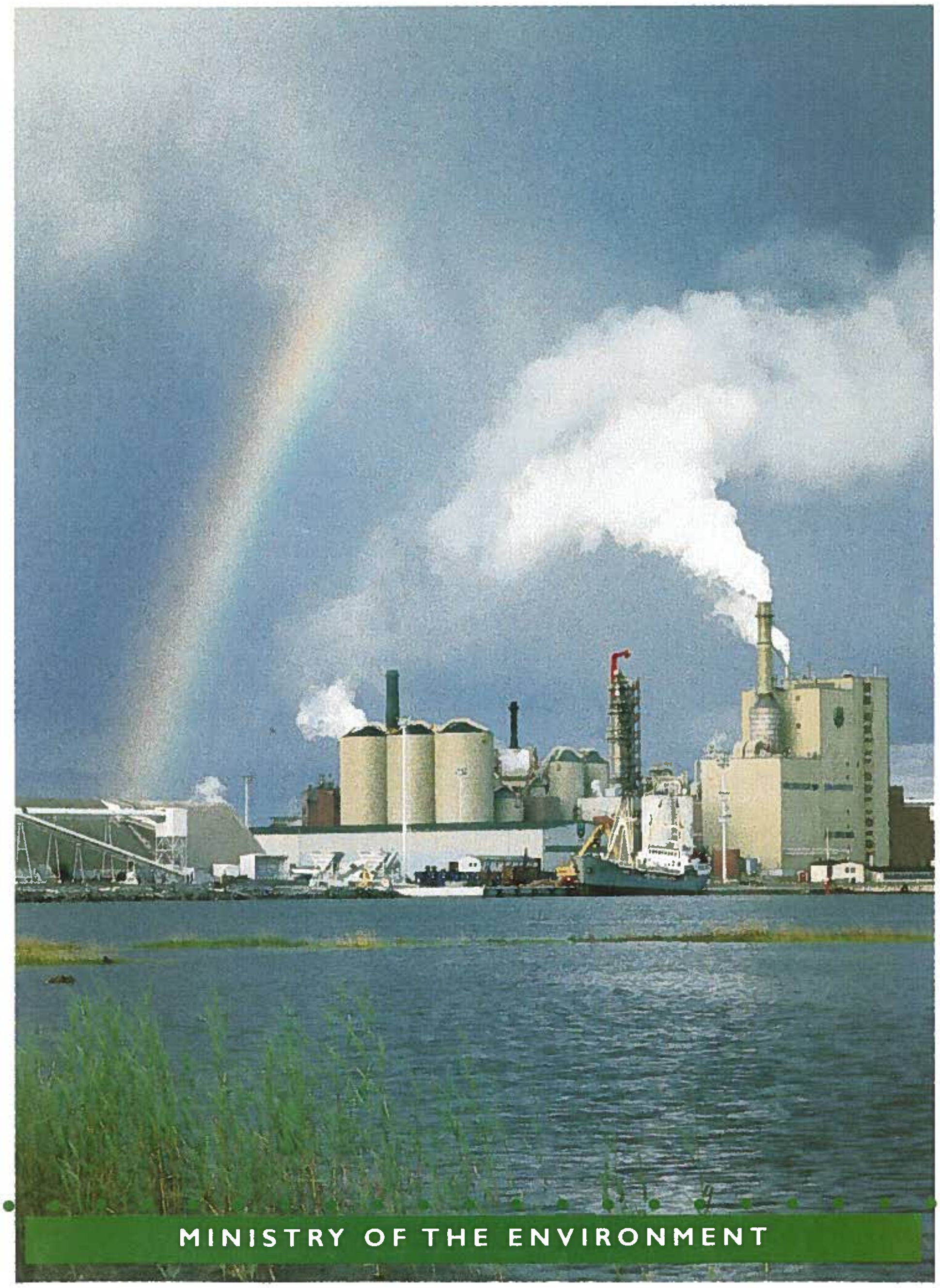
The Finnish Environment

96

ENVIRONMENTAL PROTECTION

The Finnish Background Report for the EC Documentation of Best Available Techniques for Pulp and Paper Industry



MINISTRY OF THE ENVIRONMENT

The Finnish Background Report for the EC Documentation of Best Available Techniques for Pulp and Paper Industry

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MINISTRY OF THE ENVIRONMENT

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TEKES
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FINLAND

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Introduction

The purpose of this report is to carry out the Finnish contribution to the exchange of information in the Council Directive 96/61/EC concerning Intergrated Pollution Prevention and Control, article 16, and to the preparation of the Reference Document of the European Commission on the Best Available Techniques for Pulp and Paper Industry.

In the report, the manufacturing of pulp, paper and board grades which are most important for the Finnish pulp and paper industry are discussed taking into account production capasities, the used process technologies and their effects on the discharges and emissions, solid waste generation and consumption of raw material and energy.

The general description of Finnish pulp and paper industry is supplemented with more detailed descriptions of six Finnish pulp and paper mills representing different types of products and production set-ups. The process technology of a new kraft pulp mill which started in the spring of 1996 is also described.

PI-Consulting Ltd was commissioned by the Ministry of the Environment, the Finnish Technology Development Centre (TEKES) and the Finnish Forest Industries Federation to compile this state-of-the-art report on the Finnish pulp and paper industry.

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The forest industry companies and equipment manufacturers have given valuable support to this project.

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Ministry of the Environment

Abbreviations

ADt	Air dry tonne
AL	Aerated lagoon
AOX	Adsorbable organic halogen
AS	Activated sludge
BOD_7	Biochemical oxygen demand (7 days test)
$COD_{Cr,Mn}$	Chemical oxygen demand (dichromate or permanganate)
CSF	Canadian Standard Freeness
CTMP	Chemi-thermo-mechanical pulp
D	Chlorine dioxide stage in pulp bleaching
DAF	Dissolved air flotation
DS	Dry solid
E	Alkaline extraction in pulp bleaching
ECF	Elemental chlorine free
GNP	Gross national product
GW	Groundwood
HC	High consistency
HW	Hardwood
LWC	Light weight coated (magazine paper)
m^3n	m^3 of a gas at atmospheric pressure and 20 ºC
MC	Medium consistency
NOx	Nitrogen oxides
O	Oxygen stage in pulp bleaching sequence
P	Peroxide stage in pulp bleaching sequence
Q	Stage with chelating agent addition in pulp bleaching sequence
SC	Super calendered (magazine paper)
SGW	Stone groundwood
SO_2	Sulphur dioxide
SW	Softwood
TCF	Totally chlorine free
TMP	Thermo-mechanical pulp
Tot-N	Total nitrogen
Tot-P	Total phosphorus
TRS	Total reduced sulphur
TSP	Total suspended particulates
TSS	Total suspended solids
X	Enzyme treatment in pulp bleaching sequence

Conversion coefficients for energy

1 toe = 40.6 GJ
1 MWh = 3.6 GJ

Executive Summary

The Finnish Background Report for the EC Documentation of Best Available Techniques for the Pulp and Paper Industry

According to the Council Directive concerning Integrated Pollution Prevention and Control (96/61/EC) the term **'best available techniques'** shall mean the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole:

-'**techniques**' shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned,

-'**available**' techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonable to the operator,

-'**best**' shall mean most effective in achieving a high general level of protection of the environment as a whole.

Introduction

Finland is located north of latitude 60° N and is part of the coniferous forest belt surrounding the northern hemisphere. Almost 70% of the Finnish land area is covered with forest. Due to the favourable climatic influence of the Gulf stream, the productivity of the Finnish borealic forest is quite high.

The Finnish pulp and paper industry together with the associated engineering and chemical industries is the dominant sector in the Finnish economy. In 1995 the total annual production of chemical pulp was about 6 million tonnes and of paper and board 11 million tonnes.

In 1995 the total Finnish consumption of primary energy was 31.7 Mtoe. Of this, approximately 32% was of domestic origin (table 1A). The consumption of electrical energy was 69.0 TWh (table 1B). The production of chemical pulp includes the recovery of the process chemicals. The cycle includes incineration of the spent chemicals and the dissolved wood in a recovery boiler, which produces energy. From table 1A it can be seen that nearly 10% of total primary energy comes from this source. The net consumption of energy, thermal and electrical, in the Finnish pulp and paper industry was 9.2 Mtoe and 22.9 TWh respectively in 1995. The harsh winters in Finland have a pronounced impact on energy consumption.

Table 1A. Total consumption of primary energy in Finland in 1995.

	Mtoe
Imported	21.5
Oil	8.6
Coal	3.3
Natural gas	2.9
Nuclear	4.5
Electric	2.1
Domestic	10.2
Hydro	3.2
Black liquor	2.8
Wood	2.0
Peat	1.6
Industrial waste heat	0.6
Total	31.7
Pulp and paper	9.2

Table 1B. Generation and consumption of electricity in Finland in 1995.

	TWh
Generation	69.0
Hydro power	12.8
Nuclear power	18.1
Condensation power	8.8
District heat power	11.4
Black pressure power	9.5
Net imports	8.4
Consumption	
Industry, total	37.3
Pulp and paper	22.9

The development of Finnish forestry is based on long-term experience. The systematic forest management has resulted in a growth that exceeds the felling, which, in practice, means that a considerable amount of carbon dioxide is bound because of the strong growth of the well-managed forest. Legislation passed as early as in 1928 obliges Finnish forest owners to regenerate harvested forest. The law, which is enforced by forest officials, in effect prohibits not only local harvesting in excess of local re-growth but also excessive clear felling on a national scale.

The principle of ecological sustainability has become increasingly important in Finnish forest management. According to this principle, the commercial utilization of the forest must not endanger the diversity of different species living there. As much as 10% of Finland's forested area is protected from all commercial use, a very high figure in international terms. Protected forests are government-owned and situated in eastern and northern Finland. For small, privately-owned forests in southern Finland, large-scale protection is ruled out. Under the new regime aimed at the preservation of biodiversity, no fertilizers or intensive soil-preparation methods are used to boost growth. Further measures aimed at retaining the variety of indigenous biotypes include the creation of protected ecological corridors and leaving an increased amount of standing dead wood as well as fallen dead wood to decompose in the natural way.

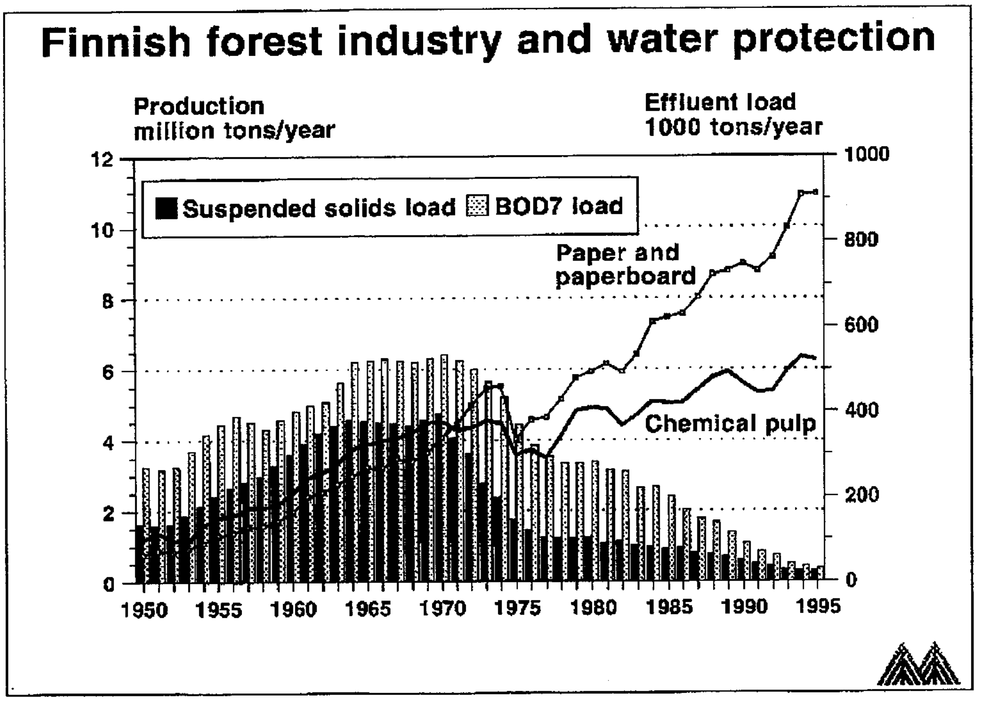
Approximately 80% of the Finnish pulp and paper industry production is exported to Europe and 10% is used domestically. The production is almost entirely based on primary fibre and, therefore, Finland plays an important role as a supplier of primary fibre to the European and international paper and board industry that utilizes recycled fibre.

The production of pulp, paper and board for the international market place is a demanding task from several standpoints. In order to succeed, the product has to meet stringent quality specifications. The generally applied concept of total quality includes improved productivity and minimum environmental impact as well as excellent performance at the customer's plant and a top-quality product at the consumer's end of the chain.

The Finnish pulp and paper industry actively co-operates with related engineering and equipment suppliers in the development of better production technology. The principal goals set for this work are the more efficient use of raw materials and energy as well as a reduced total environmental impact.

The size of the production units has increased, which has made a substantial growth in production possible in spite of the shutdown of old mills. A typical trend in the Finnish paper and board industry has been the directing of production towards products fetching a higher price arising out of the use of special skills and advanced production methods. Pulp production has abandoned the use of elemental chlorine in bleaching and offers a diversity of pulps to suit the customer's needs. Recent process developments in kraft pulping have led the Finnish industry to abandon the sulphite pulping process. The development since 1970 is characterized by an increase in the total paper production capacity of 100% and a switch to improved and specialized products.

The decrease in the number and increase in the size of the production units has resulted in an improved environmental situation. Improved production techniques in combination with internal pollution prevention and external abatement measures have been vital ingredients in the investment programmes. The degree of integration has also increased, resulting in more efficient raw material usage, efficient energy production and usage as well as advanced internal pollution abatement. The discharge of pollutants into the waterways has decreased during the period to less than 10% (in 1995 30,000 tonnes of BOD_7 and 25,000 tonnes of suspended solids) of the 1970 level, and the emission of sulphur into the air from the process and on-site energy production was 9,300 tonnes in 1995. Figure 1 demonstrates the development of production of pulp, paper and board and discharges and emissions into waterways and the air from the chemical pulping processes.



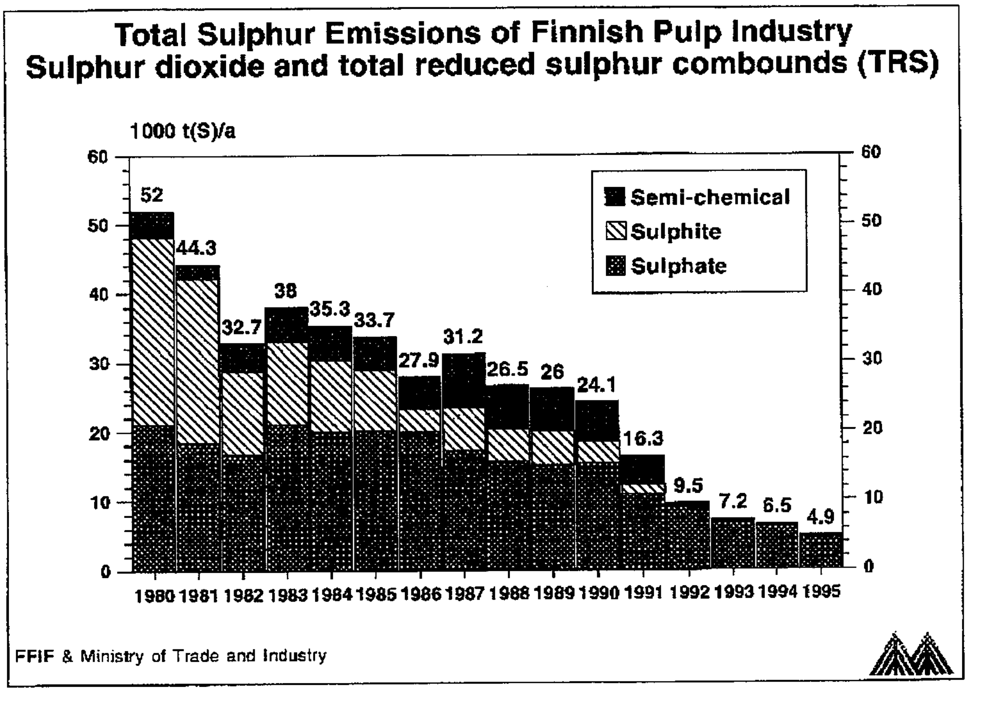


Figure 1. ***Production of pulp, paper and board 1970-1995. Discharges and emissions of pollutants into waterways and the air from the chemical pulping processes*** *(emissions from the energy production in boilers for wood-waste and fossil fuel on site is not included)*.

Paper and board

Paper and board are made from a wide variety of fibres, minerals and additives to a certain thickness and basis weight grade specifications. The products are sold by the tonne.

Products with a basis weight between 20 and 100-150 g/m^2 are normally named paper. Products with basis weights higher than this are called board.

The raw materials and principal processes in paper and board production are similar. Board is used for other purposes than paper, and, in addition to providing printability, board has to be rigid and stiff in order to protect products packed in containers made out of board.

Production of pulp

The main constituents of wood are carbohydrates and lignin. In the carbohydrate group, the most common polymer on earth, cellulose, is the backbone of the trees. Cellulose forms fibres which are glued together with lignin, forming a light and strong wooden structure.

Early in written history, man learned that fibres from plants can be formed into sheets with the aid of water. For centuries paper was made of fibres from annual plants and wool recovered from old clothes, rugs. It was not until the second half of the 19th century that the principal inventions of wood pulping were made. The implementation was immediate and since then ordinary paper has been made from wooden fibres. Wood suitable for defibration is found all over the world, both hardwood and softwood.

Timber intended for pulping is harvested, cut into logs and transported to the production site.

For most pulping processes the bark has to be removed. The debarking of logs is done mechanically, using water for washing and in winter time for deicing.

Wood residues from sawmills, sawmill chips, are also ulilized as fibre raw material in chemical and mechanical pulping.

Chemical pulping

The liberation of fibres is achieved by applying either chemical or mechanical energy to the wooden material. In chemical pulping a mixture of wood chips and an aqueous solution of chemicals is heated and the lignin dissolves. Residual lignin affects the whiteness of the pulp and further processing, called bleaching, removes the dark colour.

Sulphate pulping, also known as the kraft process, with all its process alternatives and the possibility of using a wide variety of raw materials as well as producing a wide variety of pulp grades has become the dominant chemical pulping method.

In kraft pulping, the cooking liquor is separated from the fibres after cooking. This so-called weak black liquor holds the cooking chemicals and approximately 50% of the original wood. Chemical pulp of different yield levels is made to match the requirement of the final product in which the pulp is to be used. The weak black liquor is concentrated by evaporation to a dry-solids content of at least 70%, but preferably over 80%, before incineration in a recovery boiler. A high solids content in the liquid going to combustion results in better control of the furnace, higher thermal efficiency and the successful prevention of sulphur emissions. The incineration residue is dissolved in water, and this solution is further processed to regenerate fresh cooking liquor.

In a modern kraft pulp mill wood fibre is further delignified prior to final bleaching. In order to recover additional recoverable dissolved organic solids and used chemicals, the pulp is washed using counter current flow and the liquid is combined with the weak black liquor, evaporated and burnt in the recovery boiler.

This extended delignification is performed by applying oxygen delignification or, preferably, a combination of extended cooking and oxygen delignification. The use of efficient washing equipment is an essential part of the process.

The colour of the washed pulp is dark brown and it has to be bleached before use in white paper and board products. The use of unbleached pulp is limited to brown products, such as brown liner and sack paper.

In the bleaching, chlorine chemicals are today partially or totally replaced by bleaching agents such as oxygen, ozone and hydrogen peroxide, chemicals which can be incorporated into the chemical recovery cycle without side-effects.

The amount of effluent from a bleaching plant is in the range of 5 to 40 m^3/ADt.

A modern kraft pulp mill produces more energy than it consumes. The energy production is based on using the dissolved solids in the black liquor as fuel in the recovery boiler. Bark and other wood residues are also valuable biofuels used on site in a boiler for solid fuel or delivered to a nearby energy production unit.

Malodorous gases formed in the process are comprehensively collected. Concentrated gases are burnt, either in a separate furnace equipped with a waste heat boiler or in the lime kiln, where it replaces fossil fuel. Weak malodorous gases are either washed with an alkaline washing liquid or burnt in the recovery boiler or the lime kiln.

Mechanical pulping

Mechanical pulping, means that the wooden structure is broken by applying a mechanical force, liberating fibres and fibre fragments. The pulp (groundwood, refiner pulp etc.) gives the paper properties, such as a smooth surface and low opacity, which are needed for successful printing. Mechanical pulp production is generally integrated with the production of paper and board.

The yield in mechanical pulping is 95-98 %, which means that 20-50 kg of wooden substance per tonne of pulp dissolves in the water present during the defibration. The dissolved material consists of simple carbohydrates (sugars), fats (triglycerides), fatty acids, rosins etc. and inorganic components.

The initial brightness of mechanical pulp is moderate and for some products the pulp is brightened. The two principal chemicals used for bleaching mechanical pulp are the reductive sodium dithionite and the oxidative hydrogen peroxide. Bleaching with peroxide involves the use of caustic, which causes the decomposition of wooden material, and an additional yield loss of 15-25 kg/ADt has been observed.

The components dissolved during defibration and the peroxide bleaching of mechanical pulp affect the chemical balance in the process. In order to decrease disturbances on the paper or board machine, the pulp is washed by pressing before use, or neutralizing chemicals are added.

Water-soluble components in wood are readily biodegradable and, therefore, the pollution potential is easy to remove by biological treatment of the effluent.

Paper and board production

Water is necessary as a transporting, washing and cooling medium in connection with pulp and paper production. The cellulose fibre swells in water and the surface is chemically activated. Without this natural property conventional paper making would be impossible. In this process a mixture of fibres and additives according to the recipe is diluted with water, stirred and dewatered. After the primary separation of the fibrous material and the water, more water is removed from the web by pressing. At this stage the fibres come close enough to form preliminary bonds which are confirmed and strengthened when the paper is dried. The natural paper is held together by hydrogen bonds between the individual cellulose fibres.

The production equipment has developed considerably, bringing new products with superior properties onto the market. For instance, within twenty years the production speed of machines producing newsprint or magazine paper has increased from 60 km/h to over 90 km/h. In combination with wider machines, the capacity has increased to the double per production unit.

Both paper and board can today be produced at lower basis weights than earlier without a loss of any essential properties. Therefore, less paper, by weight, is needed to produce a newspaper or magazine, or less board is needed for a box or container. The significance of this development for better total efficiency and reduced environmental impact cannot be over stated.

Table 2 shows the most typical paper and board products and their composition.

Table 2. Composition of paper and board.

Paper and board grade	Composition	
Newsprint	100%	TMP
	90-100%	DIP
	10 - 0%	bleached kraft pulp
Magazine paper		
- SC	50- 60%	mechanical pulp
	10- 25%	bleached kraft pulp
	15- 35%	minerals
- LWC	25- 45%	mechanical pulp
	25- 40%	bleached kraft pulp
	30- 40%	minerals
Fine paper	60- 75%	bleached kraft pulp
	25- 40%	minerals
Folding box board	50%	bleached kraft pulp
	40%	mechanical pulp
	10%	minerals
Kraftliner	100%	kraft pulp
Fluting	100%	NSSC pulp

SC super calendered
LWC light weight coated

Energy

In general, the heat energy used by the Finnish pulp and paper industry originates from combined power and heat generation. High-pressure steam is generated from a wide variety of wood-based fuels such as bark, black liquor and sludge as well as from peat, coal, natural gas and heavy fuel oil. The high-pressure steam releases part of its potential energy in a turbo-generator, and the thermal energy recovered by condensing is used for drying the products and heating the premises. The overall thermodynamic efficiency in this kind of system is as high as 80-88%.

Modern mechanical pulping incorporates pressurized pulping methods which make energy recovery possible in the form of low-pressure steam. This steam is used for product drying. The energy recovered is in the order of 1,000 to 1,500 kWh/tonne of pulp, representing 30-40% of the total energy consumption in the thermo mechanical pulping.

A kraft pulp mill is more than self sufficient in energy, both electrical and heat. The amount of surplus electricity in modern Finnish kraft pulp mills is about 500 kWh/tonne. Integrated pulp and paper production provides optimal conditions for energy efficiency.

The recent trend to using a gas turbine generator followed by a steam boiler and a turbo-generator (a "combi" power plant) increases the share of electrical energy compared with conventional power generation, which is preferable in the production of mechanical and deinked pulp.

Wood-based energy used by the Finnish pulp and paper industry is approximately 3.5 Mtoe/a (40% of the total energy consumption). The structure and efficiency of on-site energy generation contribute in a positive way to the striving for a considerable decrease in air pollution.

Table 3 presents figures on energy consumption for key products in the Finnish pulp and paper industry.

Table 3. Specific heat and electrical energy consumption and self-sufficiency for some key products in the Finnish pulp and paper industry.

Product	Heat energy		Electrical energy	
	Consumption (GJ/t paper)	Self-sufficiency (%)	Consumption (MWh/t paper)	Self-sufficiency (%)
Newsprint Integrated with production of				
SGW	4.8-5.8	5-10	1.7-2.1	10-15
PGW	4.8-5.8	10-20	1.8-2.2	10-15
TMP	4.8-5.8	70-100	2.4-3.3	10-15
Magazine paper (SC,LWC) Integrated with production of				
SGW (35%)	4.5-6.0	2-5	1.8-2.0	~5
PGW (40%)	4.5-6.0	5-10	2.0-2.2	~5
TMP (45%)	4.5-6.0	30-50	2.3-2.6	~5
(ash content 30%)				
Woodfree paper Integrated with production of bleached kraft pulp	14-18	70-80	1.0-1.2	85-105
Non-integrated production	7.0-7.8	0	0.7-0.9	0
Bleached market kraft pulp	13-15	100-120	0.6-0.8	110-200

Woodfree paper : paper with max. 10% mechanical pulp

Prevention of pollution

Discharges into water

The sources and types of wooden components transferred into the water phase have been indicated above. Wood components suspended and dissolved in the process water must not be allowed to accumulate in the process because of the adverse effects on production efficiency and product quality. The production machinery and equipment need clean water for washing, lubrication, cooling and sealing. Part of this water leaks into the main process giving rise to excess process water, which has to be removed.

In pulp production, fibres are dispersed and suspended in water, and in papermaking water is separated from the suspension. The water separated on the paper machine is called white water and is reused in the pulping. The fresh water used for different purposes leaves the process as excess white water. The excess white water contains solid components which are usable in the product and, therefore, the water is clarified. The separated solids are returned to the paper machine and the clear filtrate is discharged.

The fresh water used in the process gives rise to a roughly equal amount of effluent. The discharged amount of effluent can be decreased by replacing fresh water with clear filtrate in selected areas. Simultaneously the concentration of dissolved and dispersed pulp and paper components in the white water will increase. If the components are allowed to accumulate, the production efficiency and the product quality are negatively affected. The efficient removal of dissolved and dispersed colloidal material, in addition to, or in combination with, the separation of suspended solids makes it possible to reuse the water. The reuse of internally treated water replacing fresh water is referred to as water system closure and is a strongly emerging technology.

The total amount of effluent discharged in the pulp and paper industry is approximately 10-50 m^3/tonne of product. As a result of new production facilities where partial fresh water replacement by internally treated water has been implemented, the specific water consumption (effluent discharge) has decreased to the lower end of the range mentioned. The modernization of old mills has given similar results.

Effluent extracted from the process contains dissolved and dispersed substances originating from the raw materials. Most of these substances are biodegradable and, if discharged into rivers or lakes, pollution takes place, causing oxygen depletion and eutrophication.

The biological treatment of effluents is predominantly implemented in the pulp and paper industry (figure 2). The use of biological treatment by the Finnish pulp and paper industry started at the end of the 1970's when the first aerated lagoons were introduced. The lagoons were equipped with the secondary sedimentation of suspended solids. The local pollution level dropped considerably, and the effect could be observed as an improvement in the water quality in the recipient.

In the middle of the 1980's the first activated sludge plants were built, starting a new era in water pollution abatement in the Finnish pulp and paper industry. In activated sludge treatment the biodegradable substances are removed very effectively (table 4A). Wood contains substances which protect the tree against pests. These substances gives the effluent acute toxic characteristics. The acute toxicity of the effluent, measured as LC50 for water flea (*Daphnia magna*), is completely removed by activated sludge treatment.

Simultaneously with the implementation of activated sludge treatment, anaerobic treatment was tested and found useful for certain applications. Because biogas is generated as a by-product in the anaerobic treatment of highly concentrated effluents, this has an energy advantage over the aerobic treatment.

Of the wood components, lignin shows high resistance to biodegradation under the conditions prevailing in biological effluent treatment. The residual fractions of lignin present in the treated effluent are visible as a brown colour in the water. The natural brown colour in Finnish inland streams also comes from fractions of lignin as humic acids, originating from disintegrating plant material in the marshes.

The reduction rates in the activated sludge treatment of waste water from kraft pulp and paper production is shown in table 4A.

Table 4B shows the specific discharge into the recipient after external treatment from the production of bleached kraft pulp and wood-containing paper in Finland in 1995.

Table 4A. Reduction rates in activated sludge treatment (%).

	Kraft pulp	Wood-cont. paper **)
TSS	> 95	> 95
COD_{Cr}	40-70	70-90
BOD_7 *)	85-98	95-99
tot-P	40-85	40-85

*) 1.16 ´ BOD_5

**) wood-containing paper : > 10% mechanical pulp

Table 4B. Specific discharges into the recipient after external treatment in Finland 1995,average and variation

		Bleached kraft pulp		Wood-cont. paper **)	
TSS	(kg/t)	2.0	(0.2-6.0)	0.4	(0.3-1.0)
COD_{Cr}	(kg/t)	32	(13 -85)	2.4	(1.6-5.0)
BOD_7 *)	(kg/t)	1.5	(0.2-12)	0.2	(0.1-1.2)
tot-P	(g/t)	35	(5.0-95)	4.0	(3.2-13)

*) 1.16 ´ BOD_5

**) wood-containing paper : > 10% mechanical pulp

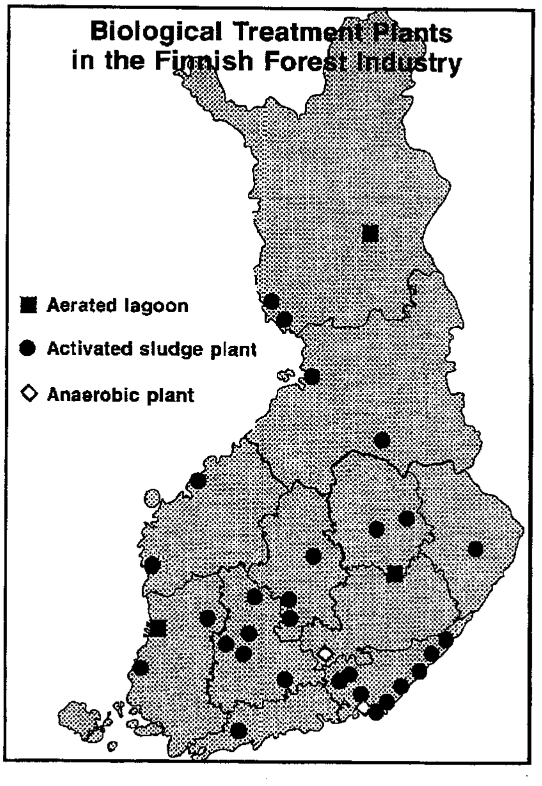


Figure 2. Biological treatment plants in the Finnish Forest Industry in Dec. 1996.

Emissions into the air

The emissions into the air from the pulp and paper industry are mainly connected with the generation of energy and recovery of cooking chemicals. The kraft pulping process gives rise to small amounts of malodorous, sulphur-containing gases, which are sensed by the human nose at very low concentrations.

Emissions into the air from the incineration of fuels and spent liquors consist of particulate matter, called fly ash or dust, and different gases. In addition to the emission of carbon dioxide, which is not discussed here, sulphur dioxide and oxides of nitrogen are considered the most important pollutants.

Flue gases are treated for the removal of particulate matter first in cyclones for coarse separation, and finally in electrostatic precipitators, where the remaining dust is almost entirely retained.
Emissions of both reduced sulphur compounds (TRS) and sulphur dioxide (SO_2) from kraft pulp recovery boilers have decreased considerably as a result of modifications made to the black liquor treatment. An increased solids content in the black liquor results in a higher temperature in the incineration, the increasing amount of vaporized sodium binds the sulphur and the emission of the latter is eliminated.

The highly concentrated malodorous gases from the kraft pulping are collected and incinerated in a separate boiler, in the lime kiln or in the recovery boiler, and weak malodorous gases are treated with alkaline washing liquor or preferably incinerated in the recovery boiler. The collection systems have developed and are today extended to cover most of the sources for bad smells in a kraft pulp mill.

Oxides of nitrogen are formed predominately from nitrogen-containing compounds present in the fuel. If the incineration temperature is above 1,000° C so-called thermal nitrogen oxides start to form through oxidation of the atmospheric nitrogen. The formation of nitrogen oxides is partially avoided by tuning the incineration itself.

In a modern plant, the incineration of solid fuels is done in a fluidized bed boiler. This technique gives good combustion efficiency at a moderate temperature, resulting in cleaner flue gases.

Table 5. Emissions into the air after treatment

Emission source	Unit	Dust	Total-S (as S)	NOx (as NO_2)
Kraft pulp				
- recovery boiler	mg/Nm³	50-200	10-50	150-250
- lime kiln	mg/Nm³	20-300	50-300	250-400
Solid fuel boiler				
- grate	mg/MJ	< 50	*)	100-300
- fuidized bed	mg/MJ	< 50	*)	50-150
Total				
- pulp (process)	(kg/ADt)	0.6 (0.2-1.5)	0.5 (0.2-2.0)	1.5 (0.9-2.0)

*) Sulphur content in fuel and discharge of SO_2 restricted by national regulation.

Solid waste

The production of pulp, paper and board in combination with pollution abatement gives rise to solid waste of various compositions.

In general, primary sludge from effluent treatment is combined with surplus biosludge from secondary treatment, pressed to a dry-matter content sufficient for destruction by incineration, with energy recovery.

The principal composition of the sludge depends on the type of product. In the case where mineral pigments are used, the ash content of the sludge can be considerable, making incineration uneconomical.

In the deinking of recycled fibre, the resulting sludge is combined and pressed with other sludge and burnt. The amount of solid waste can be as high as 40%, by weight, of the recycled paper treated.

Solid waste from the power plants is in the form of grate and fly ash, which are disposed of by landfilling or used for different applications such as soil conditioning.

Ash from bark contains the inorganic trace elements from the trees and can possibly be returned to nature as a fertilizer.

Noise

The main sources of noise in the Finnish pulp and paper industry are wood-handling, compressors, fans and ventilators. The problem is addressed and at mills located in the vicinity of towns and villages the noise sources have been insulated.

Environmental control and management

The monitoring of the emissions and the effects of the emissions on the environment are based on self-monitoring, which is carried out according to provisions included in the permit or in an emission control programme approved by the regional authority.

The monitoring programmes and the reports on the emission and recipient monitoring are available to the public. Monitoring results of emissions are regularly reported, and each mill is obliged to submit an annual report to the authorities.

Important factors connected with the control of emissions are the flow measurement, sampling method, handling and storing of samples, analysis method and accuracy, and the calculation and reporting of the results. Within Finland the monitoring results are comparable, due to the use of standardised methods, practices and guidlines given by the authorities.

It is most important to note that great care has to be taken when comparing discharge figures from different countries. Although the analytical methods are being internationally standardised, the methods of sampling, pre-treatment and statistical calculation make the correct interpretation difficult. The monitoring of emissions into the recipient should therefore be harmonized within the EU.

The environmental management systems in use in the Finnish chemical forest industry are based either on the BS 7750, the ISO 9000 or ISO 14000 series standards or the Eco-Management and Audit Scheme (EMAS), and they are usually linked to the quality systems of the company concerned. The effectiveness of the system is ensured by regular reviews and audits aiming at continuous improvement of environmental protection practices.

Costs

Regular investment in the modernization of existing mills has enabled the industry to maintain its competitiveness continuously, and this, too, is a guarantee of good environmental performance. The implementation of internal treatment at the source has considerably decreased the losses of raw materials, chemicals and energy.

The external treatment of discharges and emissions, gaseous, liquid or solid, includes capital and operating costs. A new production plant is constructed according to stringent efficiency demands, and, therefore, internal measures are highlighted, resulting in less external investment.

Both the investment cost and the operating cost are, in principle, specific to the type of treatment technology.

The technological development has brought to the market machinery which works at a higher efficiency than similar equipment in old mills. It is, therefore, evident that new installations achieve a lower consumption of raw materials and utilities and hence a lower primary environmental impact for a given production.

In every mill, modern or not, it is possible to segregate streams and integrate processes in order to save energy and raw material or, in other words, limit the use of natural resources.

Conclusions

The ultimate goal for any production is to utilize available resources in the most efficient way. All Finnish pulp and paper companies have signed the document on sustainable development issued by the ICC and they adhere to these principles in their everyday operations.

The production of pulp in Finland is normally integrated with paper and board production in order to achieve optimization regarding the consumption of utilities and total efficiency.

In Finland the engineering and other pulp and paper-related industries operating worldwide provide pulp and paper production technology, both hardware and software, to different countries. This is one reason why Finnish industry puts big efforts into the development of processes with a lower total water consumption in the pulp and paper production.

In addition to wood or other fibrous raw material, the use of water is necessary in the process. It is a fact that suitable water for the processes is not found everywhere or all the year round. The treatment of water that has been already used for reuse in the process is most important in regions where water is a limited resource. This is not the case in Finland but, nevertheless, Finnish industry has incorporated this important question early into the process development.

It has been pointed out that most of the dissolved pollutants are readily biodegradable and, therefore, biological treatment, today as an external addition, can and has to be incorporated in a system for water reuse.

From the above it is evident that in pollution abatement several methods have to be combined in order to achieve the desired result.

The integration of processes, for instance the integrated production of pulp and paper, which is typical of the Finnish forest industry, is an important component of high, overall efficiency, which simultanously means low pollution of the environment.

The main streams of wasted material from the process are in the form of liquid, gaseous and solid waste. The treatment for pollution removed from one fraction influences the other and, therefore, the total system has to be carefully scrutinized for minimal environmental impact.

By applying different methods and combinations of methods to segregated streams it is possible to optimize costs and benefits. The implementation of the best combination of available technology is in the interests of the industry itself and the driving force is improved overall performance.

In the modern Finnish pulp and paper industry, process efficiency and pollution prevention are tightly bound together through sophisticated production processes and managerial principles.

1 General description of the pulp and paper industry in Western Europe

1.1 Pulp and paper production and consumption

In developed societies the use of a multitude of paper- and board-based products is everyday reality for most people. Paper as we know it today has been in existence for over a thousand years, and it is still competing very successfully with the most modern electronic information media and the most advanced plastic and composite packaging materials. A look at the main functional uses of paper and board clearly shows what versatile raw materials they are.

Table 1.1.1 Functional use of paper and board

Functional use	Typical grades (see section 3)	Typical end products	Important trends
Information - collection - distribution - storing	- Newsprint - Coated and uncoated magazine (SC and LWC) - Coated and uncoated woodfree printing and writing	- Newspapers - Journals - Books - Computer printouts - Xerographic copies - Inserts - Illustrations	Increased use of multicolour printing and copying Electronic media taking over banking and trading documents Increased recycling as raw material Increased use of additives
Packaging - transportation - distribution - protection	- Liner - Sack - Corrugating medium - Folding box board - Liquid packaging board - Wrapping	- Bags - Boxes - Wrappings - Containers	Increased use for distribution of food Regaining market from plastics because of easier recyclability as a raw material Increased use of composites
Hygienic - personal care - disease prevention	- Tissue - Towel - Sanitary	- Toilet tissue - Diapers - Facial tissue - Industrial towels - Hospital clothing	Use increases with general living standard. End of the chain for the recycling of fibres
Speciality - a great variety	- Official papers - Filter paper - Fire resistant papers	- Notes - Stamps - Air filters - Coffee filters - Baking paper	An ever-increasing number of new applications

A trend not shown in table 1.1.1 is that more and more functions in many products are combined, such as printing on packages and towels.

One of the main reasons for the continuous use of paper and board is that they are mainly produced from a renewable raw material, i.e. vegetable fibres, and that, to a large extent, these fibres are reusable over and over again. If the fibres originate from agricultural crops, straw, bagasse (sugar cane), or grasses such as reed, there is a fresh supply every year, and if they are taken from trees, there is a new supply about every seven to sixty years depending on the species, growth place and other uses of the wood.

Historically, pulp and paper mills in Europe were, and mostly still are today, located close to some body of water as the availability of water plays a major role in the production process. Rapids in rivers were used to generate the power needed for the pulping, and the waterways were used for the transportation of both the raw materials and the products. When wood became the dominating fibre source, the size of the mills started to grow, and frequently the mills were brought as close to the raw material as possible. The use of market pulp and, more markedly, the increased use of recycled fibre now favour locating new mills close to the market for both raw-material procurement and product disposal reasons.

