NaBO_2 \quad (3)$$

Out of the totality or the shown reactions it is clear that from one mole of $Na_2B_4O_7$ 8 moles of NaOH are formed (i.e. quantitatively 8 times more), which makes this process economically viable if part of the soda in the melt is causticized, irrespectively of the use the more expensive sodium tetraborate instead of soda. The soda surplus in the melt subsequently, after the green liquor has been extracted from it, is subjected to caustization through the interaction with the recovered lime, i.e. according to the conventional technology.
The technique described above of autocaustization with the use of sodium tetraborate has been successfully introduced in the production of bleached CTMP with a closed water circuit. Furthermore, since the amount of sodium hydroxide used for the production of bleached CTMP is considerably lower than for sulphate pulp, it has been discovered that it is rational to replace all caustic with sodium tetraborate, i. e. to carry out a not partial, but a total caustization of the soda using this method. Furthermore, it has been proven, that during the bleaching process, carried out at a pH no higher than

10, a hydrolysis of the sodium metaborate takes place with the formation of sodium hydroxide and sodium tetraborate – the initial reagent, used in this case for the compensation of the losses of sodium in the system, according to the reaction:

$$4NaBO_2 + H_2O = Na_2B4O_7 + 2NaOH \quad (4)$$

Consequently, in this process, taking into account also the reactions (1)… (3), from one mole of the initial tetraborate not only 8, but rather 10 moles of NaOH are formed. (during sulphate cooking, the reaction (4) is not carried out because of a too high pH value of the process – above 13).

<u>Status of development.</u>
This method of recovery has been used in Meadow Lake at a BCTMP mill with a closed water circuit system – Millar Western (Canada). The principal scheme of recovery is extremely simple and space-saving: the melt from the recovery boiler ends up in the compartmented dissolution tank, and, from there – to the green liquor clarification tank. Thereafter, for the final release of sludge particles, the liquor is filtrated and a part of it is transferred to the chemicals preparation plant, whereas another part – for evaporation. The sludge from the green liquor clarification tank is dewatered in a centrifuge and thereafter transferred to the dump pit, whereas the centrifugate – to the melt dissolving tank. Wastewater is also evaporated and concentrated before it is fed to the recovery boiler. Sodium tetraborate is added to the cleaned diluted wastewater before it is evaporated.

<u>Achieved environmental benefits</u>
The autocaustization with the use of sodium tetraborate in order to replenish boron losses, simplifies and makes cheaper the transition of plants for the production of BCTMP into a closed water system, which is an extremely important environmental benefit from the introduction of this technique.

<u>Economic aspects of the introduction</u>
The benefits and parameters of the functioning of recovery by sodium tetraborate are:

- there is no need (or at least only a partial need) to divide the process of chemicals recovery into two stages – the stage of lime caustization and recovery. The sodium metaborate, together with the soda, may successfully participate in the cooking process as the alkaline agent.

- this technique is viable when there is a closed chemicals recovery system and a closed water circulation system for the production of bleached CTMP
- the replacement of the caustic with tetraborate in such situations is economically viable. The yearly consumption of $Na_2B_4O_7*5H_2O$ is 10 times lower than the soda consumption, whereas the consumption of tetraborate for the loading of the system before the start-up is about the same, as caustic – a 75 % yield of products as compared to the stoichiometric about 1 kg of $Na_2B_4O_7*5H_2O$ replaces 1 kg of caustic.
- the main losses of boron takes place with the green liquor sludge. If the dewatering and the washing of the sludge are carried out efficiently the boron losses do not exceed 9 %.
- only an inconspicuous quantity of ashes and green liquor sludge are transferred to the dumping site
- the design of the recovery boiler needs only a small modification in connection with some decrease in the calorific capacity of the burned liquor.

The latter also calls for some additional fuel for the ”booster lighting”, however when this is done there is a considerable decrease of the operational costs.

ET-1.7 Selective Non-Catalytic Reduction in the Recovery Boilers.

<u>Description of the technique</u>

The ”NO_x removal process” (NO_x OUT-process) – is one of a few existing processes that use the principle selective non-catalytic reduction (SNCR) in order to reduce the emissions of NO_x. The main principle of it is the thermal reduction of nitrogen oxides to form nitrogen with the aid of ammonium in accordance with the following equilibrium reactions:

$$2NO + 2NH_3 + \frac{1}{2} O_2 \rightleftharpoons 2H_2 + 3H_2O$$

$$3NO_2 + 4NH_3 \rightleftharpoons 7/2\ N_2 + 6H_2O$$

When using urea there is the following primary reaction, as a result of which ammonium is formed:

$$(NH_2)_2CO + H_2O \rightleftharpoons 2NH_3 + CO_2$$

In full-scale trials, carried out in Sweden, a water solution of urea with special additives is used as the reducing agent. The process takes place in the furnace of the boiler, which plays the role of a chemical reactor that does not require any additional equipment in the lower part of the boiler. The reaction usually takes place at a temperature range of around 1000°C. If the temperature is too high, there is a formation of additional nitrogen oxides, and – if it is too low – the formation of ammonium takes the course of unwanted side reactions. In the process of ”NO_x removal” the temperature range is widened and the special chemical additives supress the formation of ammonium as a result of side reactions. The ammonium formed as a result of undesired side reactions as well as the consumption of chemicals are the main parameters for the optimization of the process of ”NO_x removal”.

<u>Status of development</u>
A Swedish sulphate pulp producing company has carried out comprehensive tests of the patented process ”NO_x removal” at one of its recovery boilers. During the test the boiler worked with a load of 95 to 105 % of the design load. The injectors, through which the chemicals were introduced, were installed at several levels. The project showed that the thermal reduction of nitrogen oxides used in the process of ”NO_x removal” may be successfully used in recovery boilers.

<u>Achieved environmental benefits</u>
The analysis, allowing for the stoichiometry 1:1 reflects the following results of the process of ”NO_x removal”;

- the average NO_x (with the use of the process ”NO_x removal” is about 55 mg/Nm^3 (i.e. a reduction of about 30%)
- the inconspicuous ammonium increase – about 3-4 mg/Nm^3 (stoichiometry 1:1).

Depending on the stoichiometry, NO_x is reduced to 50 % (2:1 Stoichiometry), despite of the low concentration of nitrogen oxides even without any processing (however, although this is true, there is usually some increase in the ammonium emissions). In the process of carrying out the comprehensive tests of the method, no deviations or negative effects in the work of the recovery boiler or the chemicals recovery cycle have been established. The total operational costs are relatively low. The needed changes in the recovery boiler may be carried out during its usual outage for technical maintenance.

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Economic aspects of the introduction

The non-recurring expenditures for the introduction of the ”NO_x removal” process in the recovery boiler are approximately 2,2 – 2,8 M Euro. The operational costs for the maintenance of the system include the costs of the chemicals (urea and the chemical additives), electricity and heat used for the condensation of the additional amount of steam from the injection water and labour. Among the mentioned expense items urea cost is the most important factor. It is hard to make a precise evaluation of the operational costs because of the price differences in various parts of the world. However, in Sweden, during the process of testing the method, the urea costs were 154 Euro/ton, whereas the total operations costs, calculated for this recovery boiler, varied between 1,0 and 1,4 Euro/kg reduced NO_x.

ET-1.8 The Removal of Chelating Agents by Modest Alkaline Biological Treatment or its Recovery by use of ”Industrial Kidneys”

Description of the technique

Elevated concentrations of chelating agents (Q) are detected in wastewater from the production o TCF and ECF pulp, if, in the scheme, there are peroxide steps and, consequently, a precedent to the former, Q-step. The analysis of wastewater of a plant, using TCF-technique for pulp bleaching showed the presence of 25 – 40 % Q out of the total load. This corresponds to the content in the wastewater of 10 – 15 mg Q/l at a load of 2 kg Q/t pulp.

In order to reduce the consumption and discharge of Q, used in the hydrogen peroxide bleaching stages, so-called ”industrial kidneys” are used. At the Swedish plant MoDo in Domsjö, a Kemira NetFloc system was introduced in order to recycle EDTA from the effluents of the Q-step. At this company, TCF bleaching was used, and the EDTA consumption was lowered by 65 %. The Kemira NetFloc system proved to be a very efficient means of removal from the filtrate from pulp and paper production processes of such problematic substances, as extractive compounds and heavy metals.

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When introducing this technique the pH of the filtrates is increased and carbonate is added in order to cause precipitation. The metals, associated with EDTA (or DTPA) are eliminated from the complex composition and are settled. In order to achieve flocculation in the collected filtrate, polyethylene oxide (PEO) having a high molecular weight is added and the water solution of this compound is produced in an installation for the production of polymers. The PEO is introduced into the filtrate pipe. The flocculation reaction between the polyethylene oxide and the extractive compounds is concluded before the filtrate leaves the pipe. Lately it has been found that the PEO-resin flakes collect any undissolved compounds in the filtrate. This means that the settled metal salts (for instance, hydroxides, sulphates) as well as other insoluble substances are transferred to the resin sludge. The final operation is the separation of the resin sludge from the filtrate, for instance in the flotation installation. The cleaned filtrate with the recovered Q is used repeatedly in the production process; the resin sludge is either fed to the filter for the separation and washing of the green liquor sludge, or is incinerated, for instance in the bark boiler immediately after dewatering in a press.
The reduced quantity of metals entering the bleaching installation allows for the reduction of the consumption of chelating agents before the hydrogen peroxide bleaching step. Apart from this, the recovery of Q in itself means a reduced consumption of these reagents. The expected level of removal from the system of calcium, manganese and iron as well as extractive compounds, is above 80 %. This system also provides the opportunity to recover 75 % of the Q as well as to reduce the consumption of fresh water for bleaching purposes by as much as 5-8 m^3/ADt.

Status of development
The Kemira NetFloc system for EDTA recovery in wastewater from a bleaching installation is already in use at companies in a few countries.
The capacity to treat ETDA-containing wastewater from the bleaching installation at a treatment plant with the use of activated sludge in moderately alkaline conditions has been confirmed both by laboratory investigations (C.G. van Ginkel, 1997 a+b) and – industrially - at the biological stage of a wastewater treatment plant.

Achieved environmental advantages
At a plant installation for biological treatment of wastewater at a moderate level of alkalinity (pH=8-9), an average reduction of the EDTA quantity in the wastewater of 50 % was achieved (about 10 % at a pH of 7). The results also point to the fact that a pH increase to 8-9 by calcium oxide (batching of about 90 mg CaO/l) does not interfere

with the normal function of the biological treatment by activated sludge. The concentrations of EDTA in the samples with accelerated biodegradation were quite stable (2-4 mg/l). The biodegradation of EDTA increases the nitrogen yield. Consequently, the increased degradation of EDTA in the activated sludge plant is favourable not only in terms of environmental protection, but also as a means of increasing the level of nutrient N, which usually is a deficit in the wastewater from a pulp production plant.

<u>Economic aspects of introduction</u>
Additional expenses for the biodegradation of EDTA in activated sludge facilities at alkaline conditions are mainly caused by the CaO consumption.
There is no data on the economic parameters of the Kemira NetFloc.

ET-1.9 Full System Closure with the use of Industrial Kidneys

<u>Description of the technique</u>
Since it is the mainly the bleach plant which constitutes the open part of a mill, efforts are made to minimize the quantity of lignin, transferred to final bleaching. The collection of filtrates in the recovery system remains a problem zone. The filtrates need to be used repeatedly within the bleach plant in order to limit their volume. This leads to the accumulation of dissolved substances and non-process elements (NPEs) at the bleaching stages also in connection with the problems concerned with the increased consumption of chemicals and the formation of deposits on the equipment. The ”kidneys” used for the treatment of the system in order to remove such substances are indispensable both in the bleach plant and in chemicals recovery.
According to the European Union projects for the development of techniques working in a closed cycle during the production of bleached pulp, research is conducted in the field of a quest for various possibilities of repeated use of the filtrates from the bleach plants, in particular the development of industrial ”kidneys” in order to clean the system.

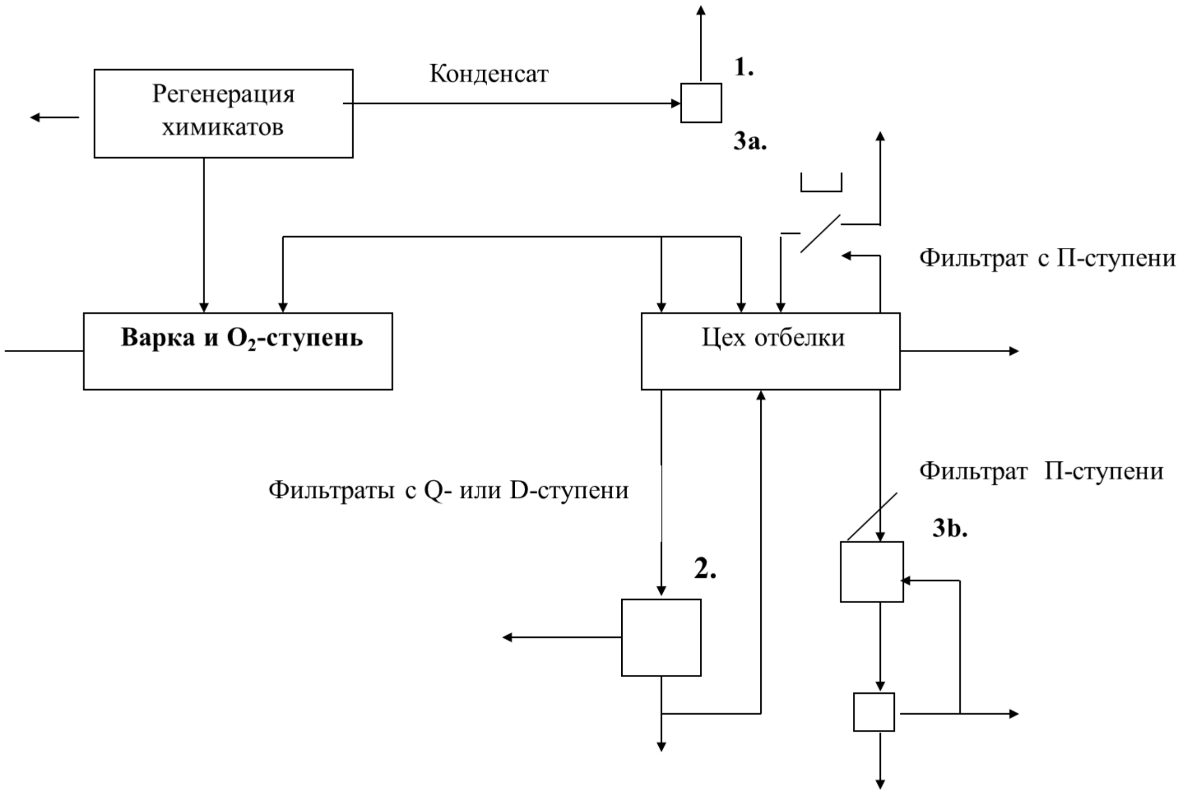

Figure 7.1 – “Kidneys” in development– according to the European Union project for the development of a technique, working according to the principle of a closed cycle during the production of bleached sulphate pulp.

1 The repeated use of condensates from a black liquor evaporation facility as bleaching washing water or as process water. It is important to note that this condensate is used in cases when a low consumption of water has been attained. The main problem is the elimination of smell, arising as a result of the presence of insignificant impurities by odorous sulphur-containing compounds.
2. The acid (Q and D-filtrates) as well as the neutral filtrates of the bleach plant are the main sourced of non-process elements, such as Al, Si, P, Ca, Ba, Mn, etc. and need to be cleaned. The aim is to create steps of crystallization and settling in combination wit a separate evaporation as well as the definition of the best way to use the returned water.
3. As for the alkaline filtrates, the objective is to:
3a) The development of mineral membranes, suitable for very fine filtration (nanofiltration), which may be used in order to reduce the amount of organic as well as inorganic compounds transferred from the peroxide bleaching stage.

