MEDITERRANEAN

Pollution Prevention in the Paper Sector

CLEANER production

Regional Activity Centre for Cleaner Production (RAC/CP)
Mediterranean Action Plan

UNEP

MAP

Regional Activity Centre
for Cleaner Production

Ministry of the Environment
Spain

Government of Catalonia
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Please inform us if any point in the study can be improved or if any inaccuracy is found.

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0. EXECUTIVE SUMMARY

Although the paper industry has always been characterised by its involvement in many of the concepts related to sustainable development, a greater effort must still be made to reduce consumption of natural resources and environmental impact. The current challenge is to adopt the measures necessary to allow for sustainable development and to guarantee companies' competitiveness, and in particular the competitiveness of SMEs.

This Manual of Pollution Prevention in the Paper Sector aims to offer tools and decision-making criteria for the implementation of progressive environmental improvements in companies in the Mediterranean Action Plan countries to achieve cleaner production.

The objective of Cleaner Production is the continual application of a preventative environmental strategy integrated into processes, products and services in order to improve efficiency and reduce risks for people and the environment. This strategy includes the evaluation and gradual adoption of the best available techniques for minimising environmental pollution which are technically and economically viable, in accordance with the specific characteristics of each production process. This manual makes it clear that the adoption of pollution prevention solutions allow the reduced consumption of natural resources (raw materials, water, energy...), reduce waste flows and increase the efficiency of production processes, which is economically beneficial to the process and therefore also increases the competitiveness of industrial installations.

Given that the primary objective of Cleaner Production is the minimisation of emissions at source, the order of action is: prevent, reduce and reuse. However, the treatment of final emissions to minimise their environmental impact should also be considered in conjunction with this.

As outlined in chapter 3, the extent of these actions depends on current legislation in each country, as there are significant differences between countries, with the exception of countries in the European Union, all of which must comply with the Directive on Integrated Pollution Prevention and Control (IPPC).

The countries of the North and East of the Mediterranean currently produce 95% of total paper products in the Mediterranean Area and consume 90% of these products. The level of industrial development reached in the different Mediterranean Areas varies, with 10 countries in which paper consumption is below 50 kg/inhab/yr (The FAO Advisory Committee on Paper and Wood Products - ACPWP).

Chapter 4 provides a description of raw materials used and the main production processes. Following on from this, chapter 5 describes the main potential sources of pollution and also normal water and energy consumption for each type of process.

The main potential sources of air pollution are due to the generation of volatile organic compounds, malodorous compounds and particles in pulp production plants and of CO_2, NO_x, SO_x and particles in suspension in energy obtaining processes.

The generation of wastewater has decreased considerably in recent years due to the closure of water circuits. For example, the Northern Mediterranean countries have attained a reduction of 90% in the last 20 years. Internal treatment of wastewater prior to its reuse has been necessary to achieve this. The main pollutants in wastewater are organic and inorganic solids in suspension and dissolved solids. Following the discovery in the 1980s of the presence of dioxins in emissions from pulp production factories, bleaching processes have been changed and the use of elemental chlorine has been forbidden in the majority of Mediterranean Action Plan countries. The adoption of ECF and TCF bleaching has reduced the emission of halogenated compounds by more than 90% since 1990. In most cases, a primary and/or secondary treatment of the process water prior to its discharge is necessary to minimise environmental impact.

Waste generation is fundamentally a result of the energy production processes, process water treatment, the recovery of black liquor in Kraft pulp production plants and the pulp preparation stages in recovered paper plants.

Chapter 6 of this manual presents different options for the prevention of pollution at source. Due to the wide variety of alternatives and possible solutions, the proposals indicated in this chapter are not the only possibilities, but rather a selection that reflects the variety of existing techniques.

Chapter 6 has been divided into three broad sections, each of which contains a series of alternatives or techniques of similar characteristics:

Section 6.2 includes Alternatives for the prevention of pollution at source (APPS), the techniques of greatest technological relevance or complexity that require a detailed description. These are presented in the form of a data sheet.

For each APPS, the chapter outlines: The process in in which it is used, the key action on which it is based, the stage or operation of the process in which it is included, the associated environmental problems, the potential benefits, the description and procedure for its application, and the economic considerations.

The Alternatives for the Prevention of Pollution at Source (APPS) included in this manual are described below.

Alternatives for the prevention of pollution at source (APPS)

- Water recirculation
- Oxygen delignification
- ECF bleaching
- TCF bleaching
- Circuit closures in the bleaching plant
- Water clarification by dissolved air flotation
- Membrane clarification of water
- Optimum water management
- Purification by scrubbing of the gases from the recovery boiler
- Purification and reuse of the most contaminated condensates from the evaporation plant.
- Processing of gases from boilers and ovens with an electrostatic precipitator.
- Improvement in the preparation of pulp, decreasing energy consumption and emissions.
- Application of steam cogeneration and energy.
- Optimisation of dewatering in the pressing section of the paper machine.

In the following section, section 6.3, other alternative technologies to be considered are outlined. While these technologies do not need as detailed a description as those in the previous section, due to their technological simplicity, more theoretical character or specificity, they are also considered viable techniques for the prevention of pollution at source. The definition, applicability, environmental aspects and economic aspects of each alternative are given.

Other Technological Alternatives to Consider that are included in this manual are outlined below:

Other technological alternatives to consider

- Dry debarking.
- The use of storage tanks with sufficient volume to optimise water consumption.
- Control and recovery of leaks and spills.
- Screening of the unbleached pulp in a closed water circuit.
- Efficient washing.
- Extended modified cooking.
- Ozone bleaching.
- Closure of the water circuits with the biological processing of the wastewater integrated into the process.
- Reduction of the loss of fibres and mineral fillers in the paper machine.
- Recovery and recycling of coating products contained in wastewater.
- Independent treatment of wastewater from coating operations.
- Substitution of potentially harmful substances for less polluting alternatives.
- Control of emissions from the wood yard.
- Increased concentration of black liquors.
- Improvement in the washing of causticising sludges.
- The use of low sulphur fuel or renewable fuels.
- Minimisation of loss from rejects in mechanical pulp factories.
- Separate collection of non-fibrous materials.
- Updating of the design of the installations in order to reduce energy consumption.
- The use of energy-efficient technologies.
- Elimination of accidental or occasional discharge.
- Training, education and motivation of personnel.
- Optimisation of process control and efficient maintenance of installations.
- Environmental management.

Section 6.4. Emerging technological alternatives, some of the most innovative technologies designed with the objective of achieving Cleaner Production in the pulp and paper sector. The definition, applicability, environmental aspects and economic aspects of each alternative is included.

The Emerging Technological Alternatives included in this manual are outlined below:

Emerging technological alternatives

- New energy efficient TMP pulp processes.
- Closure of the water circuits with evaporation and incineration of concentrates.
- Removal of chelating agents.
- Use of the Selective Non Catalytic Reduction (SNCR) process.
- Membrane bioreactor.
- Recovery of ash and CO_2 from the boiler to reduce mineral fillers used for paper production.
- Diagnostic systems.

Chapter 7 outlines some of the Final Treatments for the Minimisation of Pollution (FTMP) that currently exist. Their objective is to reduce the quantity of waste emitted into the environment by the industry, and in some cases these are complementary to the Alternatives for the Prevention of Pollution at Source in order to achieve Cleaner Production.

Chapter 7.2 includes the FTMP, in the form of data sheets, which need a more detailed description due to their technological complexity or their field of application. These are:

Final treatments for the minimisation of pollution (FTMP)

- Biological processing of wastewater.
- Capture and processing of malodorous gases.
- Installation of low NO_x burners.
- Reduction of external noise.
- Minimising of waste sent to landfill sites from mechanical pulp plants.
- On-site processing of waste and sludges (dewatering).
- Burning of de-inking sludge.

Section 7.3 includes Other Treatments for the Minimisation of Pollution (TMP) considered in this Manual, where the characteristics of these treatments allows a more simple description to be given than those included in section 7.2. For each of these TMP, the following is included: description, definition, applicability, environmental aspects and economic aspects.

The Treatments for the Minimisation of Pollution (TMP) considered in this Manual are as follows:

Other treatments for the minimisation of pollution (TMP) to be considered are:

- Primary processing of wastewater.
- Anaerobic processing as the first stage of aerobic processing.
- Tertiary processing of wastewater with chemical precipitation.
- Control of the potential disadvantages of closure of the water circuit in the paper machine.

Following this, in section 7.4, Technologically Emerging Final Treatments, the treatment of effluent using a combined process of ozonation and biofiltration is described, as an example of the technological evolution in the processing of wastewater.

Lastly, chapter 8 outlines a series of case studies with the objective of facilitating decision-making with respect to some specific treatments. A range of case studies have been taken, from very specific cases in which the advantages attained in a plant by the implementation of one of the alternatives suggested, to more general cases that show which are the most-used alternatives in a group of plants or that describe the different steps taken to achieve Cleaner Production.

The Bibliography section of this manual lists a series of publications, institutions and web pages that can provide the reader with information that is additional or complementary to the manual's content.

1. INTRODUCTION

In modern life, paper is a product that is indispensable, high quality, low cost, safe and recyclable, satisfying numerous necessities in the workplace, at home, in education, in industry, in the economy, etc. It can be used as an information medium, in the transportation of goods, to protect foodstuffs, as an absorbent material, for personal hygiene; it can also be used for artistic, ornamental and recreational purposes, etc. Paper has different properties depending on its use. It can be for purposes that are permanent or temporary, delicate or resistant, expensive or economical, abundant or scarce. It can be kept in a museum or thrown in the bin. Today, there are over 500 paper products that can be used in more than 300 applications. Paper products can be produced in quantities of thousands of tonnes, or in small quantities for special uses. As a result, the sector consists of factories of extremely varied sizes, from large factories belonging, usually, to multinational companies, to small family-owned companies with a very localised market.

Once used, the majority of products can be collected selectively and reused as secondary fibre sources, a practice that has been in use for centuries, and if this is not possible, they can be used as biofuels. Paper, therefore, forms a part of an integral carbon cycle based on the photosynthetic conversion of water, carbon dioxide, nutrients and solar energy in wood, a renewable biofuel. In this way, virgin and recycled fibres are complementary and their use should be optimised in accordance with the characteristics required of the final product.

In the same way as other industrial sectors, the paper industry is trying to achieve sustainable development. Due to its specific characteristics, this sector has for some decades complied with many of the concepts of sustainable development, while every day making a greater effort to minimise its consumption of natural resources and environmental impact.

Sustainable development requires a long-term vision in which companies focus on maintaining quality of life, which means respecting human needs and both local and global ecosystems. This dynamic process not only takes into account the environmental aspects concerned, but also the socioeconomic aspects, such as social welfare and employment. Some measures can be implemented in the short term, but others require long periods of planning and adaptation. Many companies have already adopted effective measures in a wide range of environmental and social issues and have even reached new market opportunities. However, as the industrial sector is made up of hundreds of small, medium and large companies, the development achieved by different factories varies greatly, even within the same company. This development depends fundamentally on the location of the factories, the expectations of their shareholders or owners and on the identification of new market opportunities.

It should also be taken into account that today, factories are not only faced with the sustainable development process, with all the changes that this involves, but also with the need to adapt along with the globalisation process. All things considered, the sustainable development of the paper industry presents opportunities and challenges. Paper manufacturers need to adapt to all these changes in order to find the way of maintaining mill profitability while at the same time reducing their environmental impact.

Growing environmental awareness has led industries to show greater interest in protecting the environment, together with saving electrical and thermal energy consumption, minimising the discharge of pollutant substances, reducing total water consumption and optimising energy needs.

For these reasons, a strategy has been progressively laid out to optimise industrial activities, both from the environmental point of view and from the point of view of profitability and competitiveness. The essential content of this strategy can be summarised as follows:

- A new relationship between industry and the environment, considering the latter to be a component inherent to production; with this in mind, the industry is adopting principles such as the "polluter pays. Such principles have generated additional benefits by confronting forms of inefficiency and optimising the use of raw materials and energy.

- The modernisation of environmental regulation, with the aim of reducing bureaucratic overload and the administrative costs of regulation while finding a balance between the development of environmental norms and regulations and productivity criteria, and attempting to synthesise companies' efficiency and profitability with environmental protection.
- The need for companies to deal with international competition and to adjust to quality standards and other international standards such as the ISO-9000 and ISO-14000 series.

To do this, it is acknowledged that the most effective solution to the problems of environmental pollution is to avoid the generation of waste flows by means of the application of cleaner technology, thus correcting the problem at source. This solution can be adopted both in new industries and those that are trying to modernise their productive installations.

In general, from an environmental point of view, the following factors are considered essential in this industrial sector:

- The reduction of the consumption of natural resources and the optimisation of the productive or industrial process in order to minimise the generation of waste flows.
- Increased energy efficiency.
- The minimisation of the environmental impact of processes and products.
- Encouraging closed cycles for processes and auxiliary operations.
- The use of renewable resources and the encouragement of recycling.
- Extending the life of paper products.

This manual aims to offer tools and decision-making criteria for the application of progressive environmental improvements in companies, providing information for pollution prevention in the paper manufacturing sector for the Mediterranean Action Plan countries.

According to the study published in January 2004 by the Regional Activity Centre for Cleaner Production (RAC/CP) on the “State of Cleaner Production in the Countries of the Mediterranean Action Plan” and in accordance with the stated intentions of the RAC/CP National Focal Points for cleaner production, the majority of Mediterranean companies have adopted the definition of the UNEP (United Nations Environment Programme), which states: “Cleaner production is the continuous application of an integrated, preventive strategy applied to processes, products and services in pursuit of economic, social, health, safety and environmental benefits”. While this is the case, there are also situations in which cleaner production is assimilated into concepts such as Cleaner Production Alternatives (CPA) and cleaner technologies.

In this Manual, firstly the detection of potential environmental problems in the factories of the paper sector takes place. These are:

- Liquid waste
- Solid waste / Sludges
- Atmospheric emissions
- Excessive energy consumption

Secondly, the manufacturing processes in this sector in the Mediterranean Action Plan countries are studied, describing in detail the four problematic areas mentioned above; and lastly, alternatives for pollution prevention at source are proposed, specifying as examples practical case studies of the application of some of the proposed alternatives.

This document is therefore structured as follows:

PART I: Cleaner Production / Objectives and Benefits of the Prevention of Pollution

This section defines the concept of "pollution prevention" and summarises the benefits of applying said prevention techniques.

PART II: Pollution Prevention in the Paper Sector

This section describes both the current situation for the paper sector in the Mediterranean region, and the processes associated with this sector, the waste flows generated and the main environmental impacts, suggesting alternatives for the prevention of pollution.

PART III: Case Studies

This section contains specific examples of companies that have used different pollution prevention alternatives. These case studies offer a description of the benefits, in particular in terms of cost savings, achieved by the companies concerned.

2. CLEANER PRODUCTION / OBJECTIVES AND BENEFITS OF THE PREVENTION OF POLLUTION

Cleaner production in an industrial environment is centred on the effective carrying out of production processes in such a way that the minimum quantity of internally non-reusable sub-products or waste flows is generated, while ensuring the minimum consumption of raw materials and resources.

Cleaner production is based on three areas of action:

- Prevention
- Reduction
- Internal reuse

Prevention is geared towards decision-making in the design of new plants or the redesign of existing plants, with the objective of "preventing" of pollution, that is, of not generating waste flows. To achieve this, the selection of alternatives to minimise waste flow generation predominates, thus reducing environmental impact.

Reduction or minimisation is applied to those processes that, despite already being in full use, present a margin for improvement. Modifications should consider the reduction of waste flows generated and / or the reduction in consumption of raw materials and natural resources.

Internal *reuse* considers the use of waste flows as a raw material within the company. This is a last resort for the limitation of environmental impact.

The environmental effects of these measures will be proportionally more positive, the more emphasis is placed on the concept of cleaner production.

From the point of view of costs, cleaner production must be viewed as a process that generates economic benefits with time, and therefore cleaner production reduces costs by increasing productive efficiency.

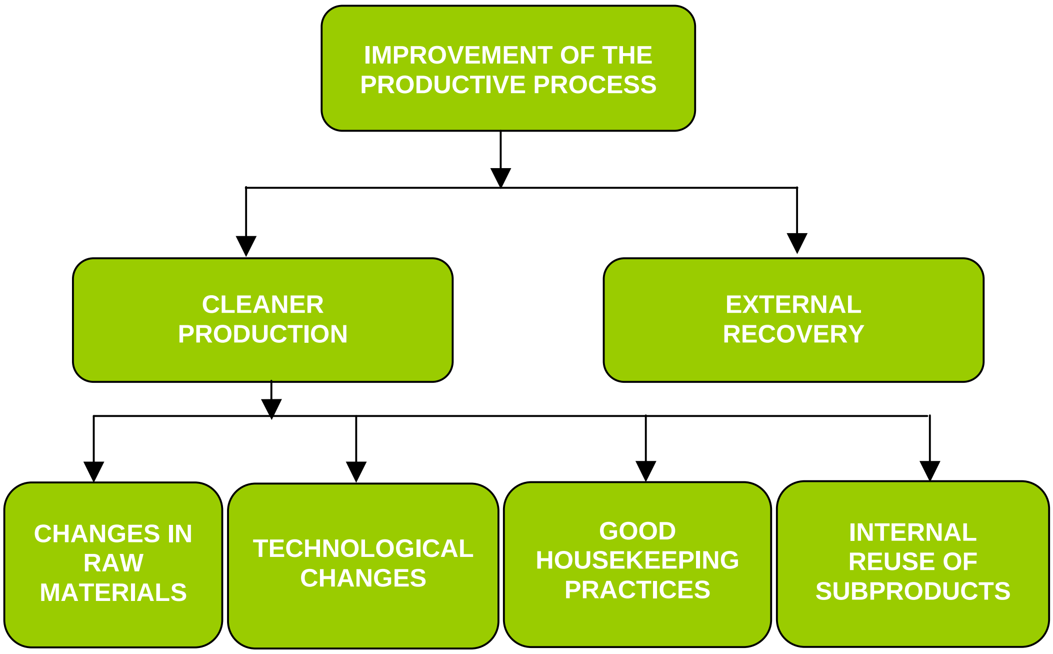
As a result, the planning and design of a process in which techniques that minimise the generation of waste flows are selected will in the medium and long term be environmentally and economically much more profitable than those processes in which only the correct processing of waste flows at the end of the process is taken into account.

Among the main causes that are progressively encouraging the increased presence of cleaner production in the pulp and paper sectors are:

- A legal framework that is constantly becoming stricter and more controlled.
- An increase in the cost of external management of waste flows.
- The incorporation into the financial management of the product of the environmental costs involved.
- Growing environmental awareness among consumers and clients.
- Improved techniques using cleaner production processes offering products of the same or higher quality.

Both in the production of pulp and of paper, cleaner production methods can be grouped along the following lines of action:

- Changes in raw materials: Measures centred on the improvement by substitution or modification of those raw materials consumed in the process for others with a less potentially pollutant effect.
- Technological changes: Measures representing modifications to the processes used.
- Organisational measures: Measures intended to achieve the correct use of equipment and systems with the aim of improving the plant's operation.
- Internal recycling of sub-products or waste flows: Reuse, with or without prior treatment in the process itself (depending on the case) of the waste flows generated, considering these as new raw materials.



Pollution Prevention as defined by the EPA (the US Environmental Protection Agency) is: "...the maximum feasible reduction in all waste generated at production sites. This involves the judicious use of resources by means of source reduction, energy efficiency, reuse of input materials used during the production process and reduced water consumption. There are two general methods of source reduction that can be used in a pollution prevention programme: product changes and process changes. These reduce the volume and toxicity of production waste and of end-products during their use and in their final disposal."

POLLUTION PREVENTION OBJECTIVES

The objective of the programme of source pollution reduction is to improve the quality of the environment by the elimination and/or reduction of the generation of waste flows. Pollution prevention includes any activity undertaken by a company in order to reduce the quantity of waste generated by its manufacturing processes before the recycling, processing or disposal of this waste in other places.

BENEFITS OF A POLLUTION PREVENTION PROGRAMME

Companies that have an effective, continuing plan for pollution prevention will have a significant competitive advantage in their industry, as they reduce operational and production costs. A pollution prevention programme can therefore provide the following benefits:

- **Protection of human health and environmental quality:** The reduction of pollutants emitted into the air, earth and water will help protect the environment and human health.
- **Reduction in operational costs:** In the long term an effective pollution reduction programme can mean savings that compensate the costs of development and of implementing the programme.
- **Employee motivation:** Employees will feel better within their company if they think that the management is committed to ensuring they have a safer working environment and at the same time collaborating as a responsible member of the community.
- **Better company image:** Demonstrating an environmental conscience improves the company's image. Companies with a culture of respect for nature generate more positive opinions. This can open new market opportunities for some products.
- **Improved compliance with environmental legislation:** By following a pollution prevention programme, the company improves its chances of avoiding infractions and fines related to environmental legislation.

3. SITUATION OF THE MEDITERRANEAN ACTION PLAN COUNTRIES

The objective of this section is to provide the reader with a general overview of the current situation in the different Mediterranean Action Plan Countries, providing socioeconomic information on the country, specific aspects of the country's industry, and the main environmental impact associated with industrial activity, particularly in the pulp and paper sectors, existing laws and regulations in the current legal framework for the prevention and control of pollution, agents involved in the promotion of cleaner production, programmes and action plans created to promote cleaner production, and those activities and tools used to encourage and promote cleaner production.

The information has been obtained from bibliographic sources of official bodies such as Institutes of Statistics, Environment Agencies, Energy Agencies, Ministries of the Economy, etc., in addition to from the second edition of the study that was published recently by the Regional Activity Centre for Cleaner Production (RAC/CP): “State of Cleaner Production in the Countries of the Mediterranean Action Plan”. This new edition updates and complements the study published by the centre in the year 2001, analysing the main advances in the Mediterranean countries in relation to the adoption of legislation, programmes and action plans for pollution prevention and the promotion of cleaner production.

The different countries of the region, grouped into three sub regions (South, North and East) are studied below. For practical reasons, this information has not been revised or approved by the National Focal Points in each Country.

3.1. SOUTHERN MEDITERRANEAN COUNTRIES

This group encompasses Algeria, Egypt, Lebanon, Libya, Morocco, Syria and Tunisia, all member states of the League of Arab States and with specific common characteristics, despite their possible political differences. All of these countries share some cultural principles and similar languages, thus facilitating common actions.