The European pulp and paper industry has undergone, and is still undergoing, a major metamorphosis in that it is developing from being a major pollutant of rivers, lakes and the sea to an almost clean industry. An outstanding example is the development in Finland during the last twenty years. The production of pulp has doubled during that time, but the release of organic substances has fallen to less than one- tenth of the level twenty years ago. Thus the efficiency of pollution abatement with regard to these pollutants has improved more than twentyfold.

The consumption of paper and board is strongly related to living standards, and over long-term periods there is a strong correlation between the increase in the consumption of these products and the growth in the GNP (Gross National Product).

Table 1.1.2 Per capita consumption 1995 (Production plus imports minus exports. Changes in stocks are not taken into account) (Pulp and Paper International (PPI) '96)

Continent	Region	Country	Apparent per capita consumption kg/year
Europe			93
	European Union		171
		Austria	192
		Belgium	237
		Denmark	214
		Finland	304
		France	164
		Germany	194
		Greece	82
		Ireland	102
		Italy	140
		Luxembourg	168
		Netherlands	201
		Portugal	82
		Spain	129
		Sweden	210
		United Kingdom	194
	Other Western	Europe	194
	Eastern Europe		19
		CIS[1)]	13
		Czech Republic	37
		Estonia	67
		Hungary	28
		Poland	40
North America			322
		Canada	230
		USA	332
Asia			25
		China	22
		Indonesia	14
		Japan	239
		Korea	147
		Thailand	37
		Turkey	27
Oceania			152
		Australia	187
		New Zealand	213
South America			31
		Brazil	35
		Chile	37
Central America		Mexico	36
Africa			6
		Egypt	9
		South Africa	43
Total world			49

1) The CIS is defined as the former USSR. Estonia, Latvia and Lithuania are not included.

As is shown in table 1.1.2, there is a tremendous variation in the worldwide consumption of paper per capita. Even within Europe the differences are dramatic. A simple mathematical calculation shows that the EU countries that are now below the EU average would need an additional capacity of 5.9 million tonnes per year to reach the present average. As the average is growing, it can be safely predicted that pulp, paper and board manufacturing will be a growth industry for many years to come.

Table 1.1.3 Apparent consumption and production of paper and board within the EU (PPI '96)

Country	Apparent consumption (1,000 tonnes)		Production (1,000 tonnes)		Balance (1,000 tonnes)	
	1994	1995	1994	1995	1994	1995
European Union	59,752	63,872[1)]	45,190	69,726[1)]	-14,562	+5,854[1)]
Austria	1,489	1,550	3,603	3,599	+2,114	+2,049
Finland	1,357	1,552	10,910	10,942	+9,603	+9,390
Sweden	1,648	1,857	9,284	9,169	+7,636	+7,312
Total	64,246		68,987			

1) Austria, Finland and Sweden included.

When Austria, Finland and Sweden entered the European Union in 1995, the paper and board supply situation changed from a 25% deficiency to a surplus of almost 10%. Finland is the country showing the largest export capacity. The EU is still a net importer of primary fibre, as is shown in table 1.1.4.

Table 1.1.4 Apparent consumption and production of pulp (primary fibre) (PPI '96)

Country	Apparent consumption (1,000 tonnes)		Production (1,000 tonnes)		Balance (1,000 tonnes)	
	1994	1995	1994	1995	1994	1995
European Union	18,791	37,351	9,493	31,835	-9,298	-5,516
Austria	1,925	1,919	1,595	1,620	-330	-299
Finland	8,552	8,894	9,962	10,089	+1,410	+1,195
Sweden	7,490	7,868	10,097	10,187	+2,607	+2,319
Total	36,758		31,147			

Sweden is the country with the highest pulp export capacity in the EU. Within the EU the countries with large forests, not only Finland and Sweden but also France, Germany and Austria as well as the countries with large plantation forests, i.e. Portugal and Spain, are the main producers of primary fibre. The production of recycled fibre is large in countries with a high population density and high per capita consumption, such as Germany, France, Belgium and the Netherlands.

Table 1.1.5 shows the size of paper and board mills as well as pulp mills for the EU countries and some other major forest industry countries.

Table 1.1.5 Average mill sizes (PPI '96)

Country	Paper and board (tonne/year)	Pulp (primary fibre) (tonne/year)
Austria	150,000	180,000
Belgium	100,000	145,000
Denmark	110,000	65,000
Finland	270,000	270,000
France	75,000	170,000
Germany	70,000	110,000
Greece	20,000	40,000
Ireland	40,000	-
Italy	35,000	40,000
Luxembourg	-	-
Netherlands	105,000	85,000
Portugal	15,000	240,000
Spain	30,000	90,000
Sweden	195,000	230,000
United Kingdom	65,000	150,000
European Union	70,000	180,000
Canada	170,000	n.a.
USA	165,000	325,000
Japan	70,000	305,000

There is generally a strong correlation between the size of the mills and the sophistication of the process technology used. The large mills, therefore, tend to be more energy efficient and cause fewer environmental problems in production.

1.2 Description of the pulp and paper production processes and raw material used

The production processes now in use basically reflect the development trends of the last twenty to thirty years. Still, in many countries the production machinery is older than that, and in some extreme cases machinery from the last century can be found in operation. Naturally, the older equipment has been modified and rebuilt to better meet today's requirements.

Some recent strong trends and their effects on the process technology and machinery are schematically discussed in table 1.2.1.

Table 1.2.1 Trends affecting pulp and paper production

Trends	Requirements	Solutions	Consequences/Prerequisites
Improved images - multicolour - resolution - combined advertising and packaging	- brightness	- bleaching of pulp - increased use of bright additives (fibres and pigments)	- lower yield and higher pollutant generation - higher energy consumption - lower strength and stiffness of chemical pulp - less fibre in end product and higher solid waste generation in recycling
	- opacity	- additives - maximum use of mechanical pulps	- no change - increased use of external energy
	- smoothness, gloss, surface strength	- more refining of pulps - increased use of surface coatings	- increased use of energy - potentially higher polluting loads
Lower basis weight (more surface per weight) - raw material efficiency - investment efficiency - reduced handling fees	- strength	- stronger chemical pulps	- lower overall yield through more selective raw material usage - more complex processes
	- stiffness	- increased use of refiner mechanical pulps - as above - increased use of additives - multilayer forming	- increased use of external energy - as above - higher pollution load - more complex machinery
Reduced pollution - water - air - soil - solid waste build-up	- increased yield		- better raw-material management
	- reduced water and energy consumption	- improved dewatering	- process water reuse - more efficient equipment and processes
	- improved recovery	- improved washing	- use of new technologies (enzymes) - improved process management
	- recycling of paper and board	- more efficient upgrading of recycled paper and board - more efficient deinking including reuse of deinking sludge	- increased generation of solid waste
	- more efficient internal treatment of process water	- integrated and improved process management	- use of advanced information systems - better training of personnel

It can generally be said that the efforts to improve the technical performance of fibres and additives tend to increase the generation of pollutants, and, therefore, more complex processes and management systems are needed to offset this effect.

The consequence is higher investment costs, which in turn must be compensated for by improved efficiency, such as a lower basis weight, and often by seeking advantages from economy of scale.

The basic principle for paper and board production is the same since in both cases a slurry of fibres and additives is dewatered on a mesh wire. The "wire section" of the paper or board machine can be constructed in many different ways. After the wire section, the saturated web is further dewatered by pressing. In multilayer products two or more layers are formed on top of each other, as on cylinder machines, or two or more webs are brought together, as on multi-wire machines, before the pressing. The press section can also feature many different constructional solutions. After the press section, the web is brought to its final dryness of more than 90% by evaporation in the so-called dryer section. Again, there are a number of technical solutions, but most frequently the temperature of the web is raised by passing it over steel cylinders heated by the condensation of steam on the inside of the cylinders. In the production of tissue the web is dried by hot air and infra-red radiation, which are also used in the drying of coatings applied to the surface of the paper or board.

The productivity of the paper machine and the properties of the paper are enhanced by additives, such as inorganic fillers, retention aids, dry- and wet-strength resins as well as sizes in the furnish. The surface properties are mainly modified by adding layers of coating to the paper or board either at the paper machine itself or at off-machine coaters. After different kinds of finishing operations, such as calendering for increased smoothness and gloss, the web is cut to customer-size rolls or sheets and packed for shipping. The paper and board manufacturing technologies are discussed in more detail in sections 3 and 4.

The overall environmental impact of the paper and board machine operation is quite modest, albeit there is some pollution as well as noise and steam plume generation. As shown in table 1.2.1, the trends to upgrade the quality of the products by increased refining of the fibres and the use of additives tend to increase the pollutant load.

The environmental impact of pulping can be serious if proper prevention measures are not taken. Pulping can be described as walking a tightrope between raw-material availability and properties at one end and the requirements for paper and board at the other. As is discussed in detail in section 3, chemical, heat and mechanical energy as well as any combination of these are used in the manufacturing of pulp. The differences between the main pulping processes are discussed in table 1.2.2.

Generally, primary fibres are favoured in products requiring i) high cleanness, like food packaging boards and special tissues, ii) extreme strength properties, like sack and liner, iii) faultless performance, like copy paper or iv) superior appearance and performance, like high quality printing papers, books and documents to be kept in archives over a long period of time. Recycled fibres are mostly used in products with a short life span, like newspapers, catalogues and inserts, and also in low-cost, high-volume products, like toilet tissue, towels and materials for outer packaging.

Table 1.2.2 The main pulping processes in Western Europe

Main category	Process	Raw material	Yield	Energy	Remarks
Chemical pulp	Sulphate (kraft)	All wood species and most non-wood plants	Low (35-55%)	Modern mills produce net energy	The dominating process both for unbleached (brown) and bleached (white) grades. Efficient recovery of processing chemicals and dissolved material. Net energy producer from burning the dissolved wood material. Complex bleach process. High final brightness attainable. Superior strength properties. Pollution potential is high but is almost eliminated with modern technology.
	Soda	Mostly hardwood, annual crops	Low (35-50%)	Modern mills are self-sufficient	In limited use mainly in developing countries. Very similar to kraft pulping.
	Sulphite	Selected species or a very complex process is required	Low (40-50%)	Limited use of external energy	Previously the dominating process because of high initial brightness and limited competition for the preferred raw material. Recovery of processing chemicals is efficient but complex. Good bleachability, but opacity is low. Strength is lower compared with kraft pulps. Air pollution through emission of SO_2 and volatile organics require complex treatment facilities. The use of the sulphite process has been steadily decreasing.
Semi-chemical pulp	NSSC (Neutral sodium sulphite cooking)	Most wood species	Intermediate (75-85%)	Limited use of external energy	Limited strength and optical properties. Pollution load high, recovery is complex and expensive. No new mills are being built and operating ones are being modified. Also, mills based on ammonium or magnesium base are in operation.

(cont. on the next page)

(table 1.2.2 cont.)

Main category	Process	Raw material	Yield	Energy	Remarks
Semi-chemical pulp (cont.)	Soda (green liquor)	Mostly hardwood species	Intermediate (70-80%)	Limited or no use of external energy	Separate recovery is very costly but a favourable solution is co-recovery with a kraft pulp mill. Normally only brown pulps for packaging grades. Pollution load is high, but can be controlled with modern technology.
Mechanical pulp	Groundwood pulp	Only selected wood species	High (95-97%)	High use of external energy	Only low density softwood and hardwood species (spruce, aspen) are normally used. Pine can be processed, but yields pulp of lower quality. The raw material has to be in the form of logs. Initial brightness good, but limited bleachability. Very good opacity, paper formation and surface properties. Water pollution is modest, but biological treatment of waste water is required. Air pollution depends on the fuel used in the generation of the external energy.
	Refiner mechanical pulp	As above	High (92-96%)	As above	The raw material is in form of chips. Strength is lower than that of chemical pulps but better than for groundwood. Optical and surface properties slightly inferior to groundwood pulp. The energy usage is higher than for groundwood, but energy can be recovered for use in paper and board production. Pollution as above.
Recycled fibre	Recycled fibre	Selective or all grades	High intermediate (75-98%)	Moderate use of external energy	Raw material, yield and energy usage are very end-use specific. Pollution is limited, but the generation of solid waste may be high. Chemical treatment of waste water often sufficient.
	Deinked pulp	Selective	As above	As above	The deinking process increases energy usage. Pollution load increases from the chemicals used and some dissolving in the deinking process. Waste water normally requires biological treatment.

General description of the pulp and paper industry in Finland

2

2.1 Pulp and paper production

The pulp and paper industry is the industrial sector showing the largest net trade balance in Finland. Further it is the heart of the so-called forest-cluster industrial sector, which is by far the most important part of the Finnish economy. The forest cluster includes, in addition, machinery for pulp, paper and board manufacturing, auxiliary equipment for the pulp and paper mills, chemicals, instruments and control equipment, and engineering work.

As already shown in section 1, Finland is the no. 2 producer of paper and board in the EU and the no. 1 exporter of these products. It is also the no. 1 producer of pulp (primary fibre) and the no. 2 exporter of pulp. Table 2.1.1 shows the annual production of different pulp, paper and board grades in Finland.

Table 2.1.1 Pulp, paper and board production in Finland
(Finnish Forest Industries Federation)

	1994 (1,000 t)	1995 (1,000 t)
CHEMICAL PULP	5,844	5,782
Unbleached kraft	687	680
Bleached softwood kraft	2,831	2,928
Bleached hardwood kraft	2,326	2,174
OTHER PULP (incl. mechanical pulp and semi-chemical pulp)	4,118	4,306
Pulp, total	9,961	10,088
PAPER	8,546	8,595
Newsprint	1,446	1,425
Printing/writing	6,096	6,315
- Mechanical	4,073	4,385
- Woodfree	2,024	1,929
Kraft paper	504	484
Other paper	500	372
BOARD	2,363	2,346
Paper & board, total	10,909	10,942

For efficiency and environmental protection reasons, only the sulphate (kraft) pulping process is still used in Finland for the production of chemical pulp.

Almost 90% of the chemical pulp is bleached. Table 2.1.1 also shows the dominance of printing and writing paper grades. Finland is the worldwide technology leader and the no. 1 producer in Europe of the highest-quality magazine paper grades (SC and LWC) as well as coated woodfree grades.

Despite a collection rate of 50-57% in Finland, the use of recycled fibre is less than 10% of the paper and board production because 90% of the products are exported. It makes poor sense in terms of environmental protection to try to increase the import of waste paper when there is an abundance of wood fibre available locally. The primary fibre in Finnish paper is needed to maintain sufficient quality in the recycled fibre stock in the EU countries importing paper from Finland.

The technology used in the Finnish pulp, paper and board industry is described in more detail in section 3.

2.2 Finnish pulp and paper mills

The annual production of the mills in 1995 as well as the number of fibre lines, and paper and board machines is compiled in Appendix 3.

The Finnish pulp and paper industry is today dominated by three large ownership concentrations. The UPM-Kymmene and Metsäliitto (Forest owners) Groups, which are entirely privately owned, and the Enso Group, in which the Government holds a majority interest. The average capacity of the chemical pulping lines is 250,000 tonnes/year. The average capacity of the mechanical pulping lines is 140,000 tonnes/year. The average capacity of the paper machines is 110,000 tonnes/year and excluding the low-capacity tissue machines the average is 120,000 tonnes/year. There are 13 machines with a capacity of over 200,000 tonnes/year. The average capacity of the board machines is 120,000 tonnes/year and there are 3 machines with a capacity of over 200,000 tonnes/year.

Several of the most advanced mills are described in detail in section 4.

2.3 Major process technology developments

There have been several major changes in the structure of and in the process technology used in the Finnish pulp and paper industry during the last fifty years. Finland is a major producer of chemical and mechanical pulps. A dramatic increase in the integrated production of pulp, paper and board has taken place, and today the Finnish pulp and paper industry's exports of bleached kraft and CTMP are less than 20% (in quantity) of the total pulp and paper exports. A similar dramatic change has taken place in paper and board exports, where white (bleached) grades have almost fully replaced brown (unbleached) grades with the exception of some packaging materials, such as liner and corrugating medium.

The above trends are the results of two major process technology changes within chemical and mechanical pulping. In chemical pulping the conventional sulphite pulping process has been completely replaced by the sulphate pulping method. Both methods were invented in the second half of the 19th century. The sulphite method was based on using calcium sulphite as the cooking chemical. The low cooking pH of 1 to 2 produced pulps of high initial brightness, 55 to 70% ISO, from spruce, birch and aspen. Pine could not be processed successfully because of the high rosin content. The good brightness made sulphite pulps the natural choice for the production of printing and writing papers and of newsprint together with stone groundwood pulp, because sulphate pulps were very dark (brown). The pH of sulphate cooking is 12 to 13 and the high pH causes discoloration of the wood. As long as there were no suitable bleaching methods, calcium sulphite mills were built to satisfy the need for bright paper-making fibres. The biggest handicap of calcium sulphite pulping is that there is no economical way of recovering the cooking chemicals for reuse, and for a period of time the spent cooking liquor was discharged directly into the recipient. The last calcium sulphite mills in operation, however, had installed evaporation and burning to recover at least the heat in the dissolved organics, but the SO_2 generated in the burning was released into the air. On the other hand, very early on there had been methods developed for the recovery of the cooking chemicals in the sulphate process.

The competitive situation between the two pulping processes changed first of all with the invention of bleaching with chlorine gas, which made the use of sulphate fibres possible in information paper grades. This breakthrough was then fur-ther strengthened with the development of chlorine dioxide bleaching, which made it possible to bleach sulphate pulps to a very high final brightness, and the pulp could be used in the most demanding paper grades. At the same time the problems related to the high content of extractives in hardwood pulp, which were harmful in the paper-making process, were solved, and birch kraft pulp became the dominant fibre source for fine paper production. The second major change in the competitive situation came about when the environmental protection situa-tion forced the sulphite mills to opt for chemical recovery. In Finland cost analyses comparing the switch to sodium- or magnesium-based cooking and installing complex recovery systems always came out in favour of switching to sulphate pulping. Two very important factors favouring the sulphate process are the possibility to pulp all wood species and the superior strength properties of the fibres. The last sulphite mill in operation, actually with a sodium base and a recovery system, was closed down in 1991. Today only one alkaline sulphite (SAP) line, which shares with chemical recovery with a sulphate mill, is in operation. One semi-chemical pulping line based on ammonium sulphite and another based on sodium sulphite produce corrugating medium.

The recent discussion about the discharges of chlorinated organic compounds (AOX) from the bleaching of chemical pulps appeared for a while to give the sulphite process a competitive edge again, but within a relatively short time span chlorine gas free (ECF) and totally chlorine free (TCF) bleaching sequences were developed for sulphate pulping, eliminating the differences between the processes.

During the last twenty years the groundwood pulping processes (SGW, PGW, PGW-S) have fallen from being the only mechanical pulping processes into second position behind refiner-based mechanical pulping (TMP). Here the two main reasons are improved strength properties and greater raw-material versatility. The higher electrical energy consumption in refiner pulping has been compensated for by efficient heat recovery (25-50%). The recovered heat is normally used for drying the paper.

3 Technical description of the most important pulp, paper and board manufacturing processes in Finland

3.1 General

In pulp production, pulping, a slurry of individual fibres in water, is produced from a multitude of raw materials holding suitable fibres i.e. wood, straws, leaves, waste paper. In paper and board manufacturing a web is formed by dewatering a slurry of fibre on a mesh wire. The slurry can hold fibres from many different pulping processes and raw materials as well as some process or product- enhancing additives and mineral pigments.

The different types of pulps are named after the predominant form of energy, chemical or mechanical, that is used to separate the fibres and/or by the raw material, e.g. recycled fibre, deinked pulp, hardwood pulp. In chemical pulping the fibres are separated by dissolving the substance, lignin, holding them together. In mechanical pulping the fibres are forced apart by attrition and in semichemical pulping there is a combination of both chemical and mechanical action. In the pulping of waste paper the use of chemicals and mechanical energy is, by comparison, low.

The dissolving action of the chemicals will naturally cause a yield loss. The dissolved substances, as well as the used chemicals, are mostly detrimental to the subsequent use of the fibres and need to be removed from the pulp, or the pulp has to be washed. The heat value of the dissolved organic material is normally recovered through combustion and the chemicals regenerated. Modern chemical pulping mills are often self-sufficient with regard to energy. In mechanical pulping the yield loss is quite small and the energy needed to perform the mechanical work, electricity, is brought into the plant. In recycled-fibre pulping both fresh chemicals and energy have to be brought into the plant. As the waste paper contains various amounts of non-fibrous material, like fillers and pigments, which are not recovered today, the yield in waste-paper pulping is between 60% and >90% and the generation of solid waste can, accordingly, be high.

Different pulps are mixed together according to the requirements of the end product. The pulps are screened to remove impurities and the fibres bleached with different bleaching chemicals to increase their whiteness. Both processes tend to reduce the yield as both suspended and dissolved organic material is removed from the pulps. This yield loss is a major source of water pollution if the substances are not separated from the water and properly disposed of.

In kraft pulping the recovery of process chemicals and in mechanical pulping the use of external energy are sources of air pollution.

The final environmental impact of any type of pulping is strictly dependent on the combined success of internal recovery at the plant and the efficiency of the external treatment.

Table 3.1.1 Typical process conditions for pulping systems in Finland

Pulps	Yield	Use of external energy	Pollution potential		Solid waste generation
			water	air	
Chemical	low	small to none	high	modest	modest
Semi-Chemical	modest	modest or small	high	modest	low
Mechanical (GW,PGW,TMP,CTMP)	high	high	modest	low or modest	low
Recycled fibre	modest	modest	modest	low	low to high

The differentiation between paper and board (actually paper board) is, to some extent, dictated by the end use but relates mostly to the surface mass (weight-by-unit area) so that the heavier grades are referred to as boards.

Paper and boards are normally grouped by their end use and the main categories are: information, packaging, hygienic and speciality grades. All categories hold products made from one or a combination of chemical, mechanical and waste-paper-based fibres, bleached or unbleached. These fibres can come from integrated production or from purchased pulps.

The environmental impact of pulp and paper manufacturing is mainly related to the pulping, but the process stages at the paper mill and additives as well as the chemicals used in manufacturing the paper and board have their impact.

Further on in the report only the paper and board grades produced in Finland in quantities that are significant to the European Union will be discussed. Thus, semi-chemical pulping, although efficiently made at three installations, will not be discussed further.

3.2 Woodhandling

3.2.1 Debarking

The pulp and paper mills using wood receive their raw material either in the form of logs directly from the forest or as by-product chips from some other wood working industry like sawmills and plywood mills. The logs are predominantly delivered with the bark on and they have to be debarked before further processing. The chips are normally free of bark and can be used as such.

Pulpwood is transported to the mills by truck or rail but also to a limited extent by floating. The most common method for debarking is drum debarking. Bark is removed from the logs by the friction arising as the logs rub against each other when made to tumble by the rotating action of the debarking drum.

During the winter time in northern countries frozen logs and snow must be melted before debarking. This can be done in the debarking drum with hot water or steam or on special de-icing conveyors before the debarking drum. The degree of debarking is controlled by the wood feed rate. Loose bark and wood sticks fall from the drum through special chutes. Bark is fed into a bark shredder and finally pressed to a dryness of 38-45% and burnt. The debarked logs are showered with water before being delivered to the pulp mill.

The logs for groundwood production are cut into certain length. For the other pulping processes the logs are reduced to chips in a chipper.

The wet debarking process uses large volumes of water. Water affects the removal of bark from the logs and the drum. Water is circulated in the drum, de-icing system and washing. Excess process water is fed into the mill's external treatment plant. In wet debarking 0.6 to 2 m^3 of water per solid m^3 of wood are discharged and in dry debarking 0.1 to 0.5 m^3/m^3.

In recent years dry debarking has been installed in many mills. Dry debarking creates bark with a lower water content, which will result in a better energy balance for the mill. Less water is needed in the debarking and the dissolved amount of organic substances is reduced. In the debarking, organic compounds like resin acids, fatty acids etc. are dissolved in the process water. Raw effluent from a debarking plant is toxic to aquatic life. Biological treatment has proven to be very efficient in eliminating the toxicity.

Table 3.2.1 Pollutant load of debarking effluent before biological treatment.

	Effluent (m^3/m^3 wood)	BOD_7 (kg/ m^3 wood)	COD_{Cr} (kg/ m^3 wood)	Tot-P (g/ m^3 wood)
Dry debarking	0.1-0.5	0.1-0.5	0.2-2	2-4
Wet debarking	0.6-2	1-3	4-6	5-7

Table 3.2.2 Pulp wood consumption in different pulping processes.

	Wood consumption (m^3 wood per tonne of pulp)
Mechanical pulps	2.8-3.2
Semi-chemical pulps	3.5-4.5
Chemical pulps	4.0-6.6

The total energy consumption in debarking is 7 -10 kWh/m^3 of wood.

3.2.2 Chip screening

A uniform chip-size distribution is necessary for the efficiency of the processes and for the quality of the pulp. The more uniform the chips are after the chipper, the lower the raw material consumption. After the chipper station the chips are screened in order to remove oversized chips, which go for further processing, and sawdust. In the most advanced applications the chips are also screened for thickness as this is a critical parameter both in chemical and mechanical pulping. Often the overall optimum is reached by sacrificing some raw material to secure stable processing conditions, which, in turn, promote better pulp quality and less pollution. The material removed in the screening operation is normally sent to a solid fuel boiler and the heat value recovered as steam or electricity.

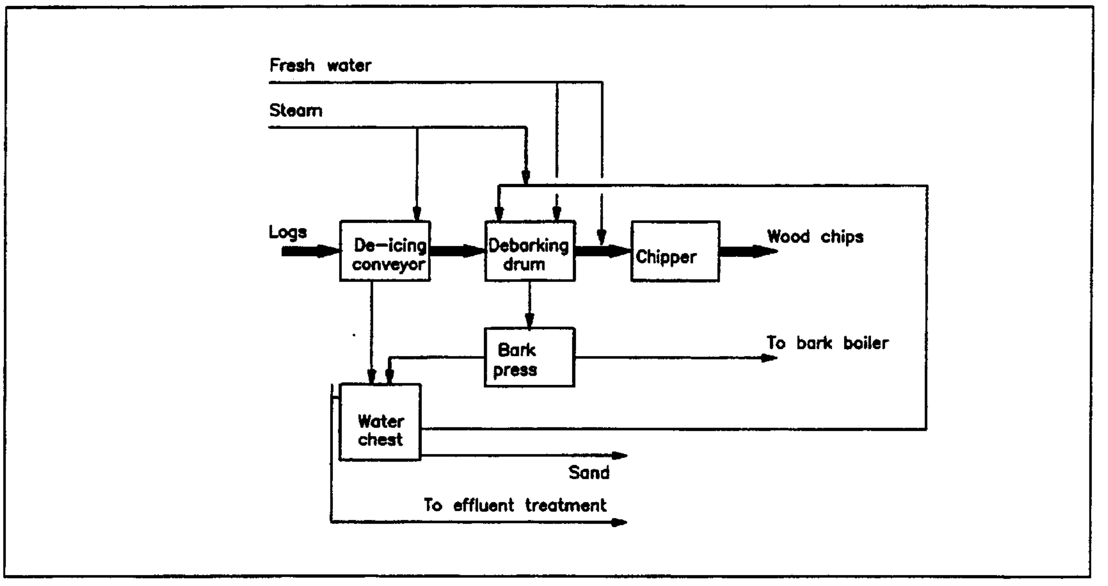


Figure 3.2.1 Wood debarking

3.3 Chemical pulp

In the chemical pulping process the fibres are liberated from the wood matrix as the lignin is removed by dissolving in the cooking chemical solution at a high temperature. Part of the hemicellulose is dissolved as well in the cooking.

Chemical pulp is manufactured by two main pulping processes, the sulphite process and the sulphate or kraft pulping process. In the sulphite process the cooking chemical is bisulphite or sulphite, and in the kraft pulp process the cooking chemicals are sodium hydroxide and sodium sulphide.

Today kraft pulping is the dominant process throughout the world for manufacturing chemical pulp. In Finland the kraft process has, in a relatively short time, taken over completely. In 1965 there were 19 sulphite pulp mills and 16 kraft pulp mills. Only 3 sulphite pulp mills were left in 1985 and in 1991 the last conventional sulphite pulp mill was shut.

The main reasons for the kraft pulp process replacing the sulphite process are that

- all wood species can be processed
- kraft pulp has superior strength properties compared with sulphite pulp
- the recovery of chemicals and energy is efficient.

3.3.1 The kraft pulping process

A kraft pulp mill can be divided into three main parts: chemical defibration (delignification) with an almost completely closed chemical and energy recovery system, bleaching with an open water system and the process external waste water treatment system. Another more conventional division is the fibre line, recovery system and external waste water treatment.

The part of the fibre line with an almost totally closed water system includes cooking, pulp washing and screening and, in most mills, oxygen delignification as well (figure 3.3.1). The process liquid is led counter-current to the pulp flow. The spent liquor (black liquor) is removed in the first pulp washing stage, concentrated and burnt. The inorganic chemicals in the black liquor are recovered after combustion, regenerated into cooking chemicals and returned to cooking. The energy produced in the combustion of the organic material dissolved in the delignification is used in the process as heat and electrical energy. In a kraft pulp mill about half of the raw material is converted into energy. In a modern kraft pulp mill more energy is produced than is consumed.

If pulp with a high brightness is being produced, the pulp has to be bleached after cooking and washing. The filtrates from bleaching are discharged from the process into the external waste water treatment. Extensive research and development work on returning the bleaching filtrates to the chemical recovery system has been going on all over the world since the 1970s. The implementation of totally chlorine free bleaching technology makes it possible to recycle the bleaching plant filtrates without the risk of corrosion and process upsets.

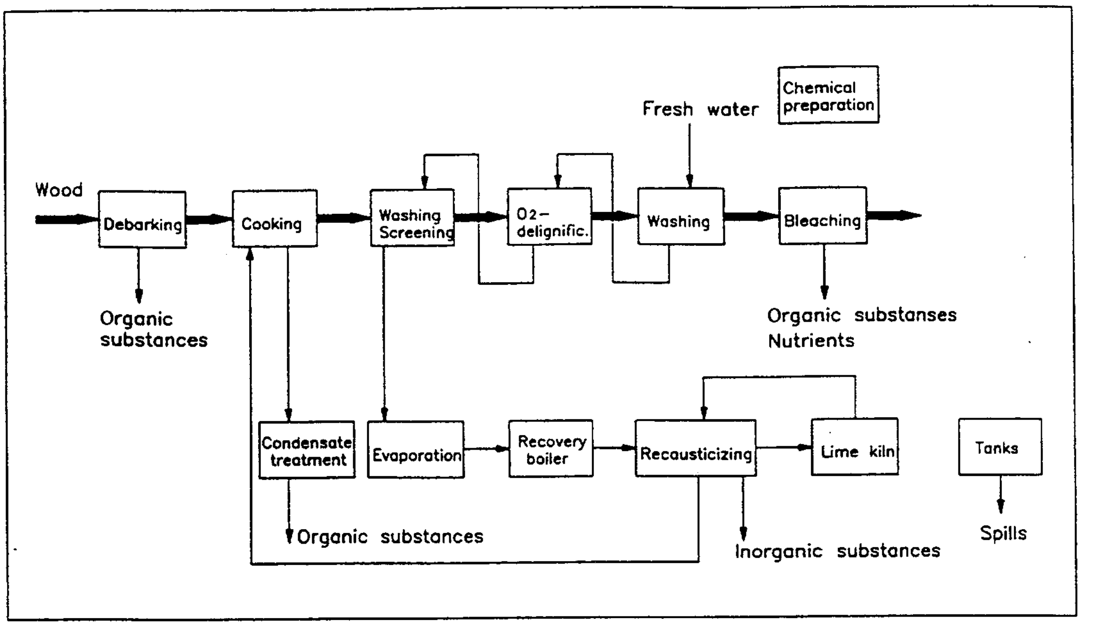


Figure 3.3.1 Sources of discharges into water from a kraft pulp mill

Delignification, washing and screening

In the kraft process the fibres are liberated in the cooking plant by dissolving the lignin and part of the hemicellulose in the cooking chemical solution (white liquor), which contains sodium hydroxide and sodium sulphide as active chemicals. The cooking process can be performed either in batch digesters or in a continuous digester. The chips are pre-heated by steam before entering the continuous digester in order to remove air, which interferes with the impregnation. After entering the digester, the chips are impregnated with cooking liquor. After impregnation the temperature is raised to 165-175° C.

The pulp coming from the cooking contains both fibres and spent cooking liquor (black liquor). About half of the wood is dissolved in the cooking. Consequently the black liquor contains inorganic chemicals and a large amount of organic substances. The black liquor is removed from the pulp in the subsequent washing and led to the chemical recovery system, where the cooking chemicals and energy are recovered.

If the objective is to produce pulp with a high brightness, the residual lignin has to be removed almost completely in a bleaching plant. The amount of residual lignin is usually reported as Kappa number. A high Kappa indicates high residual lignin in the pulp. After cooking, a typical Kappa level has been 30-34 for softwood and 18-22 for hardwood. If the Kappa is lowered further from the levels mentioned in conventional batch or continuous cooking processes, the yield and the pulp strength properties are drastically lowered.

Several cooking modification methods have been developed with the aim of removing more lignin from the wood without reducing the yield during cooking. The Kappa from the cooking of softwood can be reduced to a level of 15-25 through extended delignification, while the yield and strength properties are still maintained. This means that 25-50% less lignin is left in the pulp compared with pulp that has a Kappa of 32. The requirements for bleaching chemicals are, therefore, reduced and the effluent discharges from the bleaching plant are decreased. Comparable Kappa reductions can be achieved in the cooking of hardwood (figure 3.3.2).

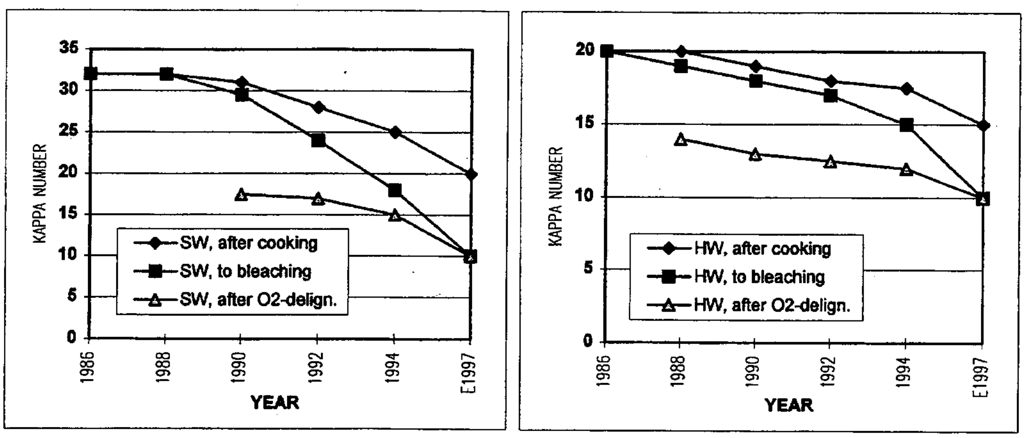


Figure 3.3.2 Kappa trends in Finnish kraft pulp mills.

Extended cooking affects several elements in the kraft process:

- the consumption of active alkali (NaOH + Na_2S) increases
- the amount of dissolved substances going to the recovery increases
- heat generation in the recovery boiler increases
- the demand for bleaching chemicals decreases
- there is a lower pollutant load in the waste water from bleaching
- in modified batch cooking the energy consumption and blow steam amount decrease in the cooking, but the steam consumption in the evaporation of the black liquor may increase.

The impact of extended cooking on production is very site specific. If the recovery system is a production bottleneck at a mill, there is a risk of a loss in production when the conversion is made to extended delignification.

Pulp washing is important for the recovery of black liquor. Modern pulp washing facilities normally recover at least 99% of the chemicals applied in the digester.

Washing the pulp coming from a conventional batch digester pulping process is normally carried out with drum washers, while a continuous digester plant utilizes the Hi-heat wash zone in the digester with additional drum washers or diffuser washers. Today there are several types of washing equipment which have been developed with the main objectives of increasing efficiency, reducing size and lowering investment costs (wash presses, wire type washers, pressure diffusers etc.). The outcome of the washing is highly dependent on the efficiency of the equipment used, the outlet consistency of the pulp and the amount of wash water applied. A reduced carry-over of black liquor with the pulp reduces the consumption of chemicals in the bleaching and the discharges from the bleaching plant. If the outcome of the washing is improved by increasing the amount of wash water, the demand for evaporation will increase as will the consumption of fresh steam in the evaporation.

The diffusion time and temperature are important variables for the effectiveness of the washing. Pressing is especially effective in the removal of dissolved organic substances, and this is one reason why wash presses have become more common, especially as the last washing stage before bleaching. Typical washing losses at Finnish mills are 6-10 kg/tonne of pulp for softwood and 8-12 kg/tonne of pulp for hardwood measured as COD_{Cr}.

Adding carbon dioxide to the wash water will improve the washing effect. Five kraft pulp mills in Finland use carbon dioxide in the pulp washing.

Before further processing, the pulp is screened in order to remove foreign particles and bundles of undesired fibres.

After cooking and screening, the delignification can be continued by oxygen in one-stage or in two stages with or without intermediate washing. Oxygen delignification can be combined with conventional and extended cooking. The organic material that is dissolved during oxygen delignification can be recovered and led to the chemical recovery system without major changes in the process. The recovery reduces the amount of organic material ending up in the waste water.

The degree of further delignification is 40-50% in a one-stage system and can be up to 70% in a two-stage system. This means that the pulp yield decreases by 1.5-2.5%. There is still lignin left that has to be removed by other chemicals when pulp with a high brightness is being produced. In oxygen delignification magnesium salt is added in order to preserve the strength of the pulp (hardwood: 0-2 kg $MgSO_4$/ADt, softwood: 2-3 kg $MgSO_4$/ADt). The consumption of oxygen is 12-15 kg/ADt of hardwood pulp and 20-25 kg O_2 /ADt of softwood pulp. The alkali (NaOH or oxidized white liquor) consumption is 12-15 kg NaOH/ADt for hardwood and 20-25 kg NaOH/ADt for softwood.

Oxygen delignification is usually an intermediate stage in the pulp washing. The wash water is added onto the last washing stage after oxygen delignification and led counter-current to the pulp flow. Washing after oxygen delignification is usually done with one or two wash presses alone or in combination with some other type of washer.

The benefits from oxygen delignification in terms of quality are brightness stability, the removal of pitch and cleanness.

The first oxygen delignification installations in the world in the early 1970's were HC (High Consistency) installations. The development of MC (Medium Consistency) technology, especially MC mixers, resulted in the development of MC oxygen delignification systems. Because of better selectivity and lower investment costs the MC system has dominated mill installations for the past ten years. Recently the industry has opted to install two-stage oxygen delignification systems to increase the selectivity of the treatment.

The first installation in Finland was started up in 1988, and by the end of 1995 80% of kraft pulp was delignified with oxygen. There are four two-stage systems in operation (1995). The oxygen is mainly purchased, but during 1996 two on-site plants are coming into operation.

Like extended cooking, oxygen delignification affects the chemical recovery system, the mill's energy balance and operating costs. There can be a slight increase in the generation of steam in the recovery boiler, but steam consumption will increase because of the increased demand for evaporation and the oxygen stage. The consumption of electrical energy will increase as will fuel consumption in the lime kiln.

The reduction of the Kappa of unbleached pulp (brown stock), whether it is achieved through extended digester delignification, oxygen delignification or some other method, will reduce the load of bleaching-plant pollutants that enter the external effluent treatment system.

Bleaching

The purpose of pulp bleaching is to remove the remaining lignin and impurities in the pulp and thus obtain certain pulp quality criteria with respect to brightness, brightness stability, cleanness and strength. The brightness of unbleached kraft pulp is rather low, below 30% ISO. Fully bleached pulp has a brightness of 88% ISO or higher.

Cooking and oxygen delignification cannot remove all the lignin without a drastic loss of yield and strength. The bleaching of chemical pulps is carried out in several stages, usually four to five. The most commonly used chemicals are chlorine dioxide, oxygen, ozone and peroxide. Chlorine has not been used as a pulp-bleaching chemical in Finland since 1993, and the use of hypochlorite ceased before that. Small amounts of chlorine are formed as a by-product in most of the chlorine dioxide generation systems used, and a part of this chlorine will be present when chlorine dioxide is used in bleaching.

Today ozone has been introduced as a very reactive bleaching agent. Chlorine dioxide, oxygen and hydrogen peroxide are less reactive. Because of the different reaction mechanisms different types of bleaching chemicals are utilized in a bleaching sequence. Acid and alkaline stages are used to complement each other.

Chlorine dioxide and ozone have to be produced on site. Peroxide, oxygen and alkali are delivered to the mills. The production of bleaching chemicals on site is discussed under the heading "Generation of bleaching chemicals on site".

The two main types of bleaching methods are the ECF (elemental chlorine free) bleaching and the TCF (totally chlorine free) bleaching. The chemicals used in ECF bleaching are chlorine dioxide, alkali (NaOH or oxidized white liquor) used for the extraction of dissolved lignin, peroxide as well as oxygen for the reinforcement of the extraction stages. The bleaching chemicals used in TCF bleaching are oxygen, ozone and peroxide. Alkali is used for extraction. The selectivity is better in bleaching than in cooking and oxygen delignification (figure 3.3.3). Chlorine dioxide and chlorine are the most selective bleaching agents. Selectivity is important as far as the total yield and pulp quality are concerned because high selectivity means that the bleaching chemical is primarily reacting with the lignin.