Other proposals:
3b) Investigate the possibilities to destruct organic compounds through filtration and biochemical decomposition
In the end, in the case of the integration of the proposed individual methods into one process, simulation methods will be used in order to determine the consequences for the water environment and the consumption of chemicals, and – in some cases – in order to calculate the energy balances. The investment risks will also be evaluated.

Status of development
There are a number of scientific projects concerned with the study of various aspects of system closure.
In the concept of a company with a closed circuit for the production of bleached pulp one might find zones, where new techniques may be introduced which would facilitate the attainment of this objective, as well as zones, where a modernization would suffice. A fully closed-circuit production of bleached pulp, giving the company the theoretical possibility to become environmentally clean, is still impossible because of the accumulation of non-process elements, which enter the production process, mainly mostly with the wood, but also with the chemicals and process water. These elements accumulate and must be purged out of the system.

Achieved environmental benefits
The intention of the modernization actions directed towards the development of a plant with a closed cycle is the virtually full cessation of the discharge of organic and inorganic compounds into the water environment as well as the minimization of the leakage of energy released within the system.

Economic aspects of the introduction
No available information.

A description of emerging techniques for Russian Sulphite and Neutral Sulphite Pulp (ET-2)

ET-2.1 Ozone Bleaching (see ET-1.1)

ET-2.2 Chlorine-free Bleaching Technique (see ET-1.2)

ET-2.3 Partial and Full Closed-Loop Bleaching (see ET-1.3)

ET-2.4 Enhanced Production of Electric Power based on Biomass Products and the Utilisation of Excess Heat (see ET-1.5)

ET-2.5 The Removal of Chelating Agents by Modest Alkaline Biological Treatment or its Recovery by use of "Industrial Kidneys" (see ET-1.8)

ET-2.6 Full System Closure with the use of Industrial Kidneys (see ET-1.9)

ET-2.7 Delignification by Hydrogen Peroxide in the Presence of a Catalyser in an Acid Environment

Description of the technique
This method allows for a deep delignification after washing of both sulphate and sulphite brown stock. The content of the residue lignin after the acid peroxide treatment is comparable with the lignin content after the chlorination step or the first chlorine dioxide step.

Status of development
Industrial full-scale experimental level.

Achieved environmental advantages
The filtrate from the washing of the pulp after acid peroxide delignification may be sent to the countercurrent washing of unbleached pulp, which would provide the possibility to a

considerable reduction of the consumption of chemicals for bleaching purposes, AOX formation in the bleaching process, as well as the content of organic compounds in the effluents of the bleach plant. The hydraulic load to the evaporation plant is not increased, which leads to the lowering of the heat consumption per product unit.

Economic aspects of introduction

Economy of chemical reagents for bleaching purposes.

A Description of Emerging Techniques for Russian Producers of Mechanical Pulp (ET-3)

ET-3.1 Bleaching of Mechanical Pulp Using Hydrogen Peroxide

Description of the Technique

The technique for mechanical pulp bleaching differs essentially from the chemical pulp bleaching process, since its foundation is the principle of lignin retention, not removal, as in the case of cooking of bleaching of chemical pulp. The groundwood pulp bleaching is carried out through the transition of the chromophore groups of the lignin into the colourless form. In that way, when increasing the brightness, the fibre yield is minimal. The process of bleaching while retaining the lignin is performed in 1-2 steps depending on the level of desired brightness. The mechanical pulp bleaching process differ, depending on the type of reagent used.
The yield drop when using peroxide bleaching is approximately 2 %. This is mainly due to the fact that the alkaline environment maintained in the process of bleaching, leading to the increased amount of soluble organic wood material, in turn leading to the increased load on the treatment plant.

Status of development
This technique has been introduced at a number of companies.

Achieved environmental benefits
The use of a unbleached pulp washing step before it is bleached is an efficient method for the reduction of its content of metals, and, in this way, it also provides the opportunity to lower the consumption of expensive chelates. The modern peroxide bleaching process proceeds at a pulp concentration of 25-35 %.

Economic aspects of introduction

Peroxide bleaching influences the properties of the pulp and – apart from the higher brightness – it increases the mechanical strength of the pulp while also decreasing the content of extractable substances and improving the water balance. If the maximum allowed – seen from an economical viewpoint – amount of peroxide is used, it is possible to increase brightness by 20 units – up to 78 – 84 % ISO. If, in the system, heavy metal ions are present, the mechanical mass is less bright and, furthermore, there is a higher consumption of peroxide as a result of its partial disintegration. This is why one adds chelates before the bleaching process (for instance EDTA or DTPA) in order for stable complexes to be formed with heavy metals (Fe, Mn, Cu, Cr). This makes possible the exclusion of any reduced pulp brightness as well as any destruction of the peroxide. EDTA and DTPA contain nitrogen, which as a component of these two chelates ends up in the wastewater.

ET-3.2 The Thermopulp Process

Description of the technique

This process at the first milling step involves comparatively low temperatures (120 – 125°C) and SEC value (500-600 kWh/ton). The pressure and temperature are increased before the second grinding step, and reach very high levels – up to 700 kPa and 170°C. Available information tells us that the use of this process allows for an energy economy of 10 – 20 %. When using this technique the decrease in energy consumption is accompanied by an insignificant lowering of the tearing strength (by approximately 5-6%) and brightness (60 % ISO instead of 62%).

The main characteristics of the RTS technique as compared to the traditional technique are the reduced duration of the hydrothermal processing of the chips, however at a higher temperature, above the lignin glass transition temperature, and also by 1,7 – 2 times higher rotation rate of the refiner discs in the first grinding step.

The *Thermopulp* technology is characterized by the relatively low chip temperature and low-intensity grinding at the first step, while the pressure and temperature are high in the second grinding step.

The *APMP* technology for the production of bleached CTMP using peroxide bleaching in an alkaline environment as well as its modification – the *P-RC- APMP* technique,

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are defined by the presence of one to three steps of intense impregnation of the chips by an alkaline solution of hydrogen peroxide through the initial replacement from it of air and water through the intensive mechanical compression in special impressafiner machines. The two-step milling is carried on at atmospheric pressure with a washing step between the milling steps. The bleaching is carried out as the pulp moves forward along the production flow in the absence of bleaching towers. When using the *PRC-APMP* method, part of the bleaching chemicals are introduced into the first step refiner, as a result of which the energy and chemicals economy is improved. Furthermore, after the first step refiner there is a high concentration pulp pool for a more complete bleaching process.

Main and side production effects

If the main effect from the introduction of the *RTS* and *Thermopulp* methods is a considerable energy economy for grinding purposes, then – as a side effect – one could also point out the higher mechanical properties of the pulp (by 6 - 11 %), the reduced quantity of waste an especially coarse fibre and shives as well as the reduced quantity of extractive substances. When using the APMP process the main effects are the possibility to do without any bleaching towers as well as the low energy consumption, especially for the grinding process. The side positive effects are the higher bleachability of the fibre, the versatility of the process through the variation of the caustic and peroxide consumption. There are – however – also negative side effects; the higher bleaching chemicals consumption, the possibility of deposits forming on the working surfaces of the refiners as a result of the use of sodium silicate, the higher energy consumption of the impressafiners as well as their higher wear.

Status of development

This technique has been introduced at European plants.

Environmental aspects

The slightly higher yield as well as the reduction of the amount of waste lead to reduced losses of fibre with the wastewater, and also the lowering of the COD content of the wastewater. When applying APMP, the yield is also increased due to the higher retention of lignin, which also lowers the COD content of the wastewater. The exclusive use of oxidation peroxide bleaching excludes the possibility of sulphur compounds presence in the wastewater.

The reduced consumption of electric energy immediately leads to the burning of less quantities of fuel when producing electricity, and, by the same token, to the reduction of the emissions to the air of carbon dioxide, NO_x, as well as ash in the form of solid waste.

Environmental aspects

The reduction of the energy consumption for milling purposes by 15 – 25 %, the lowered capital and operational costs (when using the APMP process - lowered by 25 %, mainly through the absence of bleaching towers), the higher competitiveness of the produce on the market thanks to the improved properties.

Incentives for the introduction of these techniques

The main incentive for the introduction of these techniques is the lower consumption of energy, the lowering of the capital and operational costs, the improvement of the pulp quality, the higher yield as well as the improvement of the environmental parameters of the wastewater.

ET-3.3 Introduction of RTS TMP-CTMP Production Techniques from Softwood (see 4.3.3)

ET-3.4 Introduction of Alkaline-Peroxide TMP-CTMP Production Techniques from Hardwood (see 4.3.4)

ET-3.5 Introduction of Alkaline-Peroxide TMP Production Techniques from Softwood (see 4.3.6)

ET-3.6 The Removal of Chelating Reagents through Biological Treatment at Low Alkalinity or with the Use of ”Industrial Kidneys” (see ET-1.8)

ET-3.7 Full System Closure with the use of ”Industrial Kidneys” (see ET-1.9)

ET-3.8 Biosorption on Excess Activated sludge

Description of the technique

This method was developed by KWI.

The excess activated sludge of the biological wastewater treatment equipment has a good sorption capacity in respect to the difficult-to-oxidize high molecular weight organic compounds. The method works as a local treatment of wastewater of the wood preparation plant, of the alkali extraction step after the first bleaching step, as well as of the concentrated CTMP wastewater. The best application of the method is the combination of biosorption and flotation. In this case the coagulation and the flotation may be carried out without the use of chemicals (coagulants and flocculants).

<u>Status of development</u>
Industrial full-scale experimental level

<u>Achieved environmental advantages</u>
The COD reduction efficiency reaches 50 %. At this, a higher effect is observed in respect to difficult-to-oxidize-by-biological-methods organic compounds. The organic compounds, absorbed by the sludge, after a joint flotation step, through the formation of capillaries out of the small air bubbles is dewatered easier than after settling.
A considerable reduction of the entering of organic compounds into the biological treatment system, which considerably increases the total efficiency of the treatment plant in respect to COD and BOD reduction.

<u>Economic aspects of the introduction</u>
The reduced load to the biological treatment plant permits the increase of the efficiency of the main production without any reconstruction of the biological treatment plant. The use of this technique as a local treatment of high-concentration wastewater allows for the considerable increase of the level of water circulation through the use of treated wastewater instead of fresh water.

A Description of Emerging Techniques for the Production of Paper and Board (ET-4)

ET-4.1 The Reduction of Water Consumption and Specific Discharges when Constructing the Maximum Possible Closed Recirculated Water Circuit.

Description of the technique

In order to reduce the consumption of fresh water and to reduce the discharge of wastewater removed from paper grade pulp in the process of sheet formation at a paper or board machine, the water is used in the form of whitewater at the stage of dissolution of the fibre intermediate products under dissolution of the pulp before the screening processes as well as the regulation of the concentration of the paper grade pulp.
Depending on the place of generation and content of suspended and dissolved compounds, the whitewater is divided into three flows (cycles).
The first water flow is formed by the register water from the paper sheet formation zone of the wire section, enriched by fibre and filler. This water is transferred, without clarification, to be diluted in the pulp preparation section and to the paper/board machine flow.
The second water flow (from the suction box, the couch roll, the press section and the wire cleaning section) contains two to three times less suspended matter than the register water, This water is transferred to the local internal workshop treatment station, after which the clarified water is used in the production process together with the fresh water. The trapped fibre from the local treatment station is returned to the flow.
The second flow water contains the surplus recirculated water from the secondary cycle (from the cleaners, screens, etc.). Because of the high level of pollution it is transferred, as wastewater to the chemical-mechanical and/or biological treatment at the treatment plant of the company.
The advantage of the use of such technique is the reduction of losses of raw material and energy as well as the reduction of the volume of wastewater and the consumption of freshwater.
The described techniques are introduced at many European and North American paper production companies.

Status of development

Measures for the reduction of water consumption may be carried out both at already existing and at companies in the process of being established. However, the division of the water systems of the pulp and paper production at integrated companies or the high degree of closure of the water system are more expensive measures for existing companies, since, in order to construct a closed water system, most probably, it is necessary to the construct a piping system as well as a major refurbishment of the wet part of the paper machine.

Achieved environmental benefits

Depending on the initial technical condition of the company the attainable levels of fresh water consumption for various types of paper are:

- Newsprint: 8 – 13 m^3/ton
- High quality uncoated paper: 5 – 12 m^3/ton
- High quality coated paper: 5 – 15 m^3/ton
- Thin coated paper: 10 – 15 m^3/ton
- Supercalendered paper: 10 – 15m^3/ton
- Multi-layered fluted paper: 8 – 15 m^3/ton (from primary fibre)
- Sanitary and hygienic types of paper: 10 -15 m^3/ton (from primary fibre; high-per-square-meter weight products or low-grade types of paper); 15 – 25 m^3 (from primary fibre as well as low-per-square-meter weight paper or high-end quality paper)

Economic aspects of the introduction

There is no general information on the structure of the costs for the development of closed water loops, since every company is a separate case in this respect. The expenditures mainly depend on the technical characteristics of the companies and the local conditions. The costs of the measures depend in every concrete case on the level of reconstruction of the main and ancillary equipment.

ET-4.2 The Optimization of the Wastewater Treatment Scheme Using New Local Treatment, so-called Industrial Kidneys.

Description of the technique.

Traditional filtration does not allow for the efficient removal of suspended and colloidal matter with an efficient size of less than 1 µm. Thus, small bacteria as well as colloidal particles pass through the filter. Membrane techniques, depending on the pore size of the membranes (approximately corresponding to the ”molecular weight” of the organic compounds to be removed) and the pressure of the filtration, are capable of removal of almost 100 % of the organic matter without the use of any undesired compound in the water environment.

Depending on the size of the pores of the membranes, the membrane processes are divided into microfiltration, ultrafiltration and nanofiltration.
One drawback of the membrane filtration methods is the fact that none of them has the capacity to cope with any sudden peak loads of suspended matter.
The main aspects, influencing the choice of membrane technology are: The parameters of the entrance flow, the necessary quantity and quality of the treated water as well as the requirements to the technical maintenance.
When considering these aspects, ultrafiltration may be used as an artificial kidney, cleaning the whitewater and the additional water system closure.
The artificial kidney for the treatment of whitewater in the production flow may consist of a disc filter, arch sieves as well as an ultrafiltration system. The preparatory filtered whitewater is transferred to the feeder tank of the ultrafiltration system. The capacity to treat water depends on the number of filters in use. The pressure drop is kept at an as low as possible level, 0,7 – 0,8 bar. The quality of the filtrate is relatively high in order to give the possibility to use it, for instance in the shower system or in order to concentrate or dilute chemicals used in the paper machine. The concentrate from the filter may be transferred to the main treatment plant.
The process of ultrafiltration (in order to keep the pumps running) requires 2,6 kWh of electrical power per 1 m^3 treated recirculated water. There is no information as the a comparison of the environmental parameters of the functioning of the biological treatment systems with the use of activated sludge as the systems using the integrated UV and biological treatment of the concentrates. In order to perform the membrane filtration, the crucial problem is the one concerned with the processing of liquid and solid waste.

<u>Status of development</u>
Industrial trials of membrane treatment techniques, especially the treatment of recirculated paper and board machines have been conducted only at a few companies in Europe.