Some of the main characteristics of this sub region are the modernisation of existing industry, the development of Environmental Law and of the legislative system, the adoption of environmental action plans and the establishment of national centres for cleaner production that support the strategy adopted by each country.

Industry and environment

Over the last three decades, the Southern Mediterranean countries have undergone improvements in the areas of health, education and welfare. Nevertheless, this development has been negatively affected by pressure from population increases, economic recession and armed conflicts.

Rapid population growth in the Southern Mediterranean countries, in combination with an increase in human activity, especially in urban areas, increases both pressures on the environment and the production of waste and pollution.

The Gross Domestic Product (GDP) of the Southern countries has grown considerably in the last decade. The majority of countries have implemented economic reforms and restructuring, encouraging the free market economy and decentralisation, and have managed to reduce inflation rates.

The importance of industry in these countries is considerable, representing over 25.5% of total GDP of the sub region (excluding the extraction of crude oil). Industrialisation is an important source of income for these countries, thanks to the trade of its products, job creation and the added value it brings to raw materials.

The industrial structure of the Southern Mediterranean countries has some common characteristics:

- The industrial development of the Southern Mediterranean countries is based mainly on the use of non-renewable energy sources. The oil and gas extracted in Libya, Algeria and Egypt have acquired a great deal of importance both from the point of view of exportation and of those industries with high energy consumption and added value that have proliferated in the zone.
- Besides focusing on oil and gas, the Southern Mediterranean countries tend to concentrate on other activities of extraction or processing of their raw materials such as, for example, phosphates and other minerals in Morocco, or agriculture in Syria.
- The presence of capital goods industries is relatively scarce, despite the importance that encouraging this sector would have in countries such as Egypt, Morocco and Tunisia.
- Lastly, exports of products are still very limited and the trade balance deficit is still very high. However, the situation could change with the motor of new policies to encourage exports.

Despite recent attempts to diversify the industrial fabric of these countries, providing important financial resources from national budgets to industry and the infrastructures it requires, the behaviour of the manufacturing sector in the Southern Mediterranean countries has not been satisfactory. This is a result of the dominant tendency to import goods, of the lack of industrial development strategies, of the artificial protection of national industries and of the lack of cooperation in matters of trade and industry between the countries of this sub region.

Mining and the processing of minerals and industrial metals have grown, as has the extraction of fossil fuels.

Countries such as Egypt, Syria, Tunisia and Morocco, which have well-diversified economies, still concentrate on traditional industries such as the production of foodstuffs, cement and textiles.

Few countries have been able to establish competitive industries by means of the introduction of modern technologies. Moreover, in many of these countries industry is still encouraged by policies that are incompatible with the concept of sustainability.

The model of industrial development that has been applied in the Southern Mediterranean countries has contributed to the appearance of "pollution black spots" that have caused significant environmental damage and the overloading of public infrastructures for environmental protection in big cities.

In those countries with a comparatively high level of industrialisation (for example Egypt, Morocco, Tunisia or Syria) the environmental problems are even greater as a consequence of:

- Inadequate final treatments and incorrect handling and removal of dangerous waste;
- Difficulties in controlling waste flows and industrial emissions due to a lack of equipment and qualified personnel;
- The lack of inclination on the part of the majority of polluting companies to invest in pollution reducing measures;
- The lack of specialised and trained personnel to manage the operation of waste treatment installations.

However, industry is now recognising the need to avoid or reduce waste generation using new pollution prevention technologies. This trend has succeeded in achieving gradual improvements in production and consumption behaviour.

Political and legal framework

Environmental legislation in the Southern Mediterranean countries has been extensively revised and modified in recent years. In general, the countries of the sub region are adopting a general environmental law (legal framework) that is complemented by sectorial regulations. They have all approved laws to control industrial pollution of water that directly or indirectly protect the marine environment and the majority have also approved Environmental Impact Evaluation (EIE) legislation for their permit granting systems.

In the majority of countries, the modernisation of the legal framework has enabled legal regulation of aspects related to cleaner production, mainly through laws governing waste and the introduction of new environmental requirements to the process of obtaining permits.

This is the case, for example, for the Hazardous Waste Law in Algeria and the waste minimisation requirements established by Egyptian law; Cleaner production also features in the draft waste bill in Morocco. The revision of the legal framework has been used in Tunisia to include more concrete energy and water saving requirements. Algeria has also included source pollution prevention and reduction measures and, as a second option, the reuse of waste generated.

However, a certain length of time may be necessary to achieve the complete application of these laws, as a suitable administrative structure is required. In addition to the fact that the industrial sector will have more inclination to submit to the effective application of legislation if the measures to ensure its compliance are accompanied by other proactive measures such as voluntary agreements or economic incentives, there are few incentives to adopt cleaner production, apart from the avoidance of possible fines.

Lebanon funds audits and has increased the value of favourable credits that the government gives to speed up the adoption of new environmental technologies and, among other things, environmental modernisation.

In Syria there are other incentives for cleaner industries and for those investors who invest in environmental modernisation and in adaptation to cleaner technologies.

In some countries, voluntary agreements and instruments are being put into practice to increase awareness in the industrial sector and to improve environmental responsibility. For example, Morocco has implemented the "Responsible Care" programme that has been adopted by some industries, and in Algeria systems of environmental management and environmental audits are being promoted and publicised.

In the international framework for environmental protection by means of pollution prevention, all of the Southern Mediterranean countries are members of the Basel Convention on Hazardous Wastes and the majority have signed the Stockholm Convention on Persistent Organic Pollutants. As for the depletion of the ozone layer, all of the countries have signed the Montreal Protocol and its amendments, with the exception of the Beijing Amendment of 1999. In terms of climate change, only Morocco and Tunisia have ratified and Egypt has signed the Kyoto Protocol.

Within the framework of the Mediterranean Action Plan, and with regard to those protocols that focus mainly on land-based activities, all of the Southern Mediterranean countries have ratified the Land-Based Sources Protocol, although only Morocco and Tunisia have accepted the 1995 amendments which include, among other things, the principles of "polluter pays", cleaner production alternatives (CPA), good housekeeping practices (GHP) and cleaner technologies, which should be taken into account when writing national plans for the fight against pollution. The Dangerous Substances Protocol has been ratified by Morocco and Tunisia, while Algeria and Libya have signed it.

3.1.1. ALGERIA

Introduction

Algeria is an Arab country situated in North Africa, on the Mediterranean coast. A total area of 2,381,740 km^2 and a population of approx. 31.3 million inhabitants.

The economy of the country is based mainly on the hydrocarbons industry. Algeria has the fifth largest natural gas reserve in the world. It is the second largest exporter of natural gas, and has the world's fourteenth largest crude oil reserve.

In recent years, the Algerian economy has shown annual growth of approximately 4%. However, there has been little success in reducing high unemployment levels or improving the standard of living to any great extent. The government intends to continue its efforts to diversify the economy and attract national and foreign investment in sectors other than energy.

Table 3.1.1. Indicators of the socioeconomic situation in Algeria

Area	10^6 km^2	2.4
Population	million	31.3
Increase of population	%	1.62
Life span	years	70.7
Total illiteracy	% age >15	31.1
Women illiteracy	% age >15	40.4
Energy per capita	oil kg equiv.	956
Current GDP	€$10^{9\,*}$	47.7
GDP growth	yearly %	4.1
PPP of estimated GDP	€10^9	143.0
GDP PPP per capita	€100	45.4
Gross capital formation	% of GDP	25.2
AV in agriculture	% of GDP	12.4
AV in industry	% of GDP	62.2
AV in services	% of GDP	25.4
Exports	% of GDP	33.5
Imports	% of GDP	23.4
Operational telephone lines (2001)	per 1,000 inhabitants	64
Personal computers (2001)	per 1,000 inhabitants	7.1

Source: World Bank Group and global EDGE (2002) (PPP= Purchasing Power Parity; AV = added value)

Industry and environment

Algeria has undergone significant economic growth in the last four decades, which has been characterised by considerable development of its industry. As a result, a large number of industries have been established in the North of the country, near to the major urban areas. Sustainable development has been practically ignored.

Technologies were chosen purely for reasons of productivity, often at the expense of pollution considerations, which means that today Algeria is facing serious pollution problems. Industry, and specifically the mining sector and the petrochemical, chemical and metalworking industries, is the main culprit of the country's pollution.

The industry is concentrated in the coastal areas (less than 2% of the country's total area) where the population is also most concentrated (around the large industrialised urban areas and the cities, in particular Algiers, Oran, Constantine, Annaba and Skikda).

The private industrial sector consists for the most part of of small and medium enterprises (SMEs), of which the number varies between 25,000 and 35,000. 93% of these are microenterprises, with fewer than 10 employees. SMEs are present in all branches of activity, above all in the textile and garment sector, the tanning and shoemaking sector, the construction materials sector, the food and agriculture sector and the processing sector, all of which generate large quantities of waste and wastewater.

The main impacts on the environment from industry in Algeria are:

- The deterioration of air quality (emissions of atmospheric pollutants such as combustion gases, smoke and dust, heavy metal vapours, etc);
- The pollution of water resources (rivers, reservoirs, dams, coastal waters etc);
- The generation of industrial waste;
- The main areas of industrial activity in the country are along the coastal zones.

Paper and Pulp Industry

The paper and pulp industry, like many other sectors of the Algerian economy, is heading more and more towards privatisation. The legal framework is complete and efforts are being made to attract potential investors. These efforts include intensive meetings and seminars intended to communicate fully the details of new policy and the many incentives that are offered.

Table 3.1.2. Statistics of the Paper and Pulp Industry in Algeria. Year 2002

Forested area	km^2	41,960
Production capacity of Paper and Cardboard	t	137,000
Production capacity of Pulp	t	14,000
Consumption of Paper and Cardboard per capita	kg	6.30
Paper and Cardboard operation ratio	%	28
Pulp operation ratio	%	14
Paper and Cardboard Factories	-	5
Pulp Factories	-	1
No. of employees in the Paper and Pulp Industry	-	2,400

Source: Annual Review- Africa. July 2002. PPI (Pulp and Paper International)

GIPEC (Groupe Industriel des Papiers et de la Cellulose) is the public-private company responsible for the production of pulp and paper in Algeria.

The pulp sector uses annual plants such as esparto grass and straw as a raw material. In recent years there has been a decline as a result of difficulties in the harvesting, taxation, transport and technical processing of these plants. The production of esparto grass has declined due to the increase in pulp from new woods that are highly profitable, such as eucalyptus. The strategy that is to be carried out is to continue using esparto grass for the fabrication of pulp in favour of secondary fibre.

The ratio of recovered paper is currently around 10%, while the total available is estimated to be around 400,000 tonnes, boosted by the increase in packaging from imported goods.

The consumption per capita of paper and cardboard in Algeria in the years 2002, 2001 and 2000 was of some 6.3 kg/inhab/yr. Annual paper consumption in recent years has remained at some 225,000 tonnes, and production has remained at some 41,000 tonnes per year.

According to statistics gathered by the ACPWP (The FAO Advisory Committee on Paper and Wood Products) for production in the years 2003, 2002 and 2000, the following figures are the case: 7,000 tonnes per year of cardboard for packaging, 3,000 tonnes per year of sanitary and domestic paper, 32,000 tonnes per year of recovered paper, 14,000 tonnes per year of printing paper, 21,000 tonnes per year of paper and cardboard for packaging.

As can be seen in the figures above, Algeria is a country that consumes more paper and cardboard than it produces, which makes clear the role of imports. Total imports of paper and cardboard in the year 2002 were 10% greater than the previous year, 2001. In the year 2003, 17,000 tonnes of chemical pulp were imported, 32,800 tonnes of coated paper, 1,500 tonnes of sanitary and domestic paper, 28,600 tonnes of newsprint and 52,900 tonnes of printing paper, among other types.

However, Algeria is carrying out restructuring programmes in pulp, paper and cardboard factories, by means of modernisation projects. With this restructuring, it is hoped that the domestic market will offer an important opportunity, while also encouraging the export market. Private investors are considering investing in new capacities in this sector, which is bringing new hope to a sector that has been stagnant for some time.

3.1.2. EGYPT

Introduction

Egypt is an Arab country situated in the North of Africa, on the Mediterranean coast. A total area of 1,001,450 km^2 and a population of approx. 66.4 million inhabitants.

In addition to the agricultural capacity of the valley and the Nile Delta, Egypt's natural resources include oil, natural gas, phosphates and iron ore. The country has a large enough reserve of natural gas to satisfy internal demand for many years.

The industrial sector is dominated by public companies that control almost all the heavy industry, although a process of reforms and privatisation in the public sector has begun, the aim of which is to increase opportunities for the private sector. Construction, non-financial services and the internal market are for the most part privatised. This has caused constant growth in GDP and annual growth rates.

Egypt has the second largest economy in the Arab world. The economy is dominated by the service sector, which makes up almost half of GDP.

Table 3.1.3. Socioeconomic indicators of the situation in Egypt

Area	10^6 km^2	1.0
Population	Million	66.4
Increase of population	%	1.77
Life span	Years	68.9
Total illiteracy	% age >15	43.1
Women illiteracy	% age >15	54.1
Energy per capita	oil kg equiv.	726
Current GDP	€10^9 *	76.9
GDP growth	yearly %	3.0
PPP of estimated GDP	€10^9	221
GDP PPP per capita	€100	31.7
Gross capital formation	% of GDP	17.1
AV in agriculture	% of GDP	16.8
AV in industry	% of GDP	35.0
AV in services	% of GDP	48.2
Exports	% of GDP	18.2
Imports	% of GDP	23.4
Operational telephone lines	per 1,000 inh	147
Personal computers	per 1,000 inh	15.5

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV = added value)

Industry and environment

Industry is one of the main sectors that is propelling the Egyptian economy. Including manufactures and mining, the industrial sector in Egypt constitutes around 20% of GDP and employs around 14% of the workforce. Egypt's manufacturing capacity is concentrated in relatively few industrial sectors. Seven sectors represent over 80% of establishments. The three main sectors are food and drinks, textiles and the chemical industry, which are the longest-established in Egypt. Following on from them come the non-metal mineral sector, metal production, chemical products and base metals.

Egypt is highly dependent on imports; for example, it must import almost all of the wood and paper it consumes.

In Egypt, the geographical distribution of industry is very unequal. At present, 41% of industrial production is concentrated in Greater Cairo, 17% in the Nile Delta, 16.8% in Alexandria and 14.2% in the Suez Canal area. The remaining 11% of industrial production is in Upper Egypt. This inequality of distribution has driven the country to embark on a new plan to encourage industrial investment in new communities situated in the non-agricultural areas of the country.

The public sector, dominated by large companies, plays a predominant role in the chemical and pharmaceutical industries, in engineering and in the electrical sector. Moreover, it owns large textile factories and sugar refineries.

The private sector, dominated by Small and Medium Enterprises (SMEs) encompasses companies dedicated to food and beverages, dairy products, thread and weaving and various crafts. Some of the companies in the private sector with the largest profits are those working in light tools and electrical consumables, and in fabric printing and garment making.

Alexandria is a highly industrialised area, where the following are produced: paper, metal, chemical products, pharmaceutical products, plastics, food products, oils, detergents and petrol. The majority of waste generated by these industries is dumped in Lake Mariout, the discharge ground also for processed wastewater from the wastewater treatment plant in Alexandria.

Paper and Pulp Industry

Table 3.1.4. Statistics of the Paper and Pulp Industry in Egypt. Year 2002

Production capacity of Paper and Cardboard	t	470,000
Production capacity of Pulp	t	140,000
Consumption of Paper and Cardboard per capita	kg	13
Paper and Cardboard Factories	-	11
Pulp Factories	-	3
No of employees in the Paper and Pulp Industry	-	5,500

Source: Annual Review- Africa. July 2002. PPI (Pulp and Paper International)

In recent years, consumption per capita of paper and cardboard has been of some 13 kg/inhab/yr, making annual consumption 933,700 tonnes in the year 2002. The production of paper and cardboard in recent years has remained at some 460,000 tonnes per year and the production of recovered paper has remained at 380,000 tonnes per year. Egypt consumes more paper and cardboard than it produces, which makes clear the importance of imports.

According to figures from the ACPWP (The FAO Advisory Committee on Paper and Wood Products) concerning the consumption of different types of pulp and paper in recent years, the following figures apply: 70,000 tonnes per year of cardboard for packaging, 90,000 tonnes per year of sanitary and domestic paper, 380,000 tonnes per year of recovered paper, 100,000 tonnes per year of printing paper, 240,000 tonnes per year of paper and cardboard for packaging, among other types.

The following figures are for imports registered in the year 2003: 56,100 tonnes of chemical pulp and 56,100 of bleached sulphate pulp, 1,800 tonnes of mechanical pulp, 7,100 tonnes of coated paper, 265,000 tonnes of newsprint, 2,400 tonnes of recovered paper and 87,000 tonnes of printing paper, among others.

As can be seen from these figures, Egypt imports most of the paper consumed there. However, programmes are being carried out by means of the installation of new plants or the modernisation of existing plants, to replace part of these imports with national production.

3.1.3. LEBANON

Introduction

Lebanon is an Arab country in the Eastern Mediterranean region, and borders on the Mediterranean. A total area of 10,400 km^2 and a population of approx. 4.4 million inhabitants.

Lebanon operates a competitive free market system and the country has a strong tradition of commercial *laissez-faire*. The Lebanese economy is based mainly on services; the principal growth sectors are banking and tourism.

Table 3.1.5. Socioeconomic indicators of the situation in Lebanon

Area	10^3 km^2	10.4
Population	million	4.44
Increase of population	%	1.26
Life span	years	71
Total illiteracy	% age >15	13
Women illiteracy	% age >15	18
Energy per capita	kg oil equivalent	1,169
Current GDP	€10^9 *	14.8
GDP growth	yearly %	1
PPP of estimated GDP	€10^9	16.2
GDP PPP per capita	€100	46.2
Gross capital formation	% of GDP	18
AV in agriculture	% of GDP	11.7
AV in industry	% of GDP	21
AV in services	% of GDP	67.3
Exports	% of GDP	13.9
Imports	% of GDP	41
Telephones	per 1,000 inh	NA
Computers	per 1,000 inh	56

Source: World Bank Group, Global Edge and Arabic News (2001-2002). (PPP= Purchasing Power Parity; AV = added value; NA = non available)

Industry and environment

In 1999, over 22,000 industrial units were identified in Lebanon, according to the Ministry of Industry, and 29,282 according to the Central Administration for Statistics, a figure that represents an increase of approximately 50% since the beginning of the 1990s. Over 90% of these units are microenterprises with fewer than 10 employees.

Industry is concentrated in Greater Beirut and the Lebanese Mountains. Due to a lack of urban planning, the majority of small and microenterprises are situated in residential areas, outside the industrial zones (95.6% of the industries in Greater Beirut and 75.3% in the Lebanese Mountains). Nevertheless, the larger companies (those dedicated to food processing, textiles, chemicals and cement and construction materials) are located, in general, in the industrial zones.

The figures indicate that the recovery of the industrial sector has been surprising, despite the ravages of war. Growth of the sector during the period 2001 - 2010 is expected to be between 8 and 10%.

Approximately 89% of industries belong to seven main subsectors: food and beverages (20%), metal manufacturing (16%) non-metallic minerals (12%), furniture (11%), weaving and textile finishing (16%), wood products (10%) and tanning (6%).
The majority of industrial installations are not equipped with installations for pollution control and dump contaminated wastewater into coast and surface waters, which means a great risk of pollution of surface and ground waters. In addition, illegal dumping of solid industrial waste and atmospheric emissions are a problem.

Paper and Pulp Industry

The consumption of paper and cardboard in Lebanon in recent years has been 45 kg/inhab/yr, giving an annual consumption of 161,900 tonnes. The production of paper and cardboard has remained at some 42,000 tonnes per year in recent years.

Figures from the ACPWP (The FAO Advisory Committee on Paper and Wood Products) on the production of sanitary and domestic paper and paper/cardboard for packaging show that these have remained at 6,000 tonnes and 36,000 tonnes respectively in recent years.

It can be seen that the same is the case in Lebanon as in other Southern Mediterranean countries, in which the production of paper and cardboard is very low, showing the importance of imports of these products. From FAO statistics it can be said that in recent years there have been imports of 1,000 tonnes annually of mechanical pulp, 200 tonnes per year of semi-chemical pulp, 12,800 tonnes per year of chemical pulp, 10,900 tonnes per year of bleached sulphate pulp, 700 tonnes per year of bleached sulphite pulp, 1,200 tonnes per year of unbleached sulphate pulp, 22,200 tonnes per year of coated paper, 2,600 tonnes per year of sanitary and domestic paper, 12,200 tonnes per year of newsprint, 65,200 tonnes of printing paper and 4,900 tonnes per year of recovered paper, among others.

In the last five years, the Lebanese paper industry has invested, and continues investing, in technology to improve production capacity and quality. The Syndicate of Paper and Cardboard Industries believes that the sector could produce around 250,000 tonnes of paper per year.

3.1.4. GREAT SOCIALIST PEOPLE'S LIBYAN ARAB JAMAHIRIYA

Introduction

Libya is an Arab country situated in the North of Africa, on the Mediterranean coast. A total area of 1,759,000 km^2 and a population of approx. 5.5 million inhabitants.

The Government dominates the Socialist-orientated economy in Libya by total control of the country's oil resources, representing approximately 95% of export income and 30% of gross domestic product. The income generated by oil and a low population mean that Libya has the highest GDP (and GDP purchasing power parity) in Africa. Despite efforts made to diversify the economy and encourage private sector participation, generalised control of prices, credits, trade and shares is an obstacle to growth.

The sectors of construction and non-oil-related production, which represent 20% of GDP, has moved from being represented almost exclusively by the processing of agricultural products to encompass petrochemicals, steel working and aluminium.

Table 3.1.6. Socioeconomic indicators of the situation in Lybia

Area	10^6 km^2	1.8
Population	million	5.53
Increase of population	%	2
Life span	years	72
Total illiteracy	% age >15	18
Women illiteracy	% age >15	29
Energy per capita	oil kg equiv.	3,107
Current GDP	€10^9 *	29.24
GDP growth	yearly %	NA
Estimated GDP PPP	€10^9	34.2
GDP PPP per capita	€100	65
Gross capital formation	% of GDP	13
AV in agriculture	% of GDP	7
AV in industry	% of GDP	44
AV in services	% of GDP	49
Exports	% of GDP	36
Imports	% of GDP	15
Operational telephone lines	per 1,000 inh	118
Personal computers	per 1,000 inh	NA

Source: World Bank Group, Global EDGE (2000- 2002), Arabic News and ktuell 2004. Harenberg Lexicon Verlag. (PPP= Purchasing Power Parity; AV = added value; NA = non available)

Industry and environment

As mentioned above, Libya's industrial development has depended largely on the oil sector, both in terms of income generated by investments and the importing of raw materials. Among the industrial activities are those related to the oil industry (exploration, production, transport and trade of oil-derived products) together with the metalworking sector, fertilisers, cement, chemical substances and food processing.