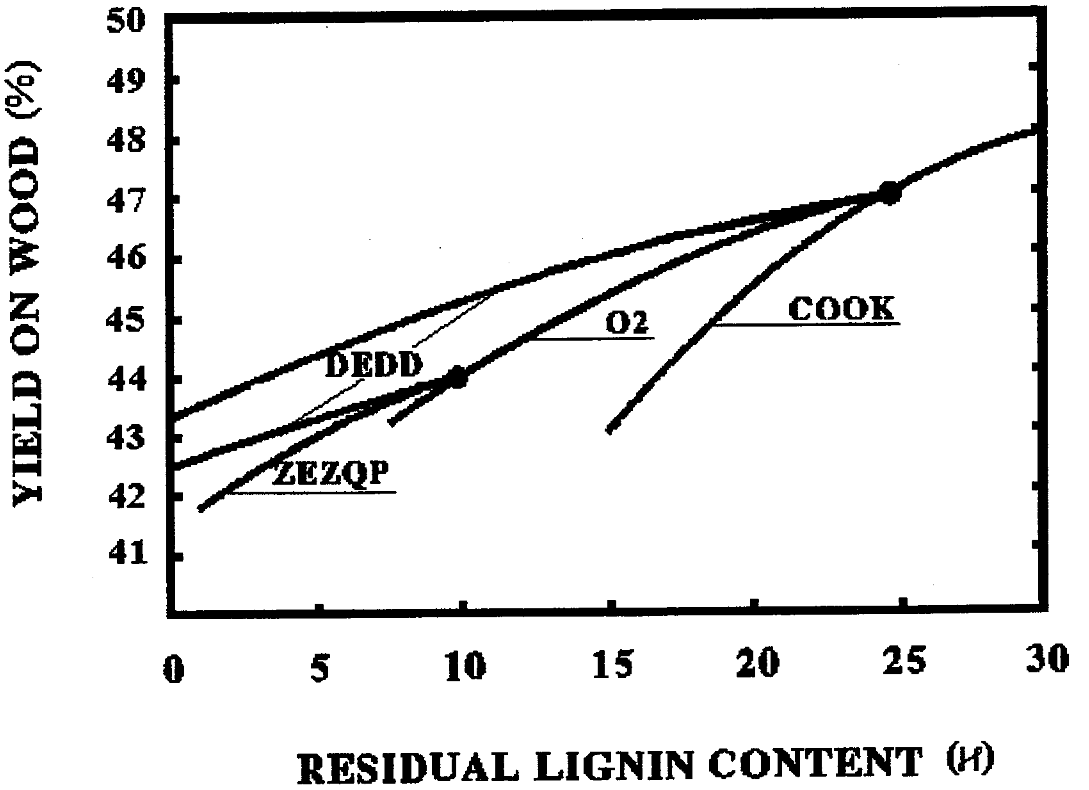


Figure 3.3.3 Delignification selectivity for hardwood.

The requirement on the lignin content (Kappa) of unbleached pulp is different for ECF and TCF bleaching in order to achieve the optimum pulp yield and quality of the final pulp. In TCF bleaching a low incoming Kappa for the pulp (10-12) is necessary to attain a pulp bleached to full brightness and with good strength properties, while ECF bleaching can be done on a pulp with a higher Kappa.

Oxygen chemical based bleaching causes a larger amount of organic material to dissolve in the bleaching compared with chlorine dioxide bleaching. Investigations show that the organic material in the effluents from TCF bleaching is more easily degradable in biological treatment than that from ECF bleaching.

TCF bleaching with peroxide requires the use of metal chelating agents (i.e. EDTA or DTPA) or the removal of metal ions with acid to avoid degradation of the hydrogen peroxide. An advantage with peroxide compared with the other oxygen bleaching chemicals is that peroxide bleaching at optimal conditions brightens the residual lignin. A larger amount of residual lignin remains in TCF bleached pulp than in ECF bleached pulp. This residue has to be stabilized to avoid post-yellowing.

Peroxide bleaching is relatively slow and requires long reaction times and, therefore, large reactor volumes or increased pulp consistency. Increased pressure makes higher reaction temperatures possible, resulting in a reduced reaction time or improved bleaching outcome.

In some bleaching plants peroxy acid (i.e. PAA or Caro's acid) is used in a pre-bleaching stage before final bleaching with hydrogen peroxide.

The change from conventional bleaching with chlorine gas to ECF bleaching at an existing mill usually requires measures such as a lower Kappa after cooking, oxygen delignification, increased chlorine dioxide capacity, oxygen and/or peroxide in the extraction stages and enzyme treatment before bleaching.

The change from ECF to TCF bleaching affects the material and energy balances of the whole mill. The consumption of wood and cooking chemicals increases, and the load of dry matter going to the recovery boiler increases due to extended delignification. In particular, the consumption of electrical energy increases when the change is made from ECF bleaching to TCF bleaching with ozone. Ozone has to be generated on site. In TCF bleaching the generation of ozone consumes about 100 kWh/ADt of pulp and the overall more complex process another 100 kWh/ADt of pulp.

In 1995 all mills producing bleach kraft pulp in Finland used ECF bleaching. Seven mills can produce TCF pulp. Two of these mills produce TCF pulp using ozone. In 1995 the main part of the bleached pulp was ECF pulp (> 90%) and less than 10% was TCF pulp (hardwood and softwood). A new Finnish pulp mill started up in the spring of 1996 with a production capacity of 500,000 t/a TCF bleached softwood kraft pulp. The bleaching technology is based on MC ozone bleaching. The new kraft pulp mill is described in more detail in section 6.

Applications with enzyme treatment before bleaching have been in use in Finland since 1991. Enzyme treatment can be combined with different bleaching sequences. The benefits obtained from enzymes are dependent on the bleaching sequence used as well as the residual lignin content of the pulp. Initially, enzymes were used in chlorine bleaching in order to reduce the amount of chlorine. Later on, enzyme treatment was combined with various TCF bleaching sequences to improve the brightness of the pulp or to decrease the consumption of bleaching chemicals. In bleaching with peroxide the brightness can be improved by 2-4 ISO units. The use of enzymes causes a small loss of yield.

Chemical and energy recovery system

The recovery system in a kraft pulp mill has three functions:

- the recovery of the inorganic pulping chemicals
- the destruction of the dissolved organic material and recovery of the energy content as process steam and electrical power
- the recovery of valuable organic by-products (e.g. tall oil).

The fuel value of the recoverable black liquor is normally enough to make the kraft pulp mills more than self-sufficient in heat and electrical energy. Organic by-products play a limited economic role in most kraft pulp mills.

The main process units in the chemical recovery system are the evaporation of the black liquor, combustion and causticizing, including lime regeneration (figure 3.3.1).

Weak black liquor from the pulp washers normally has a dissolved solids content of 14-18%. This has to be increased considerably before the liquor can be burnt in the recovery boiler. The liquor is concentrated in a multi-effect evaporation plant to a dry-solids content of 65-75%.

The viscosity of the black liquor increases drastically during evaporation when the dry-solids content increases. When the dry-solids content is high, the liquor viscosity becomes too high for pumping. At atmospheric pressure the upper limit is about 72-74% DS. To eliminate this problem two different principles are used:

- pressurizing the liquor, which allows the temperature of the liquor to be higher, which, in turn, lowers the viscosity
- changing the liquor viscosity by altering the liquor rheology through a thermal depolymerization process.

The evaporation of the liquor can be extended to concentrations of over 80% by using heat treatment on the strong black liquor and pressurized evaporation. Heat treatment has been installed in some Finnish mills.

In heat treatment some of the combustible material separates as non-condensable gases which contain TRS (total reduced sulphur). These gases are collected and burnt together with other malodorous gases.

Foul condensates (containing TRS and volatile organic compounds) from the black liquor evaporation and the cooking plant are treated in a stripper column that is normally integrated with the black liquor evaporation by using secondary steam (or primary steam). The condensate stripping makes it possible to reuse the condensate in washing the unbleached pulp and in the causticizing plant.

The concentrated black liquor is burnt in the recovery boiler to recover the sodium and sulphur content in a suitable chemical form to regenerate the pulping chemicals and recover energy from the flue gases.

The increase in the dry-solids content of the black liquor from 65-70% to 80-85% changes the material and energy balances and the burning conditions in the recovery boiler. The flue gas flow decreases as less water enters the furnace. By increasing the dry-solids content to e.g. over 80% an increase in production or extended delignification with more a efficient recovery of the black liquor can be possible in a mill where the recovery boiler is the production capacity bottleneck. The combustion temperature increases because of the lower water content. The higher temperature causes more sodium (Na) to be vaporized, and, as vaporized sodium reacts with sulphur, this results in a reduction of the sulphur emissions from the recovery boiler to almost zero. TRS emissions from the recovery boiler are well below 5 ppm. Steam generation will also increase.

The smelt leaving the recovery boiler is dissolved in water or weak white liquor to produce "green liquor". The main components of green liquor are sodium sulphide and sodium carbonate. The green liquor is clarified and causticized with lime to produce white liquor for pulping. In causticizing Na_2CO_3 is converted to NaOH. Ash residuals and other impurities are removed from the process (green liquor dregs). The lime mud ($CaCO_3$) formed in the causticizing is separated from the white liquor, washed and calcined in a lime kiln to regenerate the lime. The lime mud burning is a high-temperature, endothermic reaction, so it is necessary to use external fuel.

In the handling and burning of black liquor that has a high sulphur content, sulphur is emitted into the air as sulphur dioxide and malodorous gases. The malodorous gases contain reduced sulphur compounds (hydrogen sulphide, methyl mercapthane, dimethylsulphide and dimethyldisulphide). The non-condensible gases from the cooking plant and the stripper gases from the steam stripping of foul condensates from the evaporation plant usually contain 1-2.5 kg S/ADt.

The strong malodorous gases are collected and generally burnt in a separate burner or in the lime kiln. The practice of burning strong malodorous gases in the lime kiln is today less favoured because it might disturb the operation of the lime kiln. The flue gases are in most cases treated in a scrubber, and the scrubber water is led back to the chemical recovery system. The kraft pulp mills in Finland also collect weak malodorous gases to a varying extent. Weak gases are emitted from chip pre-steaming, screening, pulp washing, the smelt dissolver and tank ventilations etc. Weak malodorous gases contain 0.2-0.5 kg S/ADt. Weak malodorous gases are burnt in the lime kiln or the recovery boiler, or they are treated in a scrubber.

Generation of bleaching chemicals on site

Chlorine dioxide

Chlorine dioxide can only be produced as a weak gas on site and it has to be stored as a water solution. The solubility in water is relatively low (8-10 g ClO_2/l). A number of processes for the on-site production of chlorine dioxide have been developed, all based on the reduction of sodium chlorate. The generation of sodium chlorate can be integrated with the ClO_2 manufacturing on site, but most kraft pulp mills in Finland purchase the sodium chlorate.

The overall chemical reaction for the generation of chlorine dioxide is

Chlorate + Reducing agent + Acid -> Chlorine dioxide + By-products

The reducing agent and acid used have a substantial impact on the amounts of by-product chlorine, sodium and sulphur that are produced.

The overall process flowsheet is shown in figure 3.3.4.

The chlorine dioxide generation processes (chemical reactions and balances) in use in the Finnish kraft pulp industry are shown in appendix 2 .

Air emissions are usually modest, including some losses of chlorine or chlorine dioxide from storage tanks and scrubbers.

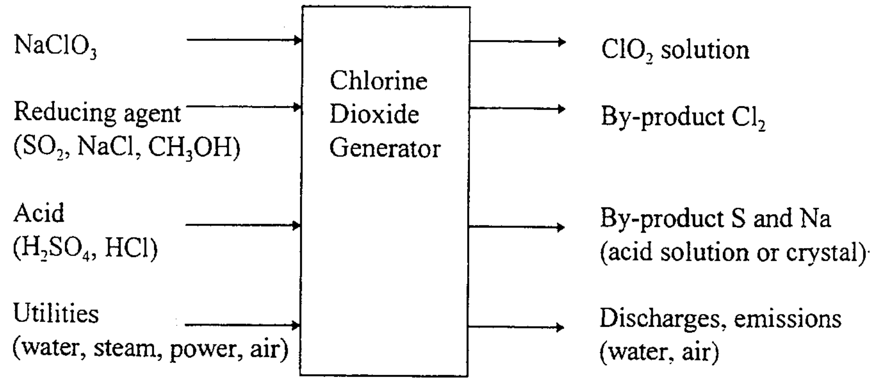


Figure 3.3.4 Overall process flowsheet for chlorine dioxide generation.

If all the by-product sodium and sulphur could be taken into the kraft pulp mill as make-up chemicals, there would be very little or no effluent, but if the sodium or sulphur by-product production is in excess of the mill's make-up requirements, these by-products have to be removed from the process. The by-product sodium and sulphur amounts produced in different chlorine dioxide generation processes are shown in the following table.

Table 3.3.1 By-product sodium and sulphur generation in some chlorine dioxide processes (based on ClO_2 use of 60 kg act. Cl/ADt of pulp).

ClO_2 process	MATHIESON	R3	R3H	R5	R6	R7	R8
S (kg/ADt)	17.1	12.1	6.0	0	0	8.6	7.3
Na (kg/ADt)	8.6	17.0	8.4	8.6	0	12.5	7.8

In the R6 process $NaClO_3$ manufacturing is integrated with the R5 process.

Ozone generation

Because of its poor stability and the low concentration of ozone in the gas, ozone is produced from oxygen or dry air on site. The ozonator consists of an alternating voltage (10,000-20,000 V) applied across two electrodes separated by a dielectric gas gap. The ozone yield and overall power efficiency are functions of the oxygen concentration of the feed gas, temperature, pressure, peak voltage and frequency. Literature data indicates that the power demand is 10-12.5 kWh/kg O_3 at concentrations of 7-10%.

Because of the low concentration of O_3 in the exit gas from the ozonator, the quantity of unreacted oxygen is still very large (ozone dosage: 7 kg O_3/ADt of pulp will give 70-120 kg O_2/ADt of pulp). This quantity is too large to be fully utilized in a kraft pulp mill (in e.g. oxygen delignification, the oxidation of white liquor or for use in the activated sludge treatment). The oxygen gas that is not utilized in these process units is, therefore, returned to the ozonator.

3.3.2 Effects of process solutions in the kraft pulping process

The impact of the different process solutions discussed in section 3.3.1 on discharges into the recipient, chemical and energy consumption, and the process and mill performance are summarized in the following table.

Table 3.3.2 Impact of process solutions. ('+' = increase, '-' = decrease, 'nc' = no change)

Process measure	Discharges and emissions from the process			Chemical consumption	Energy consumption	Process, mill performance
	Water	Air	Solid waste			
Extended cooking - continuous (c) / batch (b)	- COD/TOC - AOX	+ smell		+ cooking - bleaching + lime demand	(+) cooking (c) - cooking (b) (+) evaporation (+) lime kiln	+ energy generation + final pulp yield
Improved washing - wash press - CO_2 washing	- COD/TOC - *)			- bleaching - cooking - bleaching - cooking	+ washing (el)	*)alt. decreases wash water consumption and evaporation demand
O_2 delignification	-			+ O2-stage - bleaching	+ O2-stage (el+steam) + white liq. oxidation + caustic. & lime kiln	(+ energy generation)
Ozone stage and recovery of filtrate	-			+ O3-stage - final bleaching	+ O3-stage, + O3 generation - bleaching	
ECF -> TCF (at same incoming Kappa)	+ COD/TOC - AOX + N (chelat. agent)					- pulp yield
Enzyme treatment in bleaching	+ COD/TOC - AOX			+ enzyme - bleaching	- bleaching chemical generation	nc final pulp brightness

(cont.)

cont. (Table 3.3.2 Impact of process solutions. ('+' = increase, '-' = decrease, 'nc' = no change)

Process measure	Discharges and emissions from the process			Chemical consumption	Energy consumption	Process, mill performance
	Water	Air	Solid waste			
-heat treatment (LHT) of strong black liquor		+ TRS form.-> (+) TRS emiss.			+ evaporation, if DS increased	makes high DS possible
-pressurized evaporation					+ evaporation, if DS increased	makes high DS possible
-high DS content to the recovery boiler		- S (rec. boiler)		- S make-up demand/ + S excess		+ production capacity + energy generation
Handling of malodorous gases						
- strong gases		- TRS		- S make-up demand/ + S excess	+ handling system	+ energy generation (methanol burning with heat recovery)
- weak gases		- TRS			+ handling system	

3.3.3 Raw materials, pulp yield

All wood species can be used as raw material in the kraft pulp process, and the wood does not necessarily have to be as clean as that required for sulphite pulps and mechanical pulps. Logging and sawmill residues can also be pulped with the kraft pulp process. However, as with any production, the best results are obtained with first-class raw materials. Fresh, well-barked wood of good quality and homogeneously chipped to optimal chip size is required especially when the aim is minimum environmental impact and minimum energy consumption and at the same time the production of high-quality pulp.

In Finland about 60% of the wood raw material is softwood (pine and spruce) and 40% hardwood, mainly birch.

The yield of bleached pulp is dependent on the selectivity in delignification and bleaching, see figure.

3.3.4 Energy consumption

The major part of heat energy is consumed for heating different fluids and for evaporating water. Heat energy is also used to accelerate or control chemical reactions. Electrical energy is mostly consumed for the transportation of materials.

The manufacturing of bleached kraft pulp consumes 10-14 GJ/ADt of heat energy (steam for the production of electrical power not included). The consumption of electrical energy is 600-800 kWh/ADt, including the drying of pulp. The energy consumption for pulp drying is about 25% of the heat energy and 15-20% of the electrical energy. Over 50% of the electrical energy consumption is used for pumping.

The energy consumption depends on the process configuration, process equipment and process control efficiency.

The energy self-sufficiency of a kraft pulp mill is mainly the result of efficient energy recovery by burning 50% of the incoming wood in the recovery boiler. Secondary energy is recovered in

- the flue gas scrubber in the recovery boiler
- the flue gas scrubber in the lime kiln
- the surface condenser in evaporation
- the secondary condensate in evaporation
- the cooking plant (75-150° C)
- the vents from pulp drying
- the bleaching filtrates
- the blow steam

as warm and hot water (40-80° C).

The overall energy aspects are discussed in section 3.8.

The average electrical energy consumption in the manufacture of bleaching chemicals is presented in table 3.3.3.

Table 3.3.3 Average electrical energy consumption in the manufacture of bleaching chemicals.

Chemical and bleaching stage code		Electrical energy consumption (kWh/kg chemical)
Chlorine dioxide	**(D)**	10
Oxygen	**(O)**	0.4
Ozone	**(Z)**	10
Peroxide	**(P)**	3.5
Alkali	**(E)**	1.6

3.3.5 Internal pollution control

All the steps from wood debarking and chipping through all the delignification stages are important and affect the quality of the final product, the environmental impact and the efficiency of raw-material and energy usage.

Since the middle of 1980's the focus has been on a further decrease in the discharge of organic substances, especially chlorinated ones from bleaching. The most important measures to reduce discharges from bleaching are
- a reduced lignin content in the pulp entering the bleaching
- efficient washing of unbleached pulp
- improved process control.

Measures that reduce in particular AOX discharges from chlorine chemical bleaching are
- efficient chemical mixers in all stages
- oxygen and peroxide reinforced extraction stages
- enzyme treatment before bleaching.

The charge of active chlorine (as ClO_2) can be further reduced by increasing the temperature in the oxygen- and/or peroxide-reinforced extraction stage from 65-70 to over 90° C. A high temperature in the extraction stage may require the use of additional steam.

The key operations in the production of low-impact ECF and TCF pulps are
- good debarking efficiency
- chipping and chip screening for uniform quality
- uniform cooking to the lowest acceptable Kappa (TCF) for low amount of screen rejects
- the brown stock screen-room operation
- control of the operation.

3.3.6 Discharges and emissions into water and the air, generation of solid waste

The production of chemical pulp causes the discharge and emission of pollutants into water and the air, and the generation of solid waste. Waste water from pulp and paper production contains dissolved organic and inorganic substances and suspended solids. The organic substances are mainly dissolved wood and residues of chemicals used in the process for different reasons. The quantity and quality of the organic material in the waste water are dependent on the pulping, bleaching sequence etc.

The dissolved inorganic compounds are process chemical residues and compounds dissolved from the wood. The main components of the suspended solids in the waste water coming from the kraft pulp process are fibre, bark particles and insoluble inorganic material.

Emissions into the air are dust and different gases. The most important polluting gases are sulphur dioxide, malodorous gases and nitrogen oxides (figure 3.3.5).

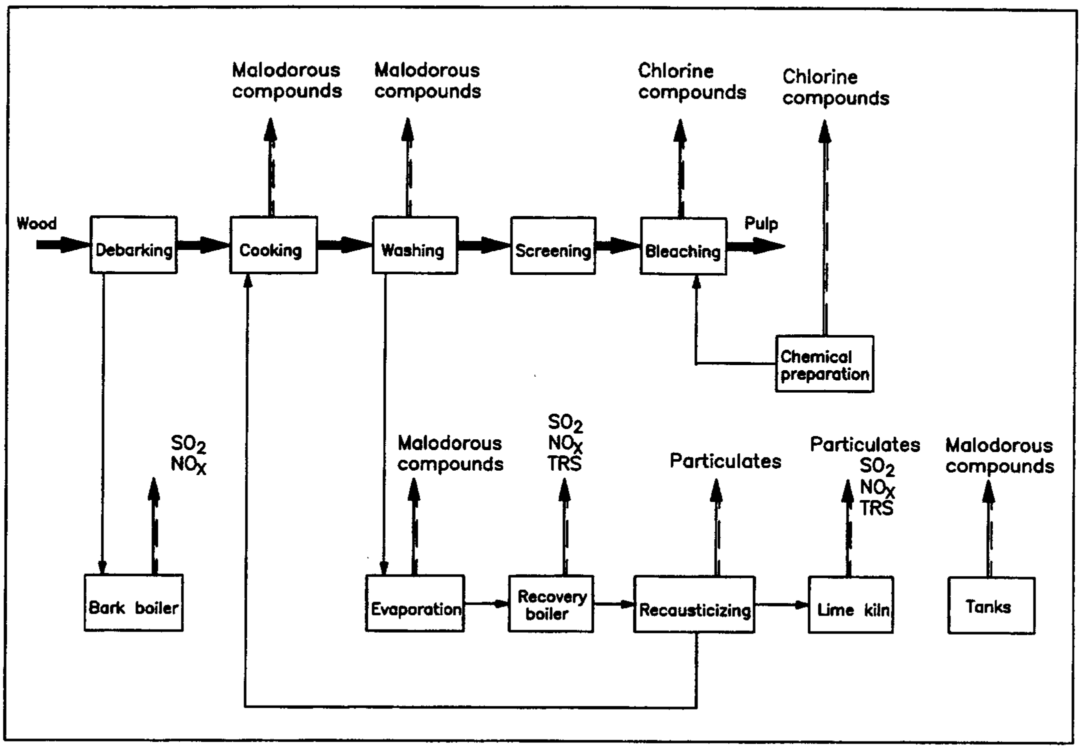


Figure 3.3.5 Sources of emissions into the air from the kraft pulp process.

The main effluent streams from the kraft pulp process are (figure 3.3.1)
- waste water from debarking
- part of the condensates from cooking and evaporation
- filtrates from bleaching
- black liquor residues (washing losses) from the handling of unbleached pulp
- spills from different process departments

The emissions from debarking are discussed in chapter 3.2.

Most of the pollutants come from bleaching (Table 3.3.4). The load is dependent on the lignin content (Kappa no.) and on the carry-over of dissolved organic substances with the pulp coming for bleaching. The discharge of AOX is also dependent on the chlorine chemicals used and the chemical charge in the bleaching.

Table 3.3.4 COD discharge from different departments in a kraft pulp mill before external treatment (kg COD_{Cr} /ADt of bleached pulp)

	COD_{Cr} (kg/ADt)
Debarking	1 - 10
Condensate	2 - 8
Spills etc.	4 - 10
Washing loss	8 - 12
Bleaching	30 - 65
Total	45 -105

The cumulative distribution of specific discharges into the recipient after external treatment from Finnish mills producing unbleached and bleached kraft pulp in 1995 (the kraft pulp production of integrates is included) is shown in figures 3.3.6-3.3.14.

The external waste water treatment is discussed in section 3.7.

The production of kraft pulp generates solid waste like sludges, ashes, rejects, dregs and lime mud. Some wood residues are also transported for landfill (table 3.3.5).

Dregs and lime mud are separated from the chemical recovery cycle in order to keep the amount of inert material and non-process chemicals in the cycle at an acceptable level and thus secure high reaction rates in the chemical recovery system.

Sludge generated in waste water treatment (primary and biosludge, bark sludge etc.) is normally burnt with a mixture of bark and wood residues (see section 3.2). Sludge burning reduces the quantity of waste considerable, but the inorganic material still remains as ash.

Wood ash from bark boilers contains nutrients taken from the forest with the wood raw material. The ash is, therefore, suitable as a fertilizer. About 35% of the wood ashes are utilized for soil conditioning.

Table 3.3.5Solid waste from Finnish kraft pulp mills (including the integrates) in 1995.

	Solid waste (t dry solid)
Waste water treatment sludge	55,000
Wood ash	50,000
Other ashes	80,000
Fibre and coating waste	27,000
Wood waste	34,000
Hazardous waste	1,400
Total	247,400

"wood ash" is fly ash and dust from the burning of wood material (e.g. from the bark boiler)

"other ashes" are ashes from fuels used in energy production other than wood and black liquor

"wood wast" is bark, chips, sawdust, wooden packages, building and demolition material etc.

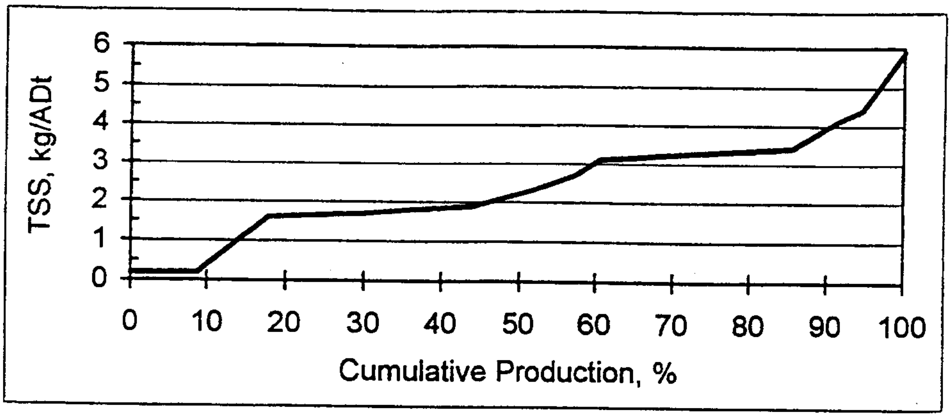


Figure 3.3.6 Cumulative distribution of specific discharge of total suspended solids, after external treatment, into the recipient from Finnish mills producing unbleached and bleached kraft pulp in 1995 *(the kraft pulp production of integrates is included).*

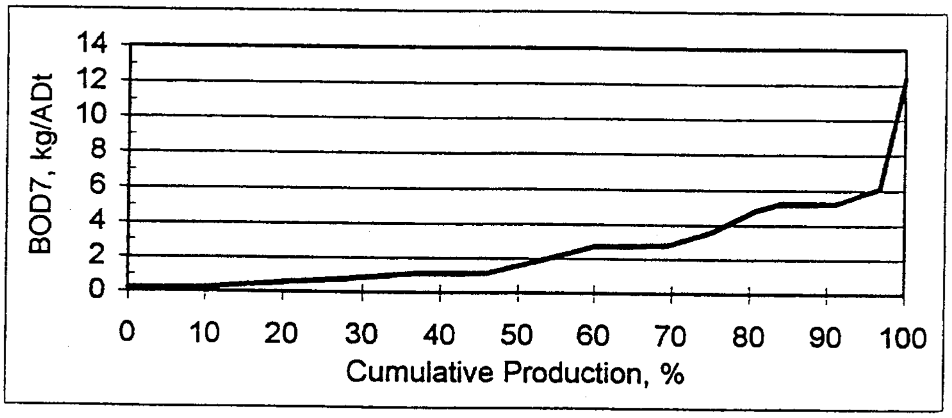


Figure 3.3.7 Cumulative distribution of specific discharge of BOD_7***, after external treatment, into the recipient from Finnish mills producing unbleached and bleached kraft pulp in 1995*** *(the kraft pulp production of integrates is included).*

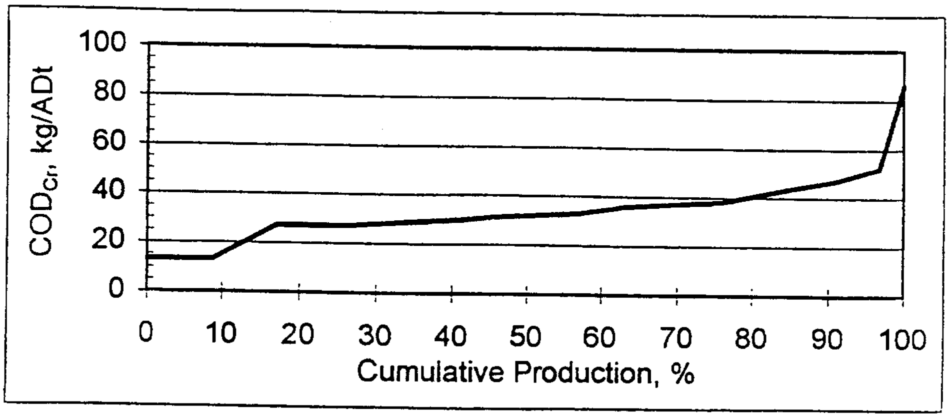


Figure 3.3.8 Cumulative distribution of specific discharge of COD_{Cr}***, after external treatment, into the recipient from Finnish mills producing unbleached and bleached kraft pulp in 1995*** *(the kraft pulp production of integrates is included).*

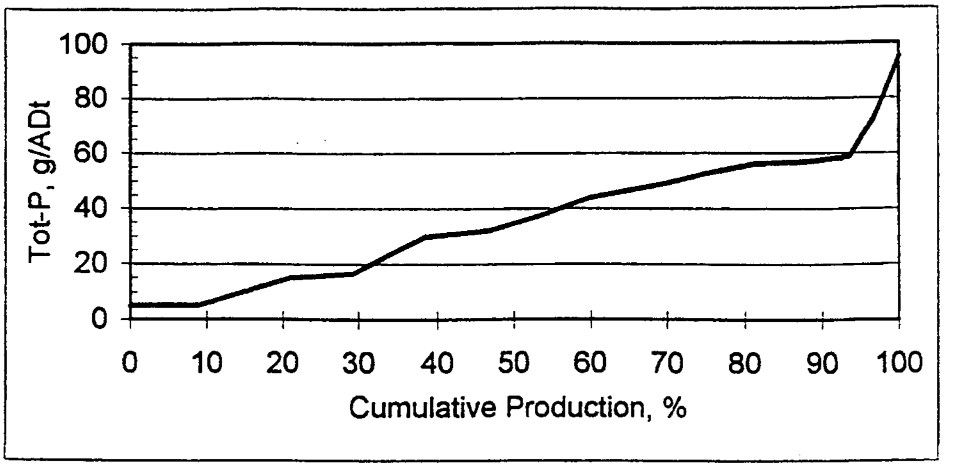


Figure 3.3.9 Cumulative distribution of specific discharge of tot-P, after external treatment, into the recipient from Finnish mills producing unbleached and bleached kraft pulp in 1995 *(the kraft pulp production of integrates is included).*

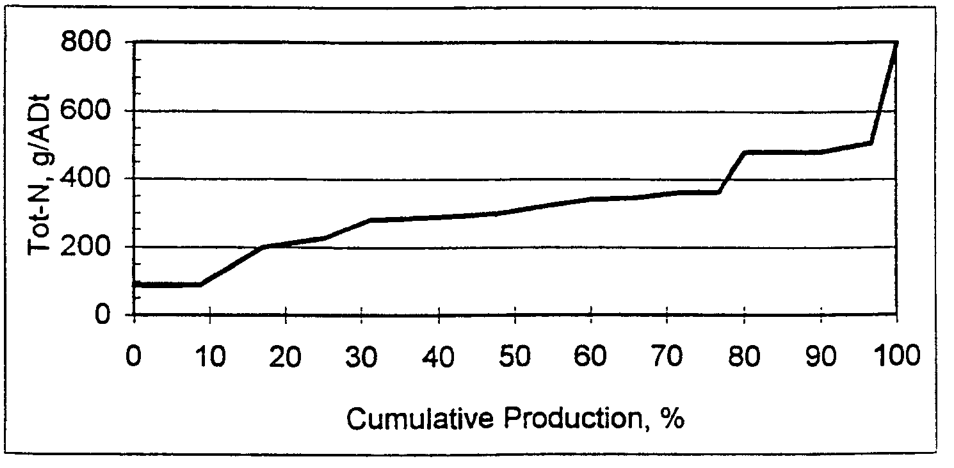


Figure 3.3.10 Cumulative distribution of specific discharge of tot-N, after external treatment, into the recipient from Finnish mills producing unbleached and bleached kraft pulp in 1995 *(the kraft pulp production of integrates is included).*

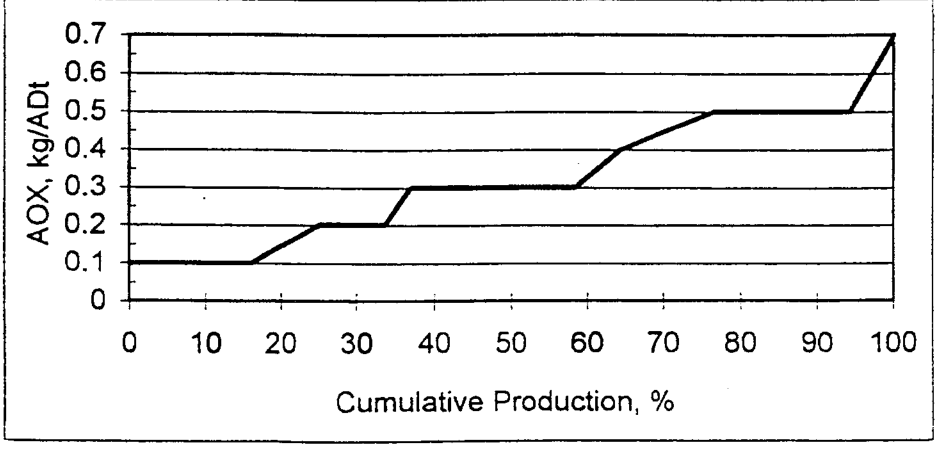


Figure 3.3.11 Cumulative distribution of specific discharge of AOX, after external treatment, into the recipient from Finnish mills producing unbleached and bleached kraft pulp in 1995 *(the kraft pulp production of integrates is included).*

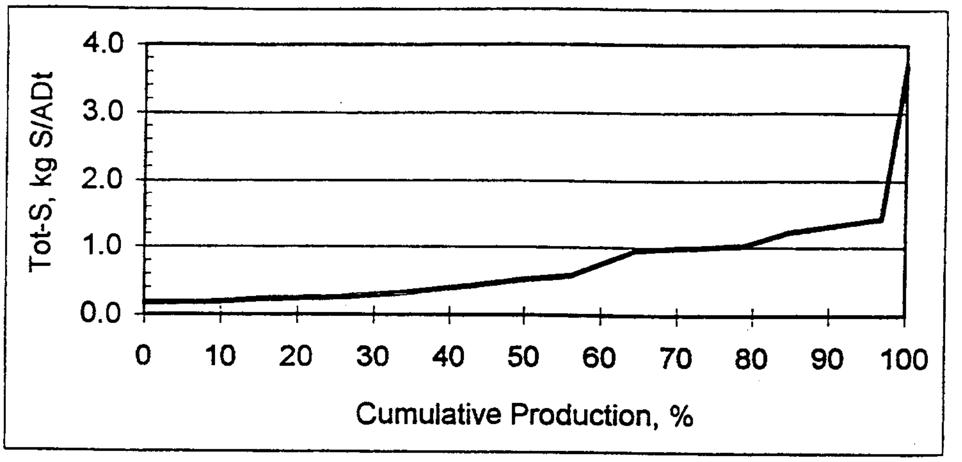


***Figure 3.3.12** **Cumulative distribution of specific emission of total sulphur into the air from Finnish mills producing unbleached and bleached kraft pulp in 1995** (the kraft pulp production of integrates is included).*

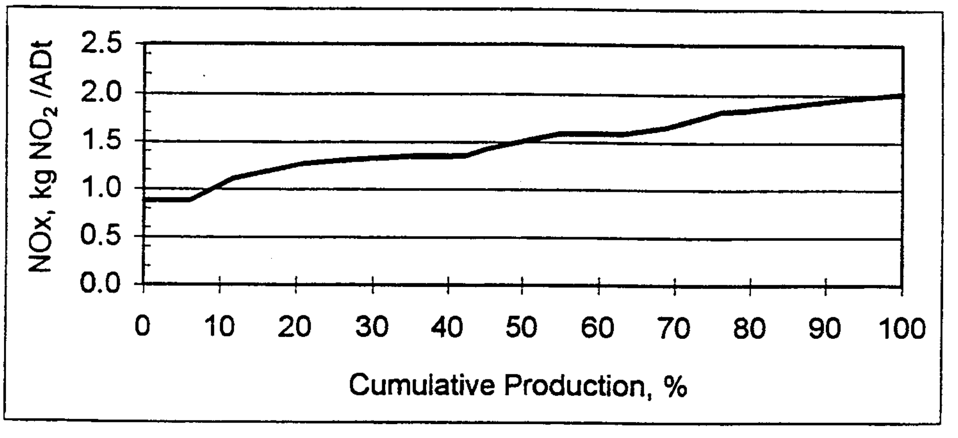


***Figure 3.3.13** **Cumulative distribution of specific emission of NOx into the air from Finnish mills producing unbleached and bleached kraft pulp in 1995** (the kraft pulp production of integrates is included).*

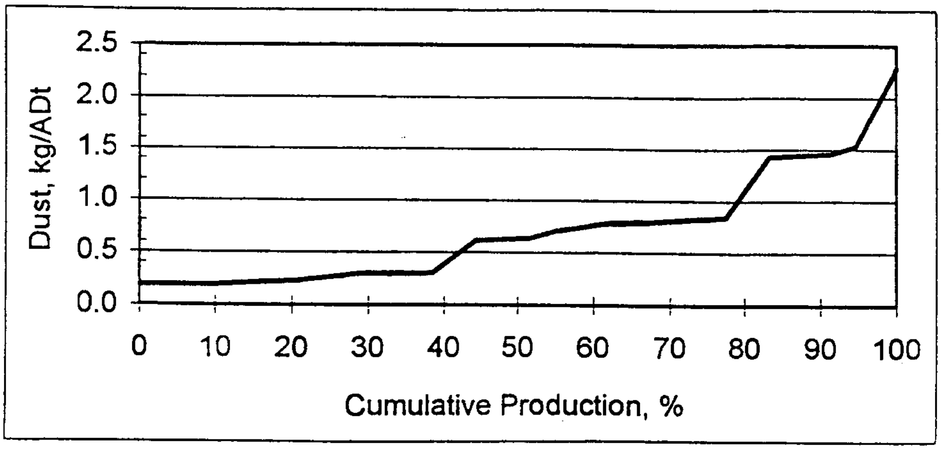


***Figure 3.3.14** **Cumulative distribution of specific emission of dust into the air from Finnish mills producing unbleached and bleached kraft pulp in 1995** (the kraft pulp production of integrates is included).*

3.4 Mechanical pulp

In mechanical pulping the wood fibres are separated from each other by mechanical energy. The action of forces creating a strain on the wood matrix causes the bonds between the fibres to break gradually and fibre bundles, single fibres and fibre fragments to be released. It is the mixture of fibres and fibre fragments that gives mechanical pulp its favourable printing properties. The wood matrix has viscoelastic properties and the softness can be influenced by chemicals and/or an increased temperature. A softer wood will release more intact fibres. The moisture content in the wood is of major importance for the pulp properties as it influences the softening of the wood. If the fibres are liberated before the lignin is soft enough, the fibres are easily damaged and result is a pulp with short fibres, a high content of fines and limited strength properties. If the moisture content in the wood is low, the temperature in the wood can rise so high that the wood changes colour - the wood burns. To prevent the wood burning, process water has to be added to cool the process.

There are two main types of equipment, grinders and disc refiners, used for mechanical pulping. In the grinders the wood is in the form of logs and in the disc refiner it is in the form of chips. The use of chips makes the refiner-based pulping somewhat more versatile with regard to the supply of the raw material and different types of pre-treatment of the wood before pulping.

The elements causing the mechanical action, grits on a pulp stone in the grinder and bar edges on a steel disc in the refiner, will give the resulting pulps a typical blend of fibres and fibre fragments. The groundwood pulp coming from the grinders will hold a higher proportion of fine material and damaged fibres. This gives the pulp good optical and paper-surface properties, which is valuable in low grammage printing papers. The more gentle treatment in the refiners produces a higher yield of intact long fibres. This gives the pulp higher strength, which is valuable in furnishes for products with a high requirement on runnability.

In the refiners and grinders the applied energy is converted through the friction created into heat. In the refiner the released heat vaporizes part of the water present and the process heat is recovered in the form of steam, which is used for drying the paper or board.

The characteristics of the pulp can be affected by increasing the processing temperature and, in the case of refining, by the chemical treatment of the chips. Both steps will increase the energy consumption as well as the pollutant level because of a lower pulping yield.