<u>Achieved environmental advantages</u>

UV membranes remove practically 100 % of the SS, 99 % of the bacteria, 100 % of the turbidity (all colloidal material is removed), 45 – 70 % of the anions. COD for dissolved matter is lowered approximately by 10 – 20 %. The membranes are subject to recycling upon the expiration of the performance life. There is no technique for the recycling of them.

Economic aspects of the introduction
The capital expenses when using membrane filtration for whitewater are approximately 0,3 Euro/m^3 (this corresponds to the capacity of 5 000 m^3/day of treated whitewater). The ordinary maintenance as well as preventive and predictive maintenance (membrane change and work hours) – around 0,05 Euro/m^3, electrical energy costs: 0,07 Euro/m^3, the costs of washing chemicals – 0,02 Euro/m^3. The total operational costs are approximately 0,14 Euro/m^3

Reference materials: RAO Bumprom materials, 2005.

ET-4.3 Increased Dryness of the Paper Sheet after the Press Section of the Paper Machine with the use of New Pulp Dewatering Technology

Description of the technique
When dewatering the paper sheet in the press section of board/paper machines, equipped with presses with ordinary press sections, the pressure in the press nip, when attaining its upper limit, provides the dryness of the paper sheet within the range of 45 – 50 %. In order to raise the dryness of the paper after the press section of the paper/board machine presses with increased press sections, so-called shoe presses are used, providing intensified dewatering of the paper sheet in the pressing section and thus increasing the dryness of the sheet. In such a press one roll is loaded against a counter roll by a hydraulic mechanism.
The construction of a shoe press provides the possibility to substantially extend the pressing zone as well as the contact time in the nip, as compared with traditional presses. The higher dryness after pressing provides energy economy, improves the passing of the sheet through the dryer due to its increased strength.

Status of development
The shoe press is used both in new and existing paper machines for the production of most types of paper.
Beginning in 1997 all high-end paper machines are equipped with shoe presses. In 1998, in USA, a paper machine was taken into operation for the production of high-end quality paper with two shoe presses.

In the field of production of testliner as well as fluting paper in Germany, the following facilities are well-known: Papierfabrik Adolf Jass/Fula, Papierfabrik Kingele/Weener, Papierfabrik Schoellershammer/Dren, Paper- och Kartonfabrik Varel/Varel, SCA packagen Industriepaper/Asshivesenburg.

Achieved environmental advantages

The dryness of the sheet after the pressing section is increased by 3 – 12 %. The savings of the specific consumption of steam in order to dry the paper are 20 -30 % and, the corresponding reduction of emissions to air as well as an increased productivity – up to 30 %.

Economic aspects of the introduction
The capital expense for the installation of a shoe press in a paper machine with the width 5 m is about 10 M Euro (including installation work). The operational costs, including the felts, covers and grinding, the drive energy for a shoe press are roughly identical to the costs of an conventional press. The savings of steam in the dryer amounts to between 10 to 15 Euro/ton steam, which, at a specific steam consumption of 2 tons of stem/ton paper and savings between 20 -30 Euro/ton paper.
In press rebuilds, the typical repayment period of the investment is about 2.5 years, if there are not further limitations for the increase in machine speed.

ET-4.4 Recovery and Recycling of Wastewater from the Paper and Board Coating Process

Description of the technique
In the process of production of coated types of paper and board, pigments, dyes and binding substances end up in the wastewater. The recovery and recycling of the clarified wastewater from the coating kitchen and the installations for the application of coating reduces the amount of solid waste by as much as 70 %, which guarantees, at the same time, the reduced consumption of chemicals used for the preparation of the coating paste as well as some reduction in the water use.
The ultrafiltration system includes a membrane filter, tanks, piping, shut-off and regulation fittings as well as instrumentation and controls.

Status of development

Lately a few coating installations have been put into operation for the production of high-end coated paper, with facilities for the treatment and recovery of the solid waste from the coating procedure.

Achieved environmental benefits.

The reduction of the content of solid waste in the wastewater from the coating facilities by up to 70 % as well as the increased level of use of the clarified recirculated water and the reduced load to the treatment plant.

Economic aspects of the introduction

The costs for one plant with the capacity of 200 – 400 m^3 per day is about 0,5 – 1,5 M Euro. The operational costa are 0,1 M Euro.

ET-4.5 Pretreatment of Effluents from the Paper and Board Coating Process.

Description of the technique

The effluent biological treatment system functions are facilitated, and there is the possibility of a repeated use of the clarified filtrate. There is a reduction of the operational load to the treatment plant as to the total suspended solids, there is a lower probability of accidental spills of suspended solids and there are fewer interruptions of the work or the primary clarifier.

The equipment consists of an equalizing basin, a multi-stage screen filter, a mixing unit and a laminar settling tank.

Status of development

Partly introduced

Achieved environmental advantages

The sediment from the thickener is recovered.

<u>The economic aspects of the introduction</u>
The costs for a local wastewater treatment system of the coating process by means of flocculation: 1,2-1,4 M Euro/thousand tons. The operational costs are 75 – 150 thousand Euro/year, excluding landfill costs.

ET-4.6 Paper and Board Sizing

<u>A general description of the technique</u>
In international practice the following group of best available technology of paper and board sizing has formed:

- a pseudoneutral sizing technique with the use of disperse resin products.
- neutral sizing with the use of disperse a alkyl ketene dimer (AKDs)
- neutral sizing involving the use of alkenyl succinic anhydride (ASA)

<u>Status of development</u>
In Russia at present three versions of the abovementioned techniques have been introduced.
In order to introduce pseudoneutral sizing, mainly a fortified resin dispersion unit named Sacocell 309, produced by Kemira, is used. The pseudoneutral technique replaced the traditional acid technique. The Sacocell glue batching equipment is extremely simple: the supply tank and the batching pulp with a flow indicator.
In order to introduce the AKD, sizing AKD of the following companies is used: Hercules, Kemira and Akzo Nobel. During the past 2 years the company SKIF as built up a production of AKD dispersions quality-wise on par with the international analogous products. The products of this company with the name Ultrasize is at present slowly replacing the products of the abovementioned companies. The equipment for the proportioning of AKD is extremely simple: a supply tank and a standard batching pump with a flow meter.

<u>Environmental aspects</u>
Pseudoneutral sizing has enabled, mainly, the minimization of the consumption of aluminium sulphate. If a company with conventional rosin sizing would consume 25 – 40 kg aluminium sulphate per ton paper, then the transfer to pseudoneutral sizing would allow for a consumption of 7 – 21 kg/ton. The consumption of the rosin product was also reduced from 9 – 25 kg/t to 6 – 16 kg/t. Furthermore, the companies started to make their products at a pH of 5,5 – 6,5, instead of 4,3 – 5,5. Consequently, there was a reduction of the sulphate ion concentration in the process water and wastewater.

<u>Economic aspects of the introduction</u>
There are many options of the AKD sizing process, however the most widespread involves the following chemicals: cationic starch of an intermediate level of substitution, which is introduced into the thick paper grade pulp to the amount of 5 – 7 kg/ton, after which calcium carbonate is introduced, and, after that, a AKD dispersion, and, finally, before the mixing pump and into the recirculated water either silicium dioxide, 1 – 4 kg/t or bentonite, 1 – 4 kg/t. Sometimes polyaluminium chloride is introduced into the recirculated water at the amount up to 1 kg/ton. The equipment used for this technique is the following:

- an automated jet cooker, boiling the starch in an automated mode, according to a pre-set sequence. Jet cookers are produced by a number of companies (for instance BVG, Germany, Valmet-Raisio, Finland, Cerrestar (Germany) and others. In Russia, there is no production of jet-cookers.
- tanks with mixers and pumps for the preparation of a calcium carbonate suspension and the feed of it to the stock;
- a supply tank with mixers and a batching pump for the feed of AKD into the stock
- a supply tank with mixers and a batching pump for the feed of Silicium dioxide into the stock
- an automated facility for the preparation of a bentonite suspension and the feed of it into the stock,
- a supply tank with mixers and a batching pump for the feed of polyaluminium chloride into the stock

The main advantages of the AKD sizing instead of rosin sizing:

- the paper is produced in a weak alkaline environment, which to a considerable degree promotes ageing resistance.
- it is possible to produce paper with a high content of filler, while refraining from the use of kaolin and replace it with the cheaper calcium carbonate, which also to a lesser degree affects the mechanical strength of the paper.

- The consumption of AKD suspension is considerably lower (2 – 5 kg/t) than the consumption of rosin size, and there is no need for the use of aluminium sulphate.
- This technique is extremely environment friendly, since the wastewater contain only suspended matter.

This sizing method is gradually replacing the ASA sizing method at large plants, since it is even more cost-efficient.
In order introduce ASA sizing ASA is used – oils from various companies: Kemira, AkzoNobel and others. This technique is quite steadily spreading at Russian companies, since it involves the possibility to produce the needed absorptive capacity at a consumption of ASA oils of 1,0 – 1,5 kg/o. It is cheaper than the dispersed AKD sizing method. However the use of ASA calls for the combination of special units of equipment:

- A cooker for the preparation of the special cat ion starch for the emulsification of the ASA
- An emulsifier, in which with the aid of which the ASA oil starch solution is converted to a thin emulsion, which directly is transferred to the feed point. This technique may be regarded as best available sizing techniques based on its higher cost efficiency (ASA is cheaper than AKD and the preparation of ASA emulsions at the plant is cheaper than the preparation of the AKD at the supplier's) and environmental safety. As for all other parameters this technology does not differ too much from AKD sizing.

ET-4.7 Strengthening of Paper and Board

Description of the technique

The strengthening of paper and board in the stock in Russia is mainly performed using board starch from various companies. The following companies supply strengthening starches: Raisio (Finland) and Ibredkrakhmal (Russia).
In order to strengthen the stock, cationic starches, preferably of an intermediate substitution degree, are introduced into the stock. The consumption of starches is 4 – 12 kg/t. In order to prepare the starch solutions at major companies (for instance Segezha TsBK) automatic jet cookers from various suppliers are used. The 2 % starch solutions, cooked at 125°C, are fed into the supply tank and, from there, are transferred to the batching points.

The jet cooker has the capacity to carry out the automated cooking of starch in the temperature interval 110 – 165 °C. The productivity of the equipment may reach 1 – 2 t/h, which is sufficient to supply a paper machine with the capacity 200 – 300 t/h. At that, such equipment units occupy an area of no more than 20 m^2. One highly important advantage of starch cooking in a jet cooker is the practically full absence of dust, the very small losses of starch (less than 0,5 %) and ease of process control.

Status of development

It has been introduced industrially.

Environmental aspects.
The technique of cooking starches for the strengthening in the cookers may be regarded as a best existing technique, since this technique all but fully excludes heavy manual labour, while the produced starch solutions have the same concentration.

Economic aspects of introduction
There is no need for any large tanks for the storage of the process starch solution. It is not necessary to have a special operator. These advantages of this technique have exercised such a strong influence on industrial engineers, so that, nowadays, the jet cookers have been distributed widely at the absolute majority of contemporary companies, where it is necessary to cook the starch continuously.

ET-4.8 Regulation of the Retention of Components of the Paper-grade Stock on the Wire of the Paper Machine

Description of the technique
In order to retain components of the paper-grade pulp during the formation of the paper sheet at the forming tale, the following more or less advanced retention system options.

- The Compozil system (a combination of cation starch and silicium dioxide)
- A system that combines the cation starch with anionic bentonite
- A system that combines cationic polyacrylamide and bentonite

The Compozil system involves the processing of the pulp by the successive introduction of cationic starch and silicium dioxide. The equipment for the execution of this system is extremely simple, apart from the jet cooker for the cooking of the cation starch. In Russia, this system has been introduced mainly by specialists of Eka Nobel.
The system, which combines the cation starch with a bentonite suspension, involves the successive introduction into the pulp of first a starch solution, and, then bentonite. This system has one evident advantage over the Compozil system. The bentonite powder is brought to the plant in a dry form, which is especially important for Russia, where sub-zero temperatures (incompatible with water silicium dioxide water dispersions) are commonplace. For the best technique option in this case it is indispensible to have a jet cooker in order to cook the starch and the automated facility for the preparation of the bentonite suspension. Such a system is used, for instance, at the Mondi mill in Syktyvkar. The system is very compact, extremely lightweight, and reliable. Such a system may work for years without repair. Using this technique makes it possible to reach a fairly high level of retention (up to 82 %) at minimal costs on chemicals.

<u>Status of development</u>
All these retention systems are introduced mainly at the major mills. At smaller and medium-size companies either simple single-component systems, or multi-component systems based on polyacrylamides (Kemira) are used.
The system, combining the cationic polyacrylamide and bentonite is at the industrial full-scale experimental level. As opposed to the cation starch-bentonite system, this system requires, apart from the jet cooker, an automatic facility for the preparation of the polyacrylamide solution. Such facilities are supplied by Kemira, Nalco and others.

<u>Environmental, aspects</u>
Through the increased retention of pulp components in the wire section of the paper/board machine, there is a reduction of the content of suspended matter in the pit water, and – correspondingly – a lower load on the treatment plant.

<u>Economic aspects of the introduction</u>
The higher speed of the dewatering of the paper sheet in the wire section. The higher retention of the fine fibres and filler reduces the load on the treatment plant,

thus saving energy due to the transfer of lesser amounts of wastewater to be treated.

A Description of Emerging Bio techniques and other Techniques, Based on new Physical and Chemical Methods (ET-5)

ET-5.1 Biobleaching of Sulphate Unbleached Pulp

Description of the technique

During the preprocessing of sulphate brownstock by xylanases, the bleaching process develops noticeably more intensively. This makes possible the development of a bleaching technique that allows for the possibility to entirely rule out the use of elemental chlorine and to fully switch to bleaching by chlorine dioxide and hydrogen peroxide. (or a bleaching technique where the consumption of chlorine dioxide is lower by 15 – 20 % and caustic by 10 – 15 %). Xylanases are efficient also in oxygen-alkaline bleaching. All this factors have led to the sharp decrease of the dioxin hazards. At present, in Finnish plants, producing sulphate brownstock, xylanase enzymes are used, whereas there is no use of elemental chlorine. The xylanase enzyme consumption is 100 – 300 g/t of pulp depending on the enzyme efficiency and the prerequisites of the pulp flow for the use of this technique.

The main principle of the technique lies in the following:

- After the washing and thickening stages small amounts of acid is added to the pulp in order to set the pH to the necessary level after which 100 – 300 g/t pulp xylanase is added. After this, in a separate tower, during 30 – 90 minutes at a temperature of 50 – 70 °C a fermentation is carried out, after which, without separating out the products of the decomposition, the pulp is transferred to be bleached by chlorine dioxide. The batching of the enzyme preparation permits the use of a very simple equipment set-up.

Status of development

At present, the use of xylanases for the bleaching of pulp is practiced at many companies. The enzymes are produced from culture liquids, mainly containing fungi and bacteria. The efficiency of the enzyme preparation depends to a great degree upon the technique used for the preparation of the mixture and the presence of other enzymes. In Finland as well as in other countries, xylanases are used for the bleaching of hardwood sulphate unbleached pulp as well as softwood – mainly for environmental reasons.

The biobleaching process spreads step by step over the world. At present, except for Finland, this process has been introduced at a number of plants in Canada, USA, Sweden and others.
In Russia, the biobleaching technique has been introduced as pilot projects at 2 companies: Xylanases for bleaching purposes are supplied by Banmark. The consumption of enzymes per ton pulp is up to 300 g.

Environmental aspects
The xylanase technique allows for the savings of 15 – 20 % of the expensive chlorine dioxide, the consumption of caustic by 10 – 15 % as well as for the almost total exclusion of the formation of chlorinated lignins, which, once entering wastewater, comprise a source of extremely poisonous dioxin substances.