Until the beginning of the 1980s, the entire industrial sector was planned by the government, which had assumed control of those aspects of industrial production considered sensitive or of an importance not accessible for the country's private sector. However, Government policy today is inclined more towards liberating industry, including the processing industries, from their dependence on outside property and control. The government is concentrating its attention on developing the petrochemical and oil industries.

The foodstuff processing industry leads the production sector, followed by other important industries such as the textile industry, and the factories of fertilisers and engineering equipment.

Although the discharge of untreated wastewater into normal drainage systems is common practice among SMEs in Libyan cities, this is not considered to cause serious pollution problems. The large oil refining installations and those related to the petrochemical, metalworking, chemical, fertiliser and textile finishing industries are for the most part situated along the coast, particularly in the Gulf of Surt. These industries frequently dump untreated wastewater through outflow pipes directly into the Mediterranean.

Paper and Pulp Industry

The consumption of paper and cardboard per capita in recent years in Libya has been of 3.14 kg/inhab/yr, making annual consumption 17,100 tonnes of paper and cardboard. Paper and cardboard production has remained at 6,000 tonnes per year in recent years.

In this case consumption is again greater than production, showing the importance of imports. The most recent figures from the ACPWP (The FAO Advisory Committee on Paper and Wood Products) show that in 2003, imports were: 1,300 tonnes of chemical pulp, 600 tonnes of bleached sulphate pulp, 700 tonnes of bleached sulphite pulp, 857 tonnes of semi-chemical pulp, 2,400 tonnes of materials for boxes, 400 tonnes of coated paper, 1,300 tonnes of newsprint, 3,900 tonnes of printing paper and 5,400 tonnes of packaging paper, among others.

3.1.5. MOROCCO

Introduction

Morocco is an Arab country situated in the North of Africa, on the Mediterranean coast. A total area of 710,000 km^2 and a population of approx. 29.5 million inhabitants.

The Moroccan economy is becoming more and more diversified. Morocco has important mineral reserves, a diversified agriculture sector (including fisheries), a significant tourist industry and a developing processing industries sector centred mainly on garment making.

Approximately one third of the processing industry is related to phosphates and another third to agriculture. The remaining third is divided between the textile industry, the garment industry and the metalwork industry.

Since the 1980s, the Moroccan Government has been following a programme of economic reforms with the support of the International Monetary Fund and the World Bank. Throughout the last decade, these reforms have contributed to an increase in per capita income, reduced inflation and lowered current account deficit.

However, population growth, migration from rural areas to urban zones and the increase in the active labour force are contributing to increased urban unemployment, despite strong economic growth and the creation of new jobs.

Table 3.1.7. Socioeconomic indicators of the situation in Morocco

Area	10^6 km^2	0.7
Population	million	29.6
Increase of population	%	1.58
Life span	years	68.4
Total illiteracy	% age >15	49.3
Women illiteracy	% age >15	61.7
Energy per capita	oil kg equiv.	359
Current GDP	€10^9 *	31.9
GDP growth	yearly %	4.5
PPP of estimated GDP	€10^9	98.5
GDP PPP per capita	€100	33.4
Gross capital formation	% of GDP	25.2
AV in agriculture	% of GDP	16.1
AV in industry	% of GDP	31.1
AV in services	% of GDP	52.8
Exports	% of GDP	29.9
Imports	% of GDP	35.9
Operational telephone lines (2001)	per 1,000 inh	204
Personal computers (2001)	per 1,000 inh	13.7

Source: World Bank Group and global EDGE (2002) (PPP= Purchasing Power Parity; AV = added value)

Industry and environment

Morocco has one of the strongest mining industries in Africa and its oil industry is an essential subsector of the country's economy. The chemical industry is undergoing a new boom thanks to the exploitation of the rich phosphate reserves.

In the parachemical sector, the pharmaceutical industry holds an important position and the country is one of the main markets in the African lubricants industry. The textile and tanning industries represent approximately a quarter of total industrial production. As for the processing of foodstuffs, the main industries are sugar production, flour milling and dairy products. Morocco also has various cement factories.

As regards activities in the production sector, the breakdown by subsections is:

- The food and agriculture industry (35%, with over 1,641 companies);
- The chemical and parachemical industries (33%, with 1,963 companies);
- The textile and tanning industries (17%, with 1,744 companies);
- The mechanics, electrical and electronic industries (12% corresponding to the electrical and mechanics industries and 3% to electronics; over 1,051 companies in total).

In Morocco, 95% of the manufacturing framework is made up of Small and Medium Enterprises (SMEs). Over 14,000 registered SMEs have been set up in urban centres and industrial estates in the country, with approximately 50% of the large installations located in Casablanca, in the Mohammedia region. Their contribution to GDP is 36% of the total and they provide 52% of total employment. The location of SMEs in densely-populated urban areas has negative consequences for the environment and the population.

Industrial activities and in particular the chemical and parachemical sectors, the food and agriculture sector (sugar and vegetable oils), and the textile and tanning sectors, have negative effects on the environment and in particular on water resources. The pollution of surface waters caused by industrial activities is high, particularly in the Sebu and Oum er-R'bia basins.

Paper and Pulp Industry

Table 3.1.8. Statistics of the Paper and Pulp Industry in Morocco. Year 2002

Forested area	km^2	85,471
Production capacity of Paper and Cardboard	t	160,000
Production capacity of Pulp	t	125,000
Consumption of Paper and Cardboard per capita	kg	9
Paper and Cardboard Operation Ratio	%	80
Pulp Operation Ratio	%	71
Paper and Cardboard Factories	-	5
Pulp Factories	-	1
No. of employees in the Paper and Pulp Industry	-	2,400

Source: Annual Review- Africa. July 2002. PPI (Pulp and Paper International)

Consumption of paper and cardboard per capita in recent years has been of some 9 kg/inhab/yr, making yearly consumption a total of 250,000 tonnes. Production of pulp and paper has remained at 129,000 tonnes per year in recent years, and yearly production of recovered paper at 30,000 tonnes.

According to figures from the ACPWP (The FAO Advisory Committee on Paper and Wood Products) in recent years 107,000 tonnes per year of chemical pulp, 107,000 tonnes per year of bleached sulphate pulp; 1,000 tonnes per year of coated paper, 1,000 tonnes per year of sanitary and domestic paper, 2,000 tonnes per year of newsprint, 30,000 tonnes per year of recovered paper and 34,000 tonnes per year of printing paper have been produced, among others.

The latest FAO statistics show that imports in the year 2003 were: 17,464 tonnes of chemical pulp, 17,060 tonnes of bleached sulphate pulp, 404 tonnes of bleached sulphite pulp, 1,000 tonnes of non-bleached sulphate pulp, 400 tonnes of mechanical pulp, 590 tonnes of semi-chemical pulp, 6,293 tonnes of coated paper, 478 tonnes of sanitary and domestic paper, 15,327 tonnes of newsprint, 3,118 tonnes of recovered paper and 21,495 tonnes of printing paper, among others.

As for the exportation of paper and pulp products, the latest statistics from the FAO show that the following quantities were exported in 2003: 75,473 tonnes of chemical pulp, 75,473 tonnes of bleached sulphate pulp, 25 tonnes of mechanical pulp, 2,529 tonnes of semi-chemical pulp, 149 tonnes of coated paper, 653 tonnes of foldable boxboard, 34 tonnes of sanitary and domestic paper, 42 tonnes of recovered paper and 1,507 tonnes of printing paper, among others.

The paper and pulp industry in Morocco is entirely private. The mill in Sobe in the kingdom of Sidi Yahia du Gharb, on the Atlantic coast, has increased pulp production by some 125,000 tonnes after only producing 100,000 tonnes per year in the past. The mill, owned by CELLUMA (Cellulose of Morocco) produces short-fibre Eucalyptus pulp for export.

The main cardboard company, CMCP (Compagnie Marocaine des Papiers et Cartons) located in Kenitra, near Rabat, produces corrugated cardboard for various types of boxes and packaging.

3.1.6. SYRIAN ARAB REPUBLIC

Introduction

Syria is an Arab country located in the Middle East, bordering on the Mediterranean Sea. A total area of 185,180 km^2 and a population of approx. 17.8 million inhabitants.

It is a developing country, with moderate incomes and a diversified economy based on agriculture, industry and an expanding energy sector.

In spite of important reforms and development projects begun at the beginning of the 1990s, the Syrian economy is still negatively affected by a number of public companies with very low profitability, very low investment levels and relatively low industrial and agricultural productivity. The oil industry has represented almost three quarters of income from exports.

The Government has changed its economic development priorities from industrial expansion towards various agricultural sectors with the objective of achieving self sufficiency, increasing income from exports and controlling migration from rural areas.

Table 3.1.9. Socioeconomic indicators of the situation in Syria

Area	10^3 km^2	185
Population	million	17.76
Increase of population	%	2.45
Life span	years	70
Total illiteracy	% age >15	24
Women illiteracy	% age >15	37
Energy per capita	kg oil equivalent	1,137
Current GDP	€10^9 *	21.9
GDP growth	yearly %	3
PPP of estimated GDP	€10^9	59.4
GDP PPP per capita	€100	35
Gross capital formation	% of GDP	24
AV in agriculture	% of GDP	23
AV in industry	% of GDP	28
AV in services	% of GDP	49
Exports	% of GDP	36
Imports	% of GDP	30
Telephones	per 1,000 inh.	115
Computers	per 1,000 inh.	16.3

Source: World Bank Group and global EDGE (2000-2003) (PPP= Purchasing Power Parity; AV = added value)

Industry and environment

Syrian industry is very diversified. The most important sectors, controlled mainly by the State, are the foodstuffs sector, textiles, chemicals, engineering and cement. Despite State control of industry, the private sector has begun to break into the textile, foodstuffs and cement industries.

Syria considers quality to be a decisive factor for surviving competition from global industrial trade, and it has therefore paid special attention to raising awareness of the concepts of Total Quality Control (TQC) and Cleaner Production (CP) and encouraged national industries to obtain ISO certification.

For the most part, the industries are made up of SMEs and the main zones of activity are concentrated around Damascus, Alepo and Homs.

The main pollutants generated by these industries are wastewater and atmospheric emissions. Solid waste is not considered a priority because companies recycle and reuse this or sell it on for other uses.

The processing of waste generated is very expensive for this type of company, which cannot afford it without economic help or incentives of some sort. As a result, pollutant treatment depends on the availability of low cost techniques in the context of existing regulations and demands.

The current Government has shown its commitment to a significant increase in amounts destined for environmental conservation and the relevant public services in the budgets of the ministries and institutions involved.

Paper and Pulp Industry

Consumption of paper and cardboard in Syria in recent years has been of some 5 kg/inhab/yr, making yearly paper and cardboard consumption some 75,000 tonnes. Paper and cardboard production in Syria has been at a level of some 1,000 tonnes per year in recent years. Most of this production is for paper and cardboard for packaging.

As Syria produces very little paper and cardboard, it is obliged to important the necessary quantities for consumption. The latest statistics from the FAO show that in the year 2003, imports were: 10,857 tonnes of chemical pulp, 10,150 tonnes of bleached sulphate pulp, 707 tonnes of bleached sulphite pulp, 12 tonnes of mechanical pulp, 100 tonnes of semi-chemical pulp, 2,944 tonnes of coated paper, 5,953 tonnes of sanitary and domestic paper, 4,460 tonnes of newsprint, 8,300 tonnes of recovered paper and 20,652 tonnes of printing paper, among others.

3.1.7. TUNISIA

Introduction

Tunisia is an Arab Country located in the North of Africa, on the coast of the Mediterranean Sea. A total area of 163,610 km^2 and a population of approx. 9.5 million inhabitants.

Historically, Tunisia's economic growth has depended on oil, phosphates, agriculture and tourism. The Government's economic policy had little success for the first years of independence. In 1986, the State launched a structural adjustment programme aimed at price liberalisation, tariff reduction and Tunisia's redirection towards a free market economy.

Since the stabilisation programme was applied, growth of internal production, measured according to real GDP growth, increased from 2.8% in the period 1982-1986 to 4.8% in the period 1991-2001. Parallel to this, inflation and the current account deficit reduced significantly.

In 1990, Tunisia joined the General Agreement on Tariffs and Trade (GATT). In addition, up to the year 2002, the Government privatised 163 state companies.

Unemployment is still very high for the country's economy at 15% of the active population, and is worsened by the rapid growth in the workforce.

Table 3.1.10. Socioeconomic indicators of the situation in Tunisia

Area	10^3 km^2	164
Population	million	9.8
Increase of population	%	1.2
Life span	years	72.7
Total illiteracy	% age >15	26.8
Women illiteracy	% age >15	36.9
Energy per capita	oil kg equiv.	825
Current GDP	€10^9 *	18.1
GDP growth	yearly %	1.9
PPP of estimated GDP	€10^9	55.2
GDP PPP per capita	€100	56.5
Gross capital formation	% of GDP	26.1
AV in agriculture	% of GDP	10.4
AV in industry	% of GDP	29.1
AV in services	% of GDP	60.5
Exports	% of GDP	45.5
Imports	% of GDP	50.4
Operational telephone lines	per 1,000 inh.	149
Personal computers	per 1,000 inh.	23.7

Source: World Bank Group and global EDGE (2002) (PPP= Purchasing Power Parity; AV = added value)

Industry and environment

The production sector has become one of the most dynamic in the Tunisian economy, showing a clear trend towards the privatisation of industry, laid out in the economic restructuring programmes. Although the service sector dominates the economy, industry is still one of the main contributors to GDP growth (around 20% in 1999), job creation and the generation of a strong currency that results from exports.

According to available data, in 2001 the Tunisian industrial sector consisted of 5,262 companies (see table below) with 10 or more employees, 2,292 of which were dedicated entirely to exports. The table shows distribution by sector. Over 85% of the industrial companies in Tunisia are SMEs.

Table 3.1.11. Number of industries in Tunisia by sector

SECTOR	No. OF INDUSTRIES	%
Food production	800	15
Construction materials, ceramics and glass	409	8
Mechanics and metalworking	464	9
Electrical and electronic	262	5
Chemical (excluding the plastics industries)	213	4
Textile and garments	2,135	41
Wood, cork and furniture	207	4
Tanning and footwear	308	6
Miscellaneous	464	9
Total	5,262	100

Source: Industry Promotion Agency

The main pollution problems are linked to uncontrolled water and energy consumption and the substantial generation of solid waste.

Paper and Pulp Industry

Consumption of paper and cardboard per capita in Tunisia in recent years has been of some 20 kg/inhab/yr, making annual consumption some 200,000 tonnes.

Table 3.1.12. Statistics of the Paper and Pulp Industry in Tunisia. Year 2002

Production capacity of Paper and Cardboard	t	140,000
Production capacity of Pulp	t	30,000
Consumption of Paper and Cardboard per capita	kg	20
Paper and Cardboard Factories	-	10
Pulp Factories	-	1
No. of employees in the Paper and Pulp Industry	-	2,000

Source: Annual Review- Africa. July 2002. PPI (Pulp and Paper International)

The Tunisian paper and pulp industry produces printing paper, corrugated cardboard, cardboard boxes and short-fibre pulp (mainly for export). With a network of medium-sized factories situated mainly in the centre of Tunisia and along the coast, the country manages around 50% of required production locally, a larger percentage than its neighbouring countries of Morocco and Algeria. The production of paper and cardboard has remained at around 94,000 tonnes per year in recent years.

The latest FAO statistics show that: the production of sanitary and domestic paper in recent years has been maintained at 4,000 tonnes per year, the production of recovered paper at 11,000 tonnes per year, the production of printing paper at 38,000 tonnes per year, and the production of paper and cardboard for packaging at 52,000 tonnes per year.

The statistics for paper imports in the year 2003 are as follows: 33,900 tonnes of chemical pulp, 33,900 tonnes of bleached sulphate pulp, 17,000 tonnes of unbleached sulphate pulp, 31,200 tonnes of material for boxes, 6,400 tonnes of coated paper, 17,500 tonnes of foldable boxboard, 700 tonnes of sanitary and domestic paper, 17,000 tonnes of newsprint, 4,500 tonnes of recovered paper, and 9,200 tonnes of printing paper, among others.

3.2. NORTHERN MEDITERRANEAN COUNTRIES

The five Northern Mediterranean countries that make up this group - Greece, France, Italy, Monaco and Spain - are considered to be high income European countries and all of them with the exception of Monaco are European Union (EU) member states. These countries share the obligation to comply with EU regulations and to adapt EU directives to National law in the short term. In the same way, they are obliged to adopt the necessary measures to satisfy the requirements of European legislation.

Industry and environment

The condition of the environment in the EU has undergone constant deterioration in recent decades. Every year, 2 billion tonnes of waste are generated, and this figure is increasing. As a result, environmental protection is one of the main challenges that Europe faces.

Like in the other EU member states, the industrial sector in the countries of the Northern Mediterranean sub region is very heterogeneous, there are wide regional variations and it is often concentrated near heavily-populated urban zones. Industry has been forced to invest in environmental treatment equipment for many years, and also to adopt technologies that are more respectful of the environment. One of the main industrial activities is the production of automobiles, which represents a quantitative and qualitative difference to other Mediterranean zones, and is particularly significant when analysing the effects of the supply chain, which enables the diffusion of cleaner production and of environmental management systems.

Political and legal framework

As EU member states, the countries in the Northern Mediterranean sub region, with the exception of Monaco, are subject to EU norms.

Environmental measures are usually adopted following directives or rulings proposed by the European Commission, provided that they are approved by the European Council. Once adopted, the Commission is responsible for ensuring their application. The Environment Directorate-General is the Commission body in charge of issues such as the environment, nuclear safety and civil protection.

During the 1970s and 1980s, EU environmental legislation was focused mainly on the establishment of emissions limits for specific pollutants. Towards the 1990s, broader initiatives were put into practice, such as the regulation of the consumption of natural resources or pollution prevention by means of "horizontal" regulations.

Many of these regulations were adopted as part of the European Community's Fifth Environment Action Programme, which established the Union's environmental strategy from 1992-2000. The programme included an integral strategy for fighting against pollution, and actions for waste reduction that were transferred to the IPPC Directive, which to a great extent matches the principles of cleaner production.

With the IPPC directive, the EU introduced the concept of Best Available Techniques (BAT) and undertook the publication of related consultation documents, the BREF, which described cleaner production solutions adopted by specific sectors and applied to particular technologies.

The objective of this Directive is to prevent or reduce to a minimum atmospheric, soil and water pollution originating from emissions from industrial installations in the member states, in order to achieve a higher level of environmental protection. The IPPC Directive defines the minimum obligations to be fulfilled by all affected industrial plants, both existing and new. These minimum obligations consist of a list of measures to prevent pollution (atmospheric, soil and water) from industrial waste flows and other waste and serve as a basis for writing exploitation permits for industrial installations.

3.2.1. SPAIN

Introduction

Spain is an industrialised European country situated in the western part of the Mediterranean basin. A total area of 504,750 km^2 and a population of approx. 41 million inhabitants.

Table 3.2.1. Socioeconomic indicators of the situation in Spain

Area	10^3 km^2	505
Population	million	41.2
Increase of population	%	0.16
Life span	years	78
Total illiteracy	% age >15	2
Women illiteracy	% age >15	3
Energy per capita	kg oil equivalent	3,084
Current GDP	€10^9 *	556.7
GDP growth	yearly %	2
PPP of estimated GDP	€10^9	709.2
GDP PPP per capita	€100	177.3
Gross capital formation	% of GDP	25
AV in agriculture	% of GDP	4
AV in industry	% of GDP	30
AV in services	% of GDP	66
Exports	% of GDP	30
Imports	% of GDP	31
Telephones	per 1,000 inh.	1,086
Personal computers	per 1,000 inh.	168

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV = Added value)

Employment levels have increased greatly, which has led to economic growth levels of above average in the Euro zone.

In recent years, Spain's economic behaviour has displayed significant strength thanks to the structural reforms carried out since the mid-1990s and the stability of the macroeconomic political framework.

Industry and environment

The rapid development experienced by Spain in the last quarter-century has turned the country into the eighth global economy among the OECD countries. In many cases, this growth has been accompanied by greater pressure on the environment, both in terms of the use of natural resources (water, soil, etc.) and of pollution generation.

The country's main industries are foodstuffs and beverages, metalwork, chemicals, shipyards, automobiles, the manufacturing of machinery, textile and garment production, and tourism. Among the goods exported by Spain, those that stand out are machinery, motor vehicles and food and consumption products.

Income from industry is distributed as follows:

Table 3.2.2. Income by manufacturing sector (2001)

SECTOR	INCOME 10^9€
Foodstuffs, beverages and tobacco	54,259
Textiles	13,400
Leather, shoes	4,086
Wood, cork	5,451
Paper, graphic arts	18,331
Refining, chemicals	40,108
Plastics, rubbers	12,446
Non-metal mineral products	18,463
Metalworking	16,876
Metal products	19,854
Machinery, equipment	23,547
Electrical and electronic goods	13,684
Vehicles	46,480
Others	9,835
TOTAL	**296,820**

Some of the greatest threats to the environment are caused by transport, the production of electrical energy, and agriculture.