Spruce is the favoured raw material for mechanical pulping in Finland. Lately there has been increasing interest in the use of aspen because of the favourable optical and paper-surface properties of aspen pulps.

3.4.1 Mechanical pulping processes

Groundwood Pulps (GW, TGW, PGW, PGW-S)

In the conventional groundwood process debarked wood logs are pressed against a grinding stone in a grinder at atmospheric pressure. The mechanical work is mainly transformed into heat and the temperature of the wood rises. The lignin softens and the bonds holding the individual fibres together weaken. The high amount of shower water used results in a consistency close to 1 to 2% after the grinder. The temperature of the shower water is normally 70-80° C.

By increasing the pressure in the grinder it is possible to raise the grinding temperature. Due to the higher temperature the wood is softer in pressurised grinding (PGW, PGW-S) than in conventional grinding (GW) and the fibres are less damaged.

Grinder-based pulps are divided into two main types, as shown in table 3.4.1, on the basis of the grinding pressure and shower water temperature .

Table 3.4.1 Main types of groundwood pulp

Goundwood pulps	Abbreviation	Shower water temperature (°C)	Pressure (bar$_g$)
Groundwood	GW	65 - 75	0
Thermo groundwood	TGW	70 - 80	0.02-0.03
Pressure groundwood	PGW	70 - 100	2-3
Super pressure groundwood	PGW-S	95 - 125	4-4.5

In the PGW process low-pressure steam is generated when the pulp slurry flashes in the blow cyclone. The recovered low pressure steam is mainly used for the production of warm process water.

Refiner Mechanical Pulps (RMP, TRMP, TNP, PRMP, CRMP, CMP, TMP, CTMP)

In refiner mechanical pulping, chips are ground between steel discs with bar patterns in a refiner. Depending on the quality, the refining can be repeated in a second-stage and sometimes even a third-stage refiner. The forces from the impact of the bars causes the chips to break down into fibre bundles, individual fibres and fibre fragments. With the progressing treatment the impact also modifies the walls of the individual fibres. Most of the applied energy (friction work) transforms into heat which flashes part of the moisture in the chips. To prevent the wood from burning in the refining zone, cooling (dilution) water has to be added. The refiners normally operate at a high discharge consistency (25-50%). The large quantity of steam released in the refining process is normally captured in a heat recovery system for further use.

In the original refiner pulping process (RMP) chips were refined at atmospheric pressure. Because of the low temperature the process produced a high amount of damaged fibres. The optical properties of the RMP pulp were relatively good. RMP systems have not been installed in Finland since the early 1970's.

To improve the pulp quality, process modifications aiming at increased softness of the wood in the refining zone have been applied. These included the preheating of chips (TRMP and TNP) or pressurization of the refiner (PRMP). These processes produce pulps of slightly higher strength and reduced shive level at almost unchanged optical properties.

A more dramatic strength improvement and shive reduction is gained in the TMP process, where the chips are heated under pressurised conditions and the refining is also pressurised. Because of the pressurised conditions the released steam can be used for the generation of steam that can be used in the drying of paper. The increased refining temperature has an adverse effect on the optical properties and increases the consumption of electrical energy.

Mild chemical pre-treatment of the chips also enhances the softening of the wood and improves the properties of pulp produced by refining at atmospheric pressure (CRMP) or pressurised refining (CTMP). In most cases chemical pre-treatment increases the energy consumption. The generation of pollutants also increases as a consequence of the yield loss caused by the chemical treatment. Different kinds of treatment are used for different wood species. Sodium sulphite is mostly used for softwoods, and lately alkaline peroxide has been predominantly used for hardwoods. The alkaline peroxide treatment reduces the energy consumption. These methods produce clean pulps of sufficient strength and acceptable optical properties and can be used as the main fibrous component in printing paper, packaging board and hygienic paper furnishes.

With stronger chemical treatment and refining at atmospheric pressure, pulps (CMP) with high-strength properties can be produced from both softwood and hardwood. Optical properties are drastically reduced and CMP can only form a minor part of the furnish for printing papers. In CMP pulping the yield can fall below 90%. Both the increase in the refining temperature and the use of chemicals have increased the generation of pollutants in mechanical pulping. The main features of the refiner pulping processes are shown in table 3.4.2.

Table 3.4.2 Main types of refiner mechanical pulps

Refiner mechanical pulp	Abbreviation	Chip pre-treatment	Refining pressure	Energy recovery potential
Refiner Mechanical Pulp	RMP	None	Atmospheric	Low
Thermo Refiner Mechanical Pulp	TRMP	Steam at atmospheric pressure	Atmospheric	Low
Thermal None Pressurised	TNP	Steam at elevated pressure	Atmospheric	Low
Chemi Refiner Mechanical Pulp	CRMP	Chemical	Atmospheric	Low
Chemi Mechanical Pulp	CMP	Heavy Chemical + pressurised heating	Atmospheric	Low
Pressurised Refiner Mechanical Pulp	PRMP	None	Elevated pressure	Moderate
Thermo Mechanical Pulp	TMP	Pressurised heating	Elevated pressure	Moderate
Chemi Thermo Mechanical Pulp	CTMP	Mild chemical and pressurised heating	Elevated pressure	Moderate

3.4.2 Screening and cleaning

After the primary pulping process the mechanical pulps contain shives and fibre bundles. These shives and fibre bundles can cause operating problems and product-quality deficiencies and have to be removed.
The two main processes for the removal of impurities from the pulp are screening and cleaning in hydrocyclones. Lately, pressurised screens with slotted plates have replaced the use of hydrocyclones in many applications. This has reduced the energy consumption as the screens operate with a lower pressure drop and at a higher pulp consistency than cyclones.

3.4.3 Bleaching of mechanical pulp

With the increased demand for high-brightness paper and board, the bleaching of mechanical pulps has become more common.

Table 3.4.3 Pulp brightness needed for different end products

Product	Brightness (% ISO)
Newsprint	58-65
Board, middle layer	65-75
Groundwood specialities	65-75
SC and LWC	68-80
Tissue and towels	75-80
Wood free grades (hardwood pulp)	80-84
Fluff pulp for diapers	78-85

The achievable pulp brightness is dependent on the initial pulp brightness. This, in turn, is species- and process-related.

Table 3.4.4 Typical initial brightness for some mechanical pulps (spruce, Picea abies)

	Shower water temperature (°C)	Brightness (% ISO)
GW	70	64-68
PGW	70	65-68
PGW	95	63-66
PGW-S	95	62-65
PGW-S	120	60-63
RMP		62-65
TMP		60-63
CTMP		65-70

The bleaching of mechanical pulps aims at changing cromoforic groups in the lignin into a colourless form without causing a yield loss.

There are two main chemicals used in the bleaching of mechanical pulps, dithionite and peroxide. Dithionite bleaching is a reductive method, while peroxide bleaching is oxidative needing a high pH environment.

Dithionite bleaching

In dithionite bleaching organic material is not dissolved from the pulp.
The maximum economical charge of dithionite is 8 to 12 kg per tonne of pulp. A higher dosage does not increase the brightness. The brightness is increased from the initial brightness level of 58-70% ISO to 70-76% ISO. In most mills a metal chelating agent (e.g. EDTA, DTPA) is used. The consistency in conventional hydrosulphite bleaching is 3-5%. Medium consistency (MC) pumping has made it possible to bleach at a 10-12% consistency with increased efficiency.

Peroxide bleaching

The yield drop in peroxide bleaching is approximately 2%, mainly due to the alkalinity during the bleaching. This influences the pulp properties: in addition to the increase in brightness, the strength of the pulp improves, the content of extractives is reduced and the water uptake capacity improves.

A higher final brightness can be reached with peroxide bleaching than with dithionite bleaching but the consequence is reduced opacity. The maximum effect of peroxide bleaching changes from the initial brightness 58-70% ISO to a final brightness 78-84% ISO. The maximum economical amount of peroxide is 3-4% of the amount of pulp.

The pH is adjusted with sodium hydroxide. Sodium silicate is added (1.5-4% of the amount of pulp) to buffer the pH and stabilise the peroxide. Chelating agents (e.g. EDTA, DTPA) are used to form complexes with heavy metals (Fe, Mn, Cu, Cr), which prevents the pulp from discolouring and the peroxide from decomposing. The dosage of chelating agents is about 5 kg per tonne of pulp. EDTA and DTPA contain nitrogen, which will show up in the waste water. The bleached pulp is finally acidified with sulphuric acid or sulphur dioxide to a pH of 5-6.

Modern peroxide bleaching is conducted at a consistency level of 25-35%.

3.4.4 Pulp properties and end-users of mechanical pulps

Mechanical pulps do not have the same strength as chemical pulps, but recent developments have led to considerable improvements. Mechanical fibres do not form fibre bonds to the same extent as chemical fibres. This gives the paper better optical characteristics, i.e. higher opacity.

Mechanical pulps are often characterised by their drainage properties. A frequently used measurement is the Canadian Standard Freeness, CSF. A low freeness value indicates a slow draining pulp with a high degree of fibrillation. Such a pulp has been produced using a high energy input in the grinding or refining.

The paper and board in which mechanical pulp is used determine the requirements for freeness, brightness and other pulp properties. Today mechanical and chemi-mechanical pulps are produced in different commercial processes in a very wide freeness range for a variety of paper and board grades. Wood containing printing paper, e.g. LWC, SC magazine paper (freeness 20-60 ml CSF) and newsprint (freeness 80-150 ml CSF) are the most common end products. The pulps are also used in paper board (freeness 450-750 ml CSF), absorbent products, e.g. tissue (300 ml CSF) and fluff (700 ml CSF), and hardwood grades in fine paper.

Pulps intended for different end uses have a distinct distribution of long-fibre, middle and fine fractions. The distribution between long fibres and fine material in a specific pulp is, besides the degree of softening of the wood, controlled by the energy input. Generally, ground wood pulp has a lower long fibre content and strength, but a higher fines content than refiner pulp. Groundwood pulp gives the paper good optical properties.

3.4.5 Raw materials, pulp yield and energy consumption

To obtain a product of optimum quality, it is necessary to have access to the best type of wood for a certain application. This will be of special importance in the years to come, when the quality demands on the high-yield pulps will increase considerably. Mechanical pulping is more restrictive in terms of the wood types that can be used as a raw material than chemical pulping.

The best wood raw material for mechanical pulping processes is spruce and aspen. Norwegian spruce (*Picea abies*) is one of the best raw materials for both grinding and refining. The brightness in aspen ground wood is good but the strength of the pulp is lower compared with spruce pulp. One reason for developing chemi-mechanical pulping processes was a higher-strength pulp.

The yield from mechanical pulps varies between 92% and 97% and without chemical treatment the yield is above 94%. The reduction of the pulp yield in peroxide bleaching is 1-2%.

The specific energy consumption in mechanical pulping is dependent on the pulping process, the properties of the raw material and, to a large extent, the quality demands on the pulp set by the end product. The freeness value is usually used for specifying the quality of the pulp. For the manufacturing of a pulp with better strength (low freeness) the energy consumption is increased.

Only a portion of the mechanical work put into the grinder or refiner is used to liberate the fibres in the wood. The rest of the work is turned into heat. The heat that is released can be recovered for other usages such as the drying of the final product. Typical recovery rates are shown in table 3.4.6. The lower figures in the energy usage range are for high-freeness pulps used in boards, and the higher figures are for low-freeness pulps used in high-quality printing papers.

The consumption of energy in screening, cleaning, reject handling, post refining and bleaching is dependent on the quality demands set by the products.

Table 3.4.6 Energy consumption and recovery of energy in mechanical pulping.

Mechanical pulp and freeness, ml CSF		Energy consumption (kWh/t of pulp)	Recoverable energy as hot water (%)	as steam (%)
GW	350-40	1,100-2,000		
PGW	350-40	1,300-2,300	30	
PGW-S	350-40	1,300-2,300	30	
RMP	350-30	1,500-3,000	70	
TMP	400-30	1,800-3,000	20	60
CTMP	700-40	1,000-3,300	20	60

3.4.6 Discharges and emissions into water and the air, generation of solid waste

A yield of 92-97% means that 30-80 kg /tonne of the wood are lost in the water phase in the form of dissolved and dispersed organic substances. The yield is dependent on the energy input and the temperature in the process and on the use of chemicals. Wood species and seasonal variations also influence the amount of dissolved solids. During mechanical pulping, the stability of the cellulose and the lignin is not affected, but simple carbohydrates, extractives, proteins and inorganic substances including nitrogen and phosphorus are dissolved and dispersed in the process water.

With a decreasing yield the BOD_7 of the water from pulping increases. Typical specific loads measured such as BOD_7, COD_{Cr} and nutrients (phosphorus and nitrogen) for different pulps are listed in table 3.4.7.

Table 3.4.7 Typical specific loads such as BOD_7, COD_{Cr} and nutrients in water from the mechanical pulping of Norwegian spruce (*Picea abies*) before external treatment.

Pulping process	Yield (%)	BOD_7 (kg/t)	COD_{Cr} (kg/t)	Nitrogen (g/t)	Phosphorus (g/t)
GW	96-97	10-12	20-30	80-100	20-25
PGW	95-96	12-15	30-50	90-110	20-30
PGW-S	95-96	13-16	45-55		
RMP	95-96	12-17	40-60	90-110	20-30
TMP	94-95	15-25	50-80	100-130	30-40
CTMP	92-94	20-35	60-100	110-140	35-45

The discharge of nitrogen in mechanical pulping originates from the wood and chelating agents (e.g. EDTA; DTPA) used in bleaching. A dosage of 2-3 kg EDTA/ tonne of pulp results in an additional discharge of 150-220 g nitrogen/tonne of pulp. The discharge of phosphorus depends on the wood.

The yield loss in connection with peroxide bleaching is 15-30 kg/tonne corresponding to an additional load of approximately 10-30 kg O_2/tonne measured as BOD_7 and COD_{Cr} respectively. The steam released in mechanical pulping processes is contaminated with volatile wood components. The amount of steam, dependent on the specific energy consumed, is some 2 tonnes per tonne of pulp at a pressure of 2 to 4 bar. The contaminated condensate can be treated separately.

In a typical integrated board or paper mill that uses mechanical pulp high-pressure steam is generated in a power plant. The energy is partially transformed into electricity in a back pressure turbo-generator and the rest is used in paper or board drying.

The fuels used are coal, bark, oil and natural gas. Approximately 20% of the electricity requirement at the mill is covered. The power plants have electrostatic precipitators for the removal of particulates from the flue gases. The emission of sulphur dioxide is limited by using selected fuels.

The solid primary waste removed from the mechanical pulping processes consists of bark and wood residues from the debarking, fibre rejects, ash from energy production and sludges from external waste water treatment (see section 3.2 and 3.7).

3.5 Recycled fibre

The use of recycled fibre in paper and board manufacturing is increasing rapidly. After deinking, recycled fibre can be used in tissue paper, newsprint and even fine paper. Recycling waste paper reduces the amount of solid waste going for landfill although the deinking of recovered waste paper generates a considerable amount of deinking sludge that usually goes for landfill.

In Finland the use of waste paper was about 5% of the raw material used in paper and board production in 1994 and 1995 (472,300 and 492,000 tonnes respectively). The recovery of the total paper and board consumed in Finland in 1995 was 58% of the recoverable paper and board consumption. The Finnish use of recycled fibre cannot be increased without increasing the import of waste paper or recycled fibre because about 90% of the total production of paper and board is exported.

Most of the recycled fibre originates from household waste paper, consisting of newspapers (65-70%), magazines (20%), leaflets and other paper products (10-20%).

Recycled fibre is used in newsprint (33%), tissue (24%) and as a raw material for different board grades (37%), replacing mechanical pulp. Newsprint can be made of 100% recycled fibre, but the average in Finnish newsprint is lower. In tissue paper the use of recycled fibre varies between 0 - 100%. Recycled fibre that is not deinked is used in the middle layer of multi-layer board and in core board. A small amount of recycled fibre is also used in magazine paper. Recycled fibres from brown packaging grades are reused in similar grades.

3.5.1 Recycled fibre processes

Recycled fibre processes can be divided in two categories:
- processes with only mechanical cleaning
- processes with mechanical and chemical cleaning.

The target in recycled fibre pulping is to minimize the content of all kinds of contaminants in the pulp and to preserve the strength of the pulp.

The quality, cleanness and brightness requirements for the recycled fibre used as a fibre raw material vary widely with different paper and board grades. In many board grades deinking is not required, but for high speed paper machines manufacturing high-brightness paper very efficient multi-stage processing is normally required.

The main stages included in the recycled fibre processes are:

- coarse classification
- repulping of waste paper
- removal of mechanical impurities
- removal of chemical impurities
- mechanical/chemical dispersion of remaining contaminants
- bleaching

Deinking is necessary for grades where brightness is important such as newsprint, printing and writing paper, tissue, and the top and bottom layers in multi-layer white boards.

Deinking is based on washing the pulp in order to remove the printing ink. A deinking plant includes the following unit operations : repulping, pre-screening for the removal of coarse contaminants, the chemical treatment of the pulp, deinking by flotation and/or washing, fine screening, cleaning and dewatering. The order of the unit operations may vary and some of the steps may be repeated either with the same or different types of equipment. Typical chemical doses in the deinking process are shown in table 3.5.1.

Table 3.5.1 Chemicals in deinking

Chemical	Use (kg/tonne of pulp)
Sodium hydroxide	10 - 20
Sodium silicate	20 - 30
Soap	5 - 8
Talc	10 - 15
Hydrogen peroxide	5 - 25
Chelating agent (DTPA)	2 - 3
Sodium dithionite	6 - 10
Sulphuric acid 8 - 10	

The yield of deinked pulp is 60-90%.

There are four deinking plants in Finland. The largest plant has an annual capacity of 100,000 tonnes. The raw material is unsorted household waste paper. The pulp is used for the on-site production of newsprint.

The amount of deinking sludge from the flotation unit is about 65 kg/tonne of recycled fibre. The deinking sludge and the reject from fine screening are burnt in the power plant. The process water is treated by dissolved air flotation (DAF) before external biological treatment. The purified water is not recirculated into the deinking process. The water used in the process is mainly white water from the newsprint paper machine.

Two deinking plants produce recycled fibre for tissue papers (capacity 60,000 tonne/a and 45,000 tonne/a). The raw material is not only household waste paper but also white woodfree and wood containing office paper depending on the quality requirements of the end product. The amount of deinking sludge varies considerably depending on the waste paper quality, and it can be as high as 240 kg/tonne of recycled fibre.

One plant produces market pulp. The annual capacity is about 60,000 tonnes. The raw material is household waste paper. The pulp is mainly used in manufacturing newsprint, magazine paper and tissue. The deinking generates about 85 kg of deinking sludge per tonne of recycled fibre. The deinking sludge is dewatered by centrifugation to 40-50% dryness. All rejects and deinking sludge go for landfill. The process water is internally treated by DAF and partially reused.

3.5.2 Pulp properties and end use

Recycled fibre has conventionally been used mostly in packaging and some other cardboard grades. Deinking is not usually necessary for these grades. Deinked pulp is mostly used in tissue and newsprint and in smaller amounts in printing paper grades of a higher quality.

The use of recycled fibre instead of primary fibre in most cases weakens the quality of the paper. For example, recycled fibre decreases the stiffness of the board. To compensate for this, more pulp is used in the board (up to 30%). Due to the higher grammage the energy consumption of the board machine increases and production efficiency decreases.

Relatively high amounts of bacteria have been found in packaging materials containing recycled fibre.

3.5.3 Energy consumption

The consumption of electrical energy is approximately 300 kWh/tonne of pulp. The use of waste paper has risen simultaneously with the increase in the demands for quality placed on the end products. Small amounts of recycled fibre can be used in more demanding paper grades like LWC and SC. This requires additional cleaning stages and the electrical energy consumption will increase to 500 kWh/tonne.

Pumping consumes almost half of the energy, screening and dispersing about one third and pulping, agitation and ventilation take up the remaining 20%.

The consumption of heat energy in the processing of recycled fibre is 1.1-2.4 GJ/tonne.

3.5.4 Discharges and emissions into water and the air, generation of solid waste

Because of different quality requirements the recycled fibre processes are designed in various ways. The composition of the waste water is dependent on the operating principle of the deinking process, raw material and the quality requirements on the produced pulp. Three of the Finnish deinking plants were investigated in 1991. In stable process conditions the primary discharge of organic substances was 30-35 kg as COD_{Cr}/ADt of pulp. The average discharge of phosphorus and nitrogen varied between 20-60 g/ADt and 175-400 g/ADt respectively. Fatty and resin acids occurred only in small amounts. The amount of AOX was 5-10 g/ADt. The content of heavy metals was low.

Waste water samples were taken after flotation but before external biological treatment.

The use of recycled fibre to replace mechanical pulp in paper or board increases the amount of solid waste generated. Depending on the waste paper quality and the requirements for the recycled fibre, the amount of solid waste varies considerably (10-40% of the raw material). About 10% are rejects such as metal, sand, plastics etc. The amount of deinking sludge is 50-250 kg dry matter/tonne of recycled fibre.

3.6 Paper and board

This section describes Finnish paper and board production. The discussion is limited to grades in which Finland plays a major role within the EU.

3.6.1 General

Production processes

Traditionally the production has been divided into integrated or non-integrated production depending on whether the main raw material, pulp, has been produced at the same site.

Almost all types of paper and board-making processes have the following basic units:

- stock preparation
- a paper or board machine consisting of
  - a wire section
  - a press section
  - a drying section
  - a reeler

Depending on the paper and board grade there are additional process units, like calenders, coaters, a coating colour kitchen, winders, rewinders and a roll wrapping station.

In the stock preparation the pulp might be refined, and before being pumped to the paper machine it is cleaned for the removal of impurities. Frequently centri-cleaners and screens are used in series.

The fibre suspension is diluted before the inlet to the paper machine (head box) to a consistency of 0.2-1.5% in order to obtain a uniform fibre distribution in the web formed on the wire. In the wire section the pulp suspension is dewatered to a consistency of about 20% by filtration. The filtrate called "white water" is valuable because of its fibre, filler and heat content. The white water is collected and reused for pulp dilution before the paper machine. This circulation of white water is called "the short circulation".

The retention of suspended solids on the wire varies 50-80% depending on the paper grade being produced. For paper grades containing mechanical pulp and filler the first-pass retention is usually lower than for grades made from chemical pulp.

In the press part the pulp is further dewatered to a 35-52% consistency and in the drying section the paper web is dried to 90-95%. The total amount of water entering the wet end always exceeds the amount of water needed for the short circulation dilution. The excess water is collected, treated and reused for the dilution (long circulation) of the pulp in different parts of the process. Clean, fresh water is used for shower water in the wire and press sections and for sealing and lubrication. This fraction of the fresh water leaks into the white water system, giving rise to excess white water, which is normally extracted as a clear filtrate. The fresh water used for cooling and sealing the vacuum system remains unpolluted and is, therefore, returned to the fresh water system or discharged, by-passing any treatment. The total consumption of fresh water is 15-50 m^3/tonne of paper. The excess white water is treated for fibre recovery. A typical water circulation system for a newsprint machine is presented in figure 3.6.1.

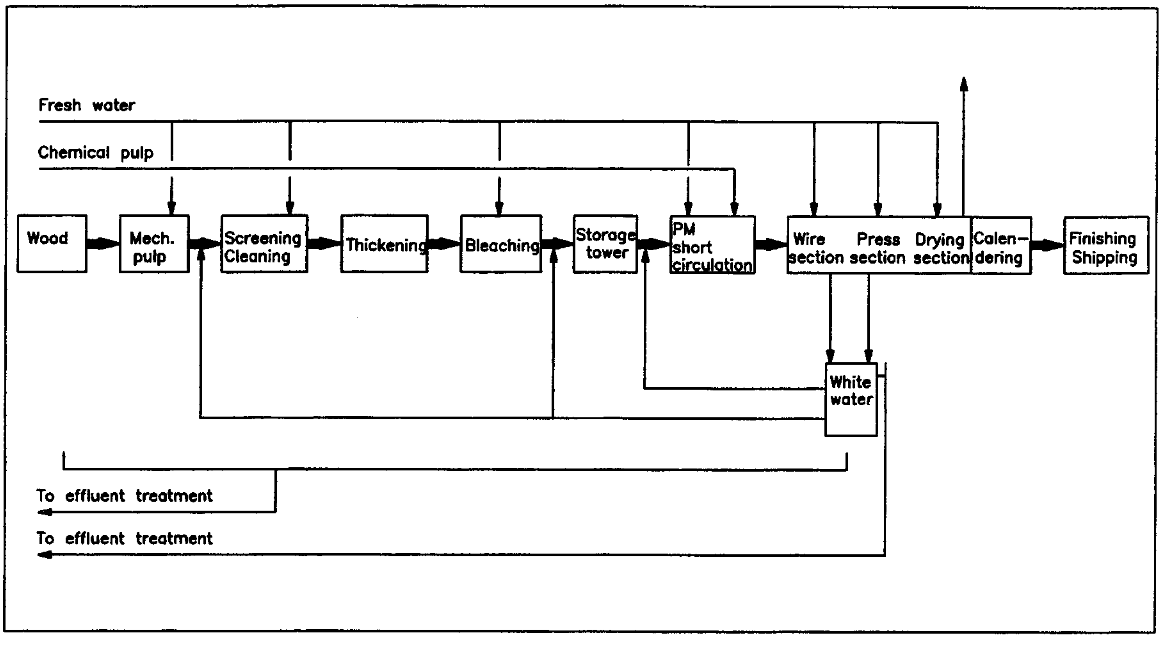


Figure 3.6.1 Block diagram of a newsprint mill

In the process some paper, broke, not approved for shipping is generated. The broke nevertheless contains some valuable raw material and is, therefore, returned to the process.

Energy consumption

About 90% of the heat energy is used for drying of the paper and the rest is used for heating the process and the building. Paper machines integrated with TMP production use steam from the heat recovery of the TMP plant. Part of the electricity needed is produced in back pressure turbines; the rest is purchased. Specific energy consumptions typical for different paper grades are given in table 3.6.1.

The average distribution of electrical energy consumption in Finnish paper mills is :

- pumping of raw materials and water 25%
- vacuum system, ventilation, pressurised air 25%
- drives, refiners, screens 38%
- electrical - IR drying 9%
- lighting and other uses 3%

Table 3.6.1 Typical average specific energy consumption figures for different paper grades (1992).

Paper grade	Consumption of electrical energy (kWh/tonne of paper)	Consumption of heat energy (GJ/tonne of paper)
Newsprint	600	5.3
Wood containing paper		
- SC	700	5.3
- LWC	700	5.3
Fine paper	750	7.5
Sack paper	1100	6.9
White board	800	7.2
Liner and fluting	520	5.7
Tissue	1000	6.9

The figures do not include the energy consumption in the pulp production.

Internal pollution control

The main principles for internal process measures are the reduction of fresh water consumption by recycling the process water, the reduction of fibre and other raw-material losses and the separation of uncontaminated water from contaminated. Excess white water is clarified before being partially discharged. The reuse of a clear filtrate replacing fresh water is common practice in several applications. However, the separation of suspended solids alone is not sufficient in cases where, for instance, slime growth causes disturbances.

Steps typically taken to reduce the fresh water consumption at the paper and board machines include the segregation of contaminated and clean streams and the reuse of the clean water fraction in the first place. On many machines so-called save-all filters have been installed with which valuable material is recovered from the white water, and a clear fraction, free of suspended solids, is obtained. This clear filtrate can be used to replace fresh water in showers and in the pulp mill. Any excess filtrate is discharged into the external treatment system. This maintains the balance of dissolved solids in the water system.

Lower fresh water consumption results in lower volumes going to the external waste water treatment, lower water costs and higher temperatures in the production system, which leads to lower steam consumption in the paper-drying section.

Spills, overflows of pulp and white water into the sewers occur in the operation of a mill. The effects and frequency of the spills can be reduced by the design and control of the white water system, the production system and by training the personnel.

Discharges and emissions into water and air, generation of solid waste

The main types of process water discharged from a paper machine are rejects from pulp cleaning and excess white water. Temporary discharges and spills (overflows of tanks, spent wash water from cleaning equipment and flushing water from flushing floors etc.) occur intermittently.

The spent cooling water and the vacuum-system sealing water are generally clean and can be recycled to some extent. Clean cooling water should be kept separate from polluted effluents in order to minimize the hydraulic load in the external treatment plant.

The amount of suspended solids primarily discharged from the process depends on the internal measures taken at the paper mill and on accuracy of operation. The main sources are cleaner rejects, occasional spills and excess white water. Most of the discharged suspended matter is separated in the primary treatment and the separated sludge is dewatered and disposed of.

The dissolved organic matter discharged from the paper production system consists of substances carried over from the integrated pulp mill or, in the case of purchased pulp, from refining the pulp and from chemical additives at the paper mill. The amount of organic substances generated at the paper mill normally corresponds to 1-5 kg/tonne and 2-10 kg/tonne of paper measured as BOD_7 and COD_{Cr}, respectively, before external treatment.

The degree of closure of the white water system normally has only a minor influence on the amount of discharged organic matter. The amount of water to be discharged will decrease with a higher closure degree and, therefore, the concentration of organic matter in the effluent will increase. With increased concentration there is a risk of a carry-over of organic matter from the process water to the finished paper if no internal water treatment is used.

The emissions into the air from paper mills consist of moist air from the drying section and flue gases from the energy production at the mill.

The main types of solid waste in connection with paper production are rejects, sludge and ashes. Other solid waste like metal, plastics, glass, chemicals, coating residues etc. are generated in smaller quantities.

Cleaning the pulp before pumping into the paper machine generates rejects that contain impurities like shives bark, sand, fibres etc. The dry solid content of the rejects is low (1-2%), and the rejects are normally discharged into the effluent collection system. In an integrated mill the screening reject may be recycled into the pulp mill. Most of the rejects end up in the sludge from the effluent treatment system.

Coating colour residues contain expensive components such as pigments and binders. The recovery of waste from the coating colour preparation is economically feasible. Furthermore, due to the high content of inorganic pigments the waste is less suitable for mixing with fibrous sludge meant for incineration.

3.6.2 Newsprint

The fact that a newspaper becomes old in one day and is then recycled or disposed of makes it possible and necessary to use cheap mechanical pulp and deinked recycled pulp as the fibre raw material. The basis weight of newsprint has been decreased from 52 g/m^2 to 45 and even 40 g/m^2 during the last two decades.

More printing area is gained but simultaneously the importance of sufficient opacity has grown. This demand is met by a high proportion of mechanical pulp in the furnish.

Traditionally, newsprint has been made of 70-85% groundwood pulp, the rest being chemical pulp. With the development of strong TMP pulps, newsprint production without chemical pulp has become possible during the last decade. Newsprint is now manufactured from TMP and /or deinked recycled fibre and only in the lightest grades is a small amount of chemical pulp used.

One of the main disadvantages of mechanical pulp is the strong yellowing that turns the paper yellow in a very short time when it is left in the daylight. But as the lifetime of a newspaper is short, this is of less importance. The initial brightness of mechanical pulp is normally 60-65% ISO, which is high enough for newsprint. Hydrosulphite bleaching is sometimes used, but peroxide bleaching is too expensive for normal newsprint grades. Some high brightness special newsprint paper grades are produced from peroxide bleached mechanical pulp.

Some chemicals are used in the production of newsprint, like dyes for shading, and in some cases fillers (5-10%), retention aids and slimecides.

All newsprint mills are integrated with mechanical and/or deinked pulping. The white water system of the paper machine is integrated into the process water system of the pulping. The effluent load from the paper machine and from the pulp production cannot, therefore, be separated. The waste water can be discharged from both departments, but since most of the organic substances are dissolved during the pulp production, fresh water should be used at the paper machine and led counter-current to the pulp and discharged from the pulping plant. The total fresh water consumption in a modern newsprint mill is 15 - 20 m^3/tonne of paper. In older mills the water consumption can be up to 40 m^3/tonne of paper. A block diagram of a typical newsprint mill is shown in figure 3.6.1.

3.6.3 Magazine paper

There are two main grades of magazine paper, uncoated supercalendered (SC) paper and light weight coated (LWC) paper. The basis weight is in the range of 40-70 g/m^2 for SC paper and 50-70 g/m^2 for LWC paper. The basis weight of the base paper in LWC paper is 30-45 g/m^2 and the paper is coated on both sides (7-15 g/m^2).

The pulp raw material in SC paper is bleached mechanical pulp and bleached chemical pulp. A typical furnish for SC paper is 50-60% mechanical pulp, 10-25% chemical pulp and filler clay 15-35%. The surface is finished by supercalendering.

The base paper furnish for LWC paper is mechanical pulp 40-60% and 30-50% chemical pulp. Fillers are not usually used. The coating is composed of pigments, latex and starch binders. The coating is 15-35% of the final LWC paper weight. The paper is coated on- or off-machine. The paper is finished by supercalendering.

The mechanical pulp is, in most cases, bleached with peroxide.

Stock preparation and paper machine

The stock preparation for SC paper includes two (or more) pulp lines, one for mechanical pulp and the other for chemical pulp, a broke handling system and facilities for the preparation and dosage of fillers.

A simple block diagram of an SC paper mill is shown in figure 3.6.2.

The stock preparation for LWC paper includes two pulp lines, two broke handling systems and a preparation and dosage system for coating agents. A simple block diagram of an LWC paper mill is shown in figure 3.6.3.

The coating is prepared in the coating kitchen.

Retention aids, slimicides and dyes are added at the paper machine wet end. Starch is often added to improve the strength properties.

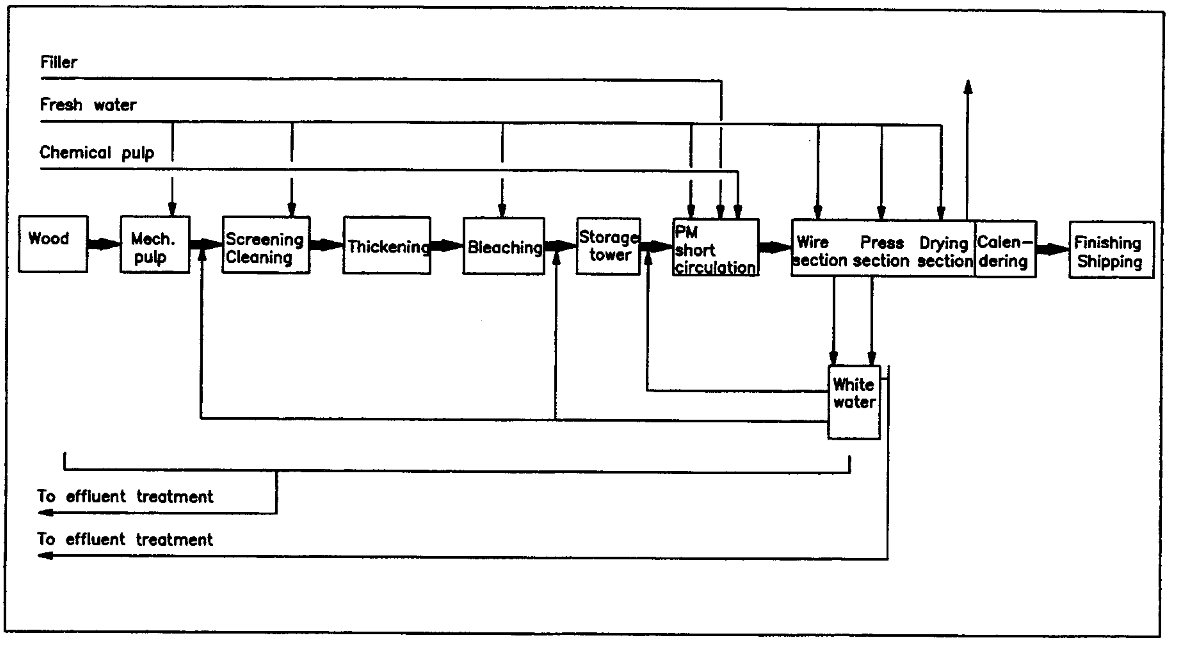


Figure 3.6.2 Block diagram of an SC paper mill

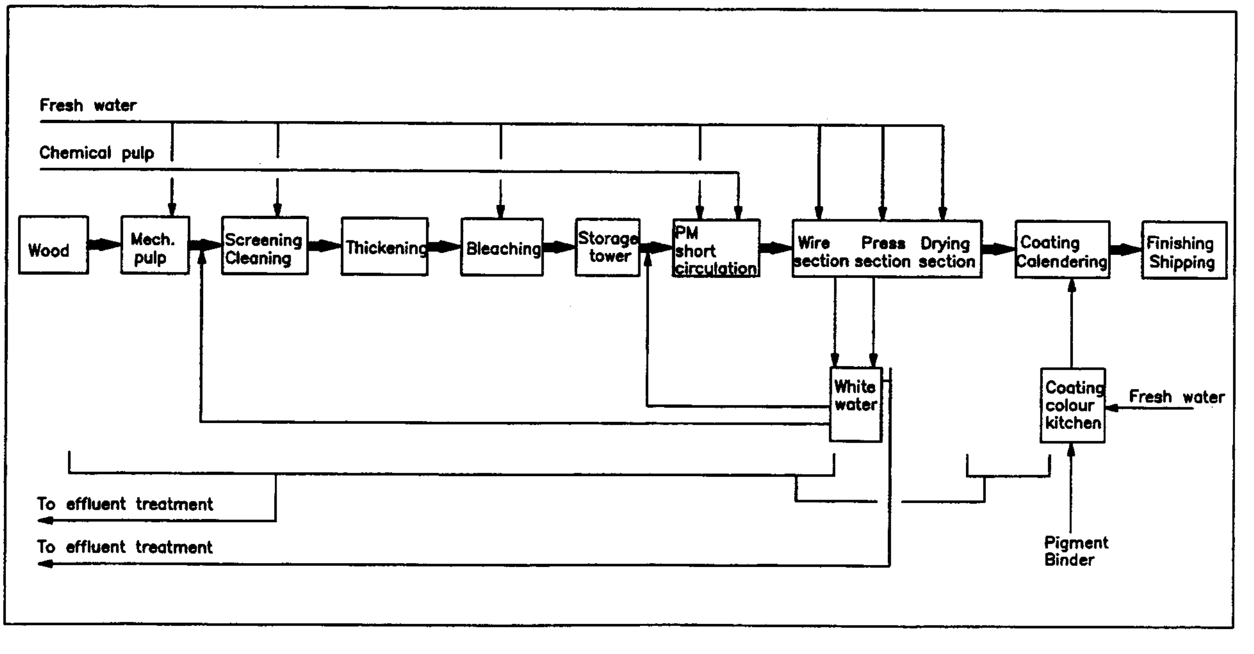


Figure 3.6.3 Block diagram of an LWC paper mill

3.6.4 Woodfree printing and writing paper

Paper used for documents archived for a long period of time has to retain its colour and integrity. For these reasons woodfree paper, also called fine paper, is made from bleached chemical pulp with the addition of a filler. Fine paper grades are sized, both internally and on the surface, in order to achieve low ink penetration. To achieve improved printability the paper is coated.

Fine paper is used for printing, writing and copying. Fine paper mostly contains 20-30% filler clay. In neutral and alkaline paper-making calcium carbonate is used.

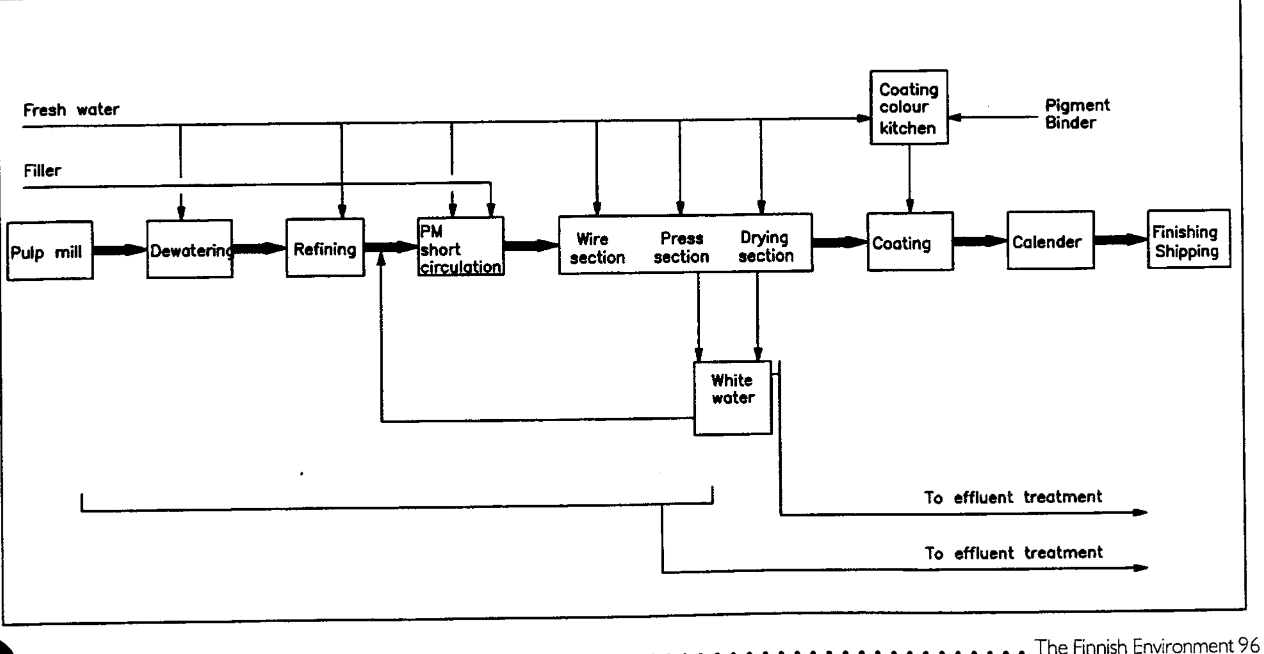
The basis weights vary in the range of 40-200 g/m^2 depending on the purpose for which the paper is used. The basis weight of copy paper is 75-80 g/m^2. Art paper, which is used for high-quality books and advertising publications, is coated twice or even three times. Up to 40% of the dry content of the final paper consists of coating in a double coated paper. The basis weight of art paper is 80-200 g/m^2.