Economic aspects of the introduction
The use of xylanase reduces the consumption of chlorine dioxide by 15 – 20 % and allows for the exclusion of the use of elemental chlorine, thereby sharply increasing the safety level of the bleaching technique as well as the environmental safety of the wastewater from the bleaching production.
The equipment used for the batching of enzymes is extremely simple: to a 1 m^3 container a batching micropump with a flow gage is connected.

ET-5.2 Biodeinking (Paper/Board Production from Waste Paper)

Description of the technique

Deinking is the process of removal of printing dye from waste paper during the processing of it into fibre pulp. In a standard set- up of the deinking technology the following is used: 1 – 3 % caustic, 1 – 3 % sodium silicate, 0,5 – 1 % hydrogen peroxide and approximately 0,5 % surface active compounds per 1 ton of produced fibre. The processing of waste paper using such a system leads to heavy contamination and mineralization of the process water, the treatment of which require substantial expenditures. Furthermore, the classical system of deinking is not very efficient when processing office waste paper, where the toner has emerged deep into the paper and even into singular fibers. Moreover, the classical deinking system has quite one weak spot – i. e. the disintegration of the dye particles in the mechanical processing of the fibre pulp. As a result, there is an increase in the share of

very dispersed dye particles that are not very susceptible to foam flotation and not easily removed from the fibre stock.
The use of cellulase intensifies the process of dye removal from the surface of the fibres in the absence of other chemicals and during a mild mechanical impact on the separated print colour, and – in particular – the toner. Research has shown that if conditions, favourable to the hydrolytic impact of the enzymes on the fibre matrix are established, then an efficient deinking process is possible by means of enzymes exclusively, without adding alkali or other chemicals.

Status of development
At present, the bio-deinking process in a number of cases has been taken to practical use, and it may be regarded as the best alternative to the classical deinking process.

Environmental aspects.

The process is attractive due to the sharp decrease of the resource-intensive deinking process as well as the sharp decrease of the mineralization of the process water. It is especially important that this process may be carried out without the use of traditional highly alkaline chemicals: sodium silicate and caustic.

Economic aspects of the introduction

Bio-deinking does not require any complicated or expensive equipment. The process may be carried out in ordinary tanks with a moderate level of mixing.
The main principle of the process of bio-deinking: 300 – 500 g/t cellulase is added to the fibre stock wit a maximum concentration of 6 – 15 % and a temperature of 60 – 60 °C and fermentation is going on at a low level of mixing for 30 – 90 minutes. Thereafter the pulp is diluted to the needed concentration and transferred to the flotation plant.
Research has shown that bio-deinking might very well compete with the classical type of deinking as far as the removal of dye goes, however as to the environmental and economic efficiency, it is superior to it. Since the batching of the enzyme is not too large, there is no need for any special equipment for its storage and batching. The enzyme preparation is supplied in 1 m^3 containers and is set-up in a convenient place close to the batching point. To carry out the batching, a standard batching micropump with a flow-rate meter is applied.
The bio-deinking technique allows for the reduction of the fibre losses with the flotation froth, the abandoning of the use of large quantities of environment unfriendly

chemicals (20 – 40 kg/t) as well as the production of a merchandize with a lower production cost. The used enzyme preparation based on cellulase is an absolutely harmless biodegradable product.
At present, cellulase for bio-deinking purposes is produced by a number of companies. In Russia, bio-deinking is not yet applied, mainly because of the fact that deinking as such is absent (only a small plant is operating at the Kamenogorsk Paper Works). However within the next 4 – 5 years the development of deinking is inevitable. As a consequence of this, there will be a need for cellulases as well.

ET-5.3 The Enzymatic Decrease of Resinous Problems.

<u>Description of the technique</u>
The problems concerned with resins (resin deposits on the equipment) are caused by adhesive resins present in the wood. The resin deposits are characteristic both for softwood fibre intermediate products and for hardwood ditto, although as to the composition of adhesive compounds the softwood and hardwood species differ substantially. The most striking demonstration of deposits of resins occurs when processing softwood, cooked by the sulphate method. Resin deposits occur in the production of groundwood pulp from softwood.
The main reason why softwood species contain adhesive resins is the presence of fatty acid triglycerides. If these triglycerides are decomposed, the deposits of resin on the equipment are reduced sharply. The use of lipase and enzymes that decompose the triglycerides into fatty acids and glycerine has proved to be efficient. The resin deposits were sharply reduced. This technique has been practiced in Japan in the production of groundwood from softwood.
The main principle of the technique: A water solution of lipase is batched into the fibre stock (preferably at an elevated temperature) in a quantity of 100 – 300 g/t with a batching micropump from a plastic 1 m^3 container. The adhesive quality of the resin is sharply reduced.
This technique, together with the technique of adsorption blocking of harmful resin by talc may be considered the bets technique, since it is extremely simple and absolutely safe as far as the environment goes.

<u>Status of development</u>

This technique is under development.

Only a few companies, for instance Novozim, produce lipase for the reduction of the problems concerned with resins.

ET-5.4 Enzymatic Decomposition of Starch during the Preparation of Sizing Solutions for Sizing Presses.

Description of the technique

For the surface sizing process of packaging material as well as for mass production of printing paper and office paper modified starches are used. This modification is directed towards a decreased viscosity of the sizing solutions and the improvement of the binding potential of the starch coating.
There are a few schemes for the implementation of the process of producing modified starch for the preparation of a sizing solution:

- modified starch is bought from a modified starch manufacturer in paper sacks containing 20 – 25 kg; the starch is subjected to cooking in a batch- or continuous-type (jet cooker) cooker and the produced solution is transferred to the sizing press.
- native starch is subjected to oxidative cooking at the plant itself (oxidation with hypochlorite or ammonium persulphate) and the produced starch solution is transferred to the sizing press;
- native starch is subjected to an enzymatic decomposition by alpha amylase in a special apparatus, where this process is carried on automatically according to an especially developed program.

Experience has shown that the best technique is the automatic production of the starch solution by means of hydrolytic decomposition by alpha amylases. This technique has the following advantages over other existing techniques:

- The consumption of alpha amylases is insignificant (a few hundred grams per 1 t) which makes the modification cheap
- The alpha amylase is an absolutely harmless non-chlorine product and does not pose any potential threat (as opposed to sodium hypochlorite)
- The automatic process according to a set program guarantees the production of a solution with stable properties and minimal losses of starch (less than 0,5 %).

When we discuss the best technique for the biodegradation of starch in order to produce the sizing solution for the sizing press, we have in mind the combination of the following best elements:

- alpha amylases
- equipment (facilities) for the accomplishment of the decomposition process
- process software
- technical and environmental safety of the process and equipment

<u>Status of development</u>
At present, the facilities and techniques for the enzymatic decomposition of starch is offered by a few companies such as Metso Paper, Ciba-Raisio, Cerestar, BVG and others. In Russia, the enzymatic starch decomposition technique for surface processing is used so far, in two mills, International Paper and Mondi Syktyvkar.

<u>Environmental aspects</u>
Starch solutions are easily combined with hydrophobic dispersions and, in a number of cases, allows for the abandoning of the sizing (hydrophobization) in the stock. This is especially important for companies where the fibrous stock is heavily polluted with anionic compounds and the sizing of the pulp and also the use of cationic starches in the stock practically does not give any economically feasible results.

<u>Economic aspects of the introduction</u>
The surface sizing technique, by which the prepared starch solution is combined with a small amount of hydrophobic agent, is very cost-efficient. As a matter of fact, if sizing a heavily polluted paper-grade stock ”in the stock”, then, in order to produce the parameter of an absorbability not exceeding 30 g/m^2, it would take 15 – 16 kg of resin products and the use of 18 – 22 kg of aluminium sulphate, while surface sizing with the addition into the solution of a hydrophobic agent would allow for the achievement of a absorbability parameter of 23 – 27 g/m^2 at a consumption rate of the hydrophobic agent of no more than 1,5 – 2,0 kg/t.

ET-5.5 Aerobic biological waste water treatment

Description of the technique

This method is mainly practiced at companies using secondary fibre. It is possible to combine the biological step with ozone treatment or membrane filtration. The efficiency of the treatment is achieved by activated sludge systems with a low load, depending on the equipment used (biofilters, moving-bed reactors, submersible filters, etc.). The COD/BOD rate of the filter samples of the wastewater after the biological treatment are rom 4 to 7 or rom 7 to 10.

Status of development

Partially introduced

Achieved environmental advantages

The activated sludge system with a high load consumes 0,3 – 0,5 kg O_2/kg removed BOD_5. The activated sludge system with a low load consumes 1,5 . 2. The specific energy consumption of the decomposition (removal) of 1 kg BOD_5 is 0,3 – 3,0 kWh.

Economic aspects of the introduction

The costs (based on the experience of a paper plant in France for the system of treatment of activated or in the production of printing paper of a capacity of 300 tons of paper per day – 3 M Euro, fluting – (100 t/day) – 1,5 M Euro.

ET-5.6 The Physical and Chemical Treatment of Wastewater from the Wood Preparation Plant

Description of the technique

During the process of preparation of the raw material: Wastewater containing large quantities of difficult-to-oxidize organic compounds is formed in the debarking drums, the defrosting conveyor and the bark press. After a coarse mechanical screening in the drum screens, where the coarse inclusions are removed, the wastewater is transferred to a receiving tank, where reagents (a coagulant and a flocculant) or activated sludge are added, the latter of which adsorbs the high-molecular-weight organic compounds. From the feed chamber the wastewater is transferred to the

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mixer, where it is mixed with whitewater, saturated with air, and is then transferred to the flotator. The air, dissolved in the whitewater under pressure and mixed with the wastewater is separated out in the form of miniscule bubbles, which adhere to the coagulated organic pollutants, as a result of which they rise to the surface and – in a thickened form – are removed from the surface of the flotator.

Status of development

There are pilot projects directed towards an introduction of the method.

Achieved environmental advantages

The wastewater of the wood preparation workshop contains a large quantity of difficult-to-oxidize organic compounds and in order to achieve a full oxidation there is a need for a considerably longer biological processing, than what is being don in traditional biological treatment plants. Moreover, when diluting in the total volume of the wastewater, the concentration of such pollutants is decreased, which also leads to the reduction of the efficiency of the treatment. The removal of a considerable amount of difficult-to-oxidize organic compounds using physical and chemical methods allows for a marked reduction of the load on the biological treatment plant as well as the volume of additional activated sludge, which favourably influences its further recovery.

Economic aspects of the introduction.

Traditionally, wastewater from the wood preparation workshop is subjected to mechanical screening to remove large inclusions and is then discharged into the joint sewerage of the plant. The treated wastewater may be used repeatedly, which reduces the total water consumption and reduced the hydraulic load to the treatment plant.
A 20 – 30 % reduction of the difficult-to-oxidise organic compounds, discharged to the treatment plant from the wood raw material preparation workshop.

ET-5.7 Wastewater Treatment

Description of the technique
The best technique for wastewater treatment is:

- the development of separate dewatering of the sludge from the primary settling tanks and the excess activated sludge

- The elimination of the conditions that lead to the formation of secondary pollution (hold-up zones, feed of the pollution trapped at the last stages to the beginning the treatment process, etc.)
- The use of physicochemical methods (flotation) for the compacting of the surplus and circulating activated sludge. This permits the avoidance of any content of activated sludge under anaerobic conditions as well as the reduction of the hydraulic load on the biological treatment plant
- The use of floto-filters for the tertiary treatment of the wastewater after the biological treatment step.
- The use of biosorption with the use of surplus activated sludge as well as the subsequent physicochemical method for the removal of suspended solids from the wastewater before it is transferred to biological treatment.
- The use of equipment for the dewatering of the surplus activated sludge that does not allow for the penetration of any finely dispersed fractions of the sludge into the filtrate
- The use of local physicochemical systems for the treatment of especially polluted wastewater from the production process
- The organization of a separate flow of the wastewater that does not contain organic compounds (for instance, wastewater with an elevated salt content from the flushing of the drum boilers) circumventing the biological treatment facility.

<u>Status of development</u>

Partly introduced

<u>Achieved environmental benefits</u>

The reduction of the pollution of the wastewater as a result of a selective treatment system. The increased quantity of non-recycled waste as well as the larger surface area for the disposal of the mud from the physicochemical treatment.

<u>Economic aspects of the introduction</u>

Reduction of water consumption through the combined use of the water circulation system. The increased costs for the purchase of chemicals.

ET-5.8 The use of Low-potential Heat.

<u>Description of the technique</u>

The use of low-potential heat from the processes for the production of compost from the surplus activated sludge and the waste from the preparation of the timber (sweepings from the territory of the reception of the wood raw material containing bark, wood waste and soil). The method is developed by TsEPL of the RAS and the Spb GTU RP.
The excess activated sludge contains "the natural ratio" of organic matter, nitrogen and phosphorus in the forms that are most readily assimilated by plants.
The excess activated sludge containing the absorbed organic compounds form the organic basis for the compost. The disintegrated bark and wood waste, containing dirt and sand are fillers, improving the structure of the compost and provide the possibility of easy aeration (by hoeing) of the composting substrate. In order to speed up the composting process one may heat the site for the maturation of the compost with the use of surplus process heat and also maintain the necessary humidity using treated wastewater. By the same token one may carry out the seeding of the compost with worms, which allows for the maturation of the compost within 2-3 months. After the maturation it is expedient to add ash from the burning of wood waste. The ash contains considerable quantities of microelements, necessary for the improvement of plant growth.
The produced compost is well fit for the growing of seedlings for reforestation purposes, the regeneration of fertility of forest soil after cutting, landscape restoration after construction work, the recovery of open pit mines, taken-out-of-service industrial sites as well as the set-up of plantation for accelerated growth of technical crops and wood.

<u>Status of development</u>
Experimental testing of the technique

<u>Achieved environmental benefits</u>
The extraction of the surplus activated sludge from the heat balance of the multi-fuel boiler of the recovery unit raises the heat efficiency and increases the specific heat production.

<u>Economic aspects of the introduction</u>

The use of compost as a soil former enables the restoration of the fertility of forest soils and, in the long-term perspective, the considerable logging increase per unit of calculated felling rate.

ET-5.9 Water Pyrolysis of Organic Waste

Description of the technique

The processing of organic waste in a water environment at supercritical parameters. The mixture of organic waste (sawdust, sediments, sludge, etc.) and water – is the reactive mixture processed at high temperature under pressure.

At high temperatures a thermal decomposition of the organic substances takes place, quite like a pyrolysis reaction. The water plays the role of the heat carrier with a high heat conversion coefficient. After the decomposition the mixture is transferred to a heat exchanger, in which the main part of the heat is returned to the process for the preparatory heating of the reaction mixture. In this way a considerable quantity of heat is returned back into the process, while this heat would have been lost when using the standard process. The cooled mixture is transferred to be separated, whereas the water is returned back to the process.

The use of a consecutive catalytic processing of the hot reaction mixture allows for the synthesizing, from the products of the decomposition of organic compounds, water insoluble or slightly volatile organic compounds, which are easily separated from the water and which may be used as fuel.

Status of development

The stage of experimental research

Achieved environmental benefits

The recycling of wood waste in order to produce alternative types of fuel.

Economic aspects of the introduction

The involvement of waste from the main production line in order to produce energy resources and possibilities to use it for other purposes.

ET-5.10 The Impregnation of Chips before Cooking

Description of the technique

The counter current impregnation is carried out in a impregnation column, mounted before the continuous digester. The process improves the impregnation of the chips before cooking as well as the uniformity of the cooking penetration.