Paper and Pulp Industry

Table 3.2.3. Statistics of the Paper and Pulp Industry in Spain. Year 2002

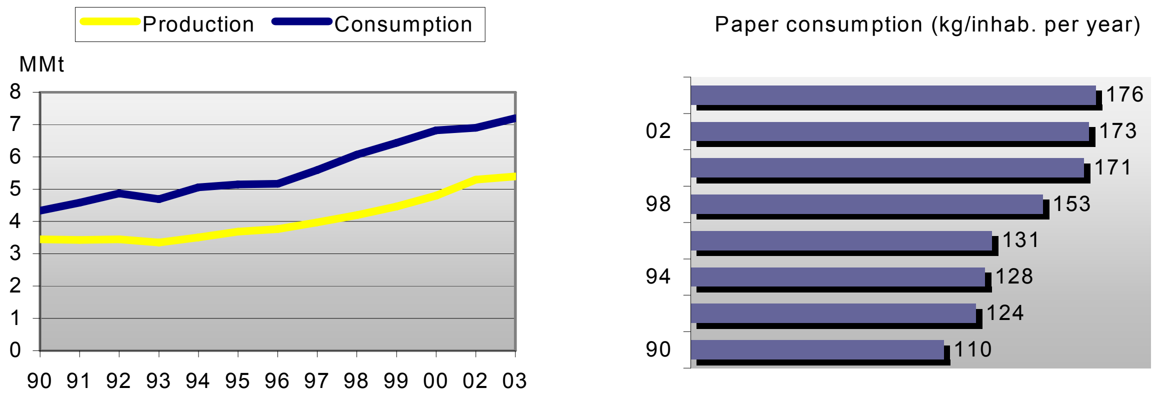
Forested area	km^2	262,732
Production capacity of Paper and Cardboard	t	5,545,000
Production capacity of Pulp	t	1,968,000
Consumption of Paper and Cardboard per capita	kg	158
Paper and Cardboard Operation Ratio	%	93
Pulp Operation Ratio	%	87
Paper and Cardboard Factories	-	132
Pulp Factories	-	15
No. of employees in the Paper and Pulp Industry	-	17,750

Source: Annual Review- Europe. July 2002. PPI (Pulp and Paper International)

In the last decade, the Spanish paper industry has entered a dynamic of large industrial projects and important investments in increased capacity, thanks to which the production of paper and cardboard has increased from 3.4 million tonnes in 1990 to 5.4 million tonnes in 2003, an increase of 58%.

In the last five years, accumulated growth in Spain has been double the average growth in European paper production. In the year 2001, there was a generalised increase for all types of paper of 7.4%. Since then, growth has slowed, with growth in 2003 of only 1.4% with respect to 2002.

Paper consumption has also increased significantly, with a level in 2003 of 7.2 million tonnes, equivalent to an increase of 3.8% with respect to 2002 and of 60% in the last ten years. This means that consumption per capita increased from 110 kg in 1990 to 176 kg in 2003. Consumption per capita is still less than in the USA (347 kg), the European Union average (196 kg) or our neighbours France (180 kg) and Italy (179 kg), which shows significant scope for growth. These figures justify the existence of projects for new plants for the coming years, with will enable the growing needs of the national market to be met.



Graphic 3.2.1.- Paper production and consumption figures in Spain

Today, Spain is one of the major producers in the EU, with 132 paper and cardboard factories, which include some of the most modern industrial plants in Europe.

The sector has 15 cellulose pulp factories with a production of 1.9 million tonnes in 2003, an increase of 10.2% with respect to 2002. The consumption of pulp was 1.7 million tonnes, an increase of 1.4% with respect to 2002.

These figures make Spain the third largest Mediterranean Action Plan producer of paper and cardboard, after France and Italy, the seventh producer of paper and cardboard in the European Union, with 6% of total production, and the fifth producer of cellulose pulp, with 5% of total European production.

The pulp and paper plants are distributed throughout the country, although the Basque Country, Catalonia and Aragon are the communities with the highest production of paper products.

Paper and cardboard exports are evolving in line with production and increased by 1.2% in 2003, reaching 1.8 million tonnes, of which 49% are of graphic papers (newsprint, printing paper and writing paper). It is worth highlighting the export of almost 400,000 tonnes of paper for corrugated cardboard, an increase of 3.2% on the previous year, and of board, exports of which increased by 16.1% (111,200 tonnes).

Imports increased by 6.4% with respect to 2002, reaching a value of 3.6 million tonnes, of which almost 2 million correspond to graphic paper and 0.9 million to paper for corrugated cardboard.

Pulp imports were 0.8 million tonnes, mainly of long-fibre pulp, while almost 1 million tonnes of short-fibre pulp was exported, with an increase of 17.6% also in line with the significant increase in pulp production.

Spain currently stands out for its high rates of recovered paper use, the highest in Europe, of 81.7% (% of recovered paper used as a raw material of the total of cellulose raw materials). The quantity of recovered paper used as raw material reaches 4.4. million tonnes, of which 900,000 tonnes of recovered paper are imported from other countries.

The sector has obtained a significant reduction in energy consumption. In 1991, an average of 9.9 GJ/t was needed to produce one tonne (unitary thermal consumption + net energy consumption), a figure that has been reduced today to 8.6 GJ/t.

The cellulose and paper industries have a total installed power of energy cogeneration of 719 MW, which has almost tripled in the last 10 years.

85% of fuel used by the paper industry in Spain is natural gas (41%) or renewable energy such as residual biomass from the fabrication process (44%). Residual biomass from the production process (cuttings, lignin...) used annually as fuel represents 832,000 tonnes oil equivalent.

3.2.2. FRANCE

Introduction

France is an industrialised European country of which the eastern side borders on the Mediterranean sea. A total area of 550,000 km^2 and a population of approx. 59.4 million inhabitants.

Table 3.2.4. Socioeconomic indicators of the situation in France

Area	10^3 km^2	551
Population	million	59.4
Increase of population	%	0.4
Life span	years	79
Total illiteracy	% age >15	NA
Women illiteracy	% age >15	NA
Energy per capita	oil kg equiv.	4,366
Current GDP	€10^9 *	1,208
GDP growth	yearly %	1
PPP of estimated GDP	€10^9	1,319
GDP PPP per capita	€10^3	24.5
Gross capital formation	% of GDP	20
AV in agriculture	% of GDP	3
AV in industry	% of GDP	26
AV in services	% of GDP	72
Exports	% of GDP	28
Imports	% of GDP	26
Telephones	per 1,000 inh	1,178
Personal computers	per 1,000 inh	337

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV = Added value)

France is the fourth largest Western industrialised economy. It has important agricultural resources, a wide, consolidated industrial base and a highly-qualified labour force. It also has a dynamic service sector of which the economic activity is constantly increasing and which is responsible for almost all new jobs created in recent years.

France has developed notable success in the telecommunications, aerospace and armaments sectors. In terms of energy production, the country has concentrated above all on the development of nuclear power which today represents some 80% of the country's electricity production. Nuclear waste is stored in reprocessing plants in French territory.

Industry and environment

France is the fourth largest industrially productive country in the world. The manufacturing industry is highly diversified and is the main source of export income.
The principal industrial sectors are:

- *The foodstuffs industry:* At present, the foodstuffs industry is the highest generator of employment in the country. France is the largest sugar beet producer in the world and the second-largest producer of wine and cheese. Among the most important foodstuffs are meat, bread and sweets.
- *Manufacture of automobiles, aircraft, ships and trains:* France is the fourth largest global manufacturer of automobiles and also has an important industry in the manufacture of ships, aircraft and trains.
- *Electrical and electronic industry:* France produces telecommunications equipment, computers, televisions, radios and other articles.
- *Metalworking industry:* The production of iron and steel, along with the aluminium industry, is another important source of employment in France.
- *Chemical and pharmaceutical industry:* France's chemical industry produces a wide range of products, ranging from industrial chemicals to plastics, fertilisers, solvents, cosmetics and pharmaceutical products.
- *Textiles industry:* This sector produces items of cotton, silk and wood.

Paper and pulp industry (*)

Table 3.2.5. Statistics of the Paper and Pulp Industry in France. Year 2002

Forested area	km^2	146,800
Production capacity of Paper and Cardboard	t	11,700,000
Production capacity of Pulp	t	3,019,000
Consumption of Paper and Cardboard per capita	kg	182
Paper and Cardboard Operation Ratio	%	82
Pulp Operation Ratio	%	98
Paper and Cardboard Factories	-	129
Pulp Factories	-	18
No. of employees in the Paper and Pulp Industry	-	23,785

Source: Annual Review- Europe. July 2002. PPI (Pulp and Paper International)

In the last ten years, paper consumption has increased by approximately 2% per year. Yearly consumption per capita of paper and cardboard is approximately 182 kg/inhab/yr, making total paper consumption for 2003 approximately 11 million tonnes (approximately 3.2% of global consumption). Paper and cardboard consumption in France can be divided in the following way: 48.9% for graphic use, 43.9% for packaging and 6.7% for sanitary and domestic use. Chemical pulp represents 82% of pulp in France.

Annual paper and cardboard production in recent years has been 9.9 million tonnes. Comparing this figure with global paper and cardboard production, 339 million tonnes in the year 2003, the French paper industry represents the ninth in global production, and fourth in Europe. Production of pulp in recent years has been 2.5 million tonnes annually, which represents 62.9% of total pulp consumption in the French paper industry. Of all the pulp produced in France, 66% is produced in integrated paper and cardboard factories, while the remaining 34% is sold to non-integrated paper and cardboard producing companies. In terms of imports and exports, it can be said that 53.6% of total paper and cardboard production is exported, while 57.5% of paper and cardboard for consumption is imported.

In terms of the consumption of raw materials for the pulp and paper industries, in 2003 France consumed 8.5 million tonnes of wood and 5.8 million tonnes of recovered paper and cardboard. In France, production of pulp and paper from recovered paper is increasing. The wood used for the pulp and paper industries consists of 75% clean wood and 25% sawmill waste. 59% comes from soft wood. 94% of wood used is of French origin.

(*) The statistics in this section come from COPACEL (Confédération française de l'Industrie des papiers, cartons et celluloses).

3.2.3. GREECE

Introduction

Greece is an industrialised European country situated in the South of Europe, bordering the Mediterranean sea. A total area of 131,940 km^2 and a population of approx. 10.6 million inhabitants.

Table 3.2.6. Socioeconomic indicators of the situation in Greece

Area	10^3 km^2	132.0
Population	million	10.63
Increase of population	%	0
Life span	years	78
Total illiteracy	% age >15	3
Women illiteracy	% age >15	4
Energy per capita	kg oil equivalent	2,635
Current GDP	€10^9*	114
GDP growth	yearly %	4
PPP of estimated GDP	€10^9	172.1
GDP PPP per capita	€100	163
Gross capital formation	% of GDP	23
AV in agriculture	% of GDP	8.1
AV in industry	% of GDP	22.3
AV in services	% of GDP	69.3
Exports	% of GDP	25
Imports	% of GDP	33
Telephones	per 1,000 inh.	1,281
Personal computers	per 1,000 inh.	81

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV = Added value)

The Greek economy has grown steadily over a number of years at a rate above predicted average EU growth. The service sector has grown to a greater extent, and more quickly. Tourism is one of the main sources of income from foreign currency in the country, despite the fact that the industry has been slow to expand and has insufficient infrastructure. The food production industry, on the other hand, has responded well to new markets in neighbouring countries. The production of high technology equipment, especially in the field of telecommunications, is one of the most dynamic sectors. Agriculture is still the source of employment for 15% of the workforce.

Industry and environment

Some of the economic activities with the greatest environmental impact in Greece are listed below:

The chemical industry

This is a sector that has managed to comply with the need of companies involved to have a good environmental record. In this sense it is well known that the Greek chemical industry has reached an adequate level of adaptation to international technological developments in the field of pollution prevention and control, giving priority to intervention at source.

The paper / textiles / tanning industries

The majority of the Greek paper industry complies with the IPPC Directive (The European directive for integrated pollution prevention and control), using progressive production techniques and adopting the majority of Best Available Techniques (BAT) quickly. On occasion, however, the incorrect operation of equipment leads to decreased technological efficiency.

Only one of the tanning industries (the biggest both in size and production levels) meets the stipulations of the IPPC Directive and has implemented any BATs as yet. In the other companies in the sector, the BATs and any other measure intended to reduce pollution are non-existent.

The textile industry is also very important in Greece. It generates a lot of employment and makes a significant contribution to national income, as it is an export sector that uses mainly locally-produced raw materials (cotton). There are some 220 companies of different sizes in the textile sector, of which 75% are small family companies, with under 10 employees. Now, however, the trend is for the creation of larger companies; small businesses are gradually disappearing.

A large part of water pollution problems are caused by textile finishing companies. Those large companies that continuously invest in BATs show continuous improvement, while those that continue to use old techniques are in constant decline. The number one necessity in terms of pollution control is the treatment of liquid waste and the removal of red sludges. The areas where the textile finishing industries are concentrated are Athens, Viotia and Thessaloniki.

The cement, glass and ceramics industries

In the cement-producing industries, the degree of use of the technology encompassed by the BAT is extremely high; in contrast, current levels of environmental protection by the lime producing industries leaves a lot to be desired. Strict emissions levels proposed by the BREF document are problematic. Greek companies dedicated to the production of asbestos and its derivatives have apparently implemented the majority of the BATs, mainly for reasons of employee health and safety. The glass industries, on the other hand, have only adopted some basic measures of pollution control.

The metalworking industries

The small and medium enterprises in this sector have economic difficulties in applying new technological developments, in contrast to the larger companies, which have reached an acceptable level of adaptation to international technological developments in terms of pollution prevention and control, prioritising actions at source.

The energy sector

This sector is composed of large lignite and oil combustion plants. The installations have large combustion units, units for processing crude oil and natural gas and units for energy production from lignite and oil, in addition to the four existing refineries.

The food industry

The food industry is one of the country's most consolidated sectors, with nearly 1/3 of the total industrial units. It is dominated by a large number of companies dedicated to poultry and pig farming, the processing of agricultural products, oil production, treatment and packaging of processed foods, dairy produce, beverages, etc. Pollution problems originate mainly from small and seasonal companies.

Paper and Pulp Industry

Table 3.2.7. Statistics of the Paper and Pulp Industry in Greece. Year 2002

Forested area	km^2	24,000
Consumption of Paper and Cardboard per capita	kg	94.75
Paper and Cardboard Factories	-	22
Pulp Factories	-	1
No. of employees in the Paper and Pulp Industry	-	5,345

Source: Annual Review- Europe. July 2002. PPI (Pulp and Paper International)

The Greek paper industry is important for the country's economy and significant among Mediterranean region countries.

In recent years (1992-2002), average paper and cardboard consumption has been 1,008,441 tonnes per year, which is 94.75 kg/inhab/yr. Greece is the seventh consumer of paper and cardboard in tonnes and the fifth consumer per capita of the MAP countries.

Paper and cardboard production in recent years (1992-2002) reached its peak between 1993-1996 (750,000 tonnes per year) and then decreased in subsequent years. 495,000 tonnes were produced in the year 2002.

Recovered paper production has also decreased recently, from 175,000 tonnes in 1999 to only 51,940 in 2002.

The most recent figures from the ACPWP (the FAO Advisory Committee on Paper and Wood Products) in terms of production, imports and exports, divided into products, are as follows:

- The pulps that are most produced in Greece are non-bleached sulphate pulp, mechanical pulp and pulp from other fibres.
- The paper and cardboard types that have been most produced in recent years (2002-2003) are domestic and sanitary paper (77,000 tonnes per year), paper and cardboard for packaging (94,000 tonnes per year), recovered paper (52,000 tonnes per year) and boxboard (48,000 tonnes per year).
- Greece is an importer of manufactured paper and cardboard products. The products imported in the greatest quantities are printing paper (317,000 tonnes per year), coated paper (197,000 tonnes per year) and paper and cardboard for packaging (195,000 tonnes per year). Exports in this sector are low, the most-exported products being those of total fibre content (111,000 tonnes per year).

3.2.4. ITALY

Introduction

Italy is an industrialised European country in the Mediterranean region, surrounded by the Mediterranean Sea. A total area of 301,300 km^2 and a population of approx. 58 million inhabitants.

Table 3.2.8. Socioeconomic indicators on the situation in Italy

Area	10^3 km^2	301.3
Population (July 2003)	million	57.9
Population growth (July 2003)	%	0.11
Life span	years	79.4
Total illiteracy	% age >15	1.4
Women illiteracy	% age >15	1.8
Energy per capita	kg oil equivalent	2,974
Current GDP	€10^9 *	1.23
GDP growth (Est. 2002)	yearly %	0.4
PPP of estimated GDP	€10^9	1.2
GDP PPP per capita	€10^3	21.4
Gross capital formation	% of GDP	19.8
AV in agriculture	% of GDP	2.8
AV in industry	% of GDP	28.9
AV in services	% of GDP	68.2
Exports	% of GDP	28.3
Imports	% of GDP	26.7
Telephones	per 1,000 inh.	1,311
Computers	per 1,000 inh.	195

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV = Added value)

Italy has gone from being a primarily agricultural economy to being the fifth global economy. It is a country of scarce resources. A large part of Italy's area is unsuitable for cultivation, so it has become a net importer of foods.

Most of the raw materials needed for manufacturing and over 80% of energy sources in the country are imported. Italy's economic strength is based on the processing and manufacture of goods, mainly in small and medium-sized family firms.

Industry and environment

Among the priority environmental questions, air pollution in the cities, soil and water management, waste management, the conservation of the surroundings and the landscape, climate change, transport management and the protection of coastal and marine areas stand out.

The main industrial sectors that generate toxic and dangerous waste are: the organic and inorganic chemical industry, area treatment, the electronics industry, mining and transport, recycling, the textile industry, the paper and pulp industry, energy production, the agriculture and food industry, and the tanning industry.

Industry employs measures to reduce its impact in some processes and sectors.

In the 1990s, the Italian industrial sector made significant advances towards improved air quality. Emissions of SO_x, NO_x, CO, VOC (from solvents), dioxins and furan decreased. This was in fact the only sector to reduce CO_2 emissions. Italy has made great progress towards establishing the infrastructures necessary to manage industrial air pollution.
Paper and pulp industry (*)

Table 3.2.9. Statistics of the Paper and Pulp Industry in Italy. Year 2002

Forested area	km^2	68,475
Production capacity of Paper and Cardboard	t	10,200,000
Production capacity of Pulp	t	750,000
Consumption of Paper and Cardboard per capita	kg	200
Paper and Cardboard Operation Ratio	%	88
Pulp Operation Ratio	%	80
Paper and Cardboard Factories	-	201
Pulp Factories	-	12
No. of employees in the Paper and Pulp Industry	-	24,800

Source: Annual Review- Europe. July 2002. PPI (Pulp and Paper International)

Consumption of paper and cardboard per capita in recent years has been 200 kg/inhab/yr, making total paper and cardboard consumption some 11 million tonnes per year. Paper and cardboard production in the year 2003 was 9.3 million tonnes, of which most was for graphics paper (2,744,783 tonnes per year), paper and cardboard for packaging (2,495,572 tonnes per year) and paper for sanitary use (543,441 tonnes per year). The production of pulp for paper was 3.6 million tonnes in the same year.

In recent years, the use of recovered paper as a raw material has been on the increase, rising from 3.7 million tonnes in 1998 to 5.1 million tonnes in 2003.

Total water consumption in Italy has decreased from 313,000,000 m^3 in the year 2001 to 312,000,000 m^3 in the year 2002, water consumption per unit of production of pulp and paper having also decreased from 35 m^3/t in the year 2001 to 34 m^3/t in the year 2002. In addition, electrical energy consumed in this sector decreased from 7,600 GWh in 2001 to 7,200 GWh in 2002, and it should be noted that there was an increase in the use of natural gas as fuel, from 81,500 tJ in 2001 to 81,900 tJ in 2002. This shows an interest in improving the environment by means of pollution prevention.

(*) These figures come from ASSOCARTA (L'associazione del l'industria cartaria rappresentante le imprese produttrici di carta, cartoni e paste per carta in Italia)

3.2.5. MONACO

Introduction

Monaco is a European country situated on the coast of the Mediterranean sea. A total area of 1.95 km^2 and a population of approx. 32,149 inhabitants.

Table 3.2.10. Socioeconomic indicators of the situation in Monaco

Area	km^2	1.95
Population (est. 2003)	thousands	32.15
Population growth (est. 2003)	%	0.44
Life span	years	79.27
Unemployment level (1998)	%	3.1
Energy per capita	kg oil equivalent	NA
Current GDP (est. 1999)	€10^9 *	745
GDP growth	yearly %	NA
PPP of estimated GDP	€10^6	770
GDP PPP per capita (1999)	€10^3	23.6
Telephones (1995)	per inh.	±1

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV = Added value)

Monaco is a small country with an economy that is based mainly on the financial, trading and tourism sectors. Tourism represents almost 25% of annual income; The Principality of Monaco has been a major tourist centre since the opening of its famous casino in 1856. Monaco is also important for its role in the field of marine sciences.

Industry and environment

Monaco's industrial sector has developed considerably in under a century. Since 1906, when the State financed the construction of the first industrial estate in Fontvieille, a number of industries have set up there, such as the Monaco brewery and companies from the flour milling sector and the chocolate production sector. In the last 20 years, almost 200,000 m^2 of industrial construction has taken place. Available land in the Principality is so scarce that industrial installations occupy buildings of up to thirteen storeys.

Today, Monaco's industry is diversified. There is a large number of companies that have a solid base in various sectors: 23 belong to the chemical, pharmaceutical and cosmetic industries; 13 to the processing of plastic materials; 21 to graphic arts, editing and cardboard products; 22 to the electrical and electronics industry and mechanical and precision engineering; 8 to the textiles and garment finishing sector, and others, such as construction firms, make up some 200 companies.

The chemical, pharmaceutical and cosmetics sector seems to be the largest, but the companies involved in the processing of plastic materials and the manufacture of electrical equipment are also important. Other sectors, such as mechanical engineering, packing, graphic arts and garment finishing are also important, although not to the same extent. The main environmental problem associated with these sectors is water pollution.

Paper and Pulp Industry

The pulp and paper industry has no relevance in Monaco.

3.3. EASTERN MEDITERRANEAN COUNTRIES

This group includes countries with a common tendency to implement similar environmental legislation to that of the European Union. Some of these countries, such as Cyprus, Malta and Slovenia have found themselves undergoing a process of adapting their legislation to that of the EU since joining this year. Turkey, as a short or medium term candidate for inclusion in the EU, is also undergoing a process of adaptation. Others countries such as Bosnia and Herzegovina, Croatia and Albania have also begun the process of adopting environmental legislation similar to that of the EU. Candidates for EU membership have begun an adaptation process with different programmes depending on their joining date, which include upgrading internal industry and compliance with environmental conditions. Israel has also been included in this group because, although it is not a member of the EU, it has many connections to this body, due in part to the similarities in the characteristics of their respective industries and the commitments made to protect the Mediterranean Sea.