Hydrophobic sizing is used to prevent liquid penetrating the paper. Almost all fine papers undergo surface sizing, which increases the stiffness, surface strength and internal bonding. Surface sizing is performed in a size press. Surface sizes are starch-based, which is important in terms of the effluent composition and discharges.

Sizes (starch or synthetic), dyes, retention aids, slimecides etc. are used at the paper machine wet end.

Fine paper mills can be non-integrated or integrated with a chemical pulp mill. In Finland all the fine paper mills are integrated. Even if a fine paper mill is integrated with a pulp mill, no white water from the paper mill is used in the pulp production. This means that the paper mill's water balance is influenced by the amount of water accompanying the pulp at the pumping consistency. The effluent from an integrated paper mill is 15 - 30 m^3/tonne of paper and 10 - 20 m^3/tonne of paper for a non-integrated paper mill. As far as the total water consumption is concerned, it would be most feasible to return an equal amount of clear white water filtrate to the pulp mill to compensate for the loss of process water that normally consumes fresh water. A block diagram for a typical fine paper mill is shown in figure 3.6.4.

Figure 3.6.4 Block diagram of a fine paper mill



3.6.5 Board

Board is usually defined by its basis weight, which is higher than that of paper. The basis weight is in the range of 125 g/m^2 to 400 g/m^2. Board is mainly used for packagings but also as a printing substrate. Board for containers can be divided into liquid container board and box board in the form of folding box board and board for corrugated board. A block diagram of a typical board machine is shown in figure 3.6.5.

The raw material in liquid board is bleached kraft pulp and bleached CTMP. Liquid packaging board mills can be partly or totally integrated with a pulp mill. These boards are manufactured on three-layer board machines, and about 50% of the middle layer can be CTMP pulp. The board is internally sized and it is surface sized as well. The board is finished with a clay coating or plastic or aluminium film. The effluent from an integrated liquid board mill is 15 - 30 m^3/tonne of board.

Dyes, retention aids, slimecides etc. are used in addition to the sizes at the board machine wet end.

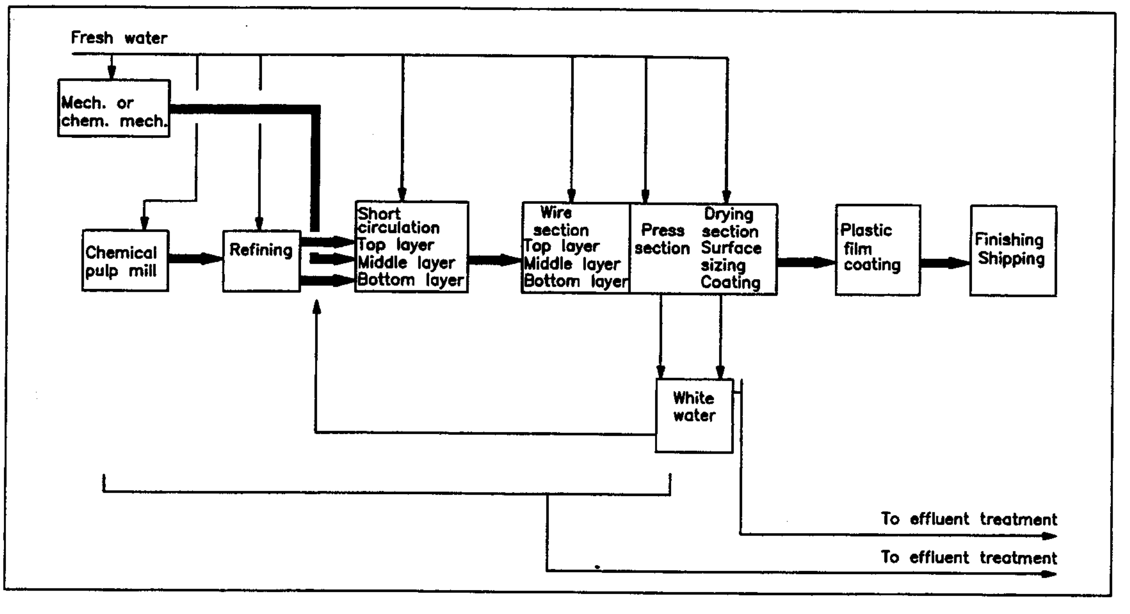


Figure 3.6.5 Block diagram of a board machine.

The raw material in folding boxboard is bleached chemical and bleached or unbleached mechanical pulp in the middle layer. Folding boxboard mills are integrated with mechanical pulp mills but the chemical pulp is normally purchased. The board consists of three layers. In order to achieve stiffness, about 60% of the middle layer is mechanical pulp. The chemical pulp is refined to create a better bonding strength and surface smoothness. The board is internally sized with rosin size and alum. The board is normally coated on one side, the other side being surface sized with starch. Dyes, retention aids, slimecides etc. are used at the board machine wet end. The effluent from a folding boxboard mill is 10 - 20 m^3/ tonne of board.

The two components in corrugated board, the kraftliner and the fluting, are produced in separate mills as the raw material and pulping process differ from each other. The kraftliner production is normally integrated with the kraft pulp mill. The raw material in kraftliner is unbleached kraft pulp for the bottom layer and bleached or unbleached kraft pulp for the top layer. No recycled fibre is used in kraftliner production in Finland. The pulps are refined for better strength properties and internally sized with rosin size. The board can be surface sized with starch or coated. Slimecides and retention aids are used at the wet end. The effluent from a kraftliner mill is 15-20 m^3/tonne of board.

In Finland the raw material in the fluting corrugated board is semi-chemical pulp from hardwood. The board machine is integrated with the pulp mill. No recycled fibre is used in the production of fluting in Finland. The effluent from a fluting mill is 4 - 10 m^3/tonne of board because paper machine white water is used in washing the pulp.

3.7 External treatment of discharges and emissions, solid-waste handling

In modern pulp and paper mills a number of internal measures are taken in order to minimize the discharge of pollutants. Today's technology allows, in theory, for a complete closure of the mill´s water system, and the breakthrough allowing for closed loop operation is around the corner. The combination of biological and physico-chemical treatment methods is feasible when a wide variety of substances, as in the process water of pulp and paper mills, have to be removed from the system in order to ensure uninterrupted production efficiency and product quality.

The pulp and paper industry discharges and emits waste products in the form of gas, liquids and solids into the air and water and for landfill. The pollutants in the discharges and emissions originate from the wood raw material, the chemicals used in the process and their reaction products.

Energy production is the main source of air pollution due to flue gases from the incineration of different fuels.

The production process is a balance where all inputs leave the process as products, waste or energy.

3.7.1 Waste water treatment

The installation of external waste water treatment in the Finnish pulp and paper industry, which began in the early 1970's, has had a significant effect on the development of production. The implementation of mechanical treatment reduced the discharge of suspended solids. A minor decrease in measured COD and BOD was noted in connection with the separation of suspended solids.

In the late 1970's biological treatment methods were implemented in the form of aerated lagoons in order to reduce the discharge of dissolved organic substances. In 1984 the first activated sludge plants in the Finnish pulp and paper industry came into operation, and today almost all production sites are equipped with this efficient effluent treatment system (28 plants in 1995). The difficulties in operation that occurred at the beginning have been solved, and the efficiency has been increased through greater experience.

Waste water treatment in aerated lagoons is in operation at three mills in Finland (spring 1996). The average efficiency is lower than for activated sludge treatment, partly due to low operating temperatures during winter time. Anaerobic treatment is implemented at two mills in Finland for certain waste water fractions. In these mills the treated effluent fraction is combined with the remaining effluent and treated aerobically before it is discharged.

The waste water's characteristics, which are process dependent, and the permit limits for the discharges into the recipient are the factors determining which treatment method/methods are the most suitable.

The effluent treatment implemented in the pulp and paper industry consists of primary or mechanical treatment, and secondary or biological treatment. Tertiary treatment is implemented when permit limits are exceeded or when the secondary treatment is interrupted.

Chemical coagulation and flocculation can be used to remove residual colloidal and suspended solids either as a tertiary step, or if biological treatment is not necessary, as an amplified primary step.

In general, effluent and water treatment produce sludge, which has to be further treated and disposed of. Sludge handling is discussed in section 3.7.3.

Mechanical treatment

The first step in the effluent treatment sequence in which suspended solids (fibres, bark particles and inorganic material such as fillers) are removed is called primary treatment. The separation of suspended solids is generally carried out by mechanical means such as sedimentation, flotation and filtration.

Mechanical treatment is always used before the biological treatment of fibre-containing effluents.

The efficiency of mechanical treatment depends on the characteristics of the waste water and the suspended material. The separation of total suspended solids (TSS) is high, >90% . The reduction of dissolved organic substances measured as the BOD and COD are low. It is worth noting that organic suspended solids consume the reagent in the analysis and are therefore included in the total-COD_{Cr}. The difference in the COD number before and after the separation step is often considerable and unfortunately misinterpreted as a real improvement of the water quality. The reductions in nitrogen and phosphorus vary between 0 and 40%. Chemical coagulation reduces phosphorus effectively.

The sludge separated from primary treatment (primary sludge) is relatively easy to dewater to a 25-40% dry-solids content.

Waste water from debarking is generally treated in a separate unit for solids removal. Part of the treated water is recirculated. The amount of bark sludge is typically 0.5 kg dry matter/m^3 of wood in dry debarking and varies between 2 and 8 kg/m^3 in wet debarking, depending on the time of year and the wood species.

Chemical treatment

The efficiency of both primary and secondary clarification is improved by the addition of coagulants and flocculants. Chemical treatment is applied to all kinds of water, from fresh to waste water. The stability of suspended particles, colloidals and certain dissolved substances in the water is disturbed by the addition of a coagulant, generally a multivalent cation. The destabilized particles are bound into large agglomerates using a flocculant and separated from the water by standard technology.

There are three main types of chemicals used :
- metallic salts
- organic polyelectrolytes
- adsorbing materials

The most commonly used metallic salts are Al-salts, but also ferric salts and lime can be used. Organic polyelectrolytes improve the flocculation of fine particles. Polyelectrolytes may be used together with coagulants to increase floc sizes, thus making the separation more efficient.

A significant removal of organic substances measured as COD can be achieved with chemical treatment provided that the colloidal and dissolved substances are affected by the coagulant or adsorbent. Simple carbohydrates and carboxylic acids are examples of substances which are not removed by chemical treatment.

Chemical treatment is used as the only treatment method in some paper and board mills in Finland and is well suited to treating special fractions such as waste water from coating. The chemical treatment of all the waste water or fractions of it is in use at 13 mills in Finland.

Biological treatment

Biological treatment utilizes the natural biological process, where micro-organisms use dissolved organic material in the water as a source of energy. In biological treatment the biodegradable dissolved and colloidal organic substances are transformed partly into a solid cell substance and partly into methane, carbon dioxide and water (anaerobic) or into carbon dioxide and water only (aerobic). The biosludge is separated before the water is discharged.

The micro-organisms need nitrogen and phosphorus for proper growth. In pulp and paper mill effluents the amount of nutrients is low compared with the amount of organic substances. It is, therefore, necessary to add phosphorus and nitrogen to the waste water to achieve efficient treatment. Waste water from the production of bleached kraft pulp usually contains enough phosphorus, and only nitrogen is added.

The waste water is neutralized prior to biotreatment by using CaO, $Ca(OH)_2$, NaOH or H_2SO_4.

The temperature of the waste water influences the functioning of the biology. The temperature must not exceed 30-35° C in aerobic processes and cooling can become necessary. Temperatures below 20° C should be avoided as the bioactivity decreases considerably.

Lignin, which is dissolved during the pulping and is, to some extent, present in the effluent, is only partially degraded in biological treatment. The remaining lignin fractions give the treated water a brown colour at a neutral pH.

Two main types of biological treatment are used:
- aerobic treatment with micro-organisms requiring oxygen
- anaerobic treatment with micro-organisms requiring an oxygen-free environment

Aerobic treatment

The aerobic treatment methods that are in use in the pulp and paper industry in Finland are activated sludge (AS) and aerated lagoon (AL). AS treatment has been installed in most of the pulp and paper mills. AL treatment is used at three mills, one of which is now installing activated sludge treatment (1996).

A scheme for activated sludge treatment, in principle, is shown in figure 3.7.1

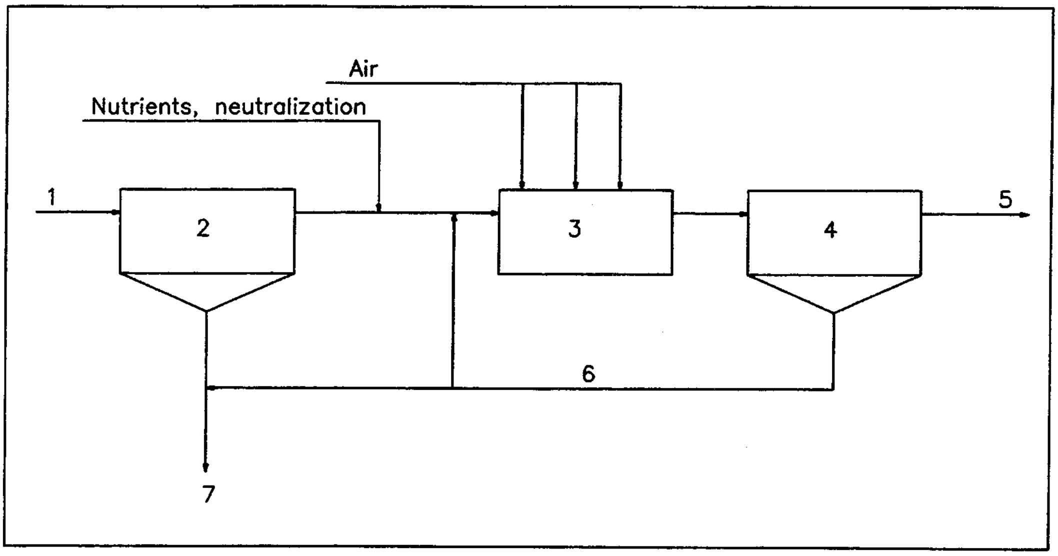


Figure 3.7.1 Activated sludge treatment plant.

1	Effluent inlet	5	Outlet
2	Primary clarification	6	Return sludge
3	Aeration	7	Excess sludge
4	Secondary clarification		

The reduction of easily degradable organic material measured as the BOD_7 is very fast in AS treatment due to the high concentration of micro-organisms. The BOD load and the hydraulic load can, therefore, be kept high. The sludge generation in activated sludge treatment is relatively high (0.4-0.7 kg DS/kg BOD-reduced) because approximately 40-50% of the organic carbon is converted into biosludge. The retention time is relatively short (10-24 h), and no mineralization of biosludge occurs as in aerated lagoon treatment. For the best possible result the addition of nitrogen and phosphorus is necessary. The addition of nutrients is controlled in proportion to the amount of biodegradable substances in the inlet, which is estimated by the BOD analysis. Overdosing is avoided by monitoring the concentration of the nutrients in the outlet.

The efficiency of the treatment varies, depending on the type of effluent. Typical reduction rates in kraft pulp effluents and paper mill effluents are shown in table 3.7.1 and table 3.7.2.

In AL treatment the biosludge production is relatively low (0.1-0.3 kg DS/kg BOD-reduced). The reduction of organic substances is lower than in AS treatment (table 3.7.1 and 3.7.2). In the summer the reduction rate is moderate, but in the winter when the temperature drops in the lagoon the efficiency decreases because of the low outside temperature and the long retention time in the lagoon (3-10 days).

Table 3.7.1 Efficiency of biological treatment of kraft pulp mill effluent.

Typical discharge loads from Finnish kraft pulp mills are presented in section 3.3.6.

Treatment method	BOD_7 (%)	COD_{Cr} (%)	Tot-P (%)	Tot-N (%)	AOX (%)
Aerated lagoon	40-85	25-50	0-15	0	20-40
Activated sludge	85-98	40-70	40-85	20-50	40-65

Table 3.7.2 Efficiency of treatment of paper mill effluent.

Typical discharge loads from Finnish pulp and paper mills are presented in sections 3.4.6, 3.5.4 and 3.6.1.

Treatment method	BOD_7 (%)	COD_{Cr} (%)	Tot-P (%)	Tot-N (%)
Aerated lagoon	40-85	30-60	0-15	0
Activated sludge	95-99	70-90	40-85	20-50
Chemical precipitation, fine paper	25-80	35-90	70-90	10-50

The removal of nutrients is generally very low in aerated lagoons. The removal depends on the removal of suspended solids, which is very low due to poor settleability. The removal of 0-15% of phosphorus has been reported, while the discharge of nitrogen seems to be increasing rather than decreasing. The increase is due to the addition of the nitrogen chemical in the treatment and nitrogen being picked up from the air by nitrogen-fixing bacteria.

The reduction of acute toxicity in the aerobic biotreatment of effluent at a pulp and paper mill is considerable.

Anaerobic treatment

In anaerobic treatment (absence of oxygen) the organic substances are degraded into carboxylic acids, which are further degraded by methane bacteria into methane and carbon dioxide. This biogas can be used for producing energy.

The advantages of anaerobic treatment compared with aerobic treatment are a lower demand for electrical power, a lower nutrient demand, lower sludge production and lower operating costs.

Because the degradation of organic matter is slower in anaerobic treatment than in aerobic treatment, the method is suitable for effluents with a relatively high concentration of easy degradable organic substances. Effluents from kraft pulp bleaching and debarking, which contain substances toxic to methane bacteria, inhibit the biological activity and are consequently not suitable for anaerobic treatment.

Anaerobic treatment is used at two Finnish mills: at a semi-chemical pulp mill for the treatment of foul condensates from the evaporation plant and at a kraft pulp and paper mill for the treatment of certain water fractions.

Other treatment methods

Contaminated water can be treated by filtration. Filtration is applied to a wide variety of water. Decreasing the size of holes or pores in the filtering medium makes the separation of suspended solids more effective. The application of tight filter mediums enables particles the size of an atom to be separated. The tighter the medium, the higher the pressure needed to force the water through and the smaller the flow for a given area.

Membrane filtration and *ultrafiltration* are methods where water containing suspended impurities is forced to pass through a membrane with very small holes. The method is used for the recovery of expensive pigments and polymeric substances with a high molecular weight.

One paper mill uses membrane filtration for the treatment of white water that is put to further use in showers, and another for coating effluents. The coating components are reused.

A recently implemented treatment is *evaporation*, also known as distillation. As it applies low pressure, the energy consumption is moderate.

Sludge handling

Mechanical, biological and chemical water treatment generate sludge that is separated by sedimentation, flotation or filtration. The dry-solids content of the separated sludge is very low (1-3%). The sludge has to be dewatered before it can be disposed of. Sludge handling is dealt with in greater detail in section 3.7.3.

Energy consumption

External treatment normally consumes energy. Anaerobic treatment is an exception if the energy content in the generated biogas is recovered by burning.

The consumption of electrical energy in activated sludge treatment is in the range of 1.2-2 kWh/kg of reduced BOD (aeration and pumping), which is the equivalent of 1 -1.5 kWh/ m^3.

The energy consumed in filtration is dependent on the drop in pressure across the medium. For example, the ultrafiltration of coating waste water consumes 3 - 5 kWh/m^3.

Evaporation at low pressure using mechanized vapour recompression consumes 5 - 15 kWh/m^3.

Typical energy consumption figures are presented in figure 3.7.3.

Table 3.7.3 Typical power consumption for different waste water treatment methods.

Type of mill - treatment method	Power consumption (kWh/t of product)
Bleached kraft	
- mechanical treatment	3
- activated sludge	46
Paper mill	
- mechanical treatment	1.5
- activated sludge	15

3.7.2 Treatment of emissions into the air

The emissions into the air from the production processes and energy production are externally treated. Today the emissions from the point sources (recovery boiler, lime kiln and auxiliary boilers) are relatively low due to the effectiveness of both the process control and the internal measures and external treatment. The reduction in the diffuse emissions of reduced sulphur compounds is still a challenge at some kraft pulp mills.

The air pollutants that are removed by external treatment are in most cases separated as solid waste (dust) or absorbed in a washing solution (dust, sulphur and chlorine compounds). The separated flow is returned to the process (kraft pulp) or disposed of. Increasingly stringent environmental protection requirements and more closed process water systems are resulting in increased difficulties in managing the sodium-sulphur balance in the kraft pulp process. Sulphur accumulates in the process, as does sodium at some kraft pulp mills. Excess sulphur results in increased sulphidity in the cooking liquor, which affect the quality of the pulp. The recirculation of the used washing solution into the process results in an increased load of inert inorganic material and an increased consumption of alkali.

At a kraft pulp mill most of the dust is emitted with flue gases from the recovery boiler, the lime kiln and the bark boiler.

The emission of dust from the recovery boiler is reduced in two stages. In the first stage the main part of the fly ash is removed from the flue gases in ash pits. The second stage is the electrostatic precipitator. The separated ash is taken to the black liquor. All the recovery boilers in Finland are equipped with electrostatic precipitators. The reduction of suspended particles is over 99% and the concentration in the flue gases is normally 50-200 mg/m^3n (0.1-0.7 kg/ADt).

The dust emitted from the lime kiln is generated by two main mechanisms. One part of the lime mud is not transformed into calcium oxide, which results in dust being formed. The other mechanism is vaporization of the sodium that is present due to poor washing of the lime mud. To control these emissions the flue gases from the lime kiln are treated in an electrostatic precipitator and/or a washer. The emission concentration is 20-300 mg/m^3n ($<$0.1-0.3 kg/ADt). The separated dust is normally returned to the lime mud system, but occasionally it has to be discarded as solid waste.

The emission of dust from power plant boilers is controlled most effectively with electrostatic precipitators. The concentration of TSP (total suspended particulates) can be reduced to less than 50 mg/m^3n and for some boilers the emission can even be below 10 mg/m^3n. The combustion of coal tends to lead to larger emissions of dust than the combustion of other fuels. This has to be considered in the design of the electrostatic precipitator.

The emission of chlorine compounds in vent gases from the bleaching of kraft pulp and chlorine dioxide generation is controlled initially by managing the process efficiently and then, if necessary, reduced further in a washer with sulphur dioxide solution being used as the absorption liquor. Typical emissions of chlorine compounds into the air are 0.05-0.3 kg Cl/ADt pulp.

Nitrogen oxides are formed during the combustion of the nitrogen in the fuel and by thermal oxidation of the combustion air. The formation of thermal NOx is low under normal circumstances. The reduction of the NOx emission from a boiler can, to some extent, be controlled by the distribution of the combustion air. This measure has already been implemented in kraft pulp recovery boilers in Finland. The formation of thermal NOx is smaller in the recovery boiler and the lime kiln than in power plants in general due to the lower combustion temperature. Typical emissions from the recovery boiler are 150-250 mg NO_2/m^3n (0.8-1.3 kg NO_2/ADt, < 100 mg NO_2/MJ) and from the lime kiln 250-400 mg NO_2/m^3n (0.2-0.3 kg NO_2/ADt, 150-200 mg NO_2/MJ). The emission of NO_x from general bark boilers is relatively low (100-300 mg NO_2/MJ) compared with the emission from coal fired boilers (300-500 mg NO_2/MJ).

If the emission of sulphur dioxide is not reduced enough by internal measures or by changing to a low-sulphur fuel, a desulphurization method has to be adopted. The most common method is based on absorption in an alkaline solution. The reduction of SO_2 varies between 80 and over 95%, depending on what alkali is used. The highest reduction rates are reached with a soluble alkali such as sodium hydroxide or carbonate.

Most of the recovery boilers are equipped with scrubbers to reduce the SO_2 content of the flue gases. In mills that burn black liquor with a high dry-solids concentration (>75% DS) the emission of SO_2 with the flue gases is very low (practically zero) and the use of a scrubber is not as essential as for recovery boilers that burn black liquor with a lower dry-solids concentration (65-70%).

The scrubber is normally divided into three zones: the chloride zone, washing zone and heat recovery zone. In the chloride zone chloride is absorbed in cold water and in the washing zone SO_2 and dust are removed. H_2S is also removed. The reduction of the SO_2 emission is about 90%. In the heat recovery zone hot water is produced for e.g. pulp washing in the bleaching plant.

Typical emissions of SO_2 from a recovery boiler equipped with a scrubber are 0.05-0.3 kg S/ADt.

The sulphur dioxide in lime kiln flue gases originates from the fuel and from the malodorous gases if these are burnt in the lime kiln. The binding of sulphur to calcium oxide is limited. Sodium carbonate is more effective for binding sulphur. This is, however, only an impurity resulting from poor washing of the lime mud and the binding is, therefore, limited. The emission of sulphur dioxide can be controlled by sulphur coming into the lime kiln or the recovery of sulphur in a flue gas scrubber. The emission of sulphur is highly dependent on the handling system for strong malodorous gases. It can be kept relatively low if strong malodorous gases are not burnt in the lime kiln (<0.05 kg S/ADt) or, if they are burnt in the lime kiln, by installing a scrubber (0.1-0.3 kg S/ADt). The sulphur content of the strong malodorous gases can be reduced by washing with oxidized white liquor before burning.

The amount of reduced sulphur compounds formed in and emitted from the kraft pulp process is influenced by several internal process conditions (combustion conditions, sulphidity, heat treatment of black liquor, lime mud wash etc.). The handling of malodorous gases is discussed in section 3.3.1.

Air pollution prevention measures increase the energy consumption to a relatively moderate extent.

3.7.3 Handling of solid waste

Solid waste is a material or an object that is removed from use and disposed of. Bark and wood residues from woodhandling should be considered as waste only when they go for permanent landfilling. Sludge from waste water treatment is burnt and the energy content is recovered, leaving ash as a solid waste.

The Finnish pulp and paper industry has 46 landfills of its own (1994). Over 90% of solid process waste is transported to these landfills. The waste transported for landfill consists of wood and bark residues, ashes, lime mud, dregs from causticizing, rejects, filler and latex waste, coating waste, waste water treatment sludge, plastics, scrap and building waste.

In 1995 the Finnish pulp and paper industry disposed of 220,000 tonnes of ashes, 150,000 tonnes of waste water treatment sludge, 56,000 tonnes of fibre and coating sludge, 45,000 tonnes of deinking sludge and 47,000 tonnes of waste wood at landfill sites. The waste quantities are given as dry solids.

Sludge from waste water treatment is one of the main groups of solid waste. A large amount of sludge is generated in primary treatment and in biological treatment with the activated sludge method. Aerated lagoons generate only small amounts of excess sludge. The generation of sludge in anaerobic treatment is also moderate. Chemical flocculation generates a considerable amount of sludge. Deinking sludge from the processing of recycled fibre is often handled together with sludge from effluent treatment.

Biological and chemical sludges have poor dewatering properties. Normally they are mixed with primary sludge and bark sludge before dewatering.

The sludge is usually thickened before being dewatered in a filter press, screw press or on a vacuum filter.

Inorganic and/or organic chemicals are used to improve the dewatering of sludge by forming larger flocs. Mixed sludge can be dewatered to a 25-35% dryness with filter presses and to 40-50% with a screw press using steam in the pretreatment stage.

In Finland dewatered sludge is burnt or sent to a landfill (60:40). In sludge burning the net energy production is about zero or negative, if the dry-solids content in the sludge is below 40% and if the sludge contains a high amount of inorganic material. To maintain good burning conditions the use of auxiliary fuel is necessary. If the sludge is mixed with bark and other wood waste material no auxiliary fuel is generally needed. Burning reduces the quantity of waste considerably. The inorganic content remains as ash, which is normally transported to a landfill site. For sludge with a low net heat value landfilling can be a better alternative than burning as far as air emissions are concerned. For a paper mill making coated paper grades the ash content of the primary sludge can be 35-60%.

Chemical sludge cannot be incinerated alone without the use of auxiliary fuel because of the high content of inorganic matter and water. The sludge is, therefore, normally transported to a landfill site. Sludge from flocculation with only synthetic organic polyelectrolytes is mostly incinerated.

In the Finnish pulp and paper industry about 60% of the generated waste water treatment sludge is burnt, normally together with bark in a bark boiler. Burning in a fluidized bed furnace with other solid fuels is common practice. One kraft pulp mill mixes biosludge and another flotation foam from resin removal with the black liquor and burns it in the recovery boiler.

One mill incinerates deinking sludge, but the other three mills producing deinked pulp dispose of the sludge at a landfill site.

The amount of solid waste for landfill is considerably reduced by sludge burning, but there is still a large amount of ash that has to be disposed of.

Most of the ash going for landfill is furnace ash and fly ash from the production of energy in auxiliary boilers.

Most of the generated ash (65%) is transported to a landfill site. Boiler ash can be used in cement and concrete and as a soil conditioner. The ashes reduce the acidity in the soil because of their high alkalinity.

In 1995 about 2,000 tonnes of hazardous waste were transported to a special waste disposal plant for destruction or returned to the manufacturer for reuse.

3.8 Energy management

3.8.1 General structure of the pulp and paper industry energy sector

The chemical forest industry does not only consume energy, it also produces substantial amounts. The forest industry utilizes about a third of the electricity generated in Finland. Two major consumers of heat and electricity are the pulp mills and the paper machines.

In mechanical pulping processes 95-97% of the wood material is retained. In chemical pulping, where the pulp yields are about 50%, most of the remainder of the organic material passes into the spent cooking liquors, which are burnt for energy production. Mechanical pulping processes require 2-4 times as much electrical energy per tonne of pulp produced than chemical processes. Groundwood mills and TMP plants have to obtain their electricity from outside.

The fuel base of the forest industry has been totally changed over the past two decades. Today, nuclear power, natural gas and wood-based energy have replaced heavy fuel oil, Table 3.8.1.

Table 3.8.1 Primary energy use in the Finnish forest industry, 1973 and 1994.

Item	1973 (%)	1994 (%)
Wood-based	36.9	39.5
Other purchased electricity	9.0	16.4
Nuclear power	0.0	15.5
Hydro power	10.9	10.2
Peat	0.2	3.3
Coal	6.8	3.0
Natural gas	0.0	8.8
Oil	36.2	3.3
Total	100.0	100.0

In 1994 some 53 per cent of the energy used by the Finnish forest industry was of domestic origin.

Electricity consumption by the forest industry in 1994 was 22.2 TWh, i.e. 62 per cent of all the electricity consumed by industry and just under a third of the country's total consumption. The estimate for the year 2000 is 25.5 TWh. In the pulp and paper industry the electricity demand is being pushed up by product upgrading, expanding production and the introduction of new environmental technology. Increased use of oxygen delignification, for example, raises electricity consumption at the bleaching plant by one-third. Biological waste water treatment plants consume electricity during pumping and aeration.

3.8.2 Specific characteristics of the pulp and paper industry energy sector

Examples of energy consumption in the production of pulp and paper are presented in table 3.8.2. These values represent the use of modern technology under Finnish circumstances.

Table 3.8.2 Computed typical specific net energy consumption by pulp and paper mills applying modern technology (pulp production included for paper grades) (ref. Kestävä paperi-research programme)

Product	Heat [GJ/t]	Electricity [MWh/t]	Total [MWh/t]
MF newsprint (100% TMP)	-1.33	2.19	1.82
SC-magazine (100% TMP)	-0.25	2.06	1.99
LWC-magazine	0.40	2.19	2.30
Fine paper	4.72	0.53	1.84
Coated fine paper	4.76	0.79	2.11
Coated box board	4.61	0.86	2.14
Bleached hard wood kraft	0.12	-0.33	-0.30
Bleached soft wood kraft	-0.88	-0.38	-0.62

(-) indicates a surplus

In 1994 the total energy consumption in the Finnish forest industry was 360 PJ. Of the fuel used about two-thirds are renewable fuels (black liquor and wood waste). The annual total consumption of electrical energy is about 20 TWh (1994, 22.2 TWh). The production of mechanical pulp consumes about 8 TWh/a and the production of paper and board about 7 TWh/a. The manufacturing of chemical pulp consumes about 5 TWh/a. On the other hand, kraft pulp mills produce about 6 TWh/a of electrical power. So the chemical pulping plants are self-sufficient in electrical energy.

One characteristic of the energy-intensive forest industry is the production of electrical power in back-pressure power plants directly connected to the production processes. About one-third of the total electrical energy is back-pressure power (table 3.8.3). The energy content of the fuel is very efficiently utilized in a back-pressure power plant. The high-pressure, superheated steam generated in the boiler is utilized for power generation in the back-pressure turbine, and the steam leaving the turbine at a lower pressure is utilized in the process as heat energy. The ratio of electrical effect/heat effect is, usually, 0.2-0.3.

Table 3.8.3 Supply of electrical power for the Finnish forest industry.

	Electrical power (GWh)	
	1991	1992
Back-pressure power	5,943	6,080
Nuclear power	5,479	5,490
Hydro power	4,034	4,650
Condensing power	2,707	1,970
Purchased electrical power	848	1,100
Gas turbine	45	90
Total	19,056	19,380

The total energy consumption in the Finnish forest industry is presented in table 3.8.4.

Table 3.8.4 Total energy consumption in the Finnish forest industry.

Item	1991 (PJ)	1994 (PJ)
Peat	11.2	11.9
Wood-based fuel	113.4	142.8
Oil	11.3	10.8
Natural gas	28.8	31.8
Coal	14.2	11.9
Own nuclear power	55.6	56.0
Own hydro power	41.0	36.6
External electrical power	36.1	59.3
Total	311.6	361.1
Fuel, total	179	209
Wood-based fuel, share of total, (%)	36	40
Peat, share of total, (%)	4	3
Consumption of electrical power, (TWh)	19.1	22.2

In kraft pulping biofuels are generated as by-products. These are bark and wood residues from wood handling and black liquor from cooking. These biofuels are used initially to cover the energy demand and, if they are not sufficient, the shortage is covered with steam produced from purchased fuel. In a modern kraft pulp mill the heat energy production from the recovered bark and black liquor exceeds the energy demand. Fossilized fuels are used mainly as support fuel. The traditional use of oil in the lime kiln has decreased substantially.

The conventional power plant configuration in a non-integrated kraft pulp mill is a recovery boiler and a bark boiler feeding a back-pressure turbine with intermediate steam tapping and, possibly, condensing. Malodorous gases are collected and burnt, mainly for environmental protection reasons as there is no/little net energy generation.

In an integrated pulp and paper mill the excess heat produced by the pulp mill is not quite enough to cover the energy consumption of the paper production. The additional demand for heat has to be produced in wood/bark boilers and auxiliary boilers. Fossilized fuel is used as support fuel in bark and sludge boilers and as the main fuel in auxiliary boilers. The fuels used in the power stations at paper mills are mainly fossil fuels, especially in non-integrated paper mills.

Peaks in energy consumption are often satisfied by using a small boiler for fossil fuel. CHP (combined heat power) plants based on gas turbine in combination with a steam boiler and steam turbine are very efficient and a few installations have been made.

Nowadays some Finnish paper and pulp mills have made energy supply agreements with energy production companies. This allows the mill organization to concentrate, technically and financially, on its core business. These new power plants are owned and maintained or only operated and maintained by the energy supplier.

The emissions from power production are dependent on the fuel, the fuel mixture and the impurities content. Oil and coal contain sulphur but natural gas does not.

A noticeable factor concerning the total discharges from the pulp and paper industry in Finland is the large share of bark used as power plant fuel. As bark does not contain sulphur, there will be no sulphur dioxide emissions, and the emission of nitrogen oxides will also be lower than in the burning of other kinds of fuel due to the low combustion temperature. When bark is being burnt together with fuels that contain sulphur, the alkaline bark ash binds some of the sulphur and thus reduces the discharge. This cannot be fully utilized, because at paper mills which predominantly consume fossil fuels the generation of bark waste is generally small.

3.8.3 Boilers used in energy production

Recovery boiler

A recovery boiler is essential for producing energy at a kraft pulp mill. The recovery boiler acts as a back-pressure power station where the black liquor separated in the pulping process is burnt. The cooking chemicals are recovered as a smelt from the bottom of the boiler and the heat generated is utilized for the generation of high-pressure, superheated steam. Part of the energy content in the high- pressure, superheated steam is utilized for generating power in a back-pressure turbine. Medium- pressure steam (1.0-1.3 MPa) extracted from the turbine and low-pressure exit steam (0.3-0.4 MPa) are utilized for covering the heat energy demand in the kraft pulp process.

Process modifications (e.g. extended delignification, oxygen delignification, water system close up) alter the properties of the black liquor. The development of black liquor properties is presented in table 3.8.5.

Table 3.8.5 Properties of black liquor

Black liquor	1982	1992	2002 estimate
Dry-solid content [tDS/ADt pulp]	1,700	1,680	1,840
Dry-solid content [%]	64	72	80
Calorific value, low [GJ/ADt]	15	13.9	13

Steam boiler

High-pressure steam for electrical power is normally produced at a paper or board mill. The low- pressure steam after the turbo generator is condensed on the paper machine to dry the product. The fuels used in the boilers are coal, peat, wood waste in the form of bark and fibrous sludge from effluent treatment.

Most of the coal and wood-waste boilers are circulating or fluidized bed boilers. These boilers offer the opportunity to use a wider range of fuels and give off lower emissions from the burning of peat and biofuels than the older grate boilers.

Fluidized bed combustion was developed in the 1970's especially for difficult fuels with a low heat content and widely varying properties such as wood waste, peat, water treatment sludges as well as other industry and municipal waste.

High efficiency, low emissions, mixed fuels and a flexibility in different load situations are typical characteristics of fluidized bed combustion, which is the only practical way of burning sludges and other waste with high water content. Although the combustion temperature is relatively low (800-950° C), the combustion efficiency is high due to the very effective mixing of the materials and heat transfer between the solid material and the flue gases. The formation of thermal NO_x is low and the NO_x emissions are relatively low due to the low combustion temperature. If the fuel contains sulphur, sulphur emissions can be prevented by the addition of lime to the bed. At temperatures below 900° C sulphur reacts with lime or calcium in the bark and the sulphur dioxide emissions are reduced considerably.

Combined heat power plants (CHP)
By utilizing gaseous fuel, like natural gas, it is possible to combine a gas turbo-generator with a steam turbo-generator and produce more electricity than heat. Combined heat power plants consist of a gas turbine, a steam boiler and a steam turbine. CHP plants are used when the need for electrical energy at a paper mill is high. The electrical effect/heat effect ratio is usually 0.8-0.9. Lately several new CHP plants have been installed by the Finnish forest industry.

3.9 Monitoring of discharges and emissions into water and the air, environmental management

Monitoring requirements are determined by the information required by the authorities and by the process control.

The statutory monitoring of discharges and emissions from Finnish industry and the effects of the emissions on the environment is based either on the Court's or municipal authority's decision or the statement given by the Regional Environment Centre. The monitoring is based on self-monitoring and it is carried out according to a programme approved by the authority. The monitoring programme is drawn up specifically for each mill. The monitoring programmes, monitoring results as well as the effluent and recipient monitoring reports are available to the public. The results of monitoring emissions are regularly reported (once a month, four times a year, once a year) and, furthermore, each mill is obliged to submit an annual report to the authorities. All the monitoring results are comparable within Finland.

Important factors connected with the monitoring of discharges and emissions are the flow measurement, sampling method, handling and storing of samples, analysis method and accuracy, and the calculation and reporting of the results.

It is most important to note that great care has to be taken when a comparison is made with the discharge and emission figures in reports from different countries. Variations in the methods of sampling, pre-treatment and analysis of the sample, calculational and reporting practices make it difficult to interpret correctly.

3.9.1 Discharges into water

Normally there are no instructions about how to measure the flow in the monitoring programme.

The mills choose the flow-measurement method themselves. The applied methods for waste water vary from open systems (e.g. Venturi flumes) to magnetic flow meters.

The sampling of waste water going into the recipient is normally made by automatic samplers controlled by a flow meter or a timer. The samples are collected for one 24-hour sample. The sample-collecting vessel is normally kept in a refrigerator (<5° C). The sampling spot must be located where the sampled liquid is properly mixed.

By using composite samples (weekly or monthly samples) the number of analyses can be reduced. These composite samples are made from frozen 24-hour samples.

The analysis frequency of waste water going into the recipient in the Finnish pulp and paper industry in 1995 is shown in table 3.9.1. Of 46 mills 27 use flow-controlled sampling and 19 time-controlled. All the mills use automatic sampling in the discharge control.

The water analyses are done on homogenised, unfiltered samples using standardized methods (SFS standards, the Finnish Pulp and Paper Research Institute methods, and methods approved by the authorities). The SFS standard methods are based on international standards.

The following analyses are done: COD_{Cr} and /or COD_{Mn}, BOD_7, TSS, AOX, P, N, pH, S, Na and specific conductivity. The corresponding SFS standard analytical methods are listed in appendix 1.

Table 3.9.1 Analysis frequency in the Finnish pulp and paper industry in 1995.
(Number of mills). Some mills analyze COD_{Mn}.