The hot liquor from the strong liquor recovery zone is fed to the lower part of the impregnation column and moves countercurrent to the chip column, loaded into the upper part of the impregnation column. At that, the chips, as they moves from the top towards the bottom are impregnated and heated. The residue active alkalinity is partly consumed for the saponification of the easily saponified components (organic, fatty and resin acids), which are brought out together with the alkali from the top part of the impregnation column.
Countercurrent impregnation allows for the improved use of residual alkalinity and the heat of the liquor, tapped from the boiler. At that, there is a reduced specific consumption of white liquor for cooking purposes, as well as the heat consumption used for the heating of the chips in the boiler to the cooking temperature.
There is an improvement of the uniformity of the cooking penetration of the chips. There is a reduction of the specific hydraulic load to the evaporation station. The cooking penetration is increased and there is a higher yield and pulp strength. There is a reduction of the quantity of waste from the screening process as well as a reduction of the bleaching reagent costs.

Status of development

Pilot projects are carried out for the introduction of the method

Achieved environmental benefits

An improved uniformity of cooking penetration of the chips lowers the specific outflow of organic compounds to the bleach plant, reduces the specific consumption of bleaching chemicals as well as the amount of organic compounds being released in the bleach plant effluents.

Economic aspects of the introduction

Through the higher intermediate product yield there is a reduced raw material and cooking chemicals consumption.

ET-5.11 Pulp Washing

As best technique is considered the use of pressure washing vessels after the washing at the bottom of the boiler (in continuous cooking) or after the extrusion of the strong liquor and the displacement by the filtrate (in batch cooking). The high temperature, which may be entertained with the use of a pressure diffusor, makes possible the increased temperature of the extrusion as well as the improved removal of the high-molecular-weight part of the organic compounds of the black liquor. As a result, the COD transferred to the bleach plant is reduced.

The best technique for washing presses is the combined use of tanks for the holding of the diluted pulp after the press, in which a diffusion of the organic compounds in the inner cavities of the fibre.

Status of development
Industrial trials

Achieved economic advantages

A reduction of the COD parameter of the wash phase. The use of a wash press as the last stage of the washing process allows for the substantially lowered consumption of washing water, which considerably lowers the hydraulic load to the evaporation station.

Economic aspects of the introduction
A lower consumption of washing water provides a substantial economy of electrical energy due to the lower transfer volumes.

ET-5.12 Pulp Screening

Description of the technique
The position of the screening unit before the oxygen-alkaline processing is regarded as best technique. This allows for an increased efficiency of shives and undercooked pulp removal from the pulp before bleaching.
The grinding of knots and their return to be screened again or transferred to cooking is not to be performed.

Status of development

Industrial trials

Achieved environmental benefits
There is a reduced consumption of pulp bleaching agents and organic impurities content of the bleach plant wastewater.

Economic aspects of the introduction
When installing a screening stage before the oxygen-alkaline processing unit, the fine shives in the pulp after the screening is "bleached through" at the oxygen-alkaline stage, which allows for a lower amount of screening waste and reduces the bleaching reagent consumption pulp bleaching.
The grinding of the knots and undercooked pulp leads to the increased content of undercooked fibre in the pulp, which leads to a larger consumption of chemicals for bleaching purposes and to the increased content of organic compounds in the wastewater from the bleaching process.

ET-5-13 Pulp Bleaching

Description of the technique

The use of presses as washing units in combination with intermediate concentration pumps in order to guarantee the evaporation of concentrations of contamination within the fibre as well as in the filtrate.
The use of intermediate concentration dynamic mixers for a higher level of mixing of the stock with the chemicals.
The organisation of a counter current pulp-washing step before the bleaching stage, separately for acidic and alkaline flows.
The use of surplus recirculated water from the drying workshop of the paper machine as washing water.

Status of development
Partly introduced

Achieved environmental benefits

The substantial decrease of water consumption as well as bleaching chemicals and the reduced content of pollutants in the bleach plant effluents that is transferred to the treatment plant.

Economic aspects of the introduction
In order to wash the pulp between the bleaching stages, wash presses are used. After the presses the stock is diluted with the filtrate from the washing process of the next stage of the bleaching process in order to improve the preparation of the stock before the next bleaching step. After the intermediate concentration pumps, dynamic intermediate concentration mixers

are installed in order to attain a uniform mixing of the bleaching reagents. In such a configuration, there is a reduction of the specific consumption of chemicals, heat and water during the pulp bleaching process.

ET-5.14 The Gasification of the Fine Fractions of the Chip Screening Waste

Description of the technique
Gasification of the fine fractions of the chip screening waste allows for a reduced use of gas, coal or fuel oil for production purposes (except for start-up)
The fine fraction of the chip screening waste is transferred to the gasification chamber through a compacting worm press. On the exit from the worm press plasma gasification of the wood waste takes place. As a consequence of this, under pressure, there is a generation of combustible pyrolysis gases that may be transferred directly to the injector of the lime burning furnaces or of the air heaters of the flash dryers as well as to other places, there fuel oil or gas are burned.

Status of development
Work is going on in order to prepare an introduction

Achieved environmental benefits
When burning wood waste, the emissions of SO_2 are considerably lower than when burning fuel oil. The reduced use of fossil fuels reduces the emissions of greenhouse gasses during the production process.

Economic aspects of the introduction
The use of fuel oil as a fuel burned in the injectors calls for the presence of a complicated and expensive system for the reception, unloading, storage, constant heating and circulation. The cost of one unit of heat received from the burning of fuel oil is considerably higher than the cost of heat, produced as a result of the burning of wood waste.

ET-5.15 Processing of the Wastewater Sludge (Cake – Compacted or Dried Sludge or Sediment) Using a Supercritical Technique SCT

Description of the technique

The SCT consists in the processing (in a flow mode) of carbon-containing biomass with approximately 90 % humidity (thickened sludge and sediment, cake) without the access to air at temperatures of 300 – 500 °C and a pressure of 220 – 250 atm., which creates the conditions at which there is no formation of carcinogenic substances (furans and dioxins).
After the SCT process technically clean water is formed, as well as a mineral residue and a gaseous component with the subsequent recycling of it in various types of energy carriers

Status of development
At the level of trials

Environmental aspects
SCT guarantees a low level of negative environmental impact, calculated per volume of output of sulphate pulp.
Additionally this technique allows for the abandoning of the compacting stage as well as the mechanical dewatering with the addition of flocculants and the reduction of the volumes of water consumption and the lowering of the costs of the recycling of the wastewater sludge by 20 – 30 %.

Economic aspects of the introduction
The capital expenditure is 25 times lower than the costs for the burning of the sludge and 10 times lower than the costs of thermal drying of the sludge, and the operational costs are 3 times lower than the costs for the burning of the sludge and 1,3 times lower than the operational costs of the thermal drying of the sludge.

ET-5-16 Technique for the Production and Use of Nanopulp in the Production of Paper and Board Products

Description of the technique
Polymer materials, including cellulose-containing materials are complex and heterogenic (multi-component) systems, the properties of which are

determined by the chemical structure of the components as well as the character and intensity of the interaction between them as well as the micro and macro structure of the material. The use in the composition of cellulose-containing composite materials built up by nano-size elements of cellulose-nanocellulose (NC) allows for the control of the properties of the products produced.
The production of nanocellulose from wood pulp involves the processes of disintegration to fibres with a diameter of 50 – 1 000 nm and a length of a few millimetres with the subsequent chemo-mechanical fragmentation including the selective acid hydrolysis during 2 – 3 hours at a temperature of 60 – 100 °C and the use of hydrochloric or sulphuric acids; the separation of the product from the water phase through centrifuging, filtration in vacuum, the homogenization in special units under high pressure. The use of cryo-drying and the processing with liquid nitrogen increases the production cost of the produce.

<u>Status of development</u>

On the level of pilot surveys

<u>Environmental aspects</u>
The introduction of nanocellulose into the composition of the paper-grade stock promotes the retention of the fine fibre and filler in the wire part of the paper machine. The processes of forming inter-fibre connection are enhanced, which promotes a more efficient structuration, compaction of the paper sheet and the reduction of ”collapse” into the pit water of the fine fibres and filler by 15 – 20 % thus reducing the load on the treatment plant.

<u>Economic aspects of the introduction</u>
The most important influence of the adding of NC is on the following quality parameters of paper and board: The burst strength (12 – 15 %), the flat crush resistance of the fluted paper specimen (15 – 20 %), breaking force (10 – 15 %) the edgewise compression strength of the fluted paper specimen 12 – 20 %).
A few of the characteristic properties of the use of nanocellulose is the high mechanical strength, comparable to the strength of carbon nanotubes and the capacity to form two- and three-dimensional reinforcing grids with chemical bonds in the composition of the nano-composite materials.

The fields of application of the various types of cellulose nanoparticles is determined not only by the high strength of the nano-fibrils and crystals, but also by such properties as a high chemical purity, biological compatibility, a developed surface, a high adsorbing capacity, insolubility and the lint-free structure.
When producing polymers for packaging glass fibre, carbon nano tubes, etc. are used as the fortifying filler. None of these materials, however, decompose within a short time interval. After two to four months in the soil, polymers containing NC have been fully disintegrated into water, carbon dioxide gas and humus substances. From this point of view the NC has an advantage for future use when producing environmentally clean biodegradable packaging.
There are other fields of efficient use of NC.
Addendum G contains a list of emerging techniques.

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Closing Remarks and Recommendations

The present digital reference document on best available technique Production of Pulp, Mechanical Pulp, Paper and Board (hereinafter: the BAT reference document) was developed in accordance with the timetable for the development in 2015 – 2017 of BAT reference documents [11] based on the order for the development, updating and publishing of BAT reference documents [12].

The reference document has been developed under observance of the requirements of the Russian Federation Act No 162-FZ [13] of the 29 June, 2015, and is consistent with the federal legislation as well as standards and rules that have been adopted by the Federal executive authorities.

As to the structure and presentation the BAT reference document mainly corresponds to the requirements of the PNST (preliminary national standards) 21-2014 [14], PNST 23-2015 [15] as well as the terms and definitions listed in accordance with PNST 22-2015 [16].

The BAT reference document on best available technique Production of Pulp, Mechanical Pulp, Paper and Board was developed in accordance with the Federal Act of the Russian Federation of the 2 January 2002 No 7-FZ based on the results of an analysis of the pulp and paper industry in the Russian Federation.

The BAT reference document applies to all production processes used in the Russian pulp and paper industry.

The reference document also covers all processes concerned with the main types of activities that may exert influence on the volumes of emissions or the scale of pollution of the environment, i.e. the:

- Raw material preparation
- Storage and preparation of fuel (black liquor, bark, wood waste, etc.);
- Production processes of support production (preparation of chemicals for bleaching as well as the recovery of lime sludge and the treatment of wastewater).

This BAT reference document does not apply to:

- The production of packaging from paper and board
- Logging operations

This BAT reference document was developed by the Technical Working Group no 1 (TRG 1) Production of Pulp, Mechanical Pulp, Paper and Board, the composition of which was approved through the Rosstandart order no 827 of the 17 July 2015, On the Technical Working Group on the Production of Pulp, Mechanical Pulp, Paper and Board.

The TRG 1 is composed of 27 representatives of, e.g.:

- Industrial entities – 49 %
- Scientific and expert organisations – 36 %
- Unions and professional associations – 11 %
- Federal and other executive authorities – 4 %

The share of representatives of large companies in the composition of the TRG 1 is 61,42 % of the total volume of market output¨
The organizational of the functions of the TRG 1 involved planned meetings (4 of them were performed), distance working audio meetings (7 performed meetings), with attendance of specialists of companies and stakeholders, as well as the participation in the work concerned with the discussion and voting on key issue as well as on the BAT reference document sections in the official information portal of the BAT Bureau (4 such sessions were performed).
In order to collect information on the production processes and equipment used at industrial companies, as well as on the sources of environmental pollution, the technological, technical and organisational actions devoted to the reduction of environmental pollution and the increased energy efficiency and resource savings, a questionnaire was prepared called A Questionnaire for Companies Containing the Form for the Collection of Data, Necessary for the Development of a Proposed Industry Branch BAT Reference Document. As a basis for the development of the Questionnaire, the PNST 23 – 2014 was applied: Best Available Techniques. Format for the Description of Technologies.
This questionnaire was sent to the plants of 63 large Russian pulp and paper companies. According to the results of the survey the coverage of the volume of commercial output was no less than 75 % and the distribution over the types of merchandize output: commercial pulp - no less than 92,95 %, paper – no less than 73 % and board: no less than 59,18 %.
The information received as a result of the survey among the companies was used when developing the present BAT reference document.
When developing the BAT reference document, material was used that was received from the Russian Producers of pulp and paper merchandize in the course of information exchange, organised by the BAT Bureau in 2015. When discussing the preliminary versions of the sections of the reference document, the representatives of companies, scientific organizations and members of the TRG 1 expressed their well-founded comments and presented additional material. The BAT reference document takes into account the results of implemented investment projects within

the pulp and paper industry, performed in Russia in 2006 – 2015, branch surveys and articles published during the past few years.
The necessary information was gathered in the process of the development of the reference document and was based on information from branch surveys, information from professional associations, information from the professional association RAO Bumprom and information from the analogous European Union document European Commission. Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board, 2015).
The BAT reference document contains the production processes, equipment, technical means and methods, etc., applied in the production of pulp, mechanical pulp, paper and board, allowing for e.g. the reduction of negative environmental impact, water and raw material consumption which constitute best available technique (hereinafter BAT). For BAT the reference document stipulates the corresponding technological BAT parameters for emissions, discharge and waste formed at the specific plant.
When describing every production process a complex evaluation has been made of the environmental impact. The sources of formation and the points of emissions have been shown as have the environmental protection measures and equipment.
The criteria for BAT has been shown, as well as the economic aspects of the introduction of BAT, the list of emerging techniques for the Russian pulp and paper industry has been determined, as well as the level of their commercial feasibility.
In order to evaluate the compliance of the BAT reference document to the present state of technical development, a comparison has been made with the analogous European reference document (BREF 2015).
The technological parameters have been developed for integrated production of sulphate and sulphite pulp, taking into account the processing of the produced pulp in order to produce various types of paper and board, for independent paper/board plants as well as separately operating (non-integrated) plants for the production of mechanical wood pulp.
Based on the analysis of domestic and foreign information, and also results from integrated research, carried out during the past few years, a list of marker substances for gaseous emissions, wastewater and waste from the production has been worked out.

The Federal Act of the Russian Federation of the 21 June no 219-FZ [18] determines that measurements when carrying out production environmental control shall be performed in regard to marker pollutants, defined for the control of environmental pollution depending on the used production processes. Marker substances are defined as the most significant representative of a group of substances, within which there is a strong correlational interdependence, chosen according to specific criteria. One property of the marker substance is the fact that its value may be used to evaluate the values of all substances belonging to the group.

Information on key issues: the field of application of the reference document, the technological parameters, their specific values, a list of marker substances and BAT constitute an agreed upon stance of the industry and have been defined through electronic voting in everybody's separate offices on the information portal of the BAT Bureau after a preliminary detailed elaboration at 4 face-to-face scheduled meetings of the TRG 1 as well as 7 distance audio meetings.

The following sections of the BAT reference document have been prepared: Introduction, Preface, Field of Application, Section 1: General Information on Russian Pulp and Paper Industry, Section 7: Emerging Techniques and Closing Provisions – by RAO Bumprom; Sections 2, 3, 4, 5, 6 by OAO Gruppa Ilim (sulphate production, board and wood raw material preparation, OAO Solikamskbumprom, the OAO TsNIIB (Sulphite production, production of mechanical pulp, paper and board) with the participation and consulting of member from the TRG 1.