Industry and environment

The countries in this sub region differ in their recent pasts. Some Eastern Mediterranean countries, specifically Albania, Bosnia and Herzegovina, Croatia and Slovenia, are currently going through phases of economic transformation as a result of reforms following the fall of Communism and the gradual opening of their markets. Central economic planning has disappeared entirely from their policies, and they have all embarked on independent programmes of liberalisation, macroeconomic stabilisation, legal and institutional reforms and privatisation. Since 1990, they have concentrated on converting their economic systems to capitalism and opening the way for foreign investment. Industry is an important component of the economy in large numbers of these countries, while at the same time the service sector is gaining more and more weight in some of them.

Political and legal framework

The countries of this sub region have made noticeable progress in passing new environmental legislation. However, this process has still not been accompanied by the effective implementation of either the old laws and regulations, or those that have been recently approved. Progress in ensuring that these regulations are followed and making sure industry adopts practices that are environmentally respectful can be classed in many cases as mediocre, or even poor.

For a large proportion of the Eastern Mediterranean countries, European Union legislation is a required reference. The EU has had a major influence on many of these countries, not only in terms of economic development, but also in terms of environmental management, providing the impulse for an early movement towards harmonisation with European regulations as a means of accelerating accession to the EU.

In the majority of these countries, the granting of permits for productive activities is a function that is shared between different government bodies and agencies, which frequently leads to an acute lack of coordination. However, some of the countries are getting around this problem by applying the IPPC system, which enables them to establish an integrated focus in granting permits. Of these countries, Slovenia, Cyprus and Malta are at a more advanced stage in the process.

In the international framework for environmental protection by means of pollution prevention, all of the Eastern Mediterranean countries have subscribed to, signed or ratified the Basel Convention on Hazardous Waste and the Stockholm Convention on Persistent Organic Pollutants. As for the depletion of the ozone layer, all of the countries have also ratified the Montreal Protocol and, with the exception of Albania, its first amendments. With regard to climate change, the majority of the countries have signed or ratified the Kyoto protocol.

Within the framework of the Mediterranean Action Plan, and with regard to those protocols that focus mainly on land-based activities, all of the countries have ratified the Land-Based Sources Protocol although only some have accepted the amendments of 1995. As for the Dangerous Waste protocol, only Albania and Malta have ratified it, and Turkey has signed it.

3.3.1. ALBANIA

Introduction

Albania is an Eastern European Country situated in the Mediterranean region. A total area of 28,750 km^2 and a population of approx. 3.5 million inhabitants.

Table 3.3.1. Socioeconomic indicators of the situation in Albania

Area	10^3 km^2	28.8
Population	million	3.2
Life span	years	74.0
Total illiteracy	% age >15	14.1
Women illiteracy	% age >15	21.3
Energy per capita	oil kg equiv.	522
Current GDP	€10^9 *	4.0
GDP growth	yearly %	5.0
PPP of estimated GDP	€10^9	12
GDP PPP per capita	€	3,854
Gross capital formation	% of GDP	19
AV in agriculture	% of GDP	32.4
AV in industry	% of GDP	22.7
AV in services	% of GDP	44.9
Exports	% of GDP	19.7
Imports	% of GDP	43.8
Operational telephone lines	per 1,000 inh.	138
Personal computers	per 1,000 inh.	7.6

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV = Added value)

Albania's conversion from a centralised economy to a market-orientated system began at the start of 1992, following which GDP fell by over 50% in relation to its maximum value registered in 1989. The democratically-elected government launched an ambitious programme of economic reforms and set the country on the road towards a market economy. Among the reforms were the privatisation and reform of the business and financial sectors.

Industry and environment

Albania is a country of low to medium income, in comparison with other countries in the zone. The limited availability of resources restricts investment in environmental protection. However, as the contribution of industrial production to GDP has diminished since 1990, the impact of industrial activity on the environment has also been considerably reduced as a result of the elimination of many dangerous sources of environmental pollution.

Apart from agriculture, which represents employment for almost half of the active population, industrial activity is currently composed of the following activities: copper mining and enriching, the mining of chrome materials, oil extraction and refining, construction materials and electrical production. Most industrial waste is generated in these industrial sectors.

The majority of state-owned industries have been closed down, leaving the waste accumulated in old industrial plants as the main environmental problem.

Paper and Pulp Industry

The Albanian paper and pulp industry is not among the most representative of the Mediterranean Action Plan countries. Consumption of paper and cardboard per capita in Albania has remained at 6.3 kg/inhab/yr in recent years, making total consumption of paper and cardboard 20,000 tonnes per year. The production of paper and cardboard in Albania in the period 2000-2002 remained at around 2,800 tonnes per year.

According the the latest available figures for the production of different types of pulp and other paper products (Source: The FAO Advisory Committee on Paper and Wood Products -ACPWP), from 1993 to 1998 Albania produced: 13,500 tonnes per year of chemical paper pulp, 13,500 tonnes per year of unbleached sulphate paper pulp, 2,000 tonnes per year of mechanical paper pulp, 400 tonnes per year of pulp from other fibres, 8,000 tonnes per year of newsprint, 4,500 tonnes per year of writing and printing paper, among others.

During the years 2000-2003, 2,000 tonnes of paper were produced each year for boxboard. In the year 1999, 1,000 tonnes of paper and cardboard for packaging were produced, while from the year 2000 to the year 2003, production increased to 2,800 tonnes per year.

The biggest imports of cellulose pulp in Albania were of semi-chemical pulp. Exports of recovered paper have increased since the year 1997, increasing from 48 tonnes per year to 88 tonnes per year in 2003. Another product that is exported is mechanical cellulose pulp.

3.3.2. BOSNIA-HERZEGOVINA

Introduction

Bosnia and Herzegovina is an Eastern European country which borders on the Adriatic sea. A total area of 51,233 km^2 and a population of approx. 3.5 million inhabitants.

Table 3.3.2. Socioeconomic indicators for Bosnia and Herzegovina

Area	10^3 km^2	51.13
Population	million	4.12
Increase of population	%	1
Life span	years	74
Total illiteracy	% age >15	NA
Women illiteracy	% age >15	NA
Energy per capita	kg oil equivalent	1,096
Current GDP	€10^9 *	4.5
GDP growth	yearly %	4
PPP of estimated GDP	€10^9	6
GDP PPP per capita	€100	15.4
Gross capital formation	% of GDP	21
AV in agriculture	% of GDP	14
AV in industry	% of GDP	30
AV in services	% of GDP	56
Exports	% of GDP	27
Imports	% of GDP	51
Telephones	per 1,000 inh.	168
Computers	per 1,000 inh.	NA

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV = Added value)

The economy of Bosnia and Herzegovina is still affected by central planning. There is an excess of staff in industry, which reflects the rigidity of the planned economy. Three years of war destroyed the economy and the infrastructures. However, advances have been considerable since peace was established. Inflation has remained low due to the fact that the currency has been fixed. Despite this, however, growth has been unequal. The most immediate worry is to revitalise the economy. To do this, the general situation should be directed towards the private sector and the free market economy.

One of the main priorities for the protection of the Mediterranean area of Bosnia and Herzegovina is the construction of a drainage infrastructure. Because the region does not have a fully developed drainage system, some villages and industries dispose of wastewater directly into inadequate septic tanks from which there are often leaks, thus contaminating underground waters.

Industry and environment

The pollution of the Adriatic river basin in Bosnia Herzegovina, which covers a total area of 12,410 km^2, comes both from localised waste emission points and scattered sources located mainly in karst areas that, due to their vulnerability, allow the pollutants to percolate quickly in to the subsoil. No concrete figures are available for industrial emissions as there is no exhaustive pollution register; legislation only includes the testing of the wastewater. Controls of atmospheric emissions and solid waste are not obligatory for companies, which means that there are no relevant quantitative or qualitative statistics available.

Large scale industry is structured mainly around companies working in the industries of: agriculture and food, aluminium, surface treatments; wood, and materials for construction, textiles and electricity (hydroelectric and thermoelectric). Due to the situation created by the war, the majority of large-scale industries that still exist operate at extremely low profitability that in many cases does not even reach 10% of the amount that was normal prior to the war. Moreover, those treatment systems that exist are no longer in use.

The main problem is the non-existence of industrial and municipal wastewater treatment plants, as this means that wastewater is discharged directly.

Paper and Pulp Industry

Table 3.3.3. Statistics of the Paper and Pulp Industry in Bosnia. Year 2002

Forested area	km^2	24,750
Production capacity of Paper and Cardboard	t	339,000
Production capacity of Pulp	t	165,000
Paper and Cardboard Factories	-	14
Pulp Factories	-	2
No. of employees in the Paper and Pulp Industry	-	1,250

Source: Annual Review- Europa. July 2002. PPI (Pulp and Paper International)

The paper and pulp industry in Bosnia and Herzegovina is not among the most representative of the Mediterranean Action Plan countries. Consumption of paper and cardboard per capita in this country has remained at around 3 kg/inhab/yr in recent years, making total consumption 10,800 tonnes per year. No reliable figures are available for total production in this country, but current production is around 30% higher than in 1990.

As seen in the table above, Bosnia had a total of 16 pulp and paper factories in the year 2002. In recent years, imports of paper products have remained at 4,361 tonnes per year. Imports of chemical pulp has evolved in a similar fashion to those of paper products, imports remaining stable at 1,840 tonnes per year since 1999. Semi-chemical pulp imports were of 22 tonnes per year in 2003.

The most recent available figures show that in 2003 the following products were exported: 1,140 tonnes per year of paper products: 44 tonnes per year of chemical pulp and 1,100 tonnes per year of recovered paper.

3.3.3. CYPRUS

Introduction

Cyprus is a European island situated in the Northeast of the Mediterranean basin. A total area of 9,250 km^2 and a population of approx. 800,000 inhabitants.

Table 3.3.4. Socioeconomic indicators of the situation in Cyprus

Area	km^2	9,250
Population	thousands	765
Population growth	%	0.6
Life span	years	78.1
Total illiteracy	% age >15	2.6
Women illiteracy	% age >15	4.0
Energy per capita	kg oil equivalent	3,203
Current GDP	€10^9 *	7.8
GDP growth	yearly %	2.0
PPP of estimated GDP	€10^9	8
GDP PPP per capita	€100	128.5
Gross capital formation	% of GDP	NA
AV in agriculture	% of GDP	NA
AV in industry	% of GDP	NA
AV in services	% of GDP	NA
Exports	% of GDP	NA
Imports	% of GDP	NA
Telephones	per 1,000 inh.	1,087
Computers	per 1,000 inh.	247

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV= Added value, NA= non available)

Cyprus has an open free market. Its economy is based on services and, in part, on light industry. The Cypriot people is one of the most prosperous in the Mediterranean. In the last 20 years, the economy has moved from agriculture to light industry and services. The service sector, including tourism, represents almost 70% of GDP and employs 62% of the total workforce.

The trade sector is vital for Cyprus, as the island is not self-sufficient in food and has very few natural resources. Cyprus must import fuel, most raw materials, heavy machinery and transport equipment.

Industry and environment

The bases of the Cypriot economy are tourism and the service sector, including telecommunications, shipping and banking.

Over time, the dense population of the coastal zones caused by tourism, services and the considerable emigration from urban areas has put great pressure on the sea coast, especially in high season. Industrial activity further contributes to this pressure, as the principal industries (energy, cement and wine production, and oil refining) are all situated on the coast. These activities are producing signs of local pollution on a small scale. Despite this, water quality is good throughout the country thanks to strict laws governing wastewater discharge and the protection of the environment and natural habitats.

Paper and Pulp Industry

In recent years (1992-2002) the consumption of paper and cardboard in Cyprus has remained at around 52,000 tonnes per year (67 kg/inhab/yr).

There are no available figures for total paper and cardboard production in recent years, although there are records (Source: The FAO Advisory Committee on Paper and Wood Products - ACPWP) that show that during the period 1992 to 2002, 10,000 tonnes per year of recovered paper were produced.

Imports of fibrous products from 1993 to 2003 were:

- Imports of paper products have increased from 1993, when imports of 3,211 tonnes were recorded, to 2003, when imports reached 4,169 tonnes.
- Imports of chemical pulp evolved in a similar fashion. In 1993, 3,121 tonnes of pulp were imported. This amount increased to reach the figure of 4,133 tonnes recorded in 2003.

Exports are fundamentally based on:

- 86 tonnes of chemical pulp in 2000 that had practically disappeared by 2003.
- In 1993, 1,181 tonnes of paper products were exported. This figure increased until 1997 (6,200 tonnes) and increased again in 2000 to some 11,200 tonnes per year, a level that was maintained in 2003.

3.3.4. CROATIA

Introduction

Croatia is an Eastern European country that borders on the Adriatic sea. A total area of 56,538 km^2 and a population of approx. 4.37 million inhabitants.

Table 3.3.5. Socioeconomic indicators of the situation in Croatia

Area	10^3 km^2	56.54
Population	million	4.37
Increase of population	%	-0.2
Life span	years	74
Total illiteracy	% age >15	1.5
Women illiteracy	% age >15	2.4
Energy per capita	oil kg equiv.	1,775
Current GDP	€10^9 *	19.2
GDP growth	yearly %	5.2
PPP of estimated GDP	€10^9	31
GDP PPP per capita	€100	71
Gross capital formation	% of GDP	24.7
AV in agriculture	% of GDP	9.7
AV in industry	% of GDP	34.2
AV in services	% of GDP	56.1
Exports	% of GDP	48.5
Imports	% of GDP	54.7
Operational telephone lines	per 1,000 inh.	742
Personal computers	per 1,000 inh.	86

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV= Added value, NA= non available)

Croatia underwent an accelerated process of industrialisation and diversification after the Second World War. Decentralisation took place in 1965 and enabled the growth of certain sectors such as tourism. Profits generated by Croatian industry were used to develop the poorest regions in the former Yugoslavia. This, in combination with the programmes of austerity and hyperinflation of the 1980s, generated a great deal of discontent, which strengthened the pro-independence movement.

Privatisation under the new Croatian government had hardly started when the Croatian war of independence (1991-1995) broke out, ravaging the country's economy. Following a period of increasing unemployment, reforms began to be applied, including a value added taxation programme, which was highly successful, the planned privatisation of State-controlled companies and the revision of budgets to reduce expenditure and deficits. Low inflation and the stable currency have been the main economic successes. However, structural reforms have lagged behind.

Industry and environment

The industrial sectors that play an active role in the economy and in the country's environmental pollution are those of energy, cement, foodstuffs, oil refining, metalworking, chemicals, pulp and paper, textiles and agriculture.

Although industry has adopted voluntary agreements, the energy production sector, in particular oil refining and the thermal energy centres, is the sector that has become most actively involved in promoting cleaner production. The situation is reversed among SMEs, as their level of compliance with environmental legislation is worse than the larger companies and they lack information and training on the opportunities of CP.

Croatia has finished the primary CP introductory phase. The concept of CP is being introduced in industry. However, the country has numerous hot spots that indicate the need for more action towards CP.

Paper and Pulp Industry

Table 3.3.6. Statistics of the Paper and Pulp Industry in Croatia. Year 2002

Forested area	km^2	24,500
Consumption of Paper and Cardboard per capita	kg	111.17
Paper and Cardboard Operation Ratio	%	65
Pulp Operation Ratio	%	68
Paper and Cardboard Factories	-	3
Pulp Factories	-	2
No. of employees in the Paper and Pulp Industry	-	1440

Source: Annual Review- Europa. July 2002. PPI (Pulp and Paper International)

The pulp and paper sector in Croatia is a significant industry, being one of the most important in the Eastern sub region of the Mediterranean Action Plan countries. Consumption of paper and cardboard has increased in recent years. The figure was 111.17 kg/inhab/yr in 2002, total paper and cardboard consumption being 493,500 tonnes.

Paper and cardboard production has also increased in recent years, reaching 467,000 tonnes of paper and cardboard produced in 2002, of which 64,000 tonnes were recovered paper.

The most relevant dates in recent years, 2000-2003 are (Source: The FAO Advisory Committee on Paper and Wood Products - ACPWP):

- Production of mechanical pulp was of some 40,000 tonnes/year and of semi-chemical pulp of some 80,000 t/year.
- The paper and cardboard products manufactured are diverse, and among them the following stand out due to production volume:
    - Paper and cardboard for packaging (220,000 tonnes per year)
    - Printing and writing paper (220,000 tonnes per year)
    - Materials for boxes (210,000 tonnes per year)
- Main imports in the sector are centred on chemical pulp and bleached sulphate pulp, with 2,000 tonnes per year of each, recovered paper (125,000 tonnes per year), printing paper (84,000 tonnes per year), coated paper (51,000 tonnes per year), paper and cardboard for packaging (44,000 tonnes per year) and newsprint (37,000 tonnes per year).
- The main exports in recent years have been mechanical pulp (40,000 tonnes per year), paper and cardboard for packaging (130,000 tonnes per year) and recovered paper (15,000 tonnes per year).

3.3.5. SLOVENIA

Introduction

Slovenia is an Eastern European country on the shores of the Adriatic sea. A total area of 20,256 km^2 and a population of approx. 2 million inhabitants.

Table 3.3.7. Socioeconomic indicators of the situation in Slovenia

Area	10^3 km^2	20.3
Population	million	2.0
Life span	years	75.9
Total illiteracy	% age >15	NA
Women illiteracy	% age >15	NA
Energy per capita	kg oil equivalent	3,288
Current GDP	€10^9	21.1
GDP growth	yearly %	2.9
PPP of estimated GDP	€10^9	26.5
GDP PPP per capita	€10^2	137
Gross capital formation	% of GDP	25.5
AV in agriculture	% of GDP	3.1
AV in industry	% of GDP	37.5
AV in services	% of GDP	59.3
Exports	% of GDP	60.1
Imports	% of GDP	60.5
Telephones	per 1,000 inh.	1,161
Computers	per 1,000 inh.	276

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV= Added value, NA= non available)

Slovenia won its independence from the former Yugoslavia in 1990. Since then, the government has implemented a comprehensive reforms programme, including price liberalising and the restructuring of industry and the economy in general. The privatisation process took place in accordance with these plans. In 1995, 215 large companies had already been privatised and 478 were privatised later. At that time, the majority of SMEs had already been privatised (56,000), in which over 90,000 people were employed.

It is currently one of the most prosperous countries in transitional Europe and holds a privileged position for joining the main modern industrial economies. Slovenian companies have traditionally tended towards a free market economy and they have the backing of relatively good economic management. The Slovenian economy depends to a large extent on foreign trade, two thirds of which is with other EU countries, the principal reason for their request to join the EU. As a result, Slovenia is very sensitive to any changes in commercial relations with its principal trade partners.

Industry and environment

Slovenia is a small economy and its companies are mainly SMEs. It has around 141,000 companies. Approximately 1.3% of the total number are companies of over 1,000 employees, while 89.7% are microenterprises or small and medium companies (SMEs) with between 1 and 99 employees. It is clear that these SMEs are very important for the national economy, although they do not have the necessary resources to invest in research and development and they are concentrated mainly in urban centres. SMEs have technical and directional assistance from institutions such as the Chamber of Commerce and Industry, the Centre for Small Business Development and some technology parks in Maribor, Ljubljana.

Of the 141,000 Slovenian companies, 80% are private. The most developed industrial sectors are chemicals, pharmaceuticals, paper production, textiles, foodstuffs and beverages, furniture-making, the manufacture of kitchen appliances, automobiles and metalworking.

Industry is without doubt one of the main polluters in Slovenia. Most air pollution comes from the metalworking industry, electricity production, the paper industry, the graphic arts industry and furniture-making (dust, SO_2, NO_x, TOC), the chemicals industry, (CO, SO_2, NH_3) and wood (TOC). Water pollution is one of the main environmental problems; the main pollutants are insoluble materials (from the paper industry, graphic arts, energy production, foodstuffs and metalworking), COD problems (generated by the paper, graphic arts and foodstuffs industries), nitrates and nitrites (from the metalworking industry), ammoniacal nitrate (from the tanning and chemical industries) and metals (from the metalworking and chemical industries). The production of solid waste is decreasing gradually.

Paper and Pulp Industry

Table 3.3.7. Statistics of the Paper and Pulp Industry in Slovenia. Year 2002

Forested area	km^2	10,000
Paper and Cardboard capacity	t	600,000
Pulp production capacity	t	230,000
Consumption of Paper and Cardboard per capita	kg	150
Paper and Cardboard Operation Ratio	%	93
Pulp Operation Ratio	%	93
Paper and Cardboard Factories	-	9
Pulp Factories	-	3 (1 sulphite, 2 mechanical/DIP)
No. of employees in the Paper and Pulp Industry	-	5,500

Source: Annual Review- Europa. July 2002. PPI (Pulp and Paper International)

Slovenia has the highest paper consumption of the Eastern European countries. Paper consumption per inhabitant per year in Slovenia is high, reaching a figure of over 150 kg/inhab/yr in 2003. Total paper and cardboard consumption is 0.5 million tonnes. Slovenia is not a major paper and cardboard producer, with 590,000 tonnes produced in 2003. This production is divided into 11% newsprint, 23% printing and writing paper, 12% sanitary paper, 23% coated paper and paper for packaging, and 31% cardboards.

Production of chemical and mechanical paste was of 134,000 tonnes in 2003, a 10% decrease with respect to the previous year, while the production of paper and cardboard, of 600,000 tonnes in 2003, decreased 3% with respect to 2002.

Since gaining its independence, Slovenia has had a pulp production deficit, as the majority of the former Yugoslavia's cellulose plants were in the Bosnia and Herzegovina region, and therefore is has to import pulp.

At present, Slovenia has 3 pulp factories, of which one is a sulphite pulp mill and the others are mechanical pulp factories. There are also 6 paper and cardboard factories. Several factories have closed in recent years due to difficulties in modernising them to comply with environmental legislation, resulting in a 22% decrease in paper and cardboard production with respect to the year 2001. In addition, 22 large companies and 40 SMEs participate in the conversion of these paper products with a capacity of 80,000 tonnes of corrugated cardboard, 72,000 tonnes of boxes and 95,000 tonnes of packaging and other converted products. There are currently 600 people working in the paper sector.

The sector's main imports were paper products, reaching an overall figure of 637,000 tonnes in 2003. The most important exports were based on printing paper, paper and cardboard for packaging, coated paper and folding boxboard. Exports were to: 14% Croatia, 13% Italy, 10% Germany, 6% Bosnia and Herzegovina, 5% Austria, 4% Hungary and 44% to other countries.