	TSS	BOD_7	COD_{Cr}	Phosphorus	Nitrogen	AOX
Analysis frequency						
Continuous	-	-	-	-	-	-
Daily	41	5	28	5	6	3
Weekly	2	28	13	20	18	4
Monthly	3	12	3	19	20	7
Less frequently	-	-	2	2	2	-

The analytical results and flow data are generally registered in computer files and the discharge loads are automatically calculated from these files. According to the PLC Guidelines of the Helsinki Commission the calculations should be based on flow-weighed mean values.

3.9.2 Emissions into the air

Provisions on emission monitoring are included in the permit or the statement given by the Regional Environment Centre or in the emission control programme, because there are no general provisions set by the authorities yet. However, a system based on a quality management system and "total uncertainties" according to ISO Guide 25 is being developed.

The operating permit for a kraft pulp mill normally shows emission-limit values for dust, SO_2, TRS and NOx. Principally, the emissions have to be measured continuously according to the control programme. Above all, SO_2 and TSR are analyzed by a continuous measuring method. The continuous measurement of dust is not very often required. NO_x emissions are not yet generally measured continuously (NO_x emission limits have been set, but the requirements have not yet come into force).

General requirements for continuous monitoring systems are that the sampling places should be representative and that the monitoring equipment should be suitable for the concentrations to be monitored and the prevailing circumstances. The emission-control data system should preferably be part of the process control system.

The continuous measurement system is generally validated by an authorized laboratory or a laboratory accepted by the authorities.

In Finland emission limit values are set per energy input for boilers (mg pollutant/MJ) or per tonne of the end product (kg pollutant/tonne product). It is, therefore, necessary to measure the concentration as well as the gas flow.

Because of the water content, solid particles and aggressive substances in the flue gas there can be a problem in taking a representative sample of the flue gas into the measuring instrument. Before the analysis, solid particles are removed by filters and moisture is removed by condensing. There are several methods for removing the moisture without at the same time removing the components that are to be analyzed. One solution is to dilute the gas (20-40 times) with dry and clean air so that the moisture content no longer interferes with the analysis. This method is often used in Finland. Experiences with methods where the sample is dried have mostly been negative in Finnish mills, especially in cases where sulphur concentrations are low and the sample contains particulate matter.

Different pollutants require different kinds of control and monitoring strategies. In a kraft pulp mill dust and NOx are emitted from a few sources and it is, therefore, easy to decide where to measure and what kind of system to use.

Monitoring the total emissions of TRS and SO_2 is more complicated. Sulphur compounds are discharged into the air from different sources such as the recovery boiler, lime kiln, burner of malodorous gases and diffuse sources. At some mills the emission of SO_2 is predominant, while at others mills it is the TRS emission. The diffuse emissions of sulphur represent a large part of the total sulphur emission. In order to monitor the total sulphur emission it is necessary to carry out measuring campaigns that cover the whole mill to determine the most important emission sources and what compounds dominate the total emission. The assessment of these results and a sulphur balance calculation are the basis for the decision concerning where continuous measurements are necessary and what kind of analyzer should be used and, on the other hand, where periodical measurements are valid.

3.9.3 Environmental management systems

The environmental management systems for the Finnish chemical forest industry are based on the BS 7750 and the ISO 9000 and ISO 14000 series standards, and they are usually linked to the quality systems of the company concerned. The effectiveness of the system is ensured by regular reviews and audits aiming at the continuous improvement of environmental protection practices.

In 1995 the first environmental management systems complying with the BS 7750 standard were certified at five mills. Seven mills incorporated environmental protection into their ISO 9000 series quality systems, in addition to the three mills which had already done so.

Environmental management systems in accordance with the ISO 14000 series are being developed at 15 mills (beginning of 1996).Two mills announced that they will develop their systems to comply with the EU regulation on environmental management and auditing, EMAS.

4 Reference Mills

The reference mills are Finnish mills that where visited in 1996 for review of the operation and interviews with the personnel.

4.1 Newsprint

4.1.1 General

The mill produces newsprint and other wood-containing papers on three paper machines.

In 1995 the total production of paper was 500,000 tons, 370,000 tonnes of which was newsprint and the rest SC magazine printing paper.

The mechanical pulp for newsprint is produced at TMP plant no. 2. The rest of the mechanical pulp is produced at TMP plant no.1 and two groundwood plants. The wood raw material is Norwegian spruce. Round wood logs are debarked and chipped on two debarking lines. The newsprint at PM3 is produced entirely from TMP without any kraft pulp or filler. For the other paper grades produced the mill uses SGW and kraft pulp purchased from Finnish mills and filler clay.

The mill is located inland by a river. The mill takes fresh water from the river and discharges treated effluent and warm cooling water back into the river. Together with the municipality the mill owns an energy production company operating a big solid waste and biofuel boiler.

4.1.2 Debarking

Spruce logs are debarked on site. The total use of wood in 1995 was 1,170,000 m^3, about 250,000 m^3 of which was purchased from sawmills as chips. The debarking is wet. Water is pumped into the drums, and water helps to remove bark through the bark chutes. The bark is pressed and sold to the energy company for fuel.

Warm clear filtrate from the paper mill is used as the process make-up water. In the winter time the filtrate is further heated with excess energy from the pulping department. Circulating water in the debarking plant is clarified. Sludge is pumped into the mill's sludge dewatering plant. Part of the overflow is taken to the biological treatment plant. The effluent data is shown in table 4.1.1.

Table 4.1.1 Clarified debarking effluent.

	Effluent flow (m^3/d)	Effluent (m^3/m^3 of wood)	COD_{Cr} (kg/m^3 of wood)
Summer	1,050	0.4	2.5-3.0
Winter	1,700	0.6	3.5-4.0

The mill is currently modernizing the debarking plant. De-icing will be done on a de-icing conveyor with steam. The COD load from debarking is expected to decrease by 20% before the effluent treatment plant. The debarking will be dry and the effluent flow is expected to be about 0.2 m^3 per m^3 of wood.

4.1.3 Stock preparation for newsprint production (PM3)

The TMP line (TMP2) produces pulp for PM3. The plant includes three two-stage refiner lines (totalling 83 MW of motor power). In 1995 the production was about 180,000 tonnes of pulp. The newsprint production of PM3 was 203,000 tonnes in 1995. The rest of the mechanical pulp was taken from the other TMP line and from the groundwood lines. The refined TMP is screened before it is stored at a consistency of about 4%. Rejects from screening are refined in reject refiners (4 MW each). The freeness of the pulp is 100 to 110 ml CSF. The pulp can be bleached with dithionite, if needed.

TMP2's energy consumption is about 2.5 MWh/t of pulp, 1.05 MWh/t (about 40%) of which is recovered as steam. The recovered heat energy is used for paper drying and represents about 65% of the steam used for newsprint drying at PM3.

The process water used on the TMP2 line is filtered white water from PM3. The only effluent discharged from the TMP2 line is about 10 l/s from chip washing.

4.1.4 Paper machine PM3

PM3 produces newsprint from TMP and some groundwood pulp. No chemical pulp or filler clay are used. The production in 1995 was 203,000 tonnes. PM3 does not have a size press and the paper is finished by an on-machine calender. The paper is then rewound and packed.

Retention chemicals, dyes and some slimecides are used at the wet end of PM3.

PM3 consumes about 13 m^3 of mechanically treated fresh water/ tonne of paper and together with the TMP2 line about 14 m^3/ton of paper. The water is mainly used in wet end showers and for diluting the wet end chemicals. In the winter time the cooling water is reused as vacuum pump sealing water and in wet end showers. In the summer, however, the cooling water is replaced by fresh water. Excess process water is discharged as a clear filtrate from a disc filter at PM3.

PM3 consumes about 0.5 MWh of electrical energy per tonne of paper and about 1.6 MWh of heat per tonne of paper for drying the paper. About 1.05 Mwh/t of this comes from the TMP plant.

4.1.5 Energy production

The heat energy is produced by the energy company in a boiler using peat (75-80%) and biofuels such as bark, sludge and wood waste (table 4.1.2). The boiler steam firstly passes a back-pressure steam turbine, and the steam is then used for drying the paper and for district heating. In 1995 the production of back-pressure electricity was 419 GWh. The production of electrical energy is 30% of the mill's total consumption. The rest of the electrical energy used is purchased from other producers. The steam production and energy for district heating were 530 GWh/a and 272 GWh/a respectively. About 30% of the mill's total heat consumption is steam from the two TMP lines; the rest is produced in the boilers.

Table 4.1.2 Fuel consumption in 1995.

	Fuel (t/a)
Peat	435,270
Bark and sludge	255,000
Coal	3,120
Oil	140

4.1.6 External treatment. Discharges and emissions into water and the air, solid waste

Effluent discharged into the external treatment plant is presented in table 4.1.3.

Table 4.1.3 Estimated effluent discharges and loads from TMP2 and PM3 going for effluent treatment (winter time from Nov. to Feb. 1994/95).

	Effluent flow (m^3/t of paper)	TSS (kg/t)	COD_{Cr} (kg/t)	BOD_7 (kg/t)
Discharge	14	4	40	20

The mill's effluent is treated in an activated sludge treatment plant (AS). The amount of effluent is 18,000 to 25,000 m^3 per day (about 13 to 16 m^3 per tonne of paper). Fibre-containing effluents are directed to sedimentation, where > 90% of the suspended solids are separated. The sludge is pumped to sludge handling. The clarified effluent is mixed with the clear filtrate from the paper mill and treated in the activated sludge treatment plant. The reduction efficiency is 96 to 98% measured as BOD_7 and 87 to 91% measured as COD_{Cr}. The biosludge is separated by sedimentation and the excess sludge is mixed with sludge from primary sedimentation and pressed. The sludge is delivered to the energy company for burning.

Table 4.1.4 Total effluent discharges from the mill in 1995

Effluent flow (m^3/d)	TSS (t/d)	COD_{Cr} (t/d)	BOD_7 (t/d)	P (kg/d)	N (kg/d)
39,800	0.58	5.0	0.38	9.3	115

Emissions into the air from the mill originate almost totally from the energy production of the big boiler. The flue gases are treated in electrostatic precipitators.

Volatile organic compounds (VOC) can occur in vents coming from the TMP and groundwood plants. VOC emissions have not been measured. The emissions that can be allocated to the newsprint production at PM3 are shown in table 4.1.5.

Table 4.1.5 Emissions into the air in 1995.
(PM3 emissions are allocated from the total figures of the mill).

	Emission total (t/a)	Emission PM3 (kg/t of paper)
SO_2 (as S)	525	1.05
NOx (as NO_2)	760	1.5
Dust	154	0.3
CO_2 fossil	552,150	1,104

Most of the solid waste that is transported to a landfill site is ashes from the boilers. Some sand is transported from the debarking plant, the rest being sludge and mixed waste.

Bark, wood residue and sedimentated sludges are all sold to the energy company as fuel.

Table 4.1.6 Material for incineration and solid waste for landfill
(as dry matter).

	Paper mill		Energy production
	incinerated (t/a)	for landfill (t/a)	for landfill (t/a)
Bark	155,530	4,900	
Sludge	41,880	2,900	
Ash			19,400
Others			25

4.2 Magazine Paper

4.2.1 General

The mill produces wood-containing and woodfree paper on four paper machines.

In 1995 the total production of paper was 705,000 tonnes, 548,000 tonnes of which was SC magazine printing paper, 102,000 tonnes MFC paper and 54,000 tonnes woodfree paper.

The mechanical pulp is produced on two TMP lines. The wood raw material is entirely Norwegian spruce. Round wood logs are debarked and chipped at the mill on one barking line. The kraft pulp is purchased from other Finnish mills.

The mill is located inland by a small river. The mill takes fresh water from the river and discharges treated effluent and warm cooling water back into the river.

The mill operates two solid waste boilers and two oil-fired boilers.

4.2.2 Debarking

All the wood raw material for the TMP plant is debarked on site on one line. In 1995 a total about 1 million m^3 of wood was used. The barking system is the so-called "dry barking". The bark is utilized for energy production at the power plant. Because of the dry barking system used, the water consumption in the debarking plant is low. The process water that is used in the debarking plant is treated water from the activated sludge treatment plant. In 1995 the average effluent flow was 0.6 m^3/m^3 of wood varying between 0.54 and 0.68 m^3/m^3 of wood (monthly mean values). The discharges from the debarking are given in table 4.2.1. The effluent is mixed with other fibre- containing effluents from the paper mill before primary sedimentation.

Table 4.2.1 Debarking effluent (total) in 1995.

	Unit	Discharge		
		Average	Maximum	Minimum
Flow	m^3/m^3 of wood	0.61	0.68	0.54
TSS	kg/m^3 of wood	0.54	0.79	0.31
COD_{Cr}	kg/m^3 of wood	2.43	5.48	1.23
BOD_7	kg/m^3 of wood	1.16	2.6	0.58

4.2.3 Stock preparation for PM1

The TMP line (TMP1) installed in 1992 includes five two-stage refiner lines with 5 x 12 MW refiners in the first stage and 5 x 8.5 MW refiners in the second stage. The production totalled 195,000 tonnes of pulp in 1995. The refined pulp is screened and cleaned before it is stored at a consistency of about 4% in two storage towers. Screening and cleaning rejects are refined in four reject refiners (8.5 MW each). The pulp is bleached with dithionite.

The energy consumption in TMP1 is 3.1-3.6 MWh/tonne of pulp, over 40% of which is recovered as steam. The heat energy is reused for heating on the TMP line and in the paper production.

The process water used in TMP1 (7-8 m³/t of pulp) is entirely filtered white water from the paper machine. The process water is discharged from pulp washing into the effluent treatment plant.

The purchased kraft pulp is slushed and diluted in the white water from the paper machine and refined before being mixed with the other paper furnish components.

The fillers come to the mill with a 90% dry-solids content and are diluted to a 50% consistency before use.

4.2.4 Paper machine (PM1)

PM1 produces SC magazine printing paper. The furnish is TMP (50-60%), bleached kraft pulp (10-25%) and talc and clay fillers (35-45%). In 1995 the production was 326,000 tonnes of paper. PM1 was installed in 1992.

PM1 does not have a size press. The paper is finished by off-machine supercalenders. The paper is then re-reeled and wrapped.

Talc and kaolin are used as fillers. Other chemicals like retention chemicals, slimicides, dyes etc. are also used at PM1.

PM1 consumes about 11 m^3 of chemically treated fresh water/tonne of paper. The water is mainly used in the wet end showers and some is used for diluting the wet end chemicals. Filtered fresh water is used for cooling purposes. The consumption of cooling and sealing water is a minimum of about 11 m^3/t of paper in the winter time (monthly mean value) and a maximum of about 19 m^3/t of paper in the summer time. In the winter time part of the cooling water can be reused as raw water for the manufacturing of chemically purified process water. In the summer time all the cooling water is discharged into the receiving water through the clean water sewer.

A white water filter produces a clear filtrate that is used in the TMP plant.

4.2.5 Energy production

The heat energy is produced for the whole paper mill in two boilers using biofuel (fluidized bed: 80 MW and 67 MW) and two oil-fired boilers (62 MW and 28 MW). About 90% of the heat energy is produced in the two fluidized bed boilers and about one-third is produced with biofuels (table 4.2.2).

In 1995 the electrical energy production was 105 GWh in the mill's own power plant and 9 GWh were produced by water power. The rest (1,612 GWh) was purchased. A heat excess of 49 GWh was sold outside the mill for district heating.

Table 4.2.2 Fuels used at the power plant.

Fuel	Heat energy production (%)
Oil	13.9
Sludge	4.5
Bark	23.5
Peat	53.8
Chips and wood waste	4.4
Total	100

4.2.6 External treatment. Discharges and emissions into water and the air, solid waste

Waste water is discharged at several points of the process. The main discharges are a clear filtrate from TMP1 and PM1 and rejects from TMP1 and PM1 (table 4.2.3)

Table 4.2.3 Effluent discharges from TMP1 and PM1 going for effluent treatment.

Discharge	Effluent flow (m^3/t of paper)	TSS (kg/t)	COD_{Cr} (kg/t)	BOD_7 (kg/t)
Clear filtrate	4.7	0.26	5.9	2.4
Reject from PM1	1.9	28.0	2.1	1.0
Miscellaneous	4.1	9.5	5.0	2.4
Total	10.7	37.8	13.0	5.8

Analytical methods see table 4.2.7.

The effluents are treated in an activated sludge treatment plant (AS) with flotation as the post- treatment. The activated sludge treatment plant was installed in 1990. Fibre-containing effluents are led to sedimentation, where 95-96% of the suspended solids are separated from the effluent and led to the sludge handling. The primary treated effluent is mixed with fibre-free effluents and treated in the activated sludge treatment plant. The reduction rates in the AS plant are shown in table 4.2.4.

Table 4.2.4 Reduction rates in the activated sludge treatment plant in 1995.
Average and variation of monthly mean value.

	Reduction (%)	
	Average	Variation
BOD_7	99	98.3-99.4
COD_{Cr}	91	88.5-93.9
Tot-P	74	15-90
Tot-N	46	0-75

The secondary sedimentation is divided into two lines. Occasional interruptions in the effluent treatment are taken care of by using tertiary treatment before discharge.

The excess biosludge is mixed with the sludge from primary sedimentation, dewatered and, to a great degree, burnt in the power plant. About 25% of the sludge is transported to a landfill site.

The specific discharges from TMP1 and PM1 and the total loads from the mill after external effluent treatment in 1995 are shown in table 4.2.5.

Table 4.2.5 The specific discharges from TMP1 and PM1 and the total loads from the mill after external effluent treatment in 1995.

		TMP1+PM1	Mill, total
Flow	m^3/t of paper	10.7	14.9
Suspended solids	kg/t of paper	0.30	0.29
COD_{Cr}	kg/t of paper	1.20	1.85
BOD_7	kg/t of paper	0.05	0.09
Tot-P	g/t of paper	2.7	3.8
Tot-N	g/t of paper	55	78

Emissions into the air

The emissions into the air originate almost entirely from the energy production. Volatile organic compounds can occur in very small amounts in vents coming from the TMP plant. VOC emissions have not been measured. The total emissions into the air from the mill and the amounts that can be allocated to the paper manufacturing at PM1 are shown in table 4.2.6.

Table 4.2.6 Total emissions into the air and the emissions allocated to PM1 in 1995.

	Total emissions		PM1 emissions
	(t/a)	(kg/tonne of paper)	(kg/tonne of paper)
SO_2 (as S)	257	0.37	0.20
NOx (as NO_2)	741	1.05	0.57
Dust	45	0.08	0.03
CO_2 fossil	210,930	300	162

Solid waste

Most of the solid waste that is transported to a landfill site is cleaner rejects from PM1 and ashes from the power plant. The rejects from TMP1 and PM1 go with the fibre-containing effluents to the primary sedimentation. The separated sludge is dewatered together with biosludge, and 75% is incinerated in the power plant. 25% of the sludge is transported to a landfill site. The ashes from the power plant also go for landfill. The bark generated in the debarking plant is totally utilized for energy production in the power plant (table 4.2.7).

Table 4.2.7 Sludge to incineration and solid waste for landfill (as dry matter).

	Total mill		TMP1 and PM1			
	(t/a)		(t/a)		(kg/tonne of paper)	
	incinerated	landfill	incinerated	landfill	incinerated	landfill
Sludge	25,028	8,252	9,532	3,143	29.2	9.6
Ash		17,100		7,795		23.9
Total						33.5

4.2.7 Monitoring of discharges

The monitoring of discharges into the receiving water is based on the Water Act and the consent given by the Water Court in August 1993. The analysis listed in table 4.2.8 is stipulated in the monitoring programme.

Table 4.2.8 Analysis used in monitoring discharges into water.

Analysis	Analytical method
pH	
Conductivity	
TSS	SFS 3037
COD_{Cr}	SFS 5504
BOD_7	SFS 3019
Tot-P	SFS 3026 and KCL 228:8
Tot-N	SFS 5505

Besides the analysis listed above, dissolved phosphorus, PO_4-phosphorus, dissolved nitrogen and NO_3-nitrogen are also analyzed .

The monitoring of emissions into the air is based on the Air Pollution Control Act and the provisions given in the decision made by the Regional Environment Centre. Emissions of dust, NO_x and SO_2 are measured according to the standard methods listed in Appendix 1 and reported as mg/MJ.

4.3 Bleached kraft market pulp

4.3.1 General

The mill is a non-integrated kraft pulp mill producing bleached ECF and TCF pulp.

In 1995 the total production of bleached pulp was 478,830 tonnes, one-third of which was softwood pulp and the rest hardwood (birch) pulp. Most of the pulp was ECF-bleached. 2% of the production was TCF-bleached hardwood pulp.

The kraft pulp mill has two fibre lines and one chemical recovery line. The pulp mill, which has been producing pulp since 1967, was completely modernized in 1992. The old fibre line was modernized and supplemented with oxygen delignification. The other fibre line and the chemical recovery were newly built.

A new external treatment plant was started up half a year before the restart of the pulp mill.

One important principle of the company's environmental policy is the implementation of the most advanced technology. Dry debarking, extended cooking, efficient washing, oxygen delignification and modern bleaching with the possible use of TCF were essential components in the choice of the technology for the modernized mill.

The old pulp mill's recovery boiler was reconstructed into a fluidized bed boiler for the burning of wood waste, bark and waste water treatment sludge.

4.3.2 Debarking

Round wood logs are debarked on two debarking lines, one for pine and one for birch. Dry debarking is used on both lines. Some steam is used in the thawing conveyor only in the winter. After the barking drums, the logs are washed. The bark is pressed and burnt in the bark boiler.

The water consumption in the debarking is 10 l/s per barking line (0.3 m^3 of water/m^3 of wood). The waste water from the debarking plant is led to the waste water treatment plant. Measured data about the pollution load from the debarking plant is not obtainable separately. Only the total effluent going to the waste water treatment is regularly analyzed.

In 1995 the total wood consumption was about 2.4 million m^3 (65% hardwood, 35% softwood), about 385,000 m^3 of which was sawmill chips. The specific wood consumption was 6 m^3 unbarked wood/ADt of softwood pulp and 4.5 m^3/ADt of hardwood pulp.

4.3.3 Process description

The pulp mill includes two fibre lines (figure 4.3.1). The older fibre line with a capacity of 600 ADt/d is mainly used for the production of softwood pulp. The other fibre line is mainly used for the production of hardwood pulp with a capacity of 1,100 ADt/d. The joint batch cooking plant includes 10 batch digesters. Oxygen delignification is done in one stage on both fibre lines. The delignification of softwood pulp is extended to a Kappa of 20-22 in cooking, and after oxygen delignification the Kappa is 14-16. The Kappa levels for hardwood pulp are 17-19 and 12-13 respectively. After oxygen delignification the pulp is washed in two wash presses.

The pulp mill produces ECF and TCF bleached softwood and hardwood pulp on both fibre lines. ECF bleaching is performed in four (softwood) or five (hardwood) stages with oxygen- and hydrogen peroxide-reinforced alkali stages. In TCF bleaching the pulp is bleached solely with hydrogen peroxide. A chelating agent is used in TCF bleaching to avoid decomposition of the hydrogen peroxide.

After bleaching the pulp is dried, cut and packed into bales for transportation.

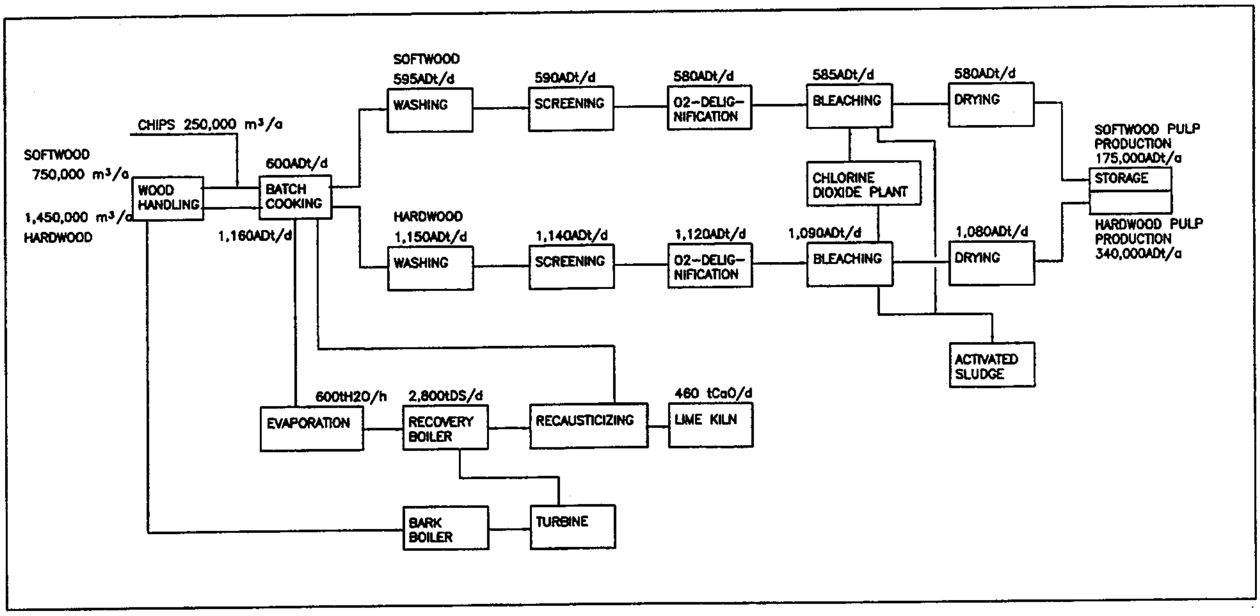


Figure 4.3.1 Block diagram of the bleached kraft pulp mill

The weak liquor from pulp washing is evaporated in a 6-effect evaporation plant (capacity: 600 t H_2O/h) and concentrated to a 72% dry-solids content and then burnt in the recovery boiler (capacity: 2,800 t DS/d).

The smelt from the recovery boiler is dissolved and pumped into the causticizing plant to regenerate the white liquor (6,000 m^3 white liquor/d). The lime mud is burnt in the lime kiln (450 t CaO/d).

Strong malodorous gases are collected from the cooking plant and the evaporation plant and burnt in a separate burner. If the gas burner is out of operation, the strong malodorous gases are burnt in the lime kiln.

Weak malodorous gases from the cooking plant are burnt in the recovery boiler as tertiary air. Weak malodorous gases from the evaporation plant are burnt as combustion air in the gas burner for strong malodorous gases; weak malodorous gases from causticizing are burnt as combustion air in the lime kiln.

Because of the very low sulphur emissions, which are the result of the efficient internal and external recovery of the sulphur, the sulphidity in the white liquor tends to rise to a high level (above 40). There is also an excess of sodium in the chemical recovery system. The sulphur and sodium content in the system are balanced by taking out white liquor from the system. The white liquor is sold to other mills. Another way of taking out the sulphur and sodium from the system is to eject into the sewer flue gas scrubbing washing liquor that contains Na_2SO_4 and waste acid from the tall oil plant.

Non-process compounds are taken out of the process chemical circulation with dregs and lime mud from the causticizing plant. The dregs and lime mud are transported to a landfill with a 45-50% dry-solids content. A large amount of phosphorus is also taken out of the system in this way. The phosphorus content in the waste water from the process is low (see table 4.3.1), due to extended delignification before bleaching and because a relatively small alkali demand for the neutralisation of the acid bleaching effluent makes it possible to use chemicals (e.g. CaO) other than lime mud in the neutralization. The phosphorus content in the waste water is further reduced in the external treatment plant before it is discharged into the recipient.

4.3.4 Energy production and consumption

The pulp mill consumed 700 kWh/ADt of electrical energy and 13 GJ/ADt of heat energy (in 1995).

Heat energy is produced in the recovery boiler and the bark boiler. The electrical energy is produced in a turbine with back-pressure steam. In 1995 the total production of electrical energy was 631 GWh and the total production of heat energy was 2,115 GWh in the recovery boiler and 627 GWh in the bark boiler (including the steam energy used for electrical energy production). No excess heat energy is sold, but excess electrical power is sold to the national net (about 600 kWh/ADt in 1995).

About 30% of the fossil fuel used in the lime kiln is replaced by tall oil and methanol from the condensate handling. Soap is also partly burnt in the recovery boiler. All the tall oil and soap is burnt on site.

4.3.5 External treatment. Discharges and emissions into water and the air, solid waste

Discharges into water

The main discharge from the process into water is the bleaching waste water. All the waste water is biologically treated before being discharged into the recipient. The polluting load coming from the pulp mill for external treatment is shown in table 4.3.1.

Table 4.3.1 Total discharge from the process going to the external waste water treatment in 1995.

	Process discharge (t/d)	Process discharge (kg/ADt)
COD_{Cr}	76.2	58
BOD_7	28.5	22
Tot-P	0.059	0.045
Tot-N	0.191	0.145
AOX	0.88	0.67

The acid waste water from bleaching is neutralized before being mixed with other waste water. After pre-screening the waste water is pumped to the primary clarifier. Clarified waste water flows to an equalization basin equipped with mixers.

The biological treatment takes place in an extended aeration (low organic loading) activated sludge treatment plant (retention time about 1 day). Before activated sludge treatment the pH and the nutrient content (phosphorus and nitrogen) of the waste water are adjusted and the water is cooled below 40° C. After biological treatment the waste water flows through an ecological pond before it is discharged into the receiving water. The ecological pond is an aerated pond into which fish and plants have been introduced. The retention time is 3-5 days.

The reduction rates of pollutants in the waste water treatment plant is shown in table 4.3.2.

If there is a larger accidental spill at the pulp mill that would cause damage to the biological treatment, the waste water is directed to the spill pond, where it is stored until it can be pumped to the activated sludge treatment at a flow rate which does not affect the biological activity.

Primary sludge and biosludge are thickened and then dewatered in a belt press to a 20% dry-solids content. The sludge is mixed with bark and burnt in the bark boiler.

Table 4.3.2 Reduction rates in the waste water treatment plant (1995)
(mean value of monthly average).

	Primary sedimentation	Activated sludge treatment	Ecological pond	Total
	(%)	(%)	(%)	(%)
COD_{Cr}	23	71	6	79
BOD_7	39	98	0	99
Tot-P	13	88	7	90
Tot-N	-	47	22	40
AOX	37	65	4	79

The specific discharges into the receiving water in 1994 and 1995 are shown in table 4.3.3.

Table 4.3.3 Specific discharges into water in 1994 and 1995
(mean value of monthly average).

		1995	1994
Flow	m^3/ADt	43	49
TSS	kg/ADt	0.2	0.3
COD_{Cr}	kg/ADt	13	14
BOD_7	kg/ADt	0.2	0.3
Phosphorus	g/ADt	5	6
Nitrogen	g/ADt	87	130
AOX	kg/ADt	0.14	0.14

The installed power of the treatment plant is 2 MW.
The annual operating costs are FIM 6 million.

Cooling water and other clean water are discharged separately (about 150 m^3/ADt).

Emissions into the air

Four parallel three-field electrostatic precipitators separate the fly ash from the flue gases of the recovery boiler. The reduction rate of the dust is >99%. The fly ash is returned to the black liquor. The flue gases from the recovery boiler are further treated in a scrubber to absorb the SO_2. If the pH of the washing liquor is well above neutral, the reduction in SO_2 will be about 90%.

The flue gases from the lime kiln are treated in an electrostatic precipitator (2 parallel 2-field). The bark boiler is also equipped with an electrostatic precipitator.

The malodorous gas burner is equipped with a scrubber to reduce the SO_2 and TRS.

The vents from the smelt dissolver are treated in an alkali scrubber before they are led to the recovery boiler scrubber. The vents from the tall oil plant are treated in a separate scrubber.

Vents from the bleaching that contains some chlorine chemicals in gas form are treated by alkaline scrubbing.

The emissions into the air in 1995 are shown in table 4.3.4.

Table 4.3.4 Total and specific emissions into the air in 1995.

	Dust	NOx (as NO_2)	SO_2 (as S)	TRS (as S)	Cl
Recovery boiler (t/a)	68	667	5	3	
Lime kiln (t/a)	3	50	15	1	
TRS-gas burner (t/a)		45	23		
Bark boiler (t/a)	24	134	10		
Other sources (t/a)	17		0.1	64	192
Total (t/a)	112	896	53	68	192
Spec. discharge (kg/ADt)	0.24	1.91	0.11	0.14	0.4

Solid waste

The solid waste disposed of at landfill sites is mainly ashes from the boilers, causticizing dregs, wood and bark waste and rejects (table 4.3.5.). In 1995 the amount of hazardous waste was 57 t (oils, solvents, paints, glue etc.).

Over 95% of the bark and wood waste from woodhandling (135,000 t DS in 1995) is burnt in the bark boiler together with primary and biosludge from the waste water treatment (5,740 t DS).

Table 4.3.5 The main types of solid waste for landfill in 1995.

	Solid waste (tonnes of 100% DS)	(kg DS/ADt)
Ashes	8,704	18.2
Dregs	4,662	9.7
Bark, wood waste etc.	4,420	9.2
Rejects	413	0.9

4.4 ECF bleached kraft pulp

4.4.1 General

The pulp mill produces fully bleached ECF softwood and hardwood pulps. The pulp mill was started up in 1985 and is located in central Finland by a lake.

In 1995 the total production of bleached pulp was 455,000 tonnes, 242,000 tonnes of which was softwood pulp and 213,000 tonnes hardwood pulp. About one-third of the pulp goes to a paper and board mill nearby, and the rest is sold to other customers. The pulp mill also produces by-products: energy, tall oil, turpentine and sodium sulphite. The production of by-products is about 14,000 t/a of tall oil, 1,400 t/a of turpentine, 8,000 t/a of sodium sulphite, 7,000 TJ/a of steam and 350 Gwh/a of electricity. Energy is used in the kraft pulp mill or in the integrate, but tall oil, turpentine and sodium sulphite are sold to other companies.

4.4.2 Debarking

Timber is mainly transported to the pulp mill by road. Rail transportation covers about 15% of the wood quantity, but more than 30% of the total amount of transportation. Being situated by waterways, minimal amounts of timber are also floated. The incoming wood is taken directly into the process. Wood is mainly stored as chips. There is only a small buffer storage of logs at the mill. About 25% of the softwood chips consumed in the kraft pulp mill come from sawmills.

Round wood logs are debarked on site on three debarking lines, one for pine and two for birch. All three are dry-debarking lines. Only in the winter is steam used for de-icing the logs. After the barking drums, the logs are washed. The bark is pressed and mixed with the dried waste water treatment sludge and burnt in the bark boiler.

About 1 million m^3 of hardwood and 1.2 million m^3 of softwood are debarked annually on site.

The water consumption in the debarking is about 3,000 m^3/d in the summer, rising to 5,000 m^3/d in the winter. Some of the water is circulated, and the overflow is led to the primary sedimentation and on to the activated sludge waste water treatment. The chemical oxygen demand (COD_{Cr}), phosphorus (tot-P), suspended solids, and pH and conductivity are analyzed regularly. Typical values are presented in table 4.4.1.

Table 4.4.1 Discharges from debarking into the effluent treatment plant.

	Unit	Discharge
Effluent	m^3/m^3 of wood	0.5-0.8
COD_{Cr}	kg/m^3 of wood	0.5-0.6
Phosphorus	g/m^3 of wood	3-5

All the wood coming to the mill either in chip or log form is weighed at the mill to determine the quantity. Quality inspection covers identification of the wood species, size, moisture content and the degree of possible fungal detoriation. For sawmill chips particle size distribution is an essential part of the quality control.

4.4.3 Kraft pulp mill

Fibre line

The pulp mill is a single line mill. There is one fibre line and one chemical recovery line (figure 4.4.1). The pulp mill produces ECF bleached softwood (pine) and hardwood (birch and aspen) pulp. Softwood and hardwood pulp is produced alternately at intervals of a few days.

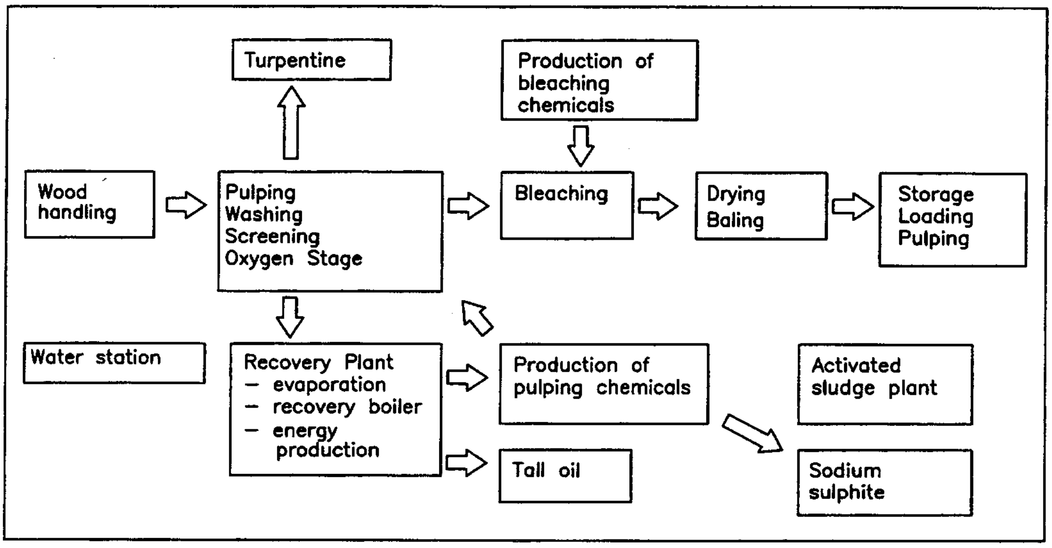


Figure 4.4.1 The kraft pulp mill

The cooking method is the so-called extended continuous cooking, which makes it possible to cook to a lower lignin content than with conventional processes. Consequently, the pulp needs less bleaching and the effluent load is substantially reduced. The chips are cooked in a Kamyr continuous digester with pre-impregnation to a Kappa of 25-27 for softwood pulp and 15-17 for birch and aspen pulp. The wood consumption is about 6 m^3/ADt for softwood and 4.5 m^3/ADt for hardwood.

After Hi-Heat and two-stage diffuser washing the pulp goes through knot screening to the screening plant. Knots are returned to the cooking. The screened pulp is washed further on a two-stage washing filter.

After the washing and screening, the pulp is delignified in an oxygen stage to a Kappa of 15-17 for softwood pulp and 12-13 for hardwood pulp. The pulp is washed before the five-stage bleaching in a press washer using evaporation condensate as the wash liquid. The process water flow is led counter-current from the washing stage after oxygen delignification to the beginning of the washing, where the liquor is separated and led to evaporation in the chemical recovery system.

During the bleaching, lignin and other impurities remaining in the pulp are removed. The bleaching chemicals used are oxygen, hydrogen peroxide and chlorine dioxide. Sodium hydroxide is used in the extraction stages. Chlorine dioxide is generated from sodium chlorate on site by the R3H process. The bleaching sequence is: D_0 - E_{OP} - D_1 - $E_{(P)}$ - D_2.

Both softwood and hardwood pulps are always available due to the integration with the paper and board mill. The pulp that is sold outside the integrate is dried to a 90% dryness, cut and baled before shipping.

The total specific water consumption is 75 m^3/ADt of bleached pulp and the specific process effluent flow is 28 m^3/ADt.

Recovery process

The weak black liquor from cooking is concentrated to a 75-80% dry-solids content by evaporation. The black liquor is thermally cracked to a lower viscosity after the first evaporation stage. Simultaneously volatile sulphur compounds are removed. This black liquor heat treatment (LHT) results in lower sulphur dioxide emissions from the recovery boiler.

The concentrated black liquor is mixed with soda ash from the electrostatic precipitators and burnt in the recovery boiler. The organic material burns into carbon dioxide, while the inorganics are obtained as a smelt, which is dissolved in weak liquor from the causticizing plant to form green liquor. The high-pressure steam generated in the recovery boiler is used in a 52 MW back-pressure turbogenerator, after which the low pressure steam is used as a source of heat where needed in the mill.

Before causticizing, the green liquor is clarified and variations in the concentration are levelled in a buffer tank. The green liquor is converted (causticized) into white liquor by the addition of lime. The white liquor formed is then filtered and stored for reuse as cooking liquor.

The lime mud is washed using secondary condensate from the evaporation. The lime mud washing filtrate is used for smelt dissolving. The washed lime mud, calcium carbonate, is burnt in the lime kiln to form CaO. Oil is used as fuel in the lime kiln. Concentrated malodorous gases are oxidized to SO_2 in the lime kiln. The sulphur in the flue gases is recovered in the scrubber as sodium bisulphite, which is used in the bleaching plant.

4.4.5 Energy production

Energy is produced in the recovery boiler, a bark boiler of the fluidized bed type and two oil-fired boilers for both the pulp mill and the paper mill. A new auxiliary boiler is being installed in 1996.

4.4.6 External treatment. Discharges and emissions into water and the air, solid waste

Discharges into water

The process waste water from the kraft pulp mill is treated in an activated sludge plant together with waste water from the debarking plant and the adjacent paper mill. The effluents containing suspended solids are clarified before the activated sludge treatment. The nitrogen content and pH in the waste water are adjusted before aeration. All the waste water going to the aeration is equalized in a lagoon of 25,000 m^3. An additional pond is available in case of an emergency. The excess biosludge from the secondary clarifier and the primary sludge are mixed, dewatered and burnt with the bark in the bark boiler.

Specific discharges are presented in table 4.4.2. The efficiency of the treatment is shown in table 4.4.3, where reduction rates are reported based on inlet and outlet numbers.