During the course of development and public discussion of the reference document, the members of TRG 1, companies and organization, 124 comments and proposals have been received, which have been taken into account in the process of preparation of the present BAT reference document.

The review of the draft reference document was carried out by the specialized technical committees for standardization TK 113 Best Available Techniques, which recommended the approval of the draft of the Digital BAT reference document Production of Pulp, Mechanical Pulp, Paper and Board in its entirety. The draft of the reference document also received 5 positive conclusions (opinions) from companies and organizations.

The BAT reference document developed is a standardization document and is mainly intended for companies, scientific and design organizations, companies and state organizations regulating the industrial and environmental activities in order to increase the competitiveness of the domestic industry.

Attachment A

(Reference)

Terms, Definitions and Abbreviations

Total nitrogen (N_{tot})	The total nitrogen content as organic and inorganic compounds in the wastewater
AOX	A parameter, showing the content in the wastewater of low- and high-molecular-weight organic compounds, containing chlorine atoms. This parameter takes into account the total quantity of organo-chlorine substances that may be adsorbed by activated carbon.
The Biochemical Oxygen Demand (BOD)	The amount of dissolved oxygen consumed during a set time and under specific conditions, under conditions of biochemical oxidation of the organic compounds present in the water.
Pollutant	A substance of a mixture of substances the quantity and (or) concentration of which are exceeding the defined standards for chemical compounds, including radioactive, other compounds and microorganisms, and which exert a negative influence on the environment.
Integrated pulp and paper production plant	Companies, which involve the production of one or a number of fibre intermediate products (pulp, mechanical pulp, CTMP), paper and/or board as well as products made from them.
Monitoring of the Environmental Impact	An integrated system for the observation of the environmental condition, the evaluation and forecast of the changes in the environmental condition under the impact from natural and industrial factors.

Best available technique BAT	The technique, based on the latest achievements of science and technology, aimed at the reduction of negative environmental impact and having a defined period of practical implementation taking into account economic and social factors.
Suspended solids (SS)	Organic and inorganic particles contained in the wastewater in the suspended condition
Dust (suspended matter)	Particles of inorganic and/or unburnt organic compounds contained in the flue gases
Wastewater flow	The volume of wastewater flowing within a time unit and the value of which is the basis for the calculation of sewerage and treatment networks and plants
Total reduced sulphur	The total amount of gaseous sulphur compounds during sulphite production mainly consisting of sulphur dioxide, whereas – during sulphate production – also including hydrogen sulphide and its organic derivatives (methyl mercaptan, dimethyl sulphide, dimethyl disulphide, which are reduced into SO_2)
Total phosphorus (P_{tot})	The total content of phosphor in wastewater in the form of organic and inorganic compounds.
Chemical oxygen demand (COD)	The amount of oxygen, consumed during chemical oxidation of the organic and inorganic compounds contained in the water under the action of various oxidizing substances. It is expressed i milligrams of oxygen equivalents per litre of water studied and – if needed – it is transformed into kg/t of produce. It is customary to assume that the COD parameter is a generalized parameter, characterizing the level of pollution of the water by substances of an organic nature. It has been determined, that the integral parameter COD is the most informative and priority parameter of the environmental state of local, circulating and wastewater.

NO_x	The total amount of nitrogen oxides, formed during the burning of various fuels in the furnaces of the boiler installations, both from the nitrogen containing compounds that are one of the constituents of it, and from the nitrogen in the air, fed to the boiler facility in order to support the combustion process.
Integrated parameters	Parameters that characterize a group of individual substances with similar properties or features
Marker substances (or markers)	The most striking representative of a correlated constellation that is chosen based on certain criteria. One peculiarity of the marker substance is the fact that its value can be the basis for the evaluation of the values of all substances forming part of the correlational constellation.
Integrated environmental permit	A document which is issued by the authorized federal executive authority to a legal entity or to an individual private business, carrying out economic and (or) other activities at the facility that exerts a negative impact on the environment and which contains the mandatory requirements within the field of environmental protection.
Waste neutralization	The processing of waste, including incineration and decontamination of waste in special installations in order to prevent the harmful impact of the waste on human health and the natural environment.
Waste handling	Activities in the process within which waste is formed, but also the activities for the collection, use, neutralisation, transport and disposal of waste
Waste disposal facility	An especially equipped installation, intended for the disposal of waste (a landfill, a sludge tank, a tailing pond, a waste rock dump)
Gas treatment	The separation from the gas or the transformation into a harmless state of air polluting substances.
Treated gas	Gas that has undergone treatment in treatment facilities to reach the needed purity.
Industrial dust	Dust, included in the composition of the emissions

Specific wastewater flow	The volume of water entering the water recipient shown per ton of merchandize produced
Stationary source	A source of environmental pollution, the location of which is defined with the use of a common state system of coordinates or which may be moved by the use of a mobile source of environmental pollution
Technological standards	Standards of emissions and discharges of pollutants, standards of maximum allowed physical impact, which are settled with the aid of technological parameters.
Technological parameters	Parameters of concentration of pollutants, volume and (or) mass of the emissions or discharge of pollutants of the formation of waste from production and consumption, water consumption and the use of energy resources shown per time unit or unit of produced merchandize (produce), operations carried out or rendered services
Specific formation of pollutants	The amount of harmful substance, formed in the course of the processing or displacement of one unit of mass of a material or during a time unit of operation of one unit of equipment.
Landfill disposal	The isolation of waste, not subject to further use, in special repositories in order the prevent the penetration of the harmful substances into the natural environment.
The national environmental protection strategy	The strategy, the objective of which is the definition of the most urgent needs in the field of environmental protection, the promotion of an extensive discussion of the environmental problems in the country, the development of environmental consciousness, the allocation of the labour and financial resources, etc.
Production and consumption waste	The leftovers of raw material, supplies, intermediate products or any other items of products, which were formed in the course of the process of production or consumption as well as good (produce) that has lost its consumption properties.

Environmental protection	Activities on the part of the state authorities of the Russian Federation, the state authorities of the constituent entities of the Russian Federation, the local autonomous authorities, NGOs and other non-commercial associations, legal entities and physical persons, aimed at the conservation and recovery of the natural environment, the rational use and restoration of natural resources, the prevention of negative impact from economic or other activities on the environment as well as the mitigation of its consequences.
Sewage treatment plant	Special engineering constructions, intended for the consecutive treatment of wastewater to remove pollutants. In a treatment plant set-up there may be facilities for mechanical (sieves, screens, traps, etc.), physical and chemical (chlorators and bactericide installations etc.) as well as biologic (biofilters, irrigation sewage fields, aerotanks, filtration fields, etc.) types of treatment.
Waste processing	The production of additional goods by using a special technique using waste as raw material
Pollution prevention	The use of processes, practical methods, materials or produce, which makes possible the avoidance of pollution or the reduce it or grapple with it. It may also include recycling, treatment, a changed process, a control mechanism, an efficient use of resources and the replacement of supplies/material.
Waste disposal	The storage and landfill disposal of waste
Developing technique	A technique based on the most recent scientific and technological achievements, permitting the achievement of a substantial environmental, economical and technological effect, and being in the state of development and introduction, not having passed a sufficiently extensive industrial trial.

Rational management of natural resources	A system of activities aimed at the provision of the economic use of natural resources and conditions as well as the most efficient mode for their restoration taking into account future interests of a developing economy and the protection of human health.
Discharge	The discharge of used water from an industrial company, an agriculture unit or community facilities to natural water recipients after or without treatment.
Technological standard	A standard for the maximum allowed emissions and discharges of compounds and microorganisms, which are set for stationary, mobile and other sources, production processes and/or equipment which reflects the maximum allowed mass of emissions and discharges of substances and microorganisms to the environment shown per unit of produced goods.
Sustainable development	The carrying out of the activities of the society in such a way, as to satisfy the main vital requirements of this and coming generations without inflicting damage on the biosphere (The Strategy for Sustainable Development was adopted by a Russian Federation ukaz of the 1 April 1996 no 440 as well as a resolution of the Government of the Russian Federation of the 8 May 1996 no 559)
Waste storage	The storage of waste at waste disposal facilities for their subsequent burial disposal, neutralization or use.

Designations and abbreviations

BAT- best available technology
BREF – BAT reference documents of the European Union on best available technology for various industrial branches
ISO – International Standardization Organization

OSPAR Convention – The 1992 Convention on the Protection of the Marine Environment of the North-East Atlantic Ocean,

OKVED, All-Russian Classification of Economic Activities

OKPD, All-Russian Classification of Products for Various Fields of Commercial Activity

BET – best existing technique

BAT – Best available technique

IE – integrated enterprise

ITS – information technology reference document (BREF)
TRG- technical working group
ET- emerging techniques

ADW- absolute dry wood
ADt- absolute dry pulp (ADP)
ADt- air dry pulp
ADS- air-dry stock
ADS- absolute dry substance
OKD- oxygen-alkaline delignification
ADOT- average day output in tons
SP- Sulphate pulping
SP- Sulphite pulping
NSSC- Neutral Sulphite Semi-chemical Pulp
SGW- groundwood pulp
RMP- refiner mechanical pulp
TMP – thermomechanical pulp
OAP – oxygen-alkaline processing
ECF – elemental chlorine free
TCF – totally chlorine free
MRB- Magnesium recovery boiler
RB- Recovery boiler
LK- limekiln
ES – electrostatic filter
NCG - non-condensable gases

HC- high-concentration
LC-low-concentration
TRS- total reduce sulphur
VOC – volatile organic carbons
PCW- Production and consumption waste
WDF- waste disposal facility
MAC- maximum allowed concentration
MAE- maximum allowed emission
SAE- Standards of maximum allowed emissions
SAD- Standard of maximum allowed discharge
P- Pollutants
ADM air-dry mass
OAD – oxygen-alkaline delignification
SS – suspended solids
AOX – adsorbed organic halogens. The total content of chlorine of the organic matter in the wastewater.
BOD_t – biochemical oxygen demand (total)
COD – Chemical oxygen demand. The amount of oxygen, consumed during the full chemical oxidation of the matter present in the wastewater.
N_{tot} Nitrogen. The total amount of organic and inorganic nitrogen, measured as total nitrogen content (N_{tot})
P_{tot} Phosphorus. The total amount of organic and inorganic phosphorus , measured as the total content of phosphorus (P_{tot})
PM - paper machine
BM – board machine
ADCS – automated control dispatch system

Attachment B (informational)

Levels of emissions and consumption corresponding to the best available techniques (BAT)

The consumption parameters are reported according to the reference document, BREF (EU), 2015 [3].

Table B. 1 The main consumption parameters of chip production

Item	Measurement unit	Consumption
Consumption of pulpwood per 1 ADt	Dense m^3/ADt	3÷6
Electrical energy per 1 m^3 merchantable wood	KW/m^3	10
Electrical energy per 1 ADt - when using ECF Bleaching	KW/ADt KW/ADt	60 45
Volume of flow formation - wet debarking - dry debarking	 m^3/ADt m^3/ADt	 3-10 0,5 – 2,5

Table B. 2 Consumption of main chemicals in the course of production of bleached and unbleached sulphate pulp

Name of the chemical	Consumption kg/ADt In the course of production of sulphate pulp	
	Unbleached	Bleached
NaOH	10-20	25 - 30
O_2	NA	5 - 25
$NaClO_3$	NA	15 – 50
EDTA	NA	0 - 4
SO_2	NA	2 - 10
H_2O_2	NA	2 - 30
O_3	NA	0 - 5
$MgSO_4$	NA	0 - 3

Name of the chemical	Consumption kg/ADt In the course of production of sulphate pulp	
	Unbleached	Bleached
CaOH	5 – 10	5 - 10
Note The absolute values of the chemicals consumption are shown recalculated as 100 % concentration. NA - None		

Table B.3 Consumption of raw material and the quantity of formed side products in the course of production of chlorine dioxide by various methods

technique	Metison[1)]	HP-A	SVP-LITE, R8	SVP-SCW, R10	SVP-HP, R11[2)]	Integrated SVPHCL or R6
Raw material (t/t ClO_2)						
Sodium Chlorate	1,8	1,65	1,65	1,64	1,65	NA
Sulphuric acid	1,40	2,10	1	0,8	0,78-1,03[2)]	NA
Sulphur dioxide	0,8	NA	NA	NA	NA	NA
Methanol	NA	NA	0,17	0,17	NA	NA
Hydrogen peroxide	NA	0,29	NA	NA	0,29 – 0,32	NA
Elemental Chlorine	NA	NA	NA	NA	NA	0,73
Steam	NA	NA	4.2	5,50	5,5	8
Electrical energy kW/h	80	80	130	160	130	8 900
By-products (t/t ClO_2)						
Chlorine as ClO_2	0	0	0	0	0	0,24
Na_2SO_4	1,20	1,10	NA	1,10	1,10[2)]	NA
H_2SO_4	1,50	1,30	NA	NA	NA	Na
O_2	NA	0,26	NA	NA	0,26	NA
Note: NA – none [1)]Used without adding salt [2)]The amount of acid, used in the process based on hydrogen peroxide depends on the operational activity						

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Table B.4 Consumption of steam at energy efficient companies producing commercial bleached sulphate pulp (annual average).

Process	Cooking	Oxygen delignific ation	Bleachin g	Drying	Evaporati on	Other	Total
Steam consumption (GJ/ADt)	1,6 – 2,0	0,2 – 0,4	1,5 – 2,0	2,2 – 2,6	4,0 – 4,5	1,5 – 2,0	11,0 – 12,0

Table B.5 A comparison of consumption in accordance with BREF (EU), 2015, of at companies producing sulphate pulp and having ECF Bleaching

Steam consumption	KAM2 (summer)	SödraVärö (according to forecasts)
Timber preparation	0	ND
Cooking	1,6	2,25
Preparation of hot water	-	0,05
Oxygen delignification	0,14	0,08
Bleaching	1,37	1,33
Preparation of bleaching chemicals	0,10	0,14
Total for the fibre line	**3,21**	**3,85**
Evaporation + stripping-column	4,01	3,78
Drying	2,20	2,17
Soot blowing + pulp blowing	1,01	1,23
Total of evaporation and recovery	**7,21**	**7,18**
Miscellaneous, losses	0,37	0,39
Works total	**10,8**	**11,4**
Purchased fuel	0	ND
Note: ND. No data		

Table B. 6 Consumption of electrical energy in accordance with EU BAT at companies using ECF bleaching (information from 2002)

Technological limits	Consumption of electrical energy (kWh/ADt)
Wood preparation	45,00
Cooking	44,0
Washing and screening of the unbleached pulp	60,0
Oxygen-alkali processing	60,0
Bleaching	80,0
Screening of the bleached pulp	45,0
Drying	120,0
Evaporation	30,0
RB	60,0
Caustization and lime burning in the LK (including the gasification of the bark as fuel)	57,0
Cooing tower (tower-cooler)	20,0
Water preparation	20,0
Wastewater treatment	30,0
Production of bleaching chemicals (including chemicals for oxygen-alkali processing)	10,0
Other consumers and losses in the network system	30,0
Total	**712,0**

Table B.7 Average level of electrical energy consumption for the production of bleaching chemicals

Bleaching chemicals and the bleaching steep (letter code)	**Electrical energy consumption (kWh/kg chemical)**
Chlorine dioxide (D)	10,0
Oxygen (O)	0,4
Ozone (Z)	10,0
Peroxide (P)	3,5
Sodium hydroxide (E)	1,6

Table B.8 Wastewater flow in accordance with the EU BAT for various types of production (annual average)