3.3.6. ISRAEL

Introduction

Israel has a diversified and technologically advanced economy, with an important although receding public sector and a powerful new generation technology sector. The main industrial sectors are high technology electronics and biomedical equipment, metal products, processed foodstuffs, the chemical industry and transport equipment. Moreover, Israel has an important service sector and is a world leader in software development.

Table 3.3.8. Socioeconomic indicators of the situation in Israel

Area	10^3 km^2	21.06
Population	million	6.5
Increase of population	%	2.0
Life span	years	78.7
Total illiteracy	% age >15	4.7
Women illiteracy	% age >15	6.6
Energy per capita	oil kg equiv.	3,123
Current GDP	€10^9 *	104.5
GDP growth	yearly %	-1.1
PPP of estimated GDP	€10^9	102
GDP PPP per capita	€10^3	16.2
Gross capital formation	% of GDP	20.1
AV in agriculture	% of GDP	3
AV in industry	% of GDP	30
AV in services	% of GDP	67
Exports	% of GDP	23
Imports	% of GDP	25.2
Operational telephone lines	per 1,000 inh.	1,285
Personal computers	per 1,000 inh.	246

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV= Added value, NA= non available)

Israel has a coherent programme of environmental legislation and policy. CP is written into legislation on toxic and dangerous substances and is controlled by means of a permit system. The application of preventative activities is linked to or takes place through the Israeli Centre for Cleaner Production and governmental bodies.

Industry and environment

On an industrial level, important advances have been made in the last two decades in the following areas: medical electronics, agrotechnology, telecommunications, fine chemistry products, computer software and hardware and diamond cutting and polishing.

The high technology sectors, in which capital and training are invested and which require sophisticated production techniques, together with considerable investment in research and development (R+D), are those with the highest levels of growth. Over 90% of annual public spending on R+D is destined for new technologies.

Paper and Pulp Industry

Table 3.3.9. Statistics of the Paper and Pulp Industry in Israel. Year 2002

Forested area	km^2	1,000
Paper and Cardboard capacity	t	320,000
Paper and Cardboard Factories	-	6
No. of employees in the Paper and Pulp Industry	-	2,100

Source: PPI (Pulp and Paper International)

Average consumption of paper and cardboard between the years 1992 and 2002 was around 900,000 tonnes per year, with consumption per capita of paper and cardboard in 2002 140.74 kg/inhab/yr. Paper and cardboard production has remained constant in the last decade at 275,000 tonnes per year.

Of most recent figures, it is noteworthy that: (Source: The FAO Advisory Committee on Paper and Wood Products - ACPWP):

- Paper and cardboard for packaging are the products produced in the greatest volume (130,000 tonnes per year). Other products of lesser importance are printing and writing paper (95,000 tonnes per year) and sanitary and domestic paper (50,000 tonnes per year). 110,000 tonnes per year are recovered paper.
- The most important imports are those of paper and cardboard for packaging and chemical pulp. The volume of exports is lower than that of imports.

3.3.7. MALTA

Introduction

As it has few raw materials and a very limited local market, Malta has based its economic development on encouraging tourism and on the export of manufactures. Since the middle of the 1980s, the expansion of these activities has become the main motor of the strong growth of the Maltese economy.

Table 3.3.10. Socioeconomic indicators of the situation in Malta

Area	km^2	320
Population	inhabitants	397,000
Increase of population	%	0.5
Life span	years	78.4
Total illiteracy	% age >15	3.4
Women illiteracy	% age >15	6.6
Energy per capita	kg oil equivalent	2,089
Current GDP	€10^9 *	3.1
GDP growth	yearly %	-0.7
PPP of estimated GDP	€10^9	5.13
GDP PPP per capita	€100	128.5
Gross capital formation	% of GDP	20.4
AV in agriculture	% of GDP	2.8
AV in industry	% of GDP	25.5
AV in services	% of GDP	71.7
Exports	% of GDP	87.8
Imports	% of GDP	92.3
Telephones	per 1,000 inh.	884
Computers	per 1,000 inh.	230

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV= Added value, NA= non available)

There is a solid manufacturing base of products with high added value such as electronic apparatus and pharmaceutical products, while the manufacturing sector has over 250 companies under foreign ownership, orientated towards exports. Tourism generates 35% of GDP.

Industry and environment

The contribution of the manufacturing sector to GDP is 26%, and its total consumption of energy generated is around 27%. The main types of industry that make up the sector range from the manufacture of semiconductors and other pieces of sophisticated equipment to the production of foodstuffs and beverages and repairs to boats. Other important activities for the country are tourism and construction.

Nearly 90% of the companies are classed as SMEs and are provided with technical assistance and managerial help by the Institute for the Promotion of Small Enterprises (IPSE). The use by SMEs of technology related to CP is practically nil and the support received by large companies for the implementation of CP is also scarce.

Paper and Pulp Industry

Consumption of paper and cardboard has increased in recent years, from 39.98 kg/inhab/yr in 1992 to 117.86 kg/inhab/yr in 2003, making total consumption of paper and cardboard 46,320 tonnes in those years.

No data is available for total paper and cardboard production in recent years, although there are records (Source: The FAO Advisory Committee on Paper and Wood Products - ACPWP) that show that for the period 1993 to 2003, two products were imported:

- Imports of chemical paper pulp decreased from 1993, when imports of 1,100 tonnes were recorded, to 2003, with imports of 350 tonnes.
- Imports of pulps have evolved in the same way: in the year 1993 1,300 tonnes were imported, dropping to around 350 tonnes in 2003.

3.3.8. TURKEY

Introduction

Turkey is a country situated between the Europe and Asia, on the coast of the Mediterranean sea. A total area of 780,580 km^2 and a population of approx. 70 million inhabitants.

Table 3.3.11. Socioeconomic indicators of the situation in Turkey

Area	km^2	775
Population	million	70
Increase of population	%	1.32
Life span	years	69.9
Total illiteracy	% age >15	14.0
Women illiteracy	% age >15	22.1
Energy per capita	kg oil equivalent	1,181
Current GDP	€10^9 *	157
GDP growth	yearly %	7.8
PPP of estimated GDP	€10^9	379
GDP PPP per capita	€100	57
Gross capital formation	% of GDP	19.0
AV in agriculture	% of GDP	13.8
AV in industry	% of GDP	26.6
AV in services	% of GDP	59.6
Exports	% of GDP	28.8
Imports	% of GDP	25.4
Telephones	per 1,000 inh.	587
Computers	per 1,000 inh.	40.7

Source: World Bank Group and global EDGE (2001-2002) (PPP= Purchasing Power Parity; AV= Added value, NA= non available)

A strategy for growth based on exports and the free market has placed the Turkish economy among those experiencing highest growth levels in the Organisation for Economic Cooperation and Development (OECD). However, the programme of reforms begun at the start of the 1980s has not been fully completed, resulting in high inflation, stimulated mainly by the public sector's large deficit.

The decrease of the importance of agriculture for the economy has coincided with the rapid expansion of the service and industrial sectors. The textiles sector represents the main Turkish manufacturing industry and is the one with highest exports. With the creation of a Ministry of the Environment in 1991, environmental questions have gradually received more attention.

Industry and environment

The main industrial sectors in Turkey are manufacturing (textiles, the chemical industry, metalworking, paper and foodstuffs), mining, energy and the construction industry. Other significant sectors are those of tourist infrastructures, automobiles and electronics. Industrial pollution in Turkey is due mainly to production activities. The manufacturing sector is the largest contributor to industrial pollution in the country.

In Turkey, small and medium enterprises represent 98.8% of production installations; The majority of the remaining 1.2% are medium-sized companies. The location of industries has recently become a relevant topic in Turkey. As government investment shows, there is currently a tendency to promote the development of existing industrial zones and to establish new ones, rather than encouraging the growth of SMEs located in isolated areas. 14% of SMEs are currently found in organised industrial areas and 38% in small industrial zones; the rest are isolated companies.

Paper and Pulp Industry

Table 3.3.12. Statistics of the Paper and Pulp Industry in Turkey. Year 2002

Forested area	km^2	779,452
Paper and Cardboard capacity	t	2,155,000
Pulp capacity	t	557,700
Consumption of Paper and Cardboard per capita	kg	35.59
Paper and Cardboard Operation Ratio	%	70
Pulp Operation Ratio	%	55
Paper and Cardboard Factories	-	36
Pulp Factories	-	11 (5 sulphate, 3 semi-chemical, 3 mechanical, 5 non wood)
No. of employees in the Paper and Pulp Industry	-	9,380

Source: Annual Review- Europa. July 2002. PPI (Pulp and Paper International)

Turkey is the fourth largest producer and consumer of pulp and paper of the Mediterranean Action Plan countries, behind the larger industries of France, Italy and Spain. However, Turkey's consumption per capita of paper and cardboard is not very high, at 35.39 kg/inhab/yr in recent years, with a total consumption of 2.5 million tonnes.

The industry has great potential for development. The existing capacity of factories in Turkey is still very low in comparison to that of the countries of the European Union, with 36 paper and cardboard factories and 11 pulp factories, of which 5 produce sulphate pulp, 3 produce semi-chemical pulp, 3 produce mechanical pulp and 5 produce non-wood pulp.

In the private sector, recovered paper makes up 75.8% of raw materials, with pulp providing 19%. Nevertheless, the quality of the paper collected is often unsuitable for the factories' existing systems, making the de-inking process extremely important.

Production of recovered paper increased from 1992 to 2002 (1 million tonnes). Paper and cardboard production also increased, although not to such a great extent. In 2002 1,643,000 tonnes of paper and cardboard were produced.

The most recent available figures for production, imports and exports by product are given below (Source: The FAO Advisory Committee on Paper and Wood Products - ACPWP):

- The pulps produced in greatest quantity in recent years (2000-2003) are chemical pulp (183,000 tonnes per year), unbleached sulphate pulp (148,000 tonnes per year) and annual plant fibre pulps (53,000 tonnes per year).
- Paper and cardboard production in Turkey encompasses all types of products, including paper and cardboard for packaging, with a production level of 1,200,000 tonnes per year, recovered paper (1,000,000 tonnes per year) and materials for boxes (850,000 tonnes per year).
- The main imports for the years 2002 and 2003 were of 600,000 tonnes per year in general: 360,000 tonnes per year of chemical pulp and 230,000 tonnes per year of recovered paper.
- Turkey's volume of exports is much lower than of imports. The most important exports in recent years (2000-2003) consisted of 4.6 million tonnes per year of paper products, of which only 3,000 tonnes per year were of recovered paper.

3.4. THE SITUATION OF THE PAPER AND PULP INDUSTRY IN THE MEDITERRANEAN ACTION PLAN COUNTRIES

In recent years, the economic climate has meant that cost reduction has been a key factor for any industrial sector. With this objective in mind, pulp and paper manufacturers have adopted numerous measures to reduce consumption of raw materials and energy, increasing the efficiency and productivity of many processes, which has contributed indirectly to the environmental improvement of these factories.

In this context, to maintain competitiveness, while improving production techniques, adopting the best available techniques that are technically and economically viable, companies in the sector will also have to find new markets for their products. The development of new, specific products that stand out, for example, for their high quality or for their production with cleaner technologies will enable these companies to compete with the Asian market, which, due to lower production costs, is rapidly encroaching on existing markets. Research, development and innovation are fundamental if these objectives are to be attained.

It is well known that paper consumption is related to a country's economic activity and cultural status, acting as an indicator of the country's level of development.

Consumption per inhabitant per year in the Mediterranean Region in 2002 ranged from 2.62 kg per inhab/year in Bosnia and Herzegovina to 204.01 kg per inhab/year in Italy. Table 3.4.1 shows consumption of the Mediterranean Action Plan countries for the different countries and different years.

Table 3.4.1. Consumption of Paper and Cardboard in PAM countries. Units: kg/inhab/year

COUNTRY	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992
Albania	6.28	6.32	6.34	6.51	17.72	17.13	15.25	13.81	13.67	13.88	13.35
Algeria	7.08	7.42	7.38	8.08	7.75	6.32	6.04	7.65	8.12	8.47	8.44
Bosnia Her.	2.62	2.66	2.72	2.81	2.93	2.89	0.09	0.09	0.08	0.20	0.06
Cyprus	69.48	70.09	68.43	67.85	66.23	64.57	63.26	67.07	66.94	64.85	87.91
Croatia	111.17	103.89	100.09	110.03	107.98	106.37	87.68	79.07	48.74	34.95	19.95
Egypt	13.24	15.09	10.26	19.21	14.67	13.41	9.37	9.39	11.27	11.06	11.03
France	182.62	183.44	192.15	185.52	182.64	168.45	156.39	165.50	168.83	155.06	157.59
Greece	85.19	100.37	102.31	100.06	100.34	92.98	92.59	87.70	105.57	106.96	68.27
Israel	104.74	130.83	133.69	123.88	105.36	111.60	107.30	120.77	120.01	117.63	119.39
Italy	204.01	190.94	195.94	183.19	166.82	166.90	142.66	145.22	149.69	132.37	136.50
Lebanon	45.02	45.77	39.59	51.56	55.98	45.27	35.52	31.52	41.52	44.19	29.64
Libya	3.14	3.20	5.69	5.80	6.19	2.98	3.03	2.52	3.23	7.94	3.95
Malta	117.86	-	91.77	92.25	89.09	58.75	49.34	57.14	58.93	46.09	39.98
Monaco	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Morocco	8.34	9.77	10.58	9.50	9.47	9.51	8.77	10.02	9.82	9.61	8.12
Slovenia	141.43	201.96	85.66	106.43	154.89	-	175.70	169.55	137.95	120.22	162.80
Spain	169.60	156.45	165.92	198.18	135.05	141.51	134.24	129.81	127.93	118.22	123.37
Syria	4.11	9.26	6.16	8.17	8.99	7.53	3.52	2.64	5.76	4.85	3.42
Tunisia	19.18	23.43	20.90	18.87	19.15	20.27	17.01	18.44	18.93	15.93	18.35
Turkey	35.39	29.12	36.72	31.85	31.33	30.82	27.17	24.80	20.49	27.00	21.46

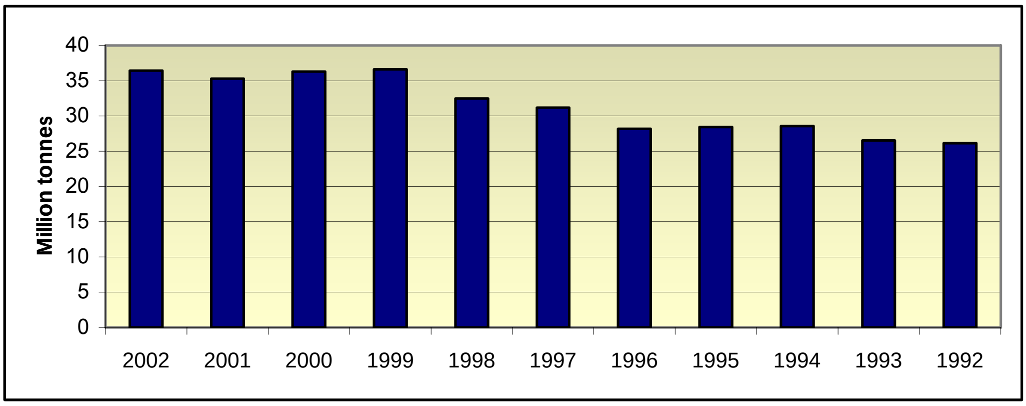
Source: The FAO Advisory Committee on Paper and Wood Products (ACPWP)

Table 3.4.2. shows total paper and cardboard consumption in the Mediterranean Action Plan countries.

Table 3.4.2. Consumption of Paper and Cardboard in metric tonnes

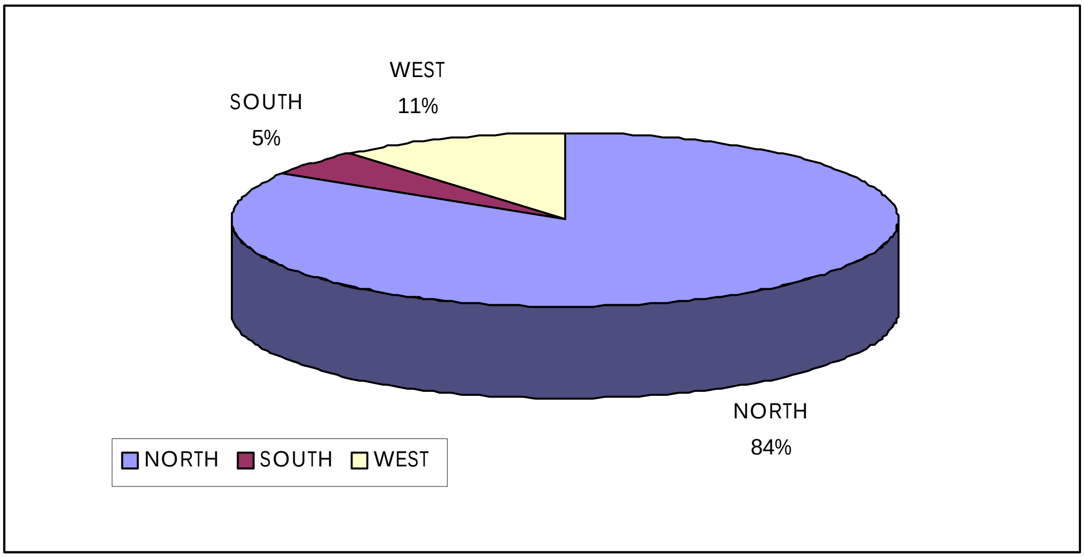
COUNTRY	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992
Albania	19,725	19,725	19,725	20,256	55,318	53,749	48,177	43,991	43,991	45,138	43,844
Algeria	221,300	228,200	223,300	240,400	227,100	182,200	171,379	213,179	222,200	226,900	221,244
Bosnia Her.	10,800	10,800	10,800	10,800	10,800	10,184	298	298	298	747	236
Cyprus	55,304	55,304	53,583	52,650	51,000	49,200	47,700	49,900	49,000	46,627	61,975
Croatia	493,500	461,800	445,000	488,300	477,500	469,100	387,300	352,100	220,500	161,626	94,349
Egypt	933,700	1,043,000	695,400	1,277,400	957,300	858,700	588,700	578,500	681,200	655,914	641,283
France	10,929,892	10,926,498	11,393,878	10,955,000	10,743,142	9,872,000	9,130,000	9,622,000	9,772,000	8,932,000	9,032,781
Greece	934,581	1,098,763	1,115,504	1,084,000	1,078,100	989,700	976,200	916,800	1,095,636	1,103,224	700,344
Israel	660,263	807,773	807,774	732,235	609,000	630,100	590,600	646,000	621,762	588,394	575,694
Italy	11,727,000	10,983,001	11,273,317	10,539,000	9,592,900	9,590,000	8,187,000	8,321,000	8,561,000	7,553,114	7,770,894
Lebanon	161,900	161,900	137,700	176,300	188,100	149,300	114,700	99,300	127,000	130,800	84,810
Libya	17,100	17,100	29,800	29,800	31,196	14,696	14,696	11,996	15,046	36,296	17,728
Malta	46,320	4,867	35,700	35,700	34,300	22,500	18,800	21,600	22,100	17,100	14,672
Monaco	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Morocco	250,886	289,170	308,000	272,000	266,800	263,700	239,400	269,000	259,300	249,497	207,149
Slovenia	280,881	401,498	170,462	212,000	309,000	-	350,700	337,400	273,000	236,232	317,131
Spain	6,949,700	6,395,000	6,761,544	8,047,300	5,461,600	5,697,600	5,382,000	5,183,800	5,091,100	4,690,100	4,879,872
Syria	71,381	157,200	102,000	132,000	141,700	115,746	52,765	38,465	81,853	67,110	46,013
Tunisia	186,550	225,450	198,900	177,600	178,200	186,300	154,330	165,061	166,839	138,152	156,359
Turkey	2,488,373	2,018,000	2,507,540	2,142,000	2,075,000	2,009,000	1,742,600	1,564,000	1,270,100	1,644,907	1,283,441

Overall paper and cardboard consumption in the MAP countries is obtained from the figures in table 3.4.2 (see graphic 3.4.1). Total paper and cardboard consumption in the Mediterranean Region in 2002 was of 36.5 million tonnes, a 40% increase since 1992 and an average annual increase of 4% in the last 10 years. There was a continuous increase between 1996 and 1999 of approximately 8% annually. However, from 1999 there was a period of stagnation due to the unstable global situation. During the period 2000-2003, only Spain showed significant growth both in paper consumption and production.



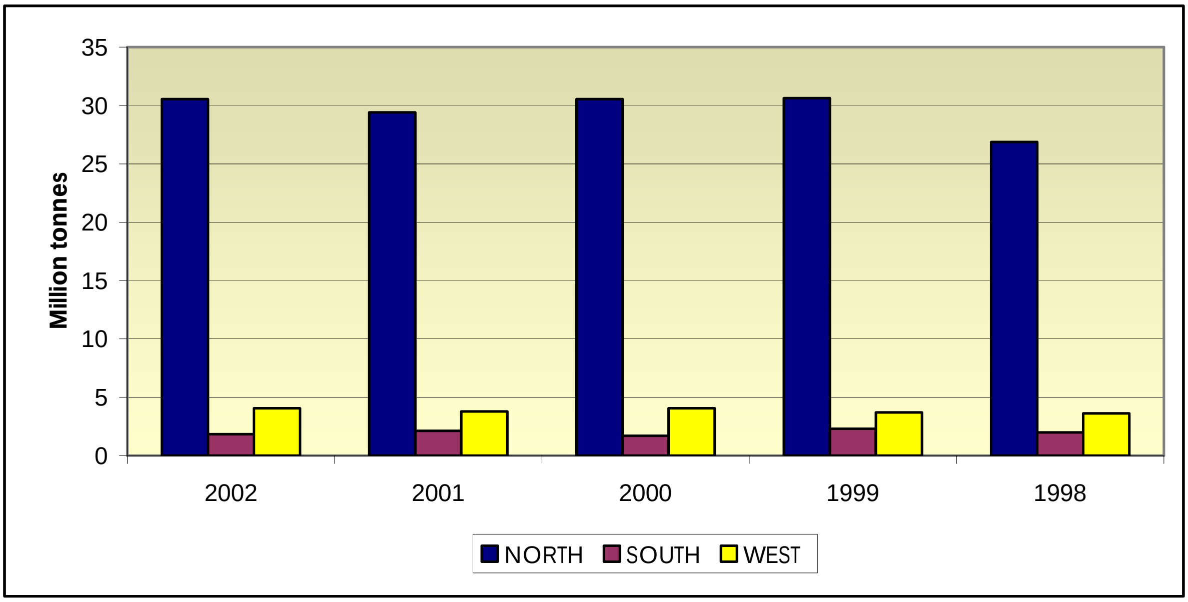
Graphic 3.4.1. Consumption of Paper and Cardboard in PAM countries

Paper and cardboard consumption varies between the different regions of the Mediterranean. See graphic 3.4.2.