About 1,000 m^3/d, or 3% of the effluent flow, and about 10% of the COD_{Cr} load going to the activated sludge treatment plant come from the paper mill.

Cooling water is discharged into the recipient in a separate "clean water" sewer.

Table 4.4.2 Specific discharges into the receiving water January - June 1996.

	Process effluent (m^3/ADt)	TSS (kg/ADt)	BOD7 (kg/ADt)	CODCr (kg/ADt)	Tot-P (g/ADt)	Tot-N (g/ADt	AOX (kg/ADt)
Kraft pulp mill	28	1.15	0.43	21	10	210	0.32

Table 4.4.3 Pollution load going to waste water treatment (mainly from the kraft pulp mill) in 1995.

(Average and min. and max. of 12 monthly mean values) **and reduction rates in the waste water treatment plant.** Production average: 1,300 ADt of pulp/d.

Waste water treatment	TSS (t/d)	BOD7 (t/d)	CODCr (t/d)	Tot-P (kg/d)	Tot-N (kg/d)	AOX (t/d)
In						
- average	8.3	22	74	100	672	1.1
- (min-max)		(14-38)	(65-92)	(90-123)	(480-900)	(0.8-1.4)
Out						
- average	3.7	1.3	34	39	238	0.6
- (min-max)		(0.7-2.8)	(30-42)	(15-50)	(130-375)	(0.4-0.7)
Reduction rates (%)						
- prim. sedimentation	92-95	-	-	-	-	-
- activated sludge treatment	60-70	95-97	60-65	80-85	60-65 *)	50-55

*) incl. addition of N before aeration

Emissions into the air

The emission points for emissions into the air and the treatment methods are shown in figure 4.4.2. Table 4.4.4 shows the specific emissions from the kraft pulp mill.

Table 4.4.4 The specific emissions from the kraft pulp mill in 1995.

		Kraft pulp mill
SO_2	(kg S/ADt)	0.25
TRS	(kg S/ADt)	0.08
NOx	(kg NO_2/ADt)	1.3
Dust	(kg/ADt)	0.9

Concentrated malodorous gases are collected and burnt in the lime kiln. Weak malodorous gases of no heating value are collected and treated in two scrubbers. At the bleaching plant and the bleaching chemical plant the process ventilation exhausts are scrubbed to remove the traces of chlorine dioxide residues before they are emitted into the air.

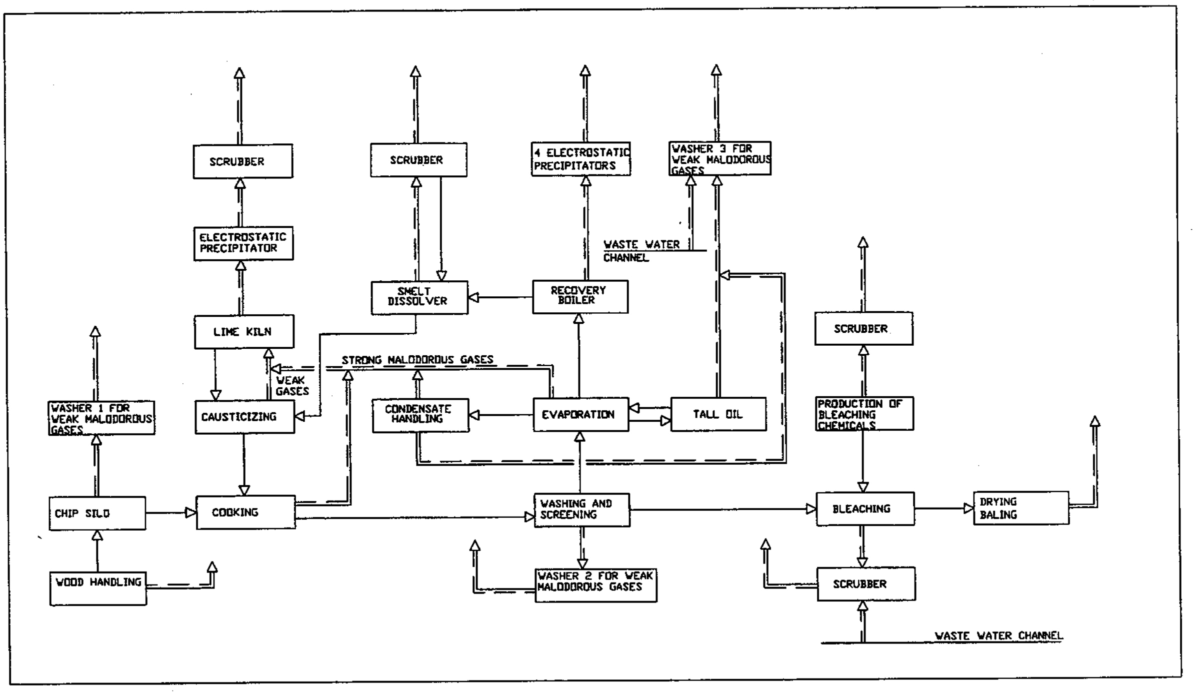


Figure 4.4.2 Emissions into the air and treatment methods.

Solid waste

Bark and other wood residues as well as the mixed sludge from waste water treatment are utilized for energy production in the bark boiler. A small amount of wood ashes was utilized as forest conditioning in 1995.

The most important types of solid waste from the kraft pulp process and energy production are lime mud and green liquor dregs, biosludge and primary sludge, rejects from wood handling and wood ashes (table 4.4.5). The amount of hazardous waste that was transported to a plant for the handling of hazardous waste was 59 t in 1995. The specific amount of total solid waste for landfill was 43 kg/ADt of bleached pulp.

Table 4.4.5 Solid waste for landfill in 1995.

	Solid waste (tonnes, as 100% DS)
Lime mud	4,392
Green liquor dregs	3,678
Bio- and primary sludge	3,931
Reject (woodhandling)	944
Wood ashes	1,794
Other	4,754
Hazardous waste	59
TOTAL	19,552

4.4.7 Water supply and treatment

The raw water used at the pulp mill is pumped from the lake nearby. Mechanically treated raw water is used as the process water. Make-up water for the recovery boiler and bark boilers is treated separately. The mechanically treated water is chemically treated by aluminium precipitation. Most of the chemically treated water is used for the final washing of the bleached pulp in the drying machine.

4.4.8 Monitoring of discharges

The discharges into the recipient are monitored according to a monitoring programme confirmed by the authorities. The suspended solids, COD and conductivity are analyzed daily and the BOD, tot-P and tot-N are analyzed twice a week. The samples are collected over a 24-hour period. AOX is analyzed once a month from a composite sample of 24-hour samples. All the analyses are based on homogenized and unfiltrated samples in accordance with standard methods.

SO_2 emissions from the lime kiln and the recovery boiler are monitored continuously as well as dust and NO_x emissions from the recovery boiler. Detailed, manual monitoring of sulphur emissions (incl. "diffuse" emissions) is carried out once a year.

4.5 Integrated bleached kraft pulp and woodfree paper

4.5.1 General

The mill produces bleached kraft pulp and coated woodfree paper on one paper machine. A new paper machine is scheduled to start up in the spring of 1997.

In 1995 the production of ECF bleach pulp was 324,740 tonnes (capacity 370,000 tonnes/a), 28% of which was hardwood (birch) pulp and 72% softwood pulp. The kraft pulp mill produces no TCF pulp. Today about 40% of the pulp production goes to the paper mill and the rest is sold to other paper mills. In 1995 the paper production was 250,000 tonnes of coated paper.

The mill is located by the estuary of a river. The mill takes fresh water from the river and discharges treated effluent and warm cooling water back into the river.

Energy for the kraft pulp mill and the paper mill is produced in the recovery boiler, in a common wood-waste boiler and the boiler for malodorous gases at the kraft pulp mill, and occasionally in an oil-fired boiler.

The waste water from the kraft pulp mill is treated in an activated sludge treatment plant and the waste water from the paper mill is treated in a chemical flotation plant. Non-contaminated cooling and cleaning water is discharged into the recipient in separate sewers.

4.5.2 Debarking

Hardwood and softwood logs (in 1995 about 1.35 million m^3) are debarked on site on one debarking line. About 30% of the softwood chips are sawmill chips. The debarking is dry barking. In winter, however, warm water or steam is used for de-icing the logs.

The logs are washed after debarking. The water consumption in the debarking is 0.2 m^3/m^3 of wood in the summer and 0.6 m^3/m^3 of wood in the winter. Some of the effluent is circulated. The overflow is treated in the waste water treatment plant of the kraft pulp mill (table 4.5.1). The bark is burnt in the wood-waste boiler.

Table 4.5.1 Discharges from debarking going for external treatment.

	Effluent flow (m^3/m^3 of wood)	BOD_7 (kg/m^3 of wood)	Tot-P (g P/m^3 of wood)
Softwood	0.2-0.6	0.5	1
Hardwood	0.2-0.6	0.2	1

4.5.3 Kraft pulp mill

The kraft pulp mill is a one-line mill producing ECF bleached hardwood and softwood pulp. The pulp mill has been modernized step by step during the 1980's and at the beginning of the 1990's.

The chips are cooked in a continuous digester with pre-impregnation to a Kappa of 30 for the softwood pulp and a Kappa of 19 for the hardwood pulp. In 1995 the wood consumption was 4.2-4.3 m^3/ADt of hardwood pulp and 5.6-5.8 m^3/ADt of softwood pulp.

After Hi-Heat and diffuser washing the pulp goes through knot separation to the screening plant. Knots are returned to the cooking. After screening, the pulp is oxygen delignified in two stages with intermediate diffuser washing to Kappa 15 for softwood pulp and 12 for hardwood pulp. The oxygen-treated pulp is washed and pressed before bleaching. The first oxygen delignification stage was installed in 1991 and the second in October 1995. The filtrate from washing after oxygen delignification goes counter-current through the washing stages in the oxygen delignification, the screening plant and the post-cooking washing and is finally recovered from the digester as weak black liquor. Clean secondary condensate (4m^3/ADt) and fresh water are used as the wash water.

The pulp is bleached in a displacement bleaching plant including two chlorine dioxide stages and an alkali extraction to full brightness (88-89% ISO). The alkali extraction is reinforced with oxygen. The first chlorine dioxide stage and the alkali extraction stage with intermediate washing are performed in the same bleaching tower. The last bleaching stage and the final washing are performed in a separate bleaching tower.

After post-screening the bleached pulp is pumped to the paper mill at a consistency of 2.2%. The pulp that is not used in the paper mill is dried on the drying machine and sold. In 1995 42% of the pulp was used in the integrate.

Weak black liquor is concentrated in a multi-stage evaporation plant to a 67% dry-solids content and burnt in the recovery boiler (capacity 2,000 t DS/d). The smelt is dissolved in weak white liquor. The cooking chemicals are regenerated in the causticizing and returned to the cooking. The lime mud is washed with warm water. The lime for causticizing is regenerated in the lime kiln. The mud is pre-dried with kiln flue gases.

Foul condensates from evaporation and the cooking plant are treated in a stripper for methanol separation. The methanol is burnt in a separate burner. The treated condensate, when contaminated, is discharged into the activated sludge treatment plant.

In 1994-1995 the specific consumption of electrical energy was 650 kWh/ADt and heat energy 10 GJ/ADt in the kraft pulp mill (including the activated sludge treatment).

In 1994-1995 the specific process water consumption was 68 m^3/ADt (including some cooling water) and the cooling water consumption was 47 m^3/ADt.

4.5.4 Paper mill

The paper mill produces multi-coated fine paper on one paper machine with an off-machine coater. The coated paper is super- or soft-calendered and delivered to the clients either as sheets or as reels. The paper mill obtains electrical and heat energy from the energy production on site, and the required additional electrical energy is purchased from the national grid.

In 1995 the production was 250,000 tonnes of paper (nominal capacity 330,000 tonnes of paper), consisting of 55% bleached kraft pulp and 45% coating pigments and fillers.

Softwood and hardwood pulp is pumped from the kraft pulp mill at a 2.2% consistency. The chemical pulp is refined in the stock preparation plant.

The process water consumption is 17 m^3/ADt of paper (13-23 m^3/ADt of paper) and the consumption of cooling water is 12 m^3/ADt of paper (11-21 m^3/ADt of paper).

In 1994-1995 the specific electrical energy consumption (including coating and and the coating kitchen, and cutting) was 920 kWh/t and the specific heat energy consumption was 6.3 GJ/t. In addition, 4,000 tonnes of liquefied petroleum gas (0.73 GJ/t) are used to generate hot air for drying at the coating machine.

4.5.5 Energy production

Energy for the pulp and paper mill is produced in the recovery boiler, a boiler for burning malodorous gases, a wood-waste boiler and occasionally in an oil-fired boiler (table 4.5.2). The wood-waste boiler is a rebuilt old recovery boiler. The wood-waste boiler will be replaced by a new fluidized bed boiler for wood waste and peat in the spring of 1997. In 1994-1995 96% of the energy was produced from renewable fuel resources (table 4.5.3).

Table 4.5.2 Energy production.

	Energy production (TJ)	
	1994	1995
Recovery boiler	5,838	5,172
Wood-waste boiler		
and oil-fired boiler	1,989	1,959
Boiler for malodorous gases	74	68
Total	7,901	7,199

Table 4.5.3 Fuels in the energy production 1994-1995.

Fuel	Share of energy production (%)	
	1994	1995
Black liquor	74.9	70.5
Wood waste, bark etc.	21.0	24.5
Malodorous gases	1.1	1
Peat	0.8	1
Oil	2.2	3

The integrate purchases peat, fuel oil, LPG and hydrogen.

Hydrogen, a by-product of the chemical industry nearby, is used as a fuel in the lime kiln, covering 45% of the total fuel consumption in the lime kiln.

Excess heat energy is sold to a chemical plant nearby and as district heating.

Electrical energy is produced mainly in one back-pressure turbo-generator (68 MW); a second (55 MW) will be installed in 1997. There is also one reserve turbine (22 MW). In 1994 396 GWh and in 1995 383 GWh of power was generated on site corresponding to 1,145 kWh/ADt. Additional electrical power needed by the paper mill is purchased.

4.5.6 External treatment. Discharges and emissions into water and the air, solid waste

Discharges into water

Kraft pulp mill

The waste water from the kraft pulp mill and the debarking plant is treated in an activated sludge treatment plant. A cleaner fraction of the effluents from the chemical recovery area and cooling water by-passes the activated sludge treatment.

Acid waste water is neutralized before being mixed with the other waste water. The waste water goes through a coarse screen before the primary sedimentation. In the primary sedimentation the reduction of suspended solids is 75% on average.

The pH in the clarified effluent is adjusted before the waste water enters the activated sludge treatment. Nitrogen is added as a nutrient. The activated sludge treatment plant consists of an equalization basin (11,000 m^3), aeration basin (25,000 m^3) and a secondary clarifier. The returned sludge undergoes separate aeration.

The reduction of organic substances in the activated sludge treatment plant is 80-96% measured as BOD_7 and 40% (35-45%) measured as COD_{Cr}. The reduction of tot-P is 35% (0-60%) and the concentration in the outlet going to the receiving water is 1.0 mg tot-P/l (0.6-1.6 mg/l). The mean tot-N reduction is about 30%, but the reduction varies over a wide range. The concentration in the outlet is about 5 mg tot-N/l (3.5-10 mg tot-N /l).

The excess biosludge is thickened and mixed with the primary sludge before being dewatered in two parallel filter belt presses. The mixed sludge is burnt in the wood-waste boiler.

The total discharges from the kraft pulp mill into the receiving water are shown in table 4.5.4.

Table 4.5.4 Total specific discharges from the kraft pulp mill into the recipient in 1994-1995.

	Flow (m^3/ADt)	TSS (kg/ADt)	BOD7 (kg/ADt)	CODCr (kg/ADt)	Tot-P (g/ADt)	Tot-N (g/ADt)	AOX (kg/ADt)
Activated sludge	36.5	2.0	1.2	28	37	200	0.37
Recovery area	30.5	0.1	0.9	3	3	70	-
Total	67.0	2.1	2.1	31	40	270	0.37

The energy consumption of the waste water treatment is 0.54 kWh/m^3, including pumping, aeration and sludge handling.

The annual operating costs are about FIM 2 million, including energy, chemicals, operating and maintenance.

Occasional and accidental spills are collected from the chemical recovery area and returned to the chemical recovery system. Smaller spills are led to the waste water treatment plant.

Paper mill

The waste water from the paper mill, including the paper machine clear filtrate, rejects from stock preparation and broke handling, waste water from the coating kitchen and size preparation, is treated with chemical precipitation. Fibre and suspended solids containing waste water are pre-treated in a primary clarifier before being mixed with the clear filtrate, pH adjustment chemicals and flocculating chemicals, and the sludge is separated by flotation in two parallel tanks. The chemical sludge is taken either directly to sludge handling or to the primary clarifier and then together with the primary sludge to sludge handling. The mixed sludge is conditioned with a polymer and then dewatered in a filter belt press before it is transported to a landfill site. The filtrate from the filter press is returned to the primary clarifier.

The discharges from the chemical treatment plant into the receiving water in 1994-1995 are shown in table 4.5.5.

The reduction of suspended solids in the waste water treatment exceeds 99%. A typical reduction for BOD_7 is 80-85%, for COD_{Cr}, 90-95%, for phosphorus 90% and for nitrogen 70-80%.

Table 4.5.5 Specific discharges from the paper mill after chemical treatment 1994-1995.

		Discharge
Flow	(m^3/t of paper)	17
TSS	(kg/t of paper)	0.8
BOD_7	(kg/t of paper)	1.3
COD_{Cr}	(kg/t of paper)	2.2
Tot-P	(g/t of paper)	2.8
Tot-N	(g/t of paper)	46

Emissions into the air

Kraft pulp mill

Strong malodorous gases are collected from the cooking plant (condenser, turpentine decanter) and the evaporation plant and burnt in a separate boiler. The flue gases have a high concentration of SO_2. The sulphur is recovered in a washer as sodium bisulphite. The treated flue gas goes further to the flue gas scrubber at the recovery boiler. The amount of bisulphate generated is enough to replace the SO_2-water amount earlier used in the washing of the bleaching plant vents and for acidification of the bleached pulp.

Weak malodorous gases are collected from black liquor tanks in the evaporation plant, soap tanks and washer in the tall oil plant, condensate tanks and tanks in the causticizing plant. The weak malodorous gases are burnt in the recovery boiler mixed with tertiary combustion air.

The smelt dissolver is equipped with a separate scrubber. The vents are further treated in the recovery boiler scrubber.

The recovery boiler is equipped with an electrostatic precipitator (two parallel) and a scrubber. The treated flue gases from the boiler of malodorous gases and the treated smelt dissolver vents are also treated in the same scrubber. The gases are washed with sodium hydroxide, and in the second stage the rest of the heat in the flue gases is recovered as warm water.

The flue gases from the lime kiln are treated in an electrostatic precipitator.

The emissions of H_2S and SO_2 from the recovery boiler and the lime kiln are monitored continuously.

The wood-waste boiler is also equipped with an electrostatic precipitator.

In 1994-1995 the total emission of sulphur into air from the kraft pulp process was 0.65 kg S/ADt (table 4.5.6) and from additional energy production 0.18 kg S/ADt

Table 4.5.6 Emissions into the air.

	SO_2 (kg S/ADt)	TRS (kg S/ADt)	Total - S (kg S/ADt)	NOx (kg NO_2/ADt)	Dust (kg /ADt)
Recovery boiler	0.13	0.02	0.15	0.88	0.72
Lime kiln	-	0.01	0.01	0.27	0.02
Other	0.19	0.30	0.49		
Process, total	0.32	0.33	0.65	1.15	0.74
Energy production	0.18	-	0.18	0.75	0.01
Pulp and paper, total	0.50	0.33	0.83	1.90	0.75

Paper mill

The main polluting emissions into the air caused by the production of paper come from the production of the energy used at the paper mill. These emissions are discussed above under the heading "Kraft pulp mill" (see table 4.5.6).

Solid waste

The generation of solid waste in 1995 is shown in table 4.5.7. Bark and wood waste are utilized for energy production in the wood-waste boiler (125,170 tonnes, calculated as dry matter). Primary and biosludge from the activated sludge treatment plant are also burnt in the waste-wood boiler (3,786 tonnes, calculated as dry matter). The ashes from the waste-wood boiler are transported to a landfill site. The sludge from the paper mill's waste water treatment is landfilled. The amount of waste from the cores used in the paper reels totalled1,068 t. This waste is returned to Finnish mills that produce core board.

Table 4.5.7 Solid waste going to a landfill site from the pulp and paper mill in 1995 (as dry solid).

	Solid waste	
	(t)	(kg/ADt)
Kraft pulp mill		
Dregs	2 760	8.5
Rejects	150	0.5
Paper mill		
Waste water sludge	18 500	74
Energy production		
Wood ashes	2 747	
Peat ashes	203	

4.6 Integrated bleached pulp and wood-containing paper

4.6.1 General

The integrate produces bleached pulp and coated wood-containing paper. There is also a sawmill and a plywood mill on the site. A new softwood kraft pulp line and a modernized hardwood kraft pulp line and chemical recovery line will come into operation at the end of 1996. The situation in 1995 is primarily presented here. The modernization of the kraft pulp mill is presented in brief in section 4.6.7.

In 1995 the kraft pulp mill produced 455,000 tonnes of ECF bleach pulp, 55% of which was hardwood (birch) pulp and 45% softwood pulp. The kraft pulp mill produced 7,000 tonnes of TCF softwood pulp. About 30% of the kraft pulp production was used in the paper mill and the rest was sold to other paper mills. In 1995 the paper production was 466,000 tonnes of coated wood- containing paper.

The mill is located inland by a large lake. The mill takes raw water from the lake and discharges treated effluent and warm cooling water back into the lake.

Energy for the kraft pulp mill and the paper mill is produced in the recovery boiler and the boiler for malodorous gases at the kraft pulp mill, in two bark boilers and a natural gas-fired gas turbine with a waste heat boiler.

The waste water from the kraft pulp mill and the paper mill is treated in an activated sludge treatment plant. Clean effluent and the cooling water are discharged into the recipient in a separate sewer.

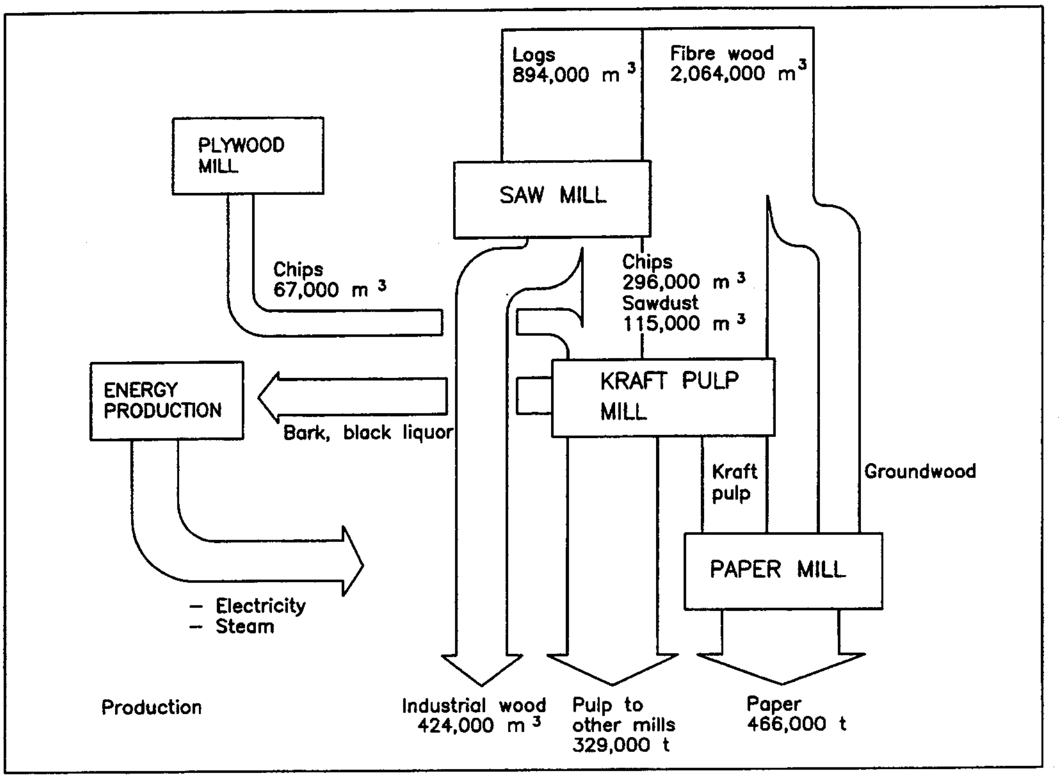


Figure 4.6.1 Fibre material balance

4.6.2 Debarking

There are two debarking plants, one for the kraft pulp mill and one for the mechanical pulp production.

Hardwood and softwood logs for the kraft pulp mill are debarked on separate debarking lines (in 1995 about 1.6 million m^3). The debarking is dry. In the winter warm water is used for de-icing the logs. The kraft pulp mill uses an additional 0.7 million m^3 of chips and sawdust from the sawmill and the plywood plant.

Wood (spruce) for the mechanical pulp production is debarked in a separate debarking plant (about 0.4 million m^3 of wood in 1995) using wet barking.

The total waste water flow from the debarking plants is 1,700 m^3/d (annual average). The effluent from the two debarking plants is treated for the separation of suspended solids in a sedimentation basin. The overflow is treated further in the activated sludge treatment plant. The clarified effluent from the sedimentation is not monitored. The sedimentation sludge is dewatered and transported to a landfill site or mixed with the bark, which is burnt in the bark boilers or transported to a landfill site.

4.6.3 Kraft pulp mill

The kraft pulp mill has separate fibre lines for hardwood and softwood. Sawdust and small-size chips are cooked in a separate continuous digester. This pulp is mixed with the hardwood pulp after cooking. Process chemicals and energy are recovered on a joint recovery line. The mill produces ECF bleached hardwood and softwood pulp and TCF bleached softwood pulp. The pulp mill is being modernized (1995-96) and the modernization is planned for completion by the end of 1996. The modernization is discussed in section 4.6.7. The mill configuration and the data presented relate to the process situation in 1995.

Pulp cooking on the hardwood fibre line takes place in five batch digesters. The wood consumption is about 4.3 m^3/ADt of pulp (3.2 m^3/ADt debarked and chipped on site and 1.1 m^3/ADt from the sawmill and plywood mill). The Kappa after cooking is 19.

The pulp is washed in two parallel four-stage DD-washers, screened and thickened before oxygen delignification in two stages to Kappa 14. The oxygen-delignified pulp is washed in a two-stage DD-washer, and the washing filtrate is led counter-current through the pulp washing to the chemical recovery system. The washed pulp is stored in a high-consistency tower and once again washed before bleaching.

On the softwood fibre line pulp cooking takes place in four batch digesters. The softwood consumption is about 5.8 m^3/ADt of pulp (3.6 m^3/ADt debarked and chipped on site and 2.2 m^3/ADt sawmill chips). The softwood pulp is cooked to Kappa 27-28.

The hardwood and softwood pulp is bleached with chlorine dioxide in separate five-stage bleaching plants with filter washing. The alkali extraction is reinforced with oxygen and peroxide. The pulp is finally treated with sulphur dioxide water or a bisulphite solution to remove residual chlorine dioxide. Hardwood pulp is bleached to 89-90% ISO and softwood pulp to 86% ISO. The chlorine dioxide is produced on site using the ERCO R8 process.

Small amounts of TCF bleached pulp are also produced (7,000 ADt of softwood pulp in 1995). TCF pulp is produced on the hardwood fibre line. The pulp is oxygen-delignified to a lower Kappa level than normal. The pulp is then treated with an enzyme and a chelating agent (EDTA) before being bleached with oxygen and peroxide (bleaching sequence QX EOP P P P).

All the bleached hardwood pulp is dried and sold to other mills in Finland and abroad. Most of the bleached softwood pulp is pumped to the paper mill. The rest is dried and sold to other paper mills. In 1995 65% of the ECF softwood pulp was used in the integrate.

The chemical recovery system was modernized in 1991 (7-stage evaporation plant, recovery boiler (capacity 2,700 t DS/d), turbo-generator and a system for collecting and burning malodorous gases). The strong black liquor is evaporated to a 75-76% dry-solids content before it is fed into the recovery boiler. The causticizing of cooking chemicals and regeneration of lime in the two lime kilns follow the conventional technique. Foul condensates from evaporation and the cooking plant are treated for the separation of methanol and malodorous compounds. The methanol and weak malodorous gases from the recovery plant are burnt in the burner for malodorous gases.

The net specific consumption of electrical energy is 770 kWh/ADt and heat energy 13.2 GJ/ADt in the kraft pulp mill (annual average 1995).

The specific process water consumption was 73 m^3/ADt and the consumption of sealing and cooling water was 72 m^3/ADt.

4.6.4 Paper mill

The paper mill produces coated LWC paper on two lines. In 1995 the production was 235,000 and 230,400 tonnes of paper respectively. The paper furnish is approximately 35% mechanical pulp, 30% chemical pulp, the rest being coating pigment, binders and additives. The electrical and heat energy consumed is partially supplied by the energy production on site. Additional electrical energy is purchased. Softwood pulp is pumped from the kraft pulp mill and coating agents are purchased.

The main process units are the groundwood mill, the base paper machines, coating kitchen, off-machine coaters, calendering of coated paper, and cutting and wrapping (figure 4.6.2).

The groundwood pulp is produced at a two-line groundwood plant. The process steps at the groundwood plant are grinding, coarse and fine screening, centri-cleaning, thickening, post-refining, peroxide bleaching and pulp storage. The production capacity of the four grinders on line 1 is 260 tonnes of GW pulp/d and that of the two PGW grinders on line 2 is 170 tonnes of pulp/a. The total annual production capacity is 150,000 t/a. In 1995 the production of mechanical pulp was 142,600 tonnes. 78% of the mechanical pulp was peroxide bleached.

The production capacity of paper line 1 is 250,000 tonnes of paper/a (700 t/d) and the basis weight is 60-80 g/m² (single coated) and 75-100 g/m² (double coated). The production capacity of line 2 is 240,000 tonnes of paper/a (675 t/d) in the grammage range of 35-70 g/m² (single coated paper grades). In 1995 the total production was 466,000 tonnes of paper.

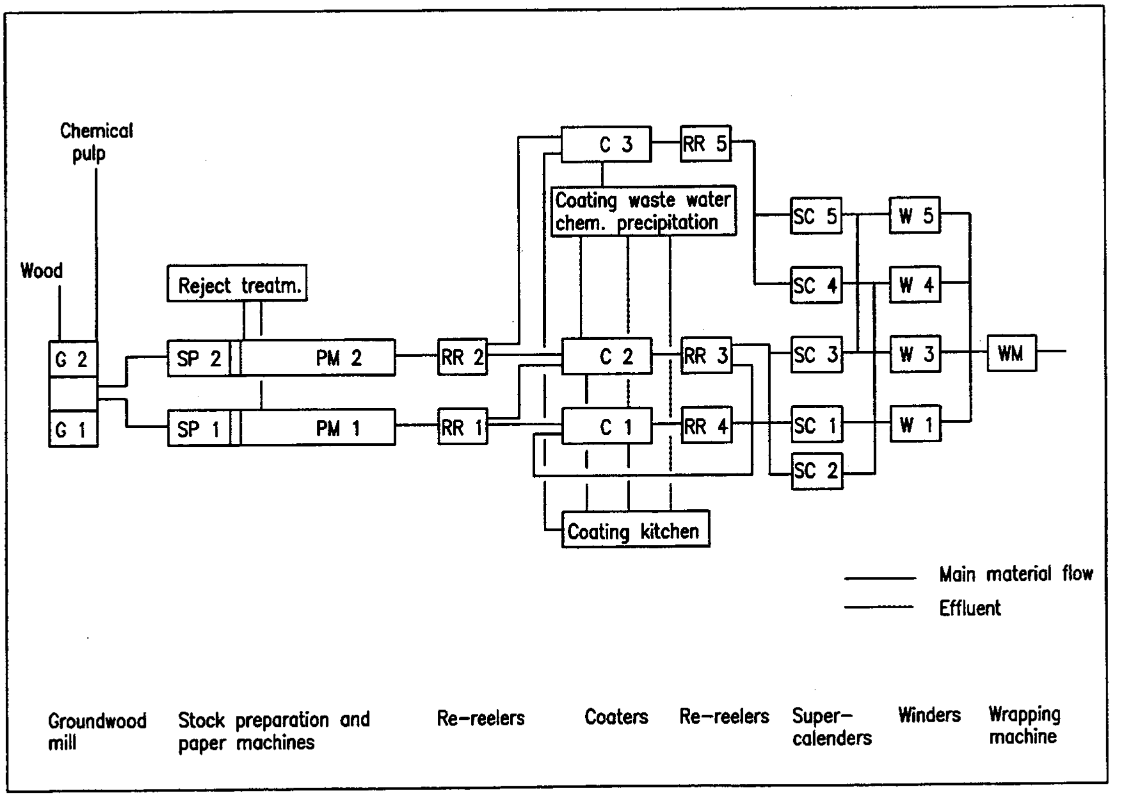


Figure 4.6.2 Principal flow diagram of the paper mill.

The production process of the base paper can be divided into stock preparation and paper production. The stock preparation consists of thickening, consistency adjustment, refining, screening, proportioning and fibre recovery. In the paper production the main process steps are stock dilution, centri-cleaning, screening, dosage of additives, web formation, dewatering in the wire section, pressing, drying, calendering and reeling. Before coating, the base paper reels are trimmed and re-reeled.

Softwood pulp is pumped from the kraft pulp mill at a 1% consistency, thickened and stored in a storage tank at a consistency of about 10%. The chemical pulp is refined in the stock preparation plant.

The production of base paper was about 375,000 tonnes in 1995. The consumption data is given in table 4.6.1. Most of the inorganic material in the paper furnish is coating pigment.

The total fibre loss is about 1.6% and the loss of coating pigment is about 3.7% in the paper mill (see table 4.6.8 Solid waste in 1995).

About 50% of the total electrical energy consumed is used in the groundwood mill, two-thirds of which again are consumed in the grinders. About one-third is consumed in the paper machine and the remaining 17% is consumed in the paper coating and finishing. About 75% of the steam is consumed in the paper machine and 15% in the coating. Natural gas is also used for drying the coated paper.

Table 4.6.1 Specific consumptions in the paper mill (per tonne of paper) in 1995.
The figures are annual averages in 1995. The specific consumptions vary between different paper grades (grammage 35-100 g/m^2, single and double coated paper).

		Line 1	Line 2
Wood consumption in groundwood plant	m^3	0.725	0.775
Purchased mechanical pulp	ADt	0.030	0.035
Chemical pulp	ADt	0.275	0.300
Coating pigments	t (100%)	0.390	0.340
Electrical energy	MWh	1.36	1.45
Steam	GJ	6.0	5.3
Natural gas	GJ	0.63	0.85

The fresh water consumption was 28 m^3/t in 1995.

4.6.5 Energy production

The energy for the whole integrate (pulp and paper mill, sawmill and plywood mill) is produced in the recovery boiler, the boiler for burning malodorous gases, two bark-fired boilers and a natural gas-fired power station with a waste-heat boiler (CHP) (table 4.6.2). The bigger bark boiler is being rebuilt into a fluidized bed boiler and the electrostatic precipitator is being enlarged to make it possible to burn a larger amount of solid waste. 66% of the energy is produced from wood-based fuels (table 4.6.3).

Table 4.6.2 Steam boilers and turbines in energy production.

	Bark boiler 1	Bark boiler 2	Recovery boiler	Boiler for malodorous gases	Gas turbine combi boiler
Steam - effect , MW	110	62	390	6	35/77
Turbine, MW	24.5	4.5	77	-	29.4
Fuel	Wood residue, Bark, Sludge, Natural gas, (oil)	Wood residue, Sludge, Natural gas, (oil)	Black liquor, Natural gas	Malodorous gases, Methanol, Natural gas	Natural gas

Table 4.6.3 Fuel consumption in energy production in 1995.

Fuel	Fuel consumption	
	(TJ/a)	(%)
Kraft pulp mill		
Black liquor	7,266	50
Natural gas	1,719	12
Malodorous gases	38	<1
Methanol	73	<1
Bark boilers and combi power station		
Wood residue, bark etc.	2,202	15
Natural gas	3,129	21
Oil	107	<1
Tall oil	47	<1

The natural gas used in the kraft pulp mill is used as an auxiliary fuel in the lime kiln and the boiler for malodorous gases and at start-ups in the recovery boiler.

No heat energy is sold outside the integrate. The heat and electrical energy production and consumption of the whole integrate in 1995 is shown in the form of a Sankey diagram in figure 4.6.3.

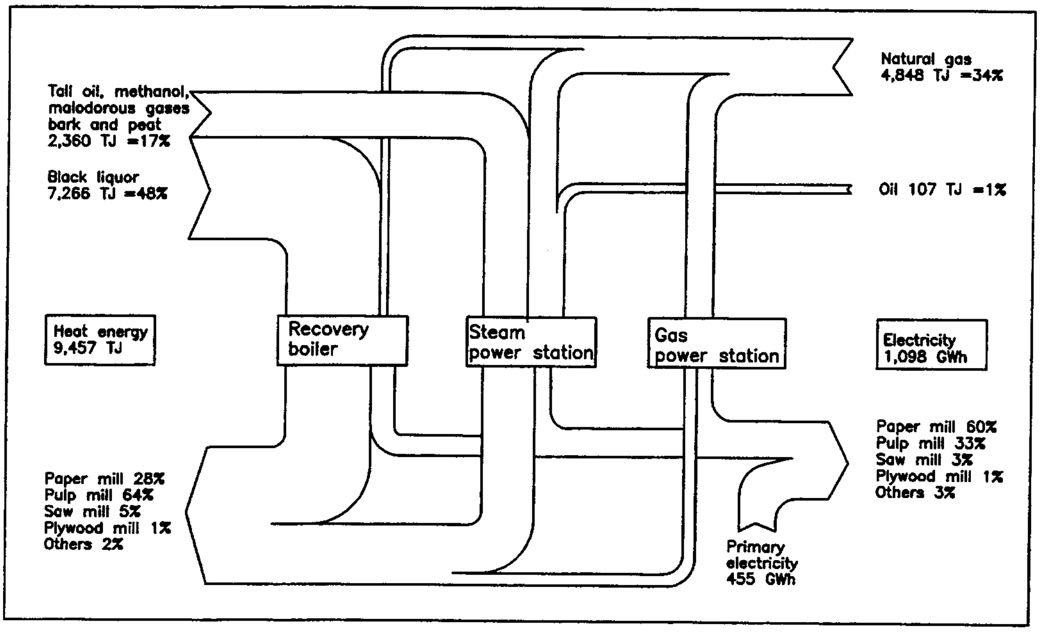


Figure 4.6.3 Heat and electrical energy balance for the integrate in 1995.

In 1995 the electrical power generation on site was 642 GWh, 385 Gwh of which was generated in the turbo-generator of the kraft pulp mill. Additionally, 455 GWh of electrical power needed by the paper mill was purchased (figure 4.6.3).

4.6.6 External treatment. Discharges and emissions into water and the air, solid waste.

Discharges into water

Kraft pulp mill

The waste water from the kraft pulp mill and clarified waste water from the debarking plants are treated in the activated sludge treatment plant together with waste water from the paper mill. Clean effluents (sealing and cooling water) from the kraft pulp mill, energy production and the paper mill are discharged directly into the recipient.

The waste water going for activated sludge treatment is neutralized before primary sedimentation. The concentration of suspended solids after primary sedimentation is 35 mg/l (annual average), giving an average reduction of 90%. The reduction of organic substances measured as BOD_7 and COD_{Cr} is not registered regularly.

After primary sedimentation, the waste water flows into an equalization pond. If there is an occasional discharge of waste water which differs in quality considerably from the normal situation, an emergency pond is available, from where water is pumped into the equalization pond. Nitrogen is added and the pH is adjusted before aeration in the activated sludge treatment. Normally, no phosphorus is added. The aeration pond in the activated sludge treatment plant is divided into three sections, in which the oxygen and sludge concentration can be controlled separately. The retention time in the aeration is approximately 24 h. In the secondary clarifier the biosludge is separated and returned to the aeration basin. The treated waste water is discharged into the recipient. The excess biosludge is thickened and mixed with the primary sludge and conditioned with polymers before dewatering in belt presses. The mixed sludge is burnt in the bark boilers or transported to a landfill site.

The total effluent streams are shown in table 4.6.4. The reduction rate (annual average in 1995) of organic substances and nutrients in the activated sludge treatment plant is shown in table 4.6.5 together with the total discharges from the kraft pulp mill and the total discharge from the integrate into the receiving water. The specific discharges are shown in table 4.6.6.

Table 4.6.4 Total effluents into the recipient from the integrate were as follows (annual average).

Sewer no.	Effluent	Flow (m^3/d)
1	from the activated sludge treatment	122,400
2	clean effluents (cooling water etc.)	101,000
3	condensates from energy production	15,000

Table 4.6.5 Total discharges into the receiving water and reduction rates in the activated sludge treatment plant in 1995.

Discharge into the recipient Discharge point/source	TSS (t/d)	BOD_7 (t/d)	COD_{Cr} (t/d)	Tot-P (kg/d)	Tot-N (kg/d)	AOX (t/d)
Total discharge	2.9	1.5	40.4	22.5	355	0.4
Discharge point						
Activated sludge treatment	1.7	0.7	36.0	17	255	0.4
Other sewers	1.2	0.8	4.4	5	100	
Discharge source						
Kraft pulp mill [1)]	2.4	1.4	34.1	21	290	0.4
Paper mill	0.5	0.1	6.3	1	65	-
Reduction rate (%) - Activated sludge treatment total	96	99	78	85	40	66

[1)] The pollution load in "other sewers" is included in the load from the kraft pulp mill.