Type of products/production	Wastewater flow
Bleached sulphate pulp	25 – 50 m^3/t
Unbleached sulphate pulp	15 - 40 m^3/t
Bleached sulphite pulp for paper production	25 – 50 m^3/t
Unbleached sulphite pulp for paper production	20 - 45 m^3/t
Sulphite pulp based on magnesium	45 - 70 m^3/t
Dissolving pulp	40 - 60 m^3/t
NSSC	11 - 20 m^3/t
Mechanical pulp	9 – 16 m^3/t
CTMP and TMP	9 – 16 m^3/t
Production of paper using waste paper, not cleaned from the typographical dyes	1,5 – 10 m^3/t (the higher limit of the range basically connected to the production of board for collapsible boxes)
Production of paper using waste paper, cleaned from typographic dye	8 - 15 m^3/t
Production of tissue paper using wastepaper cleaned from typographical dye	10 – 25 m^3/t
Non-integrated paper production	15 - 30 m^3/t

Attachment C

(Mandatory)

List of Marker Substances

Table C.1 List of marker substances

Discharges				
No.	Marker substance	Sulphate production	Sulphite/groundwood	Paper-board
1	**COD**	x	x	x
2	**BOD_{tot}**	x	x	x
3	**SS**	x	x	x
4	**N_{tot}**	x	x	x
5	**N_{tot}**	x	x	x
6	**AOX**	x	x	x
Emissions				
7	**S_{tot}**	x		
8	**NO_x[2)]**	-	x	-
9	**SO_2[2)]**	-	x	-
[1)]The total dimethyl sulphide, hydrogen sulphide and methyl mercaptan [2)] From the Magnesium recovery boilers (MRB)				

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Attachment D

(mandatory)

BAT list

No.	BAT name
1	**BAT 1** Improvement of the general environmental parameters of a pulp, paper and board production company through the introduction of system s for the maintenance of the environmental management system (environmental management systems-EMS)
2	**BAT 2** Management of Material Resources and the Appropriate Production Organisation
3	**BAT 3** The management of the system for the prevention of wastewater pollution from the storage and preparation or wood
4	**BAT 4** The optimization of the management of the system for the prevention of wastewater pollution, the reduction of the consumption of fresh water as well as the formation of wastewater in the course of the production of pulp, mechanical pulp, paper and board
5	**BAT 5** The optimal management of the system of energy consumption and energy efficiency in order to reduce the consumption of fuel and energy resources and the reduction of the industrial impact on the environment
6	**BAT 6** The prevention and reduction of emissions of gaseous emissions formed in the wastewater system
7	**BAT 7** Control of the key parameters of the production process at the company (pressure, temperature, amount of pollution in the flue gases, other key indicators according to the technological regulations of the company
8	**BAT 8** The control of the measurement of emissions to air (NO_x, SO_2, dust)
9	**BAT 9** Control and measurement of discharges to water (COD, BOD, Suspended solids, AOX, total phosphorus, total nitrogen, electroconductivity.

No.	BAT name
10	**BAT 10** Regular control and evaluation of the dissemination of odorous gases from the respective sources
11	**BAT 11** The reduction of the formation of waste, the involvement of it for repeated use and preparation before the disposal at a landfill.
12	**BAT 12** The reduction of the discharges of pollutants to recipient from the whole company, through the use of an upgraded system for ECF bleaching (without the use of elemental chlorine)
13	**BAT 13** Reduction of smell, emissions of high-concentration strong and weak non-condensable gases through the collection of strong and weak NCGs from all production processes
14	**BAT 14** Reduction of emissions of SO_2 and TRS from the recovery boiler
15	**BAT 15** Reduction of emissions of NO_x from the recovery boiler
16	**BAT 16** Reduction of emissions of TRS from the limekiln
17	**BAT 17** Reduction of emissions of NO_x from the limekiln
18	**BAT 18** Reduction of emissions of SO_2 during the burning of strong NCGs in special TRS kilns
19	**BAT 19** Reduction of emissions of NO_x during the burning of strong NCGs in special TRS kilns
20	**BAT 20** Reduction of the emissions of dust from the RB and LK when applying electrostatic precipitators (ESP) or the combination of ESP and a wet scrubber.
21	**BAT 21** The reduction of the consumption of warm energy (steam) and electrical energy
22	**BAT 22** The increased efficiency of the electric energy production
23	**BAT 23** The reduction of the emissions of pollutants to the wastewater
24	**BAT 24** Prevention and reduction of emissions of SO_2 – BAT involves the collection of all gas flows with a high SO_2 concentration from the preparation of cooking acid, from the boilers, diffusors or blow tanks as well as the transfer to be restored
25	**BAT 25** The prevention and reduction of sulphur dioxide from washing, screening and evaporation
26	**BAT 26** The reduced consumption of heat energy (steam) and electrical energy

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No.	BAT name
27	**BAT 27** Reduced consumption of fresh water, the amount of wastewater as well as the pollutant load
28	**BAT 28** The reduced consumption of thermal and electrical energy
29	**BAT 29** The reduced formation of wastewater
30	**BAT 30** The reduced consumption of fresh water and the discharge of pollutants to water at companies producing special technical types of paper
31	**BAT 31** The reduced load from the discharge of the components of the coating suspensions and binding substances, which may disturb the operation of the biological wastewater treatment station.
32	**BAT 32** The prevention and reduction of the pollution of wastewater, penetrating into the water source from the whole company.
33	**BAT 33** The reduction of emissions of volatile organic compounds (VOC) from detached or integrated coating machines
34	**BAT 34** The reduction of the quantity of waste being disposed at a landfill
35	**BAT 35** The reduction of thermal and electrical energy consumption

Attachment E

(mandatory)

List of Technological Parameters in Accordance with BAT

Table E.1 Volume of wastewater, in accordance with BAT, at the point of discharge after the production process of the plant (marker parameter).

Name of production	Unit of measurement	Annual average level of wastewater flow
Production of wood raw material preparation	m^3/t[1)]	3,00 – 10,00
Production of bleached sulphate pulp	m^3/t	25,00 – 50,00
Production of unbleached sulphate pulp	m^3/t	15,00 – 40,00
Production of bleached sulphite pulp for paper production	m^3/t	25,00 – 50,00
Production of unbleached sulphite pulp for paper production	m^3/t	20,00 – 45,00
Production of dissolving pulp	m^3/t	45,00 – 70,00
Production of neutral sulphite pulp	m^3/t	40,00 – 60,00
Production of mechanical pulp	m^3/t	11,00 – 20,00
Production of CTMP and TMP	m^3/t	09,00 – 16,00
Paper plants, using primary fibre	m^3/t	15,00 – 27,00
Paper and board plants, using secondary fibre	m^3/t	15,00 – 30,00[2)]
Production of sanitary and hygienic types of paper with the use of secondary fibre and the use of secondary fibre	m^3/t	15,00 – 25,00
[1)] The annual average level of wastewater consumption is shown per 1 ton of commercial produce [2)] A higher upper limit of the range is mainly connected to the production of board for the production of collapsible boxes.		

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Table E.2 BAT-associated production parameters, in the course of producing sulphate/sulphite pulp and groundwood pulp as part of an integrated company. Existing plants.

Production parameter		Annual average value kg/t[1)] for integrated companies with a production of sulphate pulp		Annual average value kg/t[1)] for integrated companies with a production of sulphite pulp and mechanical pulp	
		Unbleached pulp	Bleached pulp	Unbleached pulp	Bleached pulp
COD (unbleached/bleached)	kg/t	5,00 – 12,00	8,00 – 30,00	20,00 – 40,00	35,00 – 45,00
BOD_{tot} (unbleached/bleached)	kg/t	0,30 – 0,70	0,80 – 1,20	2,00 – 6,00	2,00 – 2,60
SS (unbleached/bleached)	kg/t	0,0 – 1,20	0,60 – 1,90	1,00 – 2,00	1,50 – 2,00
AOX (bleached)	kg/t[2)]		0,25 – 0,40	-	0,25 – 0,40
N_{tot}	kg/t	0,25 – 0,40	0,25 – 0,40	0,30 – 0,50	0,40 – 0,50
P_{tot}	kg/t	0,01 – 0,04	0,01 – 0,04	0,03 – 0,05	0,04 – 0,05
Wastewater flow	m^3/t[3)]	50,00 – 70,00	100,00 – 150,00	40,00 – 90,00	55,00 – 90,00
Sulphur-containing gases (total H_2S, MM, DMS)	kg/t	0,25 – 0,00	0,25 – 0,00	-	-
NO_x (in NO_2 equivalents)	kg/t	-	-	-	1,8 – 2,00 (from the MRB)
SO_2 (from the burning of sulphur-containing gases)	kg/t				2,5 – 3,00 (from the MRB)
Waste from the chemicals recovery cycle, subject to disposal	kg/t	15,00 – 20,00	15,00 – 20,00	-	15,00 – 20,00

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Production parameter			Annual average value kg/t[1)] for integrated companies with a production of sulphate pulp		Annual average value kg/t[1)] for integrated companies with a production of sulphite pulp and mechanical pulp	
			Unbleached pulp	Bleached pulp	Unbleached pulp	Bleached pulp
Biodegradable waste (in bone-dry solids)	Bark and wood waste and screening waste (shives and knots)	kg/t	400,00 – 550,00	400,00 – 550,00	400,00 – 550,00	400,00 – 550,00
	Screening waste (undercooked pulp)	kg/t	5,50 – 6,00	5,50 – 6,00	5,50 – 6,00	5,50 – 6,00
	Treatment plant sludge	kg/t	45,00 – 50,00	45,00 – 50,00	50,00 – 80,00	50,00 – 80,00
Toxicity			Absent		Present	

[1)] The parameters have been presented as commercial goods for integrated plants and the discharge to recipients from the paper production are included
[2)] The parameters have been indicated per ton air-dry bleached pulp
[3)]The wastewater consumption (fresh water) is indicated for the whole company taking into account the consumption for the cooling of the turbines

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Table E.3 BAT-associated production parameters for sulphate/sulphite pulp and groundwood pulp[1)] production as part of an integrated company. New/upgraded plants.

Production parameter		Annual average value kg/t[1)] for integrated companies with a production of sulphate pulp		Annual average value kg/t[1)] for integrated companies with a production of sulphite pulp and mechanical pulp	
		Unbleached pulp	Bleached pulp	Unbleached pulp	Bleached pulp
COD (unbleached/bleached)	kg/t	≤5,00	≤8,00	≤20,00	≤35,00
BOD_{tot} (unbleached/bleached)	kg/t	≤0,30	≤0,80	≤2,00	≤2,00
SS (unbleached/bleached)	kg/t	≤0,90	≤0,60	≤1,00	≤1,50
AOX (bleached)	kg/t[2)]		≤0,25	-	≤0,25
N_{tot}	kg/t	≤0,25	≤0,25	≤0,30	≤0,40
P_{tot}	kg/t	≤0,01	≤0,01	≤0,03	≤0,04
Wastewater flow	m^3/t[3)]	≤50,00	≤100,00	≤40,00	≤55,00
Sulphur-containing gases (total H_2S, MM, DMS)	kg/t	≤0,25	≤0,25	-	-
NO_x (in NO_2 equivalents)	kg/t	-	-	-	≤1,8 (from the MRB)
SO_2 (from the burning of sulphur-containing gases)	kg/t				≤2,5 (from the MRB)

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Technological parameter			Annual average value kg/t[1)] for integrated companies with a production of sulphate pulp		Annual average value kg/t[1)] for integrated companies with a production of sulphite pulp and mechanical pulp	
			Unbleached pulp	Bleached pulp	Unbleached pulp	Bleached pulp
Waste from the chemicals recovery cycle, subject to disposal		kg/t	≤15,00	≤15,00	-	≤15,00
Biodegradable waste (in bone-dry solids)	Bark and wood waste and screening waste (shives and knots)	kg/t	400,00 – 550,00	400,00 – 550,00	400,00 – 550,00	400,00 – 550,00
	Screening waste (undercooked pulp)	kg/t	≤5,50	≤5,50	≤5,50	≤5,50
	Treatment plant sludge	kg/t	≤45,00	≤45,00	≤50,00	≤50,00
Toxicity		Absent			Present	

[1)] The parameters have been presented as commercial goods for integrated plants and the discharge to recipients from the paper production are included
[2)] The parameters have been indicated per ton air-dry bleached pulp
[3)]The wastewater consumption (fresh water) is indicated for the whole company taking into account the consumption for the cooling of the turbines

Table E.4 BAT-associated production parameters for the production of paper and board at an integrated company. Existing plants.

Parameter	Annual average values kg/t[1)]	
	Fresh intermediate products	Secondary fibre
Chemical oxygen demand (COD)	1,80 – 5,00	4,00 – 5,00
Biological oxygen demand (BOD_5)	0,30 – 0,50	0,50 – 1,00
Total Suspended Solids (SS)	0,30 – 0,70	0,30 – 0,40
Total Nitrogen (N_{tot})	0,20 – 0,30	0,20 – 0,30
Total Phosphorus (P_{tot})	0,2 – 0,03	0,02 – 0,03
Adsorbed organohalogen compounds (AOX)	0,005 – 0,007	0,005 – 0,007
Water consumption	15.00 – 27.00	12.00 – 16.00
[1)]The values of the production parameters are indicated per ton of commercial produce. For integrated companies they are included in the numbers of the previous tables.		

Table E.5 BAT-associated production parameters for the production of paper and board at a non-integrated company. New/upgraded plants.

Parameter	Annual average values kg/t[1)]	
	Fresh intermediate products	Secondary fibre
Chemical oxygen demand (COD)	≤1,80	≤4,00
Biological oxygen demand (BOD_5)	≤0,30	≤0,50
Total Suspended Solids (SS)	≤0,30	≤0,30

Total Nitrogen (N_{tot})	≤0,20	≤0,20
Total Phosphorus (P_{tot})	≤0,2	≤0,02
Adsorbed organohalogen compounds (AOX)	≤0,005	≤0,005
Water consumption	≤15,00	≤12.00
[1)]The values of the production parameters are indicated per ton of commercial produce. For integrated companies they are included in the numbers of the previous tables.		

Table E.6. Discharges of pollutants in wastewater in accordance with EU BAT-AEL[1)], 2015, from plants producing bleached sulphate pulp.

Parameter	Average level of pollution kg/ADt
Chemical oxygen demand (COD)	7,00 – 20,00
Suspended solids (SS)	0,30 – 1,50
Total nitrogen (N_{tot})	0,05 – 0,25[2)]
Total Phosphorus (P_{tot})	0,01 – 0,03[2)] Eucalyptus: 0,02 – 0,11[3)]
AOX[4), 5)]	0,00 – 0,20

[1)]BAT-AEL is the level of discharges that corresponds to BAT, defined in accordance with Article 3 (12) of the Directive 2010/75/EC on Industrial Discharges (industrial emissions directive: IED)
[2)]Compact wastewater treatment plants may lead to an insignificant increase of the discharge parameters
[3)]The upper limit of the range concerns the companies that use eucalyptus as raw material with a high phosphorus content (in particular eucalyptus from the Pyrenean mountains)
[4)]For companies using chlorine as part of their bleaching chemicals
[5)] For companies producing pulp with an increased mechanical strength, rigidity and a high level of pureness (in particular, pulp for the production of packages for liquid products and lightly coated paper), the level of AOX discharge may reach 0,25 kg/ton ADt.

Table E.7. Discharges of pollutants in wastewater in accordance with EU BAT-AEL[1)], 2015, from plants producing unbleached sulphate pulp.