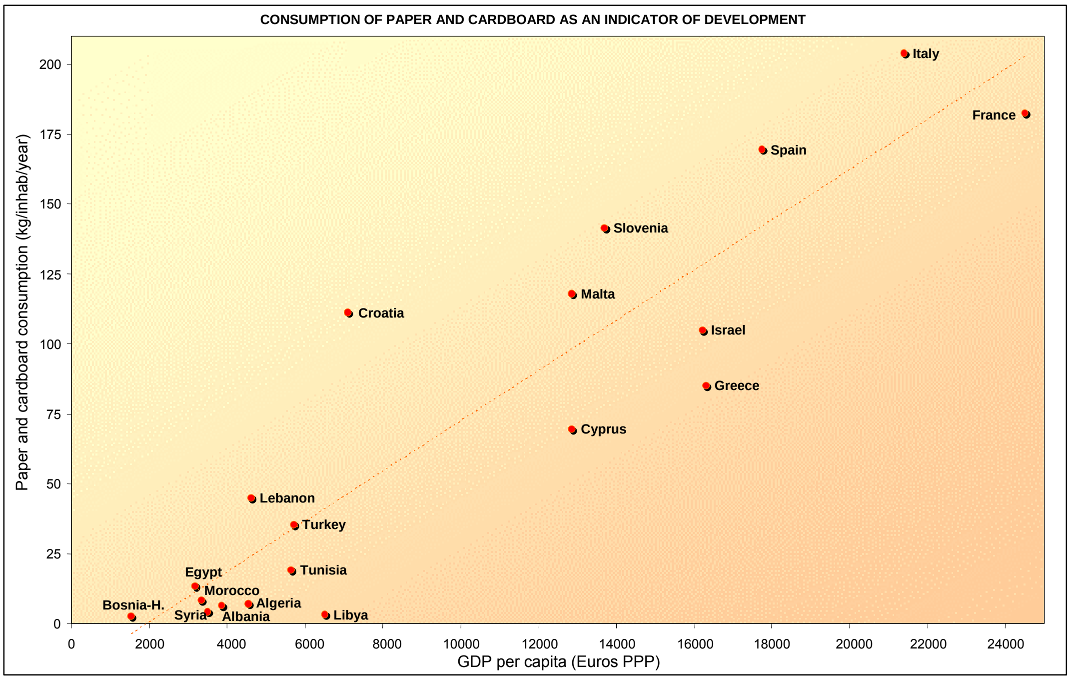
Graphic 3.4.2. Paper and cardboard consumption in the MAP countries in the year 2002

This trend has been constant over the years, as can be seen in graphic 3.4.3.



Graphic 3.4.3. Consumption of Paper and Cardboard in PAM countries

Graphic 3.4.4. shows the relationship in the MAP countries between paper and cardboard consumption and GDP per capita (kg/person per year) in the year 2002.



Graphic 3.4.4.- Consumption of paper and cardboard as an indicator of development

In terms of production, pulp production in the MAP countries has remained at around 7 million tonnes (40% of this from France and 30% from Spain), 3.78% of global production (see table 3.4.3. and graphic 3.4.13).

Table 3.4.3. Pulp production in the MAP countries in tonnes

COUNTRY	2002	2001	2000	1999	1998	1997	1996
Albania	0	0	0	0	29,400	29,400	29,400
Algeria	2,000	2,000	5,000	21,000	21,000	21,000	21,000
Bosnia Her.	0	0	0	0	0	0	0
Croatia	122,000	115,000	127,000	95,000	95,000	105,000	129,000
Cyprus	0	0	0	0	0	0	0
Egypt	120,000	120,000	75,000	60,000	60,000	60,000	60,000
France	2,915,000	3,520,000	3,520,000	3,520,000	3,520,000	3,425,000	3,327,000
Greece	0	0	5,000	5,000	13,500	13,500	40,500
Israel	15,000	15,000	15,000	15,000	0	0	0
Italy	750,000	635,000	635,000	635,000	635,000	635,000	635,000
Lebanon	0	0	0	0	0	0	0
Libya	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0
Monaco							
Morocco	219,000	219,000	219,000	219,000	231,000	225,000	203,000
Slovenia	274,000	274,000	274,000	273,000	254,000	238,000	178,000
Spain	2,125,000	2,032,000	2,014,000	2,006,000	1,990,000	1,975,000	1,958,000
Syria	0	0	0	0	0	0	0
Tunisia	10,000	10,000	14,000	14,000	14,000	16,000	12,000
Turkey	461,000	458,000	582,000	530,000	601,000	580,000	609,000

Source: The FAO Advisory Committee on Paper and Wood Products (ACPWP)

In the last decade, paper manufacturing in the Mediterranean Region has entered a process of large-scale industrial projects and investments in significant capacity increases, thanks to which production of paper and cardboard increased from 20 million tonnes in 1993 to 28 million tonnes in 2003 (see table 2.4.4. and graphic 3.4.5), an increase of 40%. Although global production of paper has decreased since 2000, it has remained stable in the Mediterranean Region. In particular, the strong development of Spanish production and the slightly lesser development of Italian production should be noted.

Table 3.4.4. Paper and cardboard production in the MAP countries in metric tonnes

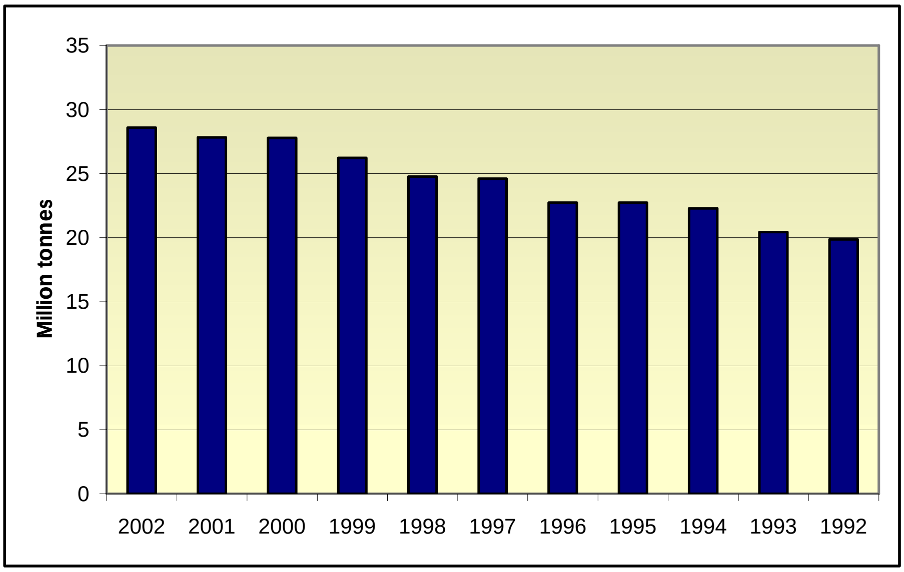
COUNTRY	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992
Albania	2,800	2,800	2,800	1,000	43,500	43,500	43,500	43,500	43,500	43,500	43,500
Algeria	41,000	41,000	41,000	26,000	55,000	65,000	56,000	78,000	87,000	93,000	91,000
Croatia	467,000	451,000	406,000	417,000	403,000	393,000	304,200	324,800	247,800	114,000	100,000
Cyprus	0	0	0	0	0	0	0	0	0	0	0
Egypt	460,000	460,000	440,000	343,000	343,000	282,000	221,000	221,000	219,000	220,000	201,000
France	9,798,000	9,625,000	10,006,000	9,603,000	9,161,300	9,143,000	8,556,000	8,619,000	8,701,000	7,975,000	7,691,000
Greece	495,000	495,000	496,000	545,000	622,000	478,000	750,000	750,000	750,000	750,000	387,000
Israel	275,000	275,000	275,000	275,000	242,000	275,000	275,000	275,000	229,000	213,000	215,000
Italy	9,273,000	8,926,000	9,129,317	8,568,000	8,253,900	8,032,000	6,954,000	6,810,000	6,705,000	6,019,000	6,040,000
Lebanon	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000
Libya	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Malta	0	0	0	0	0	0	0	0	0	0	0
Monaco	0	0	0	0	0	0	0	0	0	0	0
Morocco	129,000	129,000	109,000	109,000	110,000	107,000	106,000	106,000	103,000	99,000	102,000
Slovenia	494,000	633,000	411,000	417,000	491,000	430,000	456,000	449,000	460,000	401,000	413,000
Spain	5,364,700	5,131,000	4,765,000	4,435,300	3,544,600	3,968,000	3,768,000	3,684,000	3,503,000	3,348,000	3,449,000
Syria	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Tunisia	94,000	94,000	94,000	94,000	88,000	97,000	90,000	90,000	92,000	80,000	71,000
Turkey	1,643,000	1,513,000	1,567,000	1,349,000	1,357,000	1,246,000	1,105,000	1,240,000	1,102,000	1,032,000	1,012,600

Table 3.4.5. Production of Recovered Paper. Unit: metric tonnes.

COUNTRY	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992
Albania	0	0	0	0	0	0	0	0	0	0	0
Algeria	32,000	32,000	37,000	30,000	30,000	30,000	40,000	4,000	4,000	4,000	4,000
Croatia	64,000	64,000	64,000	64,000	64,000	52,000	52,000	52,000	52,000	58,000	0
Cyprus	10,000	10,000	10,000	-	-	10,000	10,000	10,000	10,000	10,000	10,000
Egypt	380,000	380,000	350,000	32,000	32,000	180,000	180,000	180,000	160,000	140,000	120,000
France	5,705,000	5,571,000	5,775,000	5,276,000	4,614,000	4,219,000	3,857,000	3,700,000	4,075,000	2,829,000	3,007,000
Greece	51,940	51,940	51,940	175,000	175,000	43,000	175,000	175,000	175,000	175,000	180,000
Israel	113,000	113,000	113,000	113,000	113,000	113,000	113,000	113,000	113,000	113,000	113,000
Italy	5,194,000	5,098,000	5,057,241	4,207,000	3,303,900	3,080,000	2,351,000	2,351,000	2,277,000	2,997,000	2,929,000
Malta	0	0	0	0	0	0	0	0	0	0	0
Monaco	0	0	0	0	0	0	0	0	0	0	0
Morocco	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	55,000
Slovenia	65,000	65,000	65,000	65,000	65,000	62,000	62,000	62,000	62,000	65,000	75,000
Spain	3,616,800	3,496,000	3,319,000	2,963,000	2,635,000	2,117,000	2,117,000	2,117,000	1,823,000	1,736,000	1,777,000
Tunisia	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000
Turkey	1,016,000	846,000	866,000	707,000	692,000	689,000	555,000	586,000	527,000	536,000	350,000

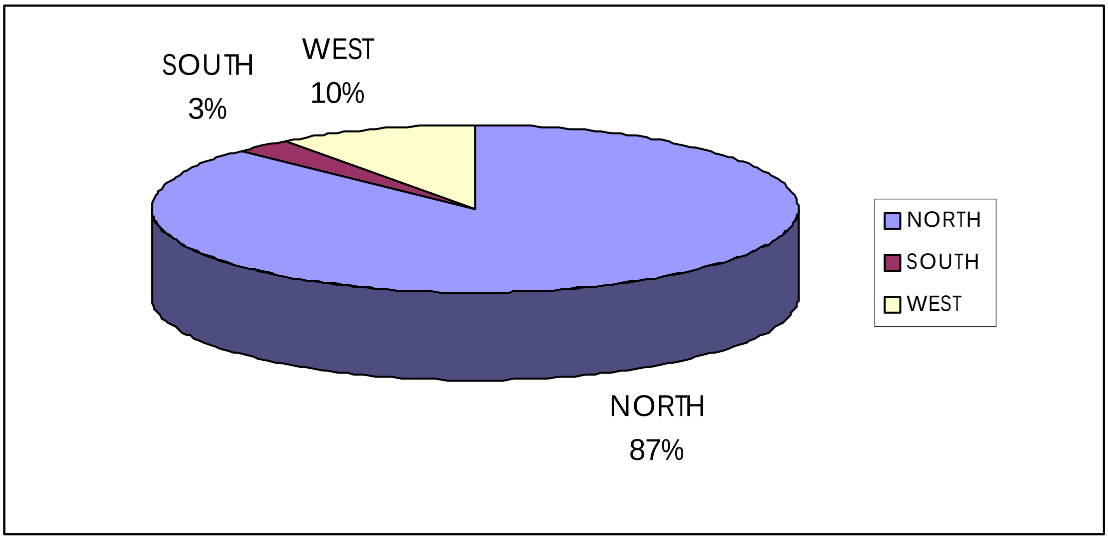
Source: The FAO Advisory Committee on Paper and Wood Products (ACPWP)

The evolution of total production in the MAP countries over the last ten years is shown in graphic 3.4.5:



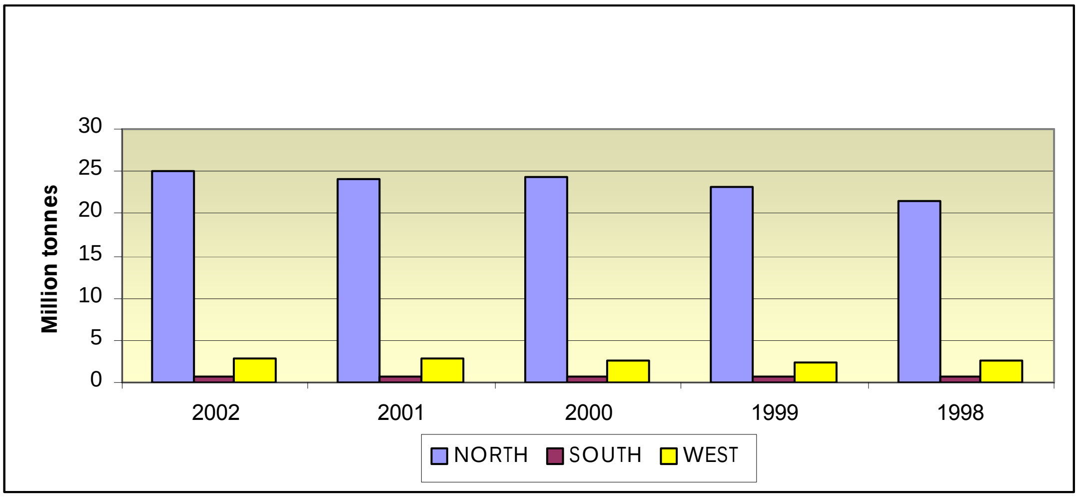
Graphic 3.4.5. Global production of Paper and Cardboard in PAM countries

In the case of paper production, there is also a notable difference between the different Mediterranean Regions (see table 3.4.4. and graphic 3.4.6).



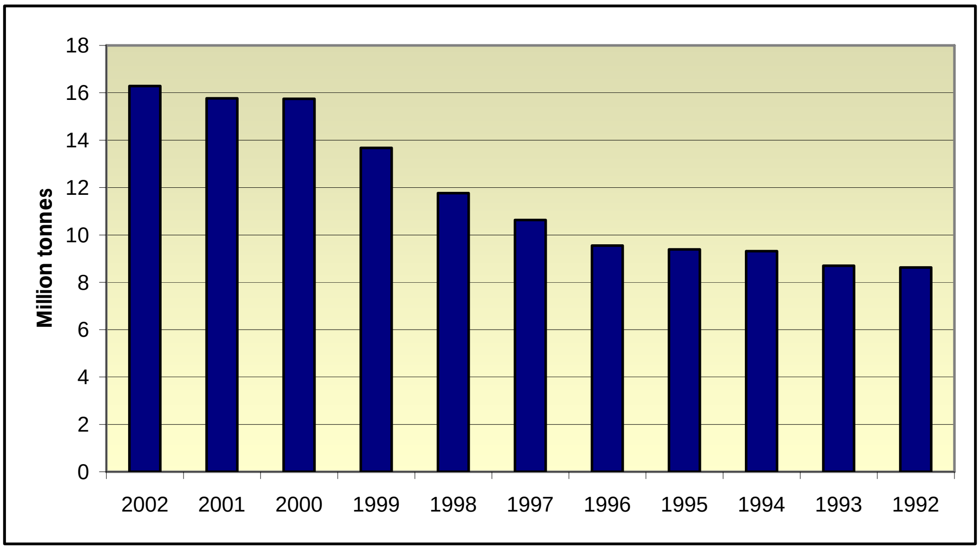
Graphic 3.4.6. Paper and Cardboard Production in the MAP countries in 2002

In a comparison of graphics 3.4.2. and 3.4.5. it can be seen that the Northern and Southern Mediterranean countries consume more than they produce, while the Eastern Mediterranean countries consume less than they produce. This shows the imports and exports markets in the different regions, and the need or otherwise for greater national production of paper and pulp.



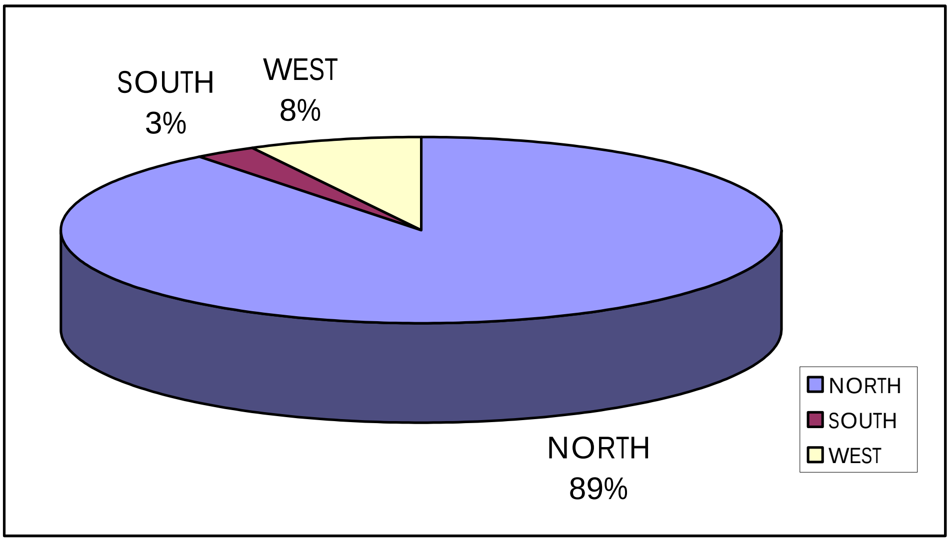
Graphic 3.4.7. Production of Paper and Cardboard in PAM countries

In terms of production of recovered paper in the MAP countries, graphic 3.4.8., an increase of 80% can be seen from 1993 to 2002, from 8.7 million tonnes to 16.3. It can be seen that the increase begins in 1996 and that from 2000 there was another period of stagnation despite increased production of recovered paper in the countries in the North of the region.



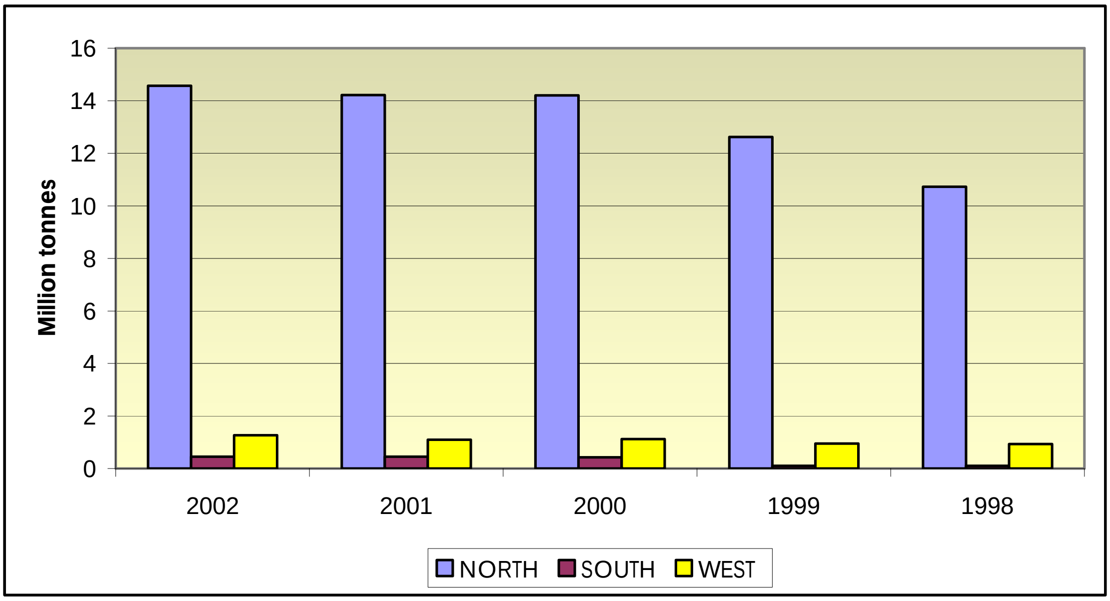
Graphic 3.4.8. Overall Production of Recovered Paper in the MAP countries

In conjunction with the global figures for recovered paper, a difference can be seen between the different regions of the Mediterranean (figure 3.4.9).