The allocation for the kraft pulp mill and paper mill of the load from the activated sludge treatment plant is based on the measurement of the incoming waste water and the reduction rates in the treatment plant.

Table 4.6.6 Specific discharges from the kraft pulp mill and the paper mill into the recipient in 1995.

	Process effluent (m3/ADt)	TSS (kg/ADt)	BOD7 (kg/ADt)	CODCr (kg/ADt)	Tot-P (g/ADt)	Tot-N (g/ADt	AOX kg/ADt)
Kraft pulp mill	73	1.9	1.1	27.0	17	230	0.32
Paper mill	21	0.4	0.1	4.9	1	50	-

The annual operating cost for the activated sludge treatment is about FIM 8 million, including energy, chemicals, operating and maintenance costs.

Paper mill

The main effluent from the paper mill consists of the clear filtrate from the paper machines. In addition, there are leakages, filtrate from the reject handling and waste water from the chemical treatment of coating-containing effluents.

All the process waste water is treated in the activated sludge treatment plant.

The reject flows from the centri-cleaners in the paper mill are collected into a two-line reject handling plant, where the suspended solids are separated in a screen, further dewatered on a belt press and transported to a landfill site. The filtrate from the screen is returned to the paper machine and the filtrate from the belt press is led to the activated sludge treatment plant.

Waste water from the paper coating and coating kitchen area is collected and treated in a chemical treatment plant with lamella clarifiers. Alum and a polymer are used as flocculation agents. The clarified water is further treated in the activated sludge treatment plant, and the separated sludge is dewatered in centrifuges and transported to a landfill site.

The discharges from the paper mill are shown in tables 4.6.5 and 4.6.6.

Emissions into the air

In the kraft pulp mill strong malodorous gases are collected from the cooking plant (condenser, turpentine decanter), evaporation plant and the methanol and turpentine handling. Methanol is separated from the foul condensates and burnt in the lime kiln. The malodorous gases are burnt in a separate burner. The flue gases from the burner have a high concentration of SO_2. The sulphur is recovered in a washer as sodium bisulphite. The bisulphite generated replaces the SO_2-water used for washing the bleaching plant vents and for acidification of the bleached pulp.

Weak malodorous gases are collected from tanks in the evaporation plant. The weak malodorous gases are burnt in the burner for malodorous gases.

The vent gases from the smelt dissolver are treated in a separate scrubber.

The recovery boiler is equipped with an electrostatic precipitator (four parallel) followed by a scrubber. The flue gases from the lime kilns are treated in scrubbers.

The main polluting emissions into the air caused by the manufacture of paper come from the production of the energy needed by the paper mill. The bark boilers are equipped with electrostatic precipitators and scrubbers to reduce emissions.

The total specific emission of sulphur (SO_2 + TRS) from the kraft pulp mill was 0.95 kg S/ADt of pulp (0.4 kg S/ADt from measured point sources and 0.55 kg S/ADt diffuse emissions) and for the paper mill (= energy production) 0.01 kg S/ tonne of paper. The amount of diffuse emissions is based on a sulphur balance calculation, which is based on an analysis of sulphur in the incoming raw material and sulphur in flows going into water and for landfill, in products and in measured emissions into the air. The difference between these measured incoming and outgoing quantities is defined as "diffuse emission into the air".

The specific emission of NO_x from the kraft pulp mill was 2 kg NO_2/ADt and the emission of dust 0.5 kg/ADt. The NOx emission from the energy production at the paper mill was 1 kg NO_2/tonne of paper.

The concentrations of TRS, SO_2 and NO_x in the flue gas from the recovery boiler are measured continuously.

Solid waste

Wood waste is utilized for energy production in the bark boiler (151,670 tonnes in 1995, calculated as dry matter), and rejects from the groundwood plant are fed into the sawdust digester in the kraft pulp mill. Mixed sludge from the activated sludge treatment is burnt in the bark boilers. The rest of the sludge and the centricleaner rejects from the paper mill are transported to a landfill site. The ashes from the bark boilers and the chemical sludge from the treatment of coating-containing waste water in the paper mill are also transported to a landfill site.

The solid-waste quantities transported to a landfill site in 1995 are shown in table 4.6.7.

Table 4.6.7 Solid waste going for landfill from the pulp and paper mill in 1995 (dry matter).

	Solid waste (t)
Ashes	4,230
Recaustisizing dregs	15,330
Rejects, fibre sludges	8,430
Waste water treatment sludges	22,550
Other solid waste	35,715

4.6.7 Modernization of the kraft pulp mill

The kraft pulp mill is being modernized, and it is planned that the new departments will come into operation at the end of 1996. The new departments are shown in Figure 4.6.4.

The new softwood pulp line (1,160 ADt/d) includes eight batch digesters, two DD-washers, two-stage oxygen delignification and ECF/TCF bleaching with DD washers and a washing press. Before bleaching, the pulp can be acid-washed or treated with chelating agents to remove heavy metals in order to avoid peroxide degradation in the bleaching. One drying machine (DM2) is being replaced by a new drying machine (DM4). Oxygen will be generated on site.

The recovery line is being modernized with a new causticizing plant and a new lime kiln, and the efficiency of the evaporation plant is being increased. The collection system of malodorous gases is being enlarged to include strong gases from the new cooking plant and weak gases from the cooking plants, washing and screening plant and the causticizing plant. The strong gases will be burnt in the existing burner for malodorous gases, and the weak gases will be burnt in the new lime kiln, in the recovery boiler and in the burner for malodorous gases.

With the new system for monitoring emissions into the air, NO_x, SO_2 and TRS are measured continuously in the flue gases from the lime kiln, the recovery boiler and the burner for malodorous gases. Furthermore, dust is also measured continuously in the flue gases from the lime kiln and the recovery boiler. The new lime kiln is equipped with two electrostatic precipitators.

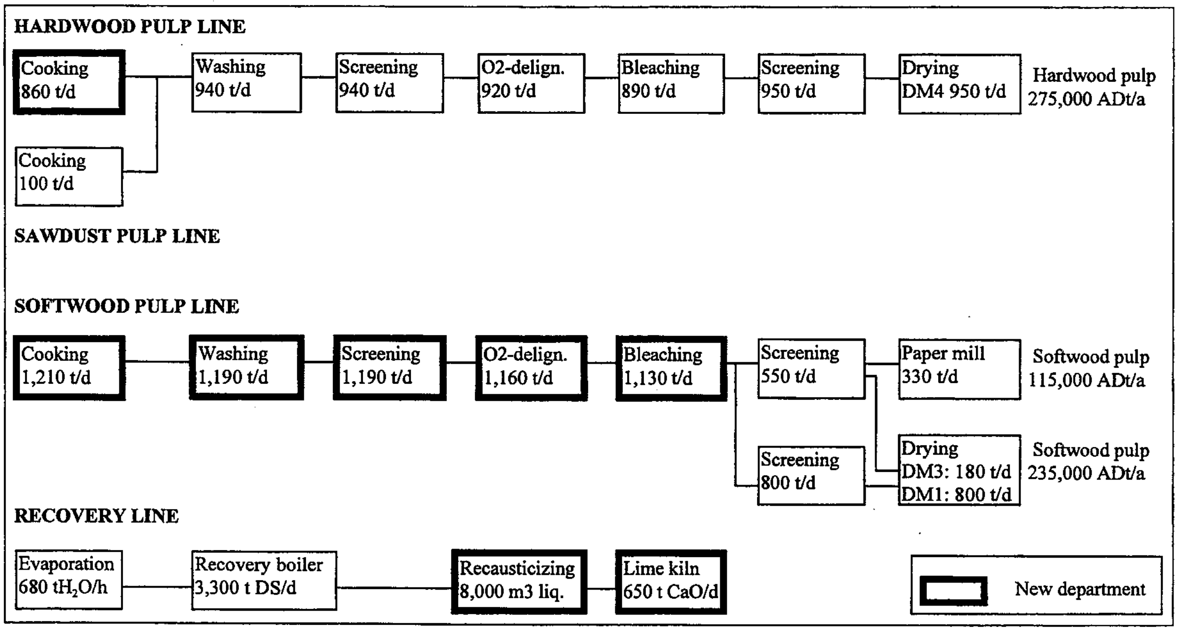


Figure 4.6.4 Block diagram of the modernization of the kraft pulp mill

The process water consumption is expected to decrease from about 80 m³/ADt to 30-40 m³/ADt because of an estimated reduction in the fresh water needed in the softwood bleaching from 60 m³/ADt to 8-12 m³/ADt (ECF) and 8 m³/ADt (TCF). The estimated changes in the discharge into the recipient are shown in table 4.6.8.

Table 4.6.8 Discharges 1995 and estimated discharges from the new kraft pulp mill.

	Unit	Discharge 1995	Estimated discharge 1997
Discharges into water			
TSS	kg/ADt	1.9	1.9
BOD_7	kg/ADt	1.1	0.3-0.5
COD_{Cr}	kg/ADt	27	10-15
AOX	kg/ADt	0.3	0.1-0.15
Tot-P	g/ADt	17	10
Tot-N	g/ADt	230	200
Process water	m³/ADt	73	30-40
Emissions into air			
Tot-S	kg S/ADt	0.95	0.7
NO_x	kg NO_2/ADt	2.0	2.5
Dust	kg/ADt	0.5	0.3

4.6.8 Discharge monitoring and analysis

The sewers to be monitored, sampling methods, analyzing frequencies and analytical methods to be used are defined in the statutory monitoring programme for discharges into water. The monitoring is performed by the mill's own laboratory. The monitoring of emissions into the air is defined in the permit for emissions into the air. The emissions of SO_2, TRS, NOx and dust from the emission point sources are monitored manually once a year by the R&D laboratory. The monitoring period for every point source is about one week. The mill is obligated to measure the emissions continuously when the modernized mill has come into operation. The monitoring programme and the analytical methods are shown in table 4.6.9.

Table 4.6.9 Statutory monitoring of discharges into the watercourse.

	Unit	Analysing frequency			Analytical method
		Sewer 1*)	Sewer 2*)	Sewer 3*)	
Flow	m^3/d	continuous	1/day	continuous	
pH		1/day	1/month	1/week	
Temperature	ºC	1/day	1/month	1/week	
Conductivity	mS/m	1/day	-	-	
Susp. solids	mg/l	1/day	1/month	1/week	SFS 3037 **)
Sodium	mg/l	1/day	1/month	1/week	
BOD_7	mg O2/l	1/week	1/month	1/week	SFS 3019
COD_{Cr}	mg O2/l	1/day	1/month	1/week	SFS 5504
Tot-P	mg/l	1/week	1/week	1/week	SFS 3026
Tot-N	mg/l	1/week	1/week	1/week	SFS 5505
AOX	mg Cl/l	1/week	-	-	SCAN W9:89 or corr.

*) see page 123, **) filter 12 μm

Costs

5

This section discusses the costs of updating the process technology to achieve resource savings and reduced environmental impact.

The financial impact of different process techniques depends on the capital investment required and on the operating cost. The operating cost depends on e.g. the total costs of chemicals, energy, personnel, wood raw material and maintenance. A very important factor that affects the financial situation is the quality requirements of the final product.

5.1 Investment costs

The total investment costs for implementing a new process technique at an existing mill is very much dependent on how the new process section fits into the existing process configuration. Modernization in one process department may create the need for process modifications in other departments. In a totally new mill all the sections of the process are planned to give sufficient quality and with optimal financial results.

Table 5.1.1 gives a summary of the investment costs for different process measures that have been discussed in chapter 3.3. The large ranges for the investment costs are due to variations in the configurations of existing mills and the need for additional modifications to the process.

5.2 Operating costs

The operating costs depend on the process configuration as a whole, on the properties and quality of the final product and, naturally, on how efficiently the process is operated. The application of a new technique/piece of equipment at an existing mill incurs installation and operation costs, but these costs may be recouped through savings (e.g. reduced raw material consumption, reduced waste generation, increased energy generation).

Because of the many factors that affect the operating costs, and the large differences in these factors between mills, a more accurate picture of the impact is obtained by calculating the costs and the savings on a case-by-case basis than if the costs are generalized. Only in this way can special situations (e.g. limiting factors like bottlenecks in the process) that may have a dramatic impact on the operating costs be considered. An overall calculation of the material and energy balance of the process/the mill in the new situation is the basis for calculating the costs accurately.

Table 5.1.1 Investment costs for different process measures for a kraft pulp mill
(production capacity 300,000 ADt/a, one-line mill).

	Investment costs (FIM million)
Dry debarking and modern chip-handling	
- a new complete plant	180-190
- modernization of existing plant	30-90
Extended cooking (batch / continuous)	
- a new complete plant (batch - cont.)	230-300
- modification of existing conventional plant to extended cooking (cont. - batch)	80-200
Brown stock washing	
- a new complete washing plant	80-140
- additional washing stage in existing washing plant	20-60
- CO2-washing	0.1
Oxygen delignification before bleaching	
- 1-stage delignification	80-90
- 2-stage delignification	90-100
Enzyme treatment	0.5-1
Bleaching	
- a new complete TCF bleaching plant (with peroxide - with ozone stage)	220-300
- additional bleaching stage	
- chelating stage	35-55
- pressurised EOP-stage	50-60
- ozone stage	70-90
Evaporation of BL	
- a new complete plant	100-120
- additional high-density concentrator	20
Handling system for malodorous gases	
- strong gases	25-35
-weak gases	15-20

6 A new kraft pulp mill

This section describes a newly built kraft pulp mill applying the most recent technologies to produce pulp with high-quality properties for a specific end use of the pulp.

6.1 General

The new kraft pulp mill producing totally chlorine free pulp (TCF) started up in March 1996. The production capacity is 500,000 tonnes of bleached softwood pulp (to be 600,000 tonnes by the end of the 1990's). It is the largest one-line mill in Finland. The consumption of wood will be about 3 million m^3/a (80% pine, 20% spruce).

The mill is situated adjacent to a paper mill, which currently produces 670,000 tonnes of SC and LWC paper. A new LWC machine is scheduled to start up in 1998.

The main product of the kraft pulp mill is bleached TCF softwood reinforcement pulp, which is used in the manufacture of wood-containing printing papers. The mill will also produce TCF pulp bleached to a higher brightness for use in the manufacture of woodfree fine papers.

The goal is to close the mill's water cycles gradually by using bleaching filtrates in pulp washing, which will result in a considerable reduction in effluents from the mill and in the consumption of fresh water. The kraft pulp mill has a closed cooling water system because the availability of fresh water is limited, and it is the first kraft pulp mill in Finland to apply cooling tower technology.

High efficiency, not only in energy generation but also in the use of energy, has been one of the main rules in the design work. The pulp mill's energy surplus is sold to the paper mill.

Part of the pulp production and the whole energy system are integrated with the existing paper mill. The two mills utilize a joint raw water supply and a new chemical raw water purification and desalination plant. The existing activated sludge treatment was expanded at the beginning of the 1990´s to treat the waste water from both mills.

Up to 40% of the pulp production will be dewatered to a dryness of about 30% and transferred to the paper mill. The rest of the pulp production will be dewatered, dried in an airborne pulp dryer and transported to other paper mills in Finland or sold as market pulp in Europe.

The paper mill is erecting a new fluidized bed power boiler in order to be able to burn the growing amount of biofuel available at the two mills. The backpressure power plant will generate power for mechanical pulping and steam for the paper machines at the paper mill as well as hot water for municipal district heating.

6.2 Process description

A block diagram of the kraft pulp mill is shown in figure 6.2.1.

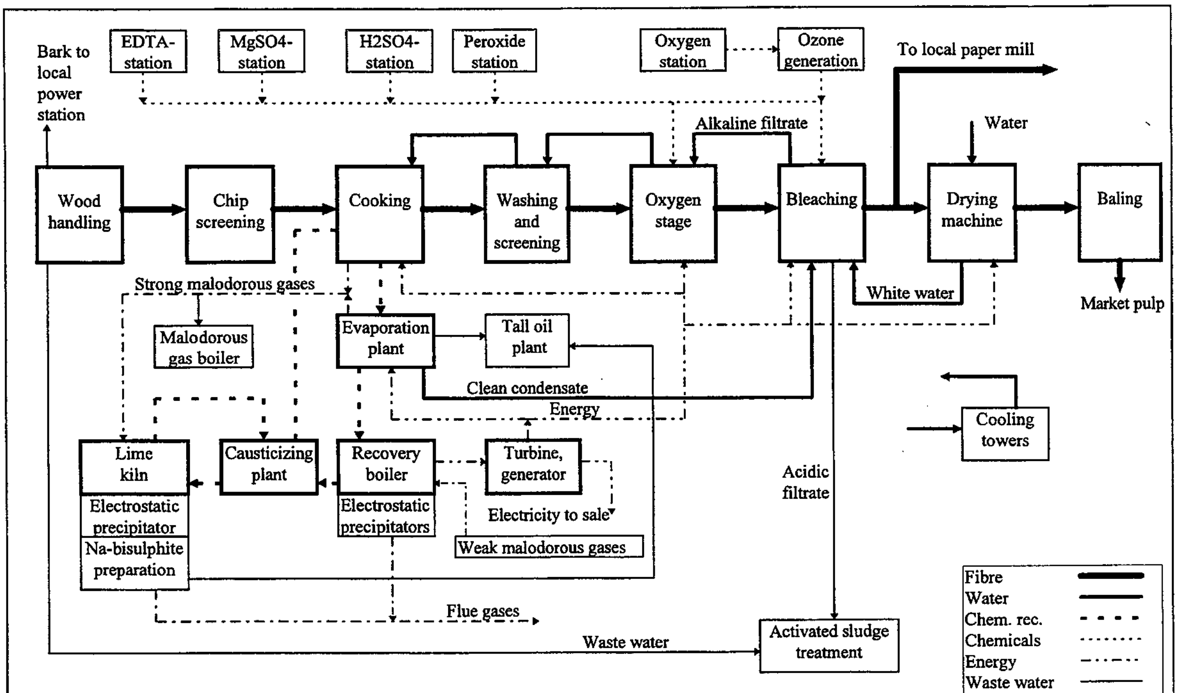


Figure 6.2.1 Block diagram of the kraft pulp mill

Both the kraft pulp mill and the paper mill are committed to decreasing their nominal water consumption. The starting level for the kraft pulp mill is 15 m^3 of fresh water per tonne of bleached pulp. The aim is to reduce the water consumption to 5-10 m^3/tonne of pulp by the end of the 1990's.

The fresh water consumption has been minimized and water is recycled wherever possible, starting with dry debarking in two drums. The bark is dried by pressing, shredded and utilized as biofuel.

The mill is designed to receive wood both as logs and as sawmill chips. The chippers, screening and reclaiming of chips are designed to produce uniform chips from batch to batch. Uniform chips reduce the need for chemicals and the cooking and bleaching conditions can be kept more stable. This helps to maintain fibre strength. Screening rejects, sawdust and large pieces of wood are removed and used as biofuel. No water is used in the chip handling.

The cooking plant consists of ten batch digesters. The cooking process is of SuperBatch type. After chip filling, the chips are impregnated with black liquor. The organic substances dissolved in the cooking liquor are displaced from the digester with washing-plant filtrate, and the hot liquor is led to the black liquor accumulators. The pulp is pumped into the discharge tank. Hot liquor from the accumulators is utilized in the next cooking and for white liquor heating. Finally, the black liquor is cooled to below 100° C before it is pumped to the evaporation plant. The heat exchangers supply most of the hot water required in the mill.

Delignification in cooking is extended (Kappa ~20) to meet the requirements of TCF-bleaching. The well-performed impregnation of the chips guarantees a low Kappa variation and low shive content in the brown stock. Because chips are cooled to below boiling point before being pumped from the digester to the discharge tank, the fibres are not damaged, the flashing of hot liquors is minimized and the liberation of malodorous gases is under control.

The washed and screened pulp is oxygen-delignified in two stages to a Kappa of < 10 and bleached. Only oxygen chemicals are used as bleaching chemicals (oxygen, hydrogen peroxide and ozone). Chelating agents and an acid wash are used in the bleaching to remove metals and prevent the hydrogen peroxide from decomposing. The alkaline bleaching filtrates are led counter-current towards the brown stock washing. Acid filtrate cannot yet be recovered because of the metal content and is discharged into the effluent treatment. The bleaching is totally based on the medium- consistency technique. The pulp is bleached to between 85 and over 88% ISO brightness.

The weak black liquor from the cooking plant is evaporated in a seven-effect evaporation plant and concentrated to a dry-solids content of over 80%. The high dry-solids content facilitates the control of the combustion in the recovery boiler and keeps the emissions of SO_2 very low.

The nominal capacity of the recovery boiler is 3,000 tonnes of dry solids per day and the steam capacity is 120 kg/s.

Three parallel three-field electrostatic precipitators separate the fly ash from the flue gases prior to venting into the air via the central stack (120 m).

The recovery boiler operates at an elevated pressure and temperature compared with conventional recovery boilers. The pressure has been elevated to 90 bars and the temperature of the superheated steam to 490° C. The high pressure maximizes energy efficiency in the generation of power.

The turbine generator (92 MW installed) generates excess power compared with the electrical power consumed at the pulp mill. The surplus is estimated to be in the range of 50% of the total generation. The major part of the back-pressure steam is used in the process and the rest is sold to the paper mill.

The smelt from the recovery boiler is dissolved and pumped into the causticizing plant. The vent gases from the smelt dissolver are treated by alkaline washing.

The causticizing plant is conventional, but the plant layout allows for changes to the process. The lime mud is dried from 80% to 100% dryness before being burnt.

Part of the sulphur in the fuel and malodorous gases that are burnt in the lime kiln is bound in the lime, whereas the rest is recovered from the flue gases in the alkaline scrubber following the electrostatic precipitator.

Soap dissolved from the wood is separated from the black liquor at the top of the impregnation liquor tank and from the evaporation liquor tanks. The soap is refined in the tall oil plant.

The pulp mill has a very comprehensive recovery system for malodorous gases. All the equipment and tanks which could possibly release malodorous gases in the cooking, brown-stock washing, evaporation and causticizing are connected to the system. All strong and weak malodorous gases are burnt. Weak gases are treated in direct contact scrubbers and burnt in the recovery boiler as tertiary combustion air. The strong malodorous gases from cooking and evaporation are normally burnt in the lime kiln. The combustible malodorous gases replace part of the fuel oil, reducing the consumption of fossil fuels. In the situation when the lime kiln is not in use there is a separate furnace equipped with a separate boiler. In the case of a breakdown in the operation of the recovery boiler, weak malodorous gases are washed with alkaline washing liquor before being emitted into the air via the central stack.

The old treatment plant for fresh water at the adjacent paper mill has been rebuilt for both capacity and quality reasons. The new process is based on two-stage flocculation with ferrisulphate and oxidizing treatment before final sand filtration.

When the consumption of fresh water is being decreased at a pulp mill, it is essential to utilize the condensates from the evaporation of the black liquor. Clean and foul condensates are collected separately. Foul condensates are purified by stripping. Both condensates are used as wash water. An advantage in using condensates in TCF bleaching is the absence of metals, although they contain volatile organic substances. The proportion of clean condensates is high in the pulp mill due to internal stripping and distillation in the evaporation units.

It is essential that secondary energy is utilized in the consumption of both energy and fresh water. The secondary condensate from the stripper is used instead of warm water in the fibre line and in the causticizing plant. Warm water is used only in places where the water needs to be especially clean. The hot water produced in the process is used not only to heat the process but also to heat the buildings in the winter.

Cooling and heating water is collected into a common network and cooled in a cooling tower. The cooling tower supplies cold water for the mill. The additional cold water is received from the paper mill's water plant.

The estimated total heat consumption by the pulp mill is below 11 GJ/tonne of pulp produced. The power consumption is estimated at 600 kWh/t .

The new circulating fluidized bed boiler at the paper mill (start-up in the summer of 1996) will use bark and wood residues from the pulp mill and the paper mill, biosludge and, additionally, peat and coal when required. The steam will be used in the paper mill.

The total investment cost of the kraft pulp mill was FIM 2.5 billion .

6.3 External treatment

The pulp mill effluents are treated in an activated sludge treatment plant together with the effluents from the paper mill. The treatment plant consists of a primary clarifier, activated sludge treatment, a secondary clarifier and sludge treatment.

Excess biosludge is thickened in decanting tanks, mixed with primary sludge and dried with screw presses to a dry-solids content of over 40%. The dewatered sludge is burnt together with bark and other biofuels in a fluidized bed boiler at the paper mill and later on in the new circulating bed boiler at present being constructed for generating energy for the paper mill.

7

Discussion

Finland is a country distinguished by its remote location, sparse population and vast forests. A shortage of other basic raw materials early on focussed the industrial effort on wood-based products. The relative remoteness of continental industrial centres and their supply of machinery encouraged the rapidly evolving Finnish chemical forest (pulp, paper and board) industry to establish its own machine shops. Later a diverse chemical and electronics industry supplying the pulp and paper industry with agents, additives, components and control systems sprang up. Today these support industries are global players, supplying the international pulp and paper industry worldwide. Together with the basic forest industry they form the heart of the Finnish industrial complex.

The importance of the forest industry for the development of the country makes its only natural that Finland has been a forerunner in forging international agreements that secure the well-being of the forests and the natural surroundings in general by adherence to sound environmental protection practices. Consequently, all Finnish pulp and paper companies have signed the ICC accord on the principles for sustainable development, and they adhere to these principles in their everyday operations.

Forewarned by the devastating results of the uncontrolled logging practices during the peak of the wood tar and charcoal production era, the authorities and the forest owners realised that controlled and systematic forestry principles had to be applied to secure the long-term supply of the raw material. Early legislation regulates cutting rights and lays down the responsibility for regenerating harvested forests. The Finnish forests, over sixty per cent of which are owned by relatively small private owners, are being managed by a web of voluntary forest associations. These associations promote members' rights and maintain a comprehensive training programme. It has, therefore, been easy to implement new forestry practices like biodiversity and landscape protection as they have emerged from new knowledge gained and society's requests for a wide range of uses for the forests. These new practices have also met with success. It should be remembered that in Finland "every man's right" to move freely about in the forest and collect berries and mushrooms has been acknowledged since ancient times. Thanks to the early protective measures and the progressive forestry principles, there is today more wood in the Finnish forests than before the establishment of the pulp and paper industry.

Despite challenging adverse economic factors like generally small population centres and the long distances between them, the collection of waste paper and board and the reuse of recycled fibre are at a high level in international terms in Finland.

Despite the low population density and the abundant availability of good-quality water, the Finnish pulp and paper industry has taken a very responsible stand on environmental issues. While doubling the production, the industry has been able to reduce the discharges of pollutants into water to one- tenth of the level thirty years ago and the emission of sulphur into the air to a mere fraction of the past. The present high standards of environmental protection have been reached through an intensive investment programme in improved processes and pollution abatement techniques.

All Finnish pulp and paper mills must have an environmental permit, specifying the limit on discharges and emissions into water and the air as well as the generation of solid waste. A fruitful dialogue between the authorities and the industry has led to a situation where Finnish industry has to meet limits that are often very tight but attainable within reasonable costs. In Finland there is a general striving towards a more holistic view on environmental protection issues in order to avoid the adverse situation where pollutants are transformed from one form into another or from one receiving body into another. Finland also adheres to the principles of full openness, standardized testing procedures and reporting practices. In Finland the compulsory discharge measurements performed by the mills are public knowledge. This allows for a fair comparison between the Finnish mills with regard to their environmental impact and the efficiency of their pollution abatement actions.

It is most unfortunate that there still is a lack of international standards for making environmental performance records public. The useful benchmarking of the industry's performance in different European countries could be based on them.

It appears that before the BAT Reference Document can be used for the European pulp and paper industry there has to be an agreement on the global harmonization of the procedures for sampling and testing pollutants as well as on how to report the results and the related operating conditions. Further, there has to be agreement or an understanding on how different geographical locations and climatic conditions affect factors like energy and water consumption.

In general, there is often a good correlation between efficiency, and especially resource-usage efficiency, and pollution abatement. Therefore, the industry has put in a lot of effort to bring down the specific usage of wood, additives, water and energy. The higher overall efficiency is a result of more functional products, improved processes and equipment, and new control and management schemes. As a consequence, pollution abatement is increasingly moving away from "end-of-the-pipe" solutions towards process internal solutions, such as energy recovery and reuse, and the closed loop operation of process water systems. It now, therefore, seems reasonable to suggest that in the establishment of a BAT Reference Document for the pulp and paper industry, more effort should go into specifying the sought-for result, and the industry should be left with sufficient freedom on how to reach these results.

Recently market forces in the form of consumers' awakened interest into the environmental impact of the production of the goods they use have proved to be a strong motivator for the industry to use sound production methods. With the increased use of Eco-labelling of products the authorities need to provide unbiased information to support the consumers in their buying decisions and execute supervision so that this market place-related positive motivator leads the development in a direction beneficial for all parties.

The special stature of the pulp and paper industry in Finland has attracted both good human resources and sufficient capital to support the extremely strong growth it has undergone during the last thirty years. In that time span the production capacity has more than doubled, the more competitive kraft (sulphate) process has entirely replaced the sulphite process in chemical pulping, thermomechanical pulping has overtaken groundwood in mechanical pulping, and paper and board manufacturing has moved from commodity to higher-value speciality grades. Today the Finnish pulp and paper industry is characterised by integrated production, large production units, specialized products, customized processes and top-class, modern equipment.

Integrated production facilitates a more complete usage of the different wood species as they grow in the forest. Likewise, the potential best usage of a tree for different products - lumber, plywood, pulp, paper or board - can be realized. Further, the part of the wood that does not end up in a product can be used for energy production. Actually, only the ash of the portion of the wood used for energy production, well below one-tenth of one per cent of the original weight of the wood, needs to be disposed of. The ash can be brought back to the forest as fertilizer or used for soil binding purposes. In the integrated production of pulp and paper the water usage can be more efficient than in two separate installations, and naturally there will be a significant reduction in the cost of waste water treatment installations. In the most usual cases excess process water in the paper or board manufacturing can be brought back and reused in the pulp making. Even greater is the synergy in relation to reduced energy usage. The excess heat and power generated in the kraft mill is used advantageously in the paper or board mill as is the heat in the process steam recovered in the TMP plant. In the integrated production plants the use of back-pressure generation, which is so typical of the Finnish forest industry, provides great savings.

The significance of the size of the production units basically lies in reduced capital and operating costs per unit of product. Though the cost of the main process machinery need not be lower, the cost of auxiliary equipment and support processes such as pollution abatement facilities is reduced. From the simple fact that the larger units in most cases are also more modern, it follows that the larger production units are more efficient when it comes to both productivity and resource usage. The inherent value of the large production units is further enhanced with the on-going mergers of the forest industry companies into larger corporations. The larger companies can better implement marketing and sales efforts that will facilitate long, continuous, single grade runs on the large paper and board machines, which will greatly enhance the overall efficiency.

The move towards more specialized products has been compulsory in order to offset adverse competitive factors like distance to the market and the lack of sufficient domestic energy resources. The Finnish industry's switch from being a major supplier of market chemical pulp to a supplier of mainly paper and board has been a remarkable change. In addition, the remaining shipments of kraft and mechanical pulps represent products with properties tailored for specific end uses. The rapid development of new specialized products is the result of the advanced academic training programme in pulp and paper making in Finland and extensive research taking place in the industry's own central Finnish Pulp And Paper Research Institute facilities, universities, suppliers' pilot plants and, to a major degree, also at the mills. The new products better fulfil the end users' requirements, and this while fewer resources, with the exception of power consumption in some grades, have been used in the manufacturing stage.

The higher power consumption is a consequence of the extensive use of TMP pulping in the Finnish paper industry. The high power consumption is offset by the reuse of the heat in the process steam efficiently recovered in the TMP plant and the better raw material efficiency stemming from the reduced use of chemical pulp in the printing paper and board grades in question. It is remarkable that both pressurised grinding, PGW, and high-pressure refiner pulping, TMP, were developed in Finland with its abundance of forest, when the main goal has been to reduce the use of chemical pulp.

Meanwhile, there have also been great improvements in the field of chemical pulping in Finland. Within kraft pulping the batch cooking technology has been revitalised to yield a process with superior heat economy and producing a long-fibre pulp with unique strength properties. New bleaching sequences have been developed so that in the most modern kraft mill the discharge of process water from the bleaching plant is only 5 m^3/tonne of pulp. Similar spectacular developments in the chemical-recovery cycle include increasing the dry matter of the black liquor to be fired in the recovery boiler to over eighty per cent. This has further improved the favourable energy balance of modern kraft mills and all but eliminated the emission of sulphur compounds from the recovery boiler into the air. The collection of malodorous gases has in several mills been taken so far that the remaining occasional small outbursts are no longer considered harmful to the environment.

One other customized process is the use of back-pressure turbines for the generation of power. The process takes advantages of the need for low-pressure steam in the drying of pulp, paper and board. Lumber and plywood drying are also frequently hooked up to the same steam supply as well as the district heating system of some nearby municipality.

In the field of pollution abatement the activated sludge technology for the treatment of discharged process waters has been refined to the point where the BOD removal efficiency is extremely high and also the removal of phosphorus and nitrogen is significant. Lately, new technologies such as membrane filtration and vacuum evaporation have come into use in the internal purification of process waters, bringing the concept of closed loop operation one step nearer.

The equipment used in the wood room has lately undergone a very rapid development. Today the wood room can be operated without the discharge of process water by using the dry debarking process. The quality of the chips and, even more important, the consistency of the quality has greatly improved the stability and efficiency of the downstream processes.

In the different washing operations in the pulp mill more efficient wash presses and displacement washers have been introduced. This has reduced the specific consumption of water and increased the amount of dissolved solids and chemicals being captured for regeneration and energy production. The equipment facilitating the revolutionary change to the medium-consistency pumping of pulp slurries from the conventional low-consistency was developed by Finnish scientists. The new technology has reduced the amount of water being pumped around in certain pulp and paper mill departments, with a factor of four greatly reducing the energy consumption.

The Finnish electronics industry has developed advanced new sensors and control systems for the pulp and paper-making processes, which, in turn, have increased the overall efficiency.

To sum up, it can be said without exaggeration that the most specialized and modern sectors of the Finnish pulp, paper and board industry represent state-of-the-art knowledge and technology and can well serve as an example to others striving for efficiency and minimal environmental impact at their own mills.

Appendix I

Standard analytical methods

Waste water

	Standard methods	
	SFS	Corresponding method
TSS(GFA)	SFS 3037	
BOD_7	SFS 3019	SS 02 81 43 (1. ed.)
	SFS 5508	SS 02 81 43 (2. ed.)
COD_{Cr}	SFS 5504,	Dr Lange
	SFS 3020	SS 02 81 42
COD_{Mn}	SFS 3036	SS 02 81 18
Tot-P	SFS 3026	SS 02 81 27
Tot-N	SFS 5505	
AOX		SS 02 81 04, SCAN W9:89, DIN 38409

SFS Finnish Standards Association
SS Swedish standard

Emissions into the air

	Standard methods	
	SFS	Corresponding method
Dust	SFS 3866	
SO_2	SFS 5265	SS 02 84 21
TRS	SFS 5727	EPA nr 16A
NO_x		SS 02 84 25, ISO-CD 10849, EPA nr 7

Chlorine dioxide generation methods in use in Finland

	MATHIESON	R3	R3H	R5	R6	R7	R8	LURGI R6
Input chemicals ($t/t\ ClO_2$)								
$NaClO_2$	1.75	1.68	1.68	1.75		1.68	1.65	
NaCl		1.15				0.35	0.03	1.08
H_2SO_4	1.30	1.73	0.80			0.40	1.10	
HCl			0.70	1.40				
SO_2	0.75					0.40		
CH_3OH							0.15	
Cl_2					0.80			
El power (MWh)					8.50			
By products ($t/t\ ClO_2$)								
Na_2SO_4	1.20	2.30	1.20			1.60		
H_2SO_4	1.60							
$Na_3H(SO_4)_2$							1.30	
Cl_2	0.00	0.70	0.70	0.80	0.30	0.20		0.10
H_2					0.05			
NaCl				0.95				
NaOH								0.70

The chemical reactions for chlorine dioxide generation

Generation method		Chemical reaction
MATHIESON		$SO_2+2NaClO_3+H_2SO_4$ -> $2ClO_2+2NaHSO_4$
R3		$NaClO_3+NaCl+H_2SO_4$ -> $ClO_2+½Cl_2+ Na_2SO_4+H_2O$
R3H		$NaClO_3+HCl+½H_2SO_4$ -> $ClO_2+½Cl_2+½Na_2SO_4+H_2O$
R5		$NaClO_3+2HCl$ -> $ClO_2+½Cl_2+NaCl+H_20$
R6	**c)**	$NaClO_3+2HCl$ -> $NaCl+ClO_2+½Cl_2+H2O$
	a)	$NaCl+3H_2O$ -> $NaClO_3+3H_2$
R6-LURGI	**b)**	H_2+Cl_2 -> $2HCl$
R7		$NaClO_3+HCl+½H_2SO_4$ -> $ClO_2+½Cl_2+½Na_2SO_4+H_2O$
R8		$6NaClO_3+4H_2SO_4+CH_3OH$->$6ClO_2+2Na_3H(SO_4)_2+5H_2O+CO_2$

The Finnish pulp and paper mills 1995

(Finnish Forest Industries Federation)
a: number of lines, b: number of machines, c: annual production (1,000 t).

	Chemical pulp		Mechanical pulp		Paper		Board	
	a	c	a	c	b	c	b	c
A Ahlstrom Corporation								
Ahlstrom Alcore							1	47
Ahlstrom Kauttua					4	58		
Enso Group								
Anjalankoski Mills			2	420	3	425	1	152
Corenso/ Varkaus							1	64
Corenso/Pori							1	74
Heinola Mill			1	234			1	231
Imatra Mills	3	671			3	238	4	703
Kotka Mills	1	111	1	80	2	241		
Oulu Mills	1	325			1	250		
Summa Mills			2	339	3	412		
Varkaus Mills	1	181	2	270	4	480		
Veitsiluoto Mills	1	296	1	82	4	652		
Enocell Oy	2	479						
Kemijärven Sellu Oy	1	178						
Pankakoski Boards Oy			1	23			2	74
Tervakoski Oy					5	99		
Keräyskuitu Oy (recycled fibre)			1	60				
Metsä-Botnia OyAb								
Kaskinen Mill	1	394						
Kemi Mills	2	506					1	298
Metsä-Serla Oy								
Kangas Mill					2	121		
Kirkniemi Mills			2	117	2	329		
Kyro Mills			2	82	1	81	1	73
Lielahti Mill			1	106				
Tako Mills			1	61			3	158
Äänekoski Mills	1	455	1	32	1	112	1	97
Savon Sellu Oy			1	213			1	224
Serla Oy					5	106		
Myllykoski Paper Oy			1	220	4	479		
Nokian Paperi Oy					3	80		
Stromsdal Oy			1	19			1	40
Sunila Oy	2	319						
UPM-Kymmene Corporation								
Joutseno Pulp	1	316						
Jämsänkoski			2	392	4	704		
Kaipola				340	3	603		
Kajaani			2	419	3	498		
Kaukas, Lappeenranta Mills	2	462	2	143	2	466		
Kaukas, Voikka mills			1	245	4	454		
Kymi Paper Mills	2	507	1	20	5	561		
Lohjan Paperi					2	52		
Rauma Mills			2	325	3	684		
Simpele Mills			1	72	1	43	1	125
Tervasaari Mills	1	171			3	211		
Wisaforest	2	527			1	134		
Total production		5898		4314		8634		2359
Number of lines and average size	24	250	30	140	78	110	20	

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Sammandrag	Syftet med denna rapport är att informera kommissionen om de i miljövårdshänseende bästa tekniska lösningar som tagits i bruk i massa- och pappersindustrin i Finland. Rapporten är avsedd som bakgrundsmaterial för en rapport som kommissionen kommer att låta utarbeta som en del av informationsutväxlingen enligt artikel 16 i Europeiska gemenskapernas råds direktiv 96/61/EG om samordnade åtgärder för att förebygga och begränsa föroreningar. Rapporten innehåller en allmän beskrivning av massa- och pappersindustrin i Finland, produktionen, tekniken, utsläppen i vatten och luft samt avfallet, vidare förbrukningen av råvara och energi. Dessutom ingår i rapporten en övergripande granskning av miljövården i sex fabriker.
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The Finnish Environment

ENVIRONMENTAL PROTECTION

The Finnish Background Report for the EC Documentation of Best Available Techniques for Pulp and Paper Industry

The purpose of this report is to carry out the Finnish contribution to the exchange of information in the Council Directive 96/61/EC concerning Intergrated Pollution Prevention and Control, article 16, and to the preparation of the Reference Document of the European Commission on the Best Available Tehniques for Pulp and Paper Industry.

In the report, the manufacturing of pulp, paper and board grades which are most important for the Finnish pulp and paper industry are discussed taking into account production capasities, the used process technologies and their effects on the discharges and emissions, solid waste generation and consumption of raw material and energy.

The general description of Finnish pulp and paper industry is supplemented with more detailed descriptions of six Finnish pulp and paper mills representing different types of products and production set-ups. The process technology of a new kraft pulp mill which started in the spring of 1996 is also described.

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