Parameter	Average level of pollution kg/ADt[2)]
Chemical oxygen demand (COD)	2,50– 8,00
Suspended solids (SS)	0,30 – 1,00
Total nitrogen (N_{tot})	0,10 – 0,20[3)]
Total Phosphorus (P_{tot})	0,01 – 0,02[3)]

[1)]BAT-AEL is the level of discharges that corresponds to BAT, defined in accordance with Article 3 (12) of the Directive 2010/75/EC on Industrial Discharges (industrial emissions directive: IED)
[2)]The level of BAT-AEL discharges vary within a certain range in connection with the fact that the non-integrated plants for the production of commercial pulp are taken into account, as well as integrated plants,

Parameter	Average level of pollution kg/ADt[2)]
…with a production of pulp production (the discharges from the paper production are included). [3)]Compact wastewater treatment plants may lead to an insignificant increase of the discharge parameters.	

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Attachment F

(reference)

Methods for the Control of Production Parameters in Wastewater

Table F.1 Methods for the control of production parameters in wastewater

No of the methods	Name of the method
Wastewater toxicity	Method for the determination of the toxicity of the water, water-soil extracts, wastewater sludge and waste by the lethality rate and changes in fertility of Ceriodaphnia FP.1.39.2007.03221
	Method for the determination of the toxicity of the water, water-soil extracts, wastewater sludge and waste by the lethality rate and changes in fertility of Daphnia FP.1.39.2007.03222
	Biological control methods. Method for the determination of the toxicity of the water, water-soil extracts, wastewater sludge and waste by the changes in the level of fluorescence of chlorophyll and the amount of cells of algae. FP1.39.2007.03223
BOD_{tot}	A Method for the performance of measurements of the biochemical demand of oxygen after p days of incubation (BOD_{tot}) in surface- and freshwater, drinking water, waste water and treated wastewater. PND F 14.1:2:3:4. 123-97 (issued in 2004).
Suspended solids	The method for the performance of measurements of the content of suspended matter and the total content of impurities in samples of natural and treated wastewater by a gravimetric method PND F 14.1:2.110-97 (issued 2004).
Phosphates (total Phosphorus)	A method for the measuring of mass concentration of phosphate ions in samples of natural and treated wastewater by a photometric method of reduction of ascorbic acid: PND F 14.1:2.112-97 (issued 2004).
Total Nitrogen	PND F 14.1;2.206-04. Quantitative chemical analysis of water. This method of performing measurements of mass concentration of total nitrogen in natural water and wastewater.

No of the methods	Name of the method
AOX	GOST R 542613-2010 Pulp and Paper Industry Production Processes. Method for the Determination of the Content of Organochloric compounds (AOX) in Natural Water and Wastewater of Pulp and Paper Industry Plants
COD BOD_{tot}	Method for the Performance of Measurements of the Chemical Oxygen Demand in Natural Waster and Treated Wastewater. PND F 14.1:2.100-94 (edition of 2004).
	Method for the determination of the dichromate oxidizability (chemical oxygen demand) of samples of natural and drinking water as well as wastewater by a photometric method with the use of the liquid analyser Fluorat-02. PND F 14.1:2:4. 190-03 (2007 edition)
	Method for the performance of measurements of the chemical oxygen demand (COD) of samples of natural water and wastewater using the titrimetric method TsV 3.01.17-10 A FR.1.31.2002.00639

Attachment G

(Reference)

List of Emerging Techniques

Table G.1 List of emerging techniques

No.	**Name of the emerging technique**	**Time for commercial availability**
1. List of emerging techniques for Russian sulphate pulp production (ET1)		
1	**ET-1.1** Ozone bleaching	3 – 5 years
2	**ET-1.2 Chlorine-free Bleaching Technique (TCF)**	3 – 5 years
3	**ET-1.3** The Partial and Full Closing of the Water Circuit of the Bleach plant	3 – 5 years
4	**ET-1.4** Gasification of Black Liquor	3 – 5 years
5	**ET-1.5** The Increased Production of Electric Energy based on Biomass Products and the Recovery of Surplus Heat.	3 – 5 years
6	**ET-1.6** Borate Autocaustization	3 – 5 years
7	**ET-1.7** Selective Non-Catalytic Reduction in the Recovery Boilers.	3 – 5 years
8	**ET-1.8** The Removal of Chelating Agents through Biological Treatment at Moderate Levels of Alkalinity or with the use of ”Industrial Kidneys”	3 – 5 years
9	**ET-1.9** The Full Closure of the System Working with ”Industrial Kidneys”	3 – 5 years
2 A list of emerging techniques for Russian sulphite and neutral sulphite pulp (ET-2)		
10	**ET-2.1** Ozone Bleaching (see ET-1.1)	3 – 5 years
11	**ET-2.2** Chlorine-free Bleaching Technique – TCF (see ET-1.2)	3 – 5 years
12	**ET-2.3** The Partial and Full Closing of the Water Circuit of the Bleach plant (See-1.3)	3 – 5 years
13	**ET-2.4** The Increased Production of Electric Energy based on Biomass Products and the Recovery of Surplus Heat (see ET-1.5)	3 – 5 years
14	**ET-2.5** The Removal of Chelating Agents through Biological Treatment at Moderate Levels of Alkalinity or with the use of ”Industrial Kidneys” (see ET-1.8)	3 – 5 years
15	**ET-2.6** The Full Closure of the System Working with ”Industrial Kidneys” (see ET-1.9)	3 – 5 years
16	**ET-2.7** Delignification with the Aid of Hydrogen Peroxide in the Presence of a Catalyser in an Acid Environment	3 – 5 years
3. List of Emerging Techniques for Russian Producers of Mechanical Pulp (ET-3)		
17	**ET-3.1** Bleaching of Mechanical Pulp with Hydrogen Peroxide	3 – 5 years
§18	**ET-3.2** The Thermopulp Process	3 – 5 years
19	**ET-3.3** Introduction of RTS TMP-CTMP Production Techniques from Softwood (see 4.3.3)	3 – 5 years
20	**ET-3.4** Introduction of Alkaline-Peroxide TMP-CTMP Production Techniques from Hardwood (see 4.3.4)	3 – 5 years

21	**ET-3.5** Introduction of Alkaline-Peroxide TMP Production Techniques from Softwood (see 4.3.6)	3 – 5 years
22	**ET-3.6** The Removal of Chelating Reagents through Biological Treatment at Low Alkalinity or with the Use of ”Industrial Kidneys” (see ET-1.8)	3 – 5 years
23	**ET-3.7** The Full Closure of the System Working with ”Industrial Kidneys” (see ET-1.9)	3 – 5 years
24	**ET-3.8** Biosorption on Surplus Activated sludge	3 – 5 years
4 List of Emerging Techniques for the Production of Paper and Board (ET-4)		
25	**ET-4.1** The Reduction of Water Consumption and the Specific Discharges when Constructing the Maximum Possible Closed Recirculated Water Circuit.	3 – 5 years
26	**ET-4.2** The Optimization of the Wastewater Treatment System with the use of New Internal Workshop Treatment, so-called Industrial Kidneys.	3 – 5 years
27	**ET-4.3** Increased Dryness of the Paper Sheet after the Press Section of the Paper Machine with the use of New Pulp Dewatering Technology	3 – 5 years
28	**ET-4.4** Recovery and Recycling of Wastewater from the Paper and Board Coating Process	3 – 5 years
29	**ET-4.5** The Local Preparatory Treatment of Wastewater from the Paper and Board Coating Process.	3 – 5 years
30	**ET-4.6** Paper and Board Sizing	3 – 5 years
31	**ET-4.7** Strengthening of Paper and Board	3 – 5 years
32	**ET-4.8** Regulation of the Retention of Components of the Paper-grade Stock on the Wire of the Paper Machine	3 – 5 years
List of Emerging Biotechniques and other Techniques, based on new Physical and Chemical Methods (ET-5)		
33	**ET-5.1** Biobleaching of Sulphate Unbleached Pulp	3 – 5 years
34	**ET-5.2** Bio-deinking (The Production of Paper/Board from Waste Paper)	3 – 5 years
35	**ET-5.3** The Enzymatic Decrease of Resin Problems.	3 – 5 years
36	**ET-5.4** Enzymatic Decomposition of Starch during the Preparation of Sizing Solutions for Sizing Presses.	3 – 5 years
37	**ET-5.5** The Secondary of Biological Treatment using an Aerobic Method	3 – 5 years
38	**ET-5.6** The Physical and Chemical Treatment of Wastewater from the Wood Preparation Workshop	3 – 5 years
39	**ET-5.7** Wastewater Treatment	3 – 5 years
40	**ET-5.8** The use of Low-potential Heat.	3 – 5 years

41	**ET-5.9** Water Pyrolysis of Organic Waste	3 – 5 years
42	**ET-5.10** The Impregnation of Chips before Cooking	3 – 5 years
43	**ET-5.11** Pulp Washing	3 – 5 years
44	**ET-5.12** The Sorting of Pulping Stock	3 – 5 years
45	**ET-5-13** Pulp Bleaching	3 – 5 years
46	**ET-5.14** The Gasification of the Fine Fractions of the Chip Screening Waste	3 – 5 years
47	**ET-5.15** Processing of the Wastewater Sludge (Cake – Compacted or Dried Sludge or Sediment) Using a Supercritical Technique SCT	3 – 5 years
48	**ET-5-16** The Technique for the Production and Use of Nanopulp in the Production of Paper and Board Products	3 – 5 years

Attachment H

(Mandatory)

Energy Efficiency

1. A short description of the industry from the viewpoint of resource and energy consumption

Pulp and paper production is energy-consuming. In order to supply the process steam, heat and electrical energy at the companies, there are heat-electric generating plants, bark and wood energy boilers, recovery boilers and other energy equipment. All types of fuel are used, such as nature gas, coal and fuel oil. There is a large share of use of renewable sources of energy – biofuel, including bark and wood waste, black liquor and treatment plant sludge. (see 1.1.3)
In connection with this it is necessary to take some action for the increased energy efficiency of the pulp and paper production process.

2. The main production processes, associated with energy use.

The pulp and paper production technological processes are associated with a considerable use of heat and electrical energy.

3. The consumption of energy resources in the course of production of pulp and paper products (See Section 3)

Table H 1. Energy consumption of pulp and paper production.

Name of the energy resource	**Measurement unit**	**Consumption per 1 t commercial produce[1)]**	
		Minimum	maximum
Wood preparation			
Steam for 1 dense m³ of pulpwood	Gcal/dens m³	0,002	0,008
Electrical energy for 1 dense m³ of pulpwood	kWh/1 dense m³	7,30	33,50
Sulphate pulp production			
Unbleached pulp			
			Per 1 ton of ADt based on cooking
Heat energy:			
Cooking workshop	Gcal/ton	0,49	1,79
Oxygen-alkaline delignification	Gcal/ton	0,81	0,81

Name of the energy resource	**Measurement unit**	**Consumption per 1 t commercial produce[1)]**	
		Minimum	maximum
Electrical energy			
-cooking workshop	kWh/ton	100,00	167,00
-oxygen-alkaline deligni-fication	kWh/ton	12.00	16.00
Bleached pulp		Per 1 t air-dry commercial pulp	
Thermal energy	Gcal/ton	0,20	1,33
Electrical energy	kWh/ton	62,00	263,00
Production of Chlorine dioxide using the Metison or the HPA method			Per one ton of chlorine dioxide
Electrical energy	kWh/ton	80,00	
Production of Chlorine dioxide using the Chemetics integrated method			Per one ton of chlorine dioxide
Steam	Ton/ton	8,00	
Electrical energy	kWh/ton	8 900,00	
Neutral sulphite pulp production			
Steam	Gcal/ton	0,43	0,55
Electrical energy	kWh/ton	189,00	335,00
Sulphite pulp production			
Unbleached pulp			Per one ton of chlorine dioxide
Bleached pulp			Per one ton of chlorine dioxide
See the section on sulphate pulp production			
Mechanical pulp production			
Defibred wood pulp			
Steam	Gcal/ton	-	-
Electrical energy	kWh/ton	1 441,41	1961,56
Thermomechanical pulp			
Steam	Gcal/ton	015	0,40
Electrical energy	kWh/ton	2 328	2 509

Name of the energy resource	**Measurement unit**	**Consumption per 1 t commercial produce[1)]**	
Chemo-thermomechanical pulp			
Steam	Gcal/ton	0,15	0,4
Electrical energy	kWh/ton	2 328	2 509
Chemo-mechanical pulp (aspen)			
Steam	Gcal/ton	0,30	0,40
Electrical energy	kWh/ton	1 200	1 400
Chemicals recovery			
Electrical energy	kWh/ton	24,00	85,00
Steam	Gcal/ton	1,30	2.10
Caustization and lime recovery			
Fuel for lime burning	Kg standard fuel	200,00	300,00
Steam	Gcal/ton	0,12	0,35
Electrical energy	kWh/ton	130,00	160,00
Paper production			
Steam	Ton/ton	1,50	3,50
Electrical energy	kWh/ton	400,00	1 000,00
Paper production			
Steam	Ton/ton	2,00	3,00
Electrical energy	kWh/ton	435,00	650,00
Wastewater treatment			
Electrical energy	kWh/ton	350	980,00

[1)] The consumption of energy resources depends on a number of factors, including the choice of products, the technical level of the equipment, the technique used, the quality of the wood and other raw material, the used chemicals and supplies as well as the use of a modern system for the control of the production process, etc.

4. Best available technique, applied for an improved energy efficiency and the optimization and reduction of resource consumption (see section 5)

Table H.2 Best available technique applied for an improved energy efficiency and the optimization and reduction of resource consumption (see section 5)

BAT 5 The optimal management of the system of energy consumption and energy efficiency in order to reduce the consumption of fuel and energy resources and the reduction of the industrial impact on the environment of the production processes and the combined heat and power plant.
BAT 11 The reduction of the formation of waste, the involvement of it for repeated use and preparation before the disposal at a landfill (including energy production)
BAT 21 The reduction of the consumption of warm energy (steam) and electrical energy
BAT 22 The increased efficiency of the electric energy production
BAT 26 The reduced consumption of heat energy (steam) and electrical energy
BAT 28 The reduced consumption of thermal and electrical energy
BAT 35 The reduction of thermal and electrical energy consumption

5 Economic aspects of BAT introduction for the increased energy efficiency and the optimization and reduction of resource consumption

In section 6 there is a discussion of economic aspects of an increased energy efficiency. The use of resource saving technique allows for the reduced level of energy resources consumption.

6 Emerging techniques for the increased energy efficiency and the optimization and reduction of resource consumption: (see section 7)

Table H.3 Emerging techniques for the increased energy efficiency and the optimization and reduction of resource consumption

ET-1.4 Gasification of Black Liquor
ET-1.5 The Increased Production of Electric Energy based on Biomass Products and the Recovery of Surplus Heat.
ET-4.1 The Reduction of Water Consumption and the Specific Discharges when Constructing the Maximum Possible Closed Recirculated Water Circuit.
ET-5.14 The Gasification of the Fine Fractions of the Chip Screening Waste
ET-5.15 Processing of the Wastewater Sludge (Cake – Compacted or Dried Sludge or Sediment) Using a Supercritical Technique SCT Among the listed 48 ET (see Attachment G) the major part is resource saving and promotes the reduction of energy resources consumption

Additional types of activities of the production of pulp, mechanical pulp, paper and board and the corresponding BAT reference documents (according to the Resolution of the Russian Federation Government of the 31 October 2014 no 2178-r) are shown in table 2 of the Reference document under the condition that the set power of the boiler facilities are companies of the first category (see field of application).

Table h 4 Additional types of activities

Type of activity	Corresponding BAT reference document
Production of steam and electrical	The burning of fuel at large industrial companies for the production of energy
Industrial systems for the cooling (towers, laminar heat exchangers)	Industrial cooling systems

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