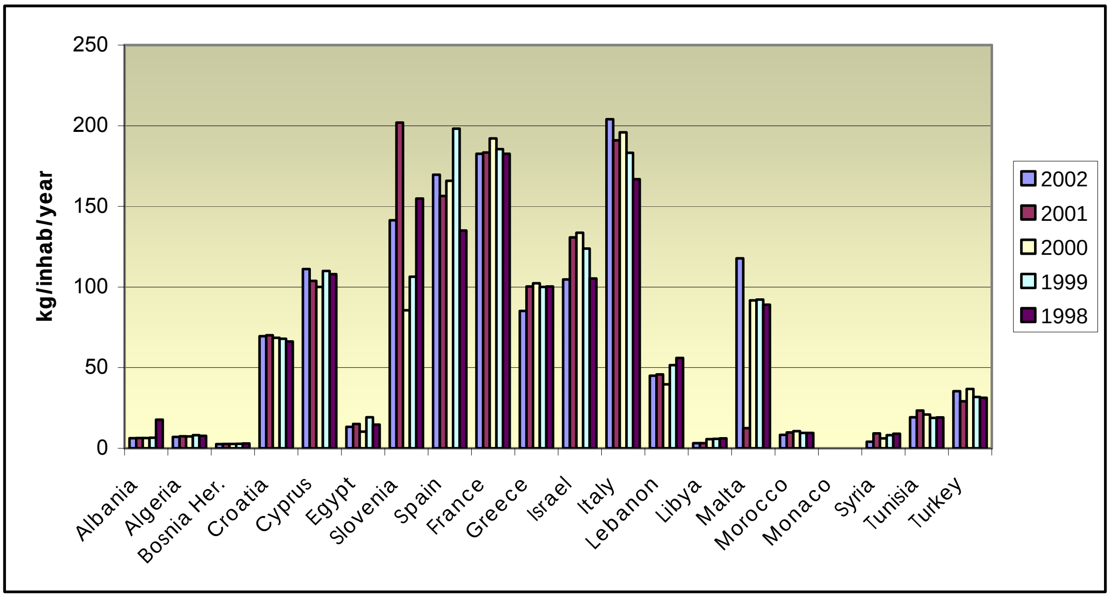
Graphic 3.4.9. Recovered Paper Production in the MAP countries in the year 2002

If the evolution of the production of recycled paper by region over several years is analysed, an increase can be seen in all zones. In the Southern Mediterranean area, there was practically no recycled paper produced in 1998 whereas in 2002, 453,000 tonnes were produced. In contrast, the Eastern Mediterranean countries already produced 934,000 tonnes of recycled paper in 1998, which in 2002 had increased to 1,269,000 tonnes.

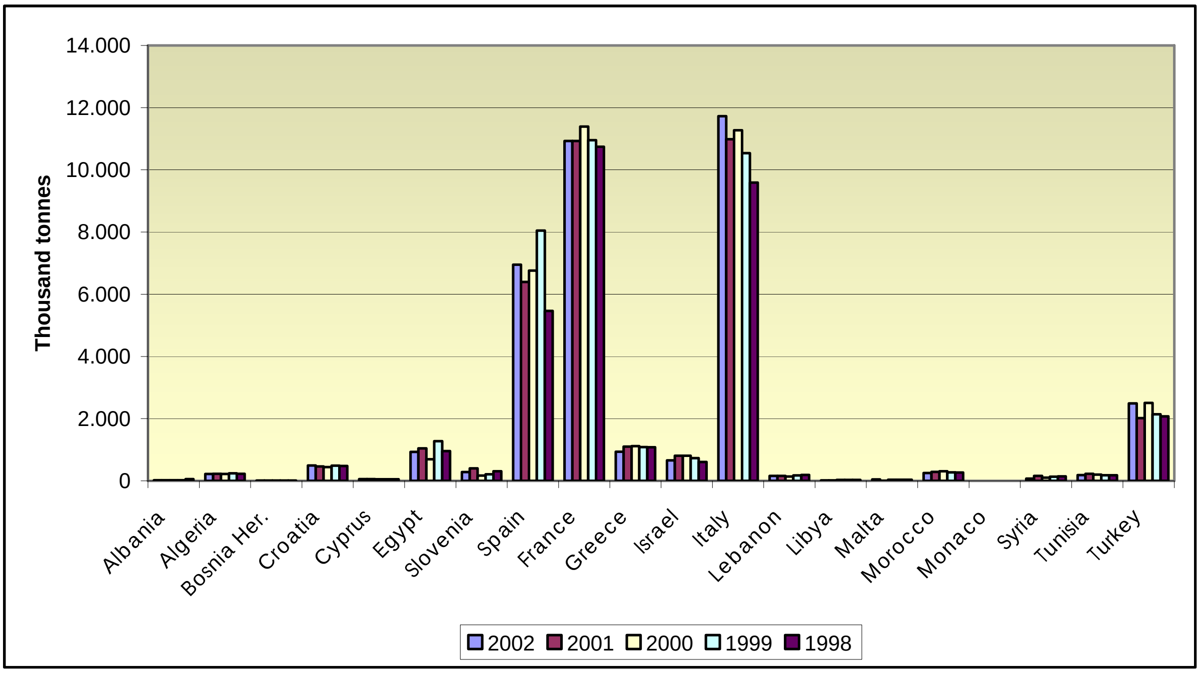


Graphic 3.4.10. Recovered Paper Production in the MAP countries

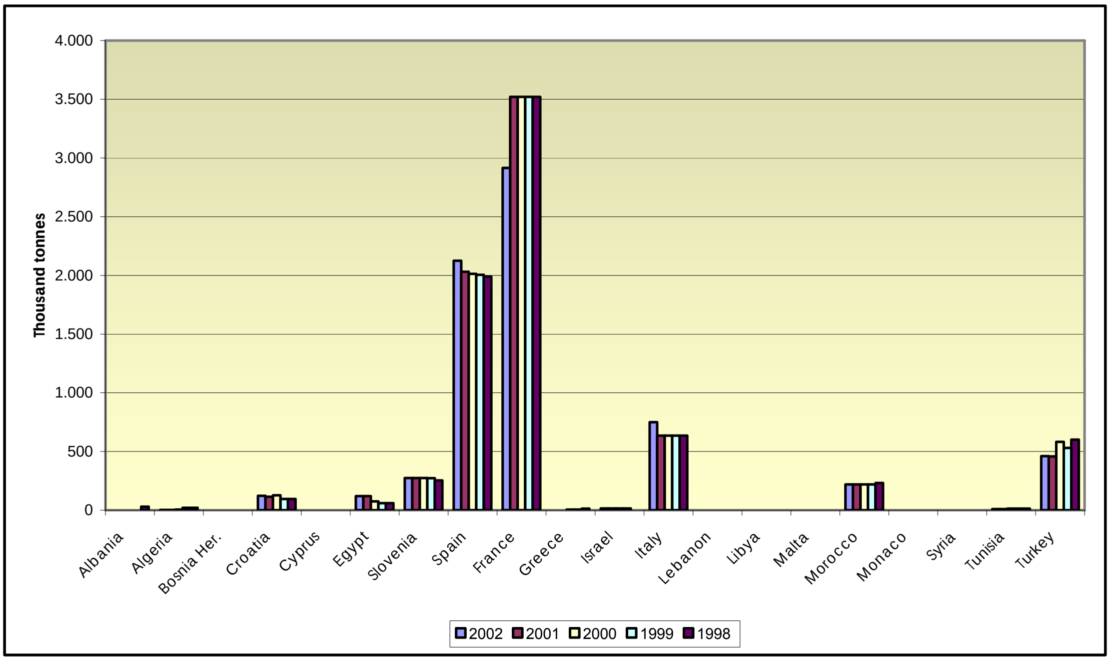
The following graphics show the evolution of the consumption and production of pulp, paper and cardboard for each country:



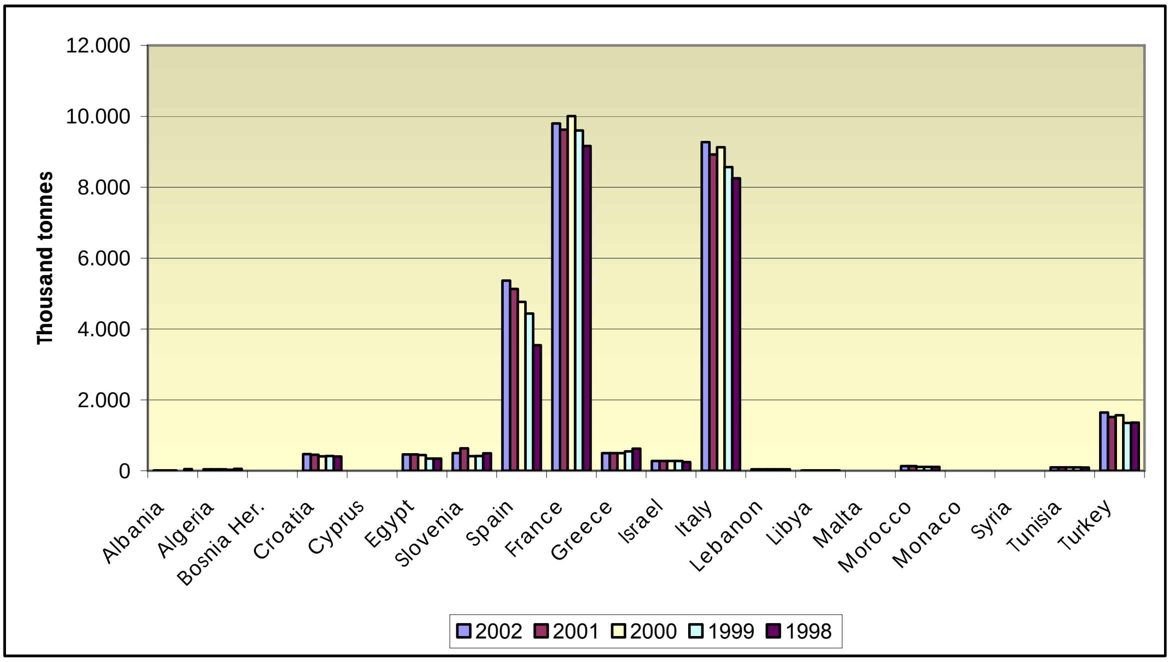
Graphic 3.4.11. Consumption per capita of Paper and Cardboard in PAM countries



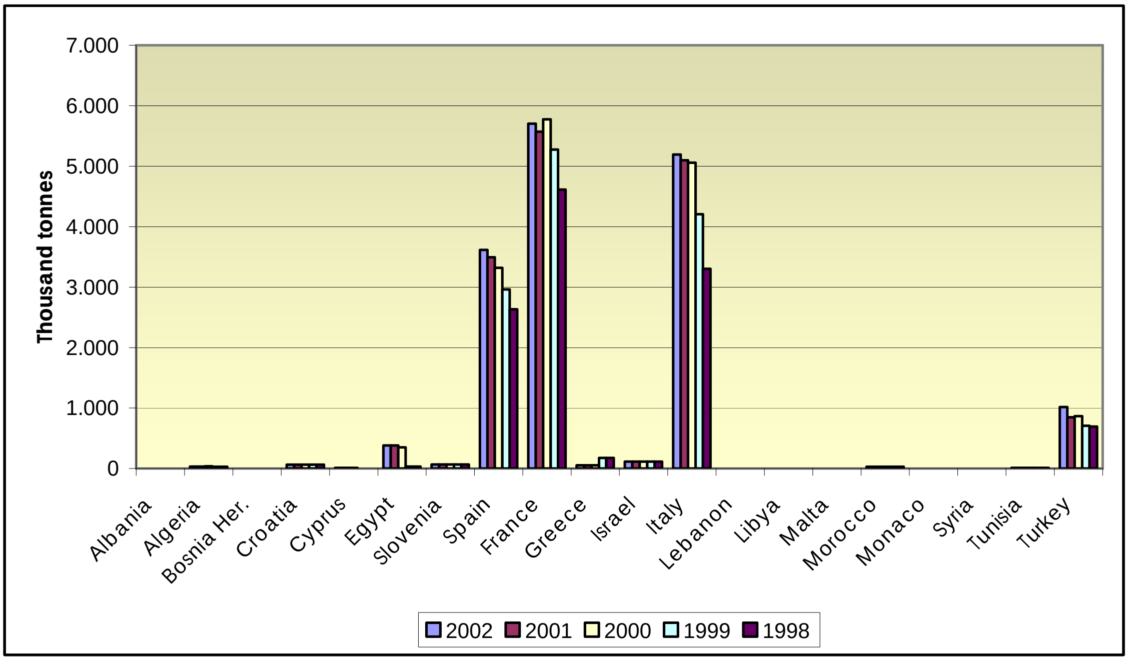
Graphic 3.4.12. Consumption of Paper and Cardboard in PAM countries



Graphic 3.4.13. Pulp Production in the MAP countries



Graphic 3.4.14. Production of Paper and Cardboard in PAM countries



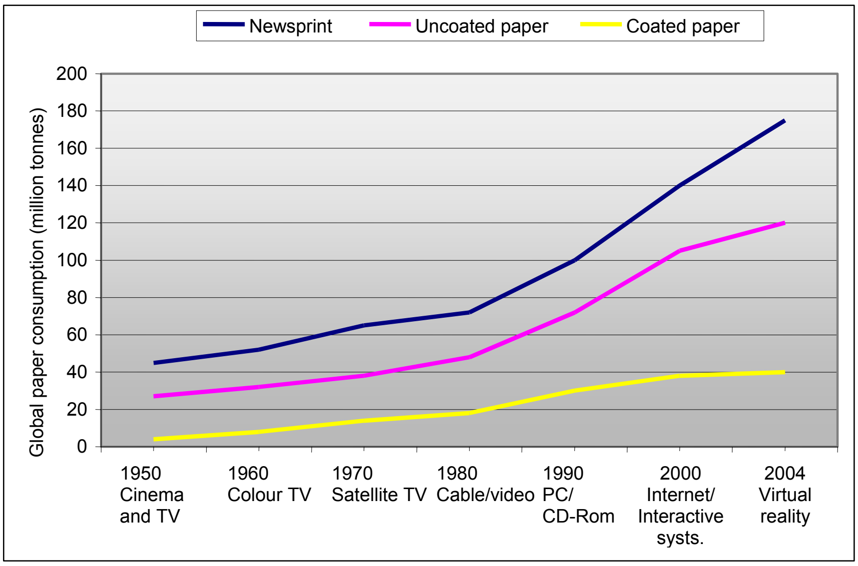
Graphic 3.4.15. Recovered Paper production in the MAP countries

Paper factories contribute to the development of small communities and rural areas. The commitment of the factories to the local communities varies depending on their geographical situation. For instance, in developing countries the factories might co-finance local schools, while in more developed countries they usually sponsor local sports teams.

The development of new technologies suggested in the beginning that there would be decreased demand for paper products. However, this effect has not been seen, in fact the opposite is true. Communication, culture, education, trade, transport etc. are areas in which the application of new information technologies is causing spectacular developments. The computer-printer combination has turned homes and offices into small-scale printing works and Internet users receive the products they have bought on-line delivered to their door, conveniently packed in paper or cardboard. Internet is demonstrating that it is a wonderful sales outlet for books and magazines, and the latest technologies open new possibilities in the world of publishing.

There is no doubt that the Internet is a highly effective, quick and cheap means of finding and exchanging information, and that computers enable us to manipulate this information easily, which has resulted in an exponential increase in the quantity of information available, the flow of information and the consumption of paper. However, it is important to differentiate the different types of reading. The objective of reading for action is to gain rapid access to reliable data that enables a decision to be made, and there is no doubt that in this case paper has been replaced. In the case of reading to learn, studies show that learning is more effective if the material on which the information is held has a fixed spatial relationship with the text. This means that although there is a marked tendency to prefer technical documentation on-line, reading a printed sheet is more effective than reading the same information on the computer screen, which means that such information is usually printed. Lastly, in reading for relaxation there is a strong tendency to prefer texts on paper.

Figure 3.4.16. shows the evolution of global paper consumption in relation to new information technologies. The constant evolution of paper is closely linked to the major technical achievements of civilisation, from the printing press to office automation. In the almost one million years of its history, not only has paper shown its compatibility with successive technical advances, but these have been indissolubly linked to the development of new paper products.



Graphic 3.4.16. Influence of technological advances on global paper consumption

In short, over the last decade there has been a significant increase in paper consumption, although a change in demand for different products is foreseen, with higher demand for the higher quality grades increasing in the developed countries and for the higher necessity grades in developing countries.

4. DESCRIPTION OF PROCESSES

4.1. PAPER PRODUCTS

One of the reasons for the importance of paper in our daily lives is the enormous number of different uses for this product. Paper can adapt to many different uses, with up to 500 different varieties of paper in production.

Paper types can be classified into four wide groups, taking into account the use to which they will be put:

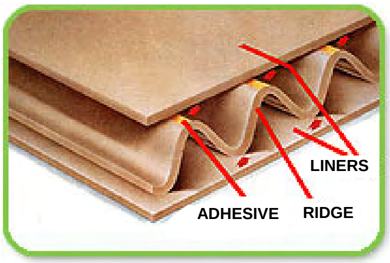
Containers and packaging:

- **Paper for corrugated cardboard:** Papers used in the different layers of corrugated cardboard. These are made essentially from recovered paper, although virgin pulp can be incorporated in different proportions.

Rolls of corrugated cardboard

Corrugated cardboard

Corrugated cardboard is a structure formed by one or more sheets of corrugated paper, glued onto one or between various sheets of paper or flat cardboard to make the facing sides (Liners). The strength of this material is based on the combined and vertical force of the different sheets of paper. To increase strength, the ridge of the cardboard has to work vertically, as shown in the following graphic:



- **Kraft paper for sacks:** High-strength paper used in the manufacture of large sacks for construction materials, animal feed, etc.

- **Boxboard:** This is used in the manufacture of folding boxes and containers. It is a compact material resulting from the combination, when damp, of various layers of paper on top of each other, of virgin pulp and/or recovered paper, which are moulded together by compression. It is usually finished with a covering coating layer.

Paper for printing and writing:

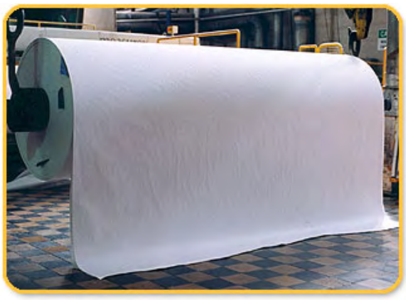
This is used for magazines, books, exercise books, diaries, envelopes, leaflets, posters, office paper, etc. It can be coated or not, depending on its intended use.

Newsprint:

Used for the printing of newspapers, this is manufactured mainly using recovered paper or mechanical pulp. It can be white or slightly coloured and its average grammage (see below) varies between 40 and 52 g/m^2, although it can reach 65 g/m^2.

Toilet and sanitary paper, tissue paper:

Fine paper, of low grammage, manufactured from virgin fibre or recovered paper, or a mixture of the two. These are used for personal hygiene (toilet paper, sanitary towels, nappies, tissues...), in the domestic environment (kitchen towel, serviettes, tablecloths, coffee filters...) and as sanitary and industrial cleaning material. Creping increases the specific surface area of the paper and opens the fibres, resulting in greater absorption and flexibility than would be the case for a sheet of normal paper.



Reels of tissue paper

It is important to consider the most important characteristics of each product, which depends on the end use of the product. In general, the final characteristics of the paper are determined by the characteristics of the fibres, the process of obtaining pulp, the presence of different fillers, pigments and additives, and the different steps in the paper manufacturing process.

The most important properties to be taken into consideration are:

Structural properties

- **Grammage:** this is the mass of the unit of surface area of the paper, expressed in grammes per square metre. This has to be consistent for all the product of this type. Depending on the requirements of the user.
- **Thickness:** This is a critical measure of uniformity. Its variations affect the mechanical strength and the optical properties, and therefore the quality of the reels.

- **Formation:** Bad formation is bad distribution of the fibres in the sheet. This influences the strength, the capacity for coating tolerance, the printing characteristics and the quality of writing paper.
- **Directionality:** This is due to the orientation of the fibres in the direction of the machine. It affects the mechanical properties of the paper.
- **Porosity:** This is important for some uses. For example, paper with low porosity is problematic in the priming of sacks, and very porous paper is problematic in vacuum paper feeding for printers.
- **Smoothness:** This is important for print quality and cost. It depends on the short fibre content. Moisture content is also a critical parameter for smoothness.

Mechanical properties of paper

- **Tensile strength:** This determines the behaviour of the paper when subject to tension. It indicates how the paper will resist tension during the passage of the reels through different equipment, during the printing process or when the paper is introduced into a photocopier. It is also very important for paper for packaging and containers. Low strength can lead to delamination of printed sheets, due to the pull from ink stickiness. Strength when damp is important for toilet and sanitary paper.
- **Resistance to splitting:** This shows the resistance of the paper to impacts from instruments that exert a specific pressure on the paper. This is important for products for packaging and containers.
- **Resistance to tearing:** This is related to the fibre-fibre bonds and to the orientation of fibres in the sheet. It is important, for example, in paper for containers, packaging and books.
- **Resistance to folding:** This is important for books, leaflets, banknotes, maps etc.
- **Rigidity and curvature:** This is important in ensuring that the corners of the sheets do not fold over and warp, in particular as a result of printing inks. However, a sheet that is too rigid will cause problems for photocopiers.

Properties of appearance

- **Brightness:** The degree of brightness depends on the fibres used and the concentration of fillers and pigments. Specifications depend on the final use of the paper.
- **Lustre:** The level of lustre desired also depends on the final use of the paper. For example, a high lustre is suitable for improving print quality for advertisements in magazines, but is a negative characteristic for a book.
- **Opacity:** This measures the light retained by the particles of the sheet through which it is passed. It is modified with refining and the proportion of fillers and colorants. It is one of the specifications for printing and writing papers.

Influence of the environment on paper properties

- **Humidity:** This is a critical factor during the coating process as it influences the dimensional stability of the sheet. Excessive humidity results in blackening during calendering and a very dry paper that may crack.
- **Dimensional stability:** This depends on humidity and the capacity of the fibres to swell and absorb water.
- **Permanence of the paper:** This represents the resistance of the paper to deterioration due to environmental conditions. Ageing depends on the lignin content of the pulp, which produces

cracking and yellowing in the paper. It is very important for papers for permanent use: archives, books, etc.

Table 4.1.1. shows an outline of the most important properties for each class of paper.

Table 4.1.1. Most important properties of the paper

PAPER FOR PACKAGING AND CONTAINERS
Economical High strength: length of tears, tearing and splitting rates Rigidity Dimensional stability High protection: low levels of penetration by humidity, grease etc. Few impurities in the case of papers in direct contact with foodstuffs Good print quality
WRITING PAPER
Good formation Sufficient strength and rigidity Good resistance to ink penetration Appropriate surface for writing and erasing Sufficient opacity to avoid transparency Good appearance and brightness Permanence
PRINTING PAPER
High uniformity to enable the printing process to be controlled Good opacity, brightness, lustre, formation etc., as these properties influence print quality. Moderate strength Dimensional stability Curvature

Each type of product requires different properties of the paper, which are obtained by optimising the selection of raw materials, the content of fillers, pigments and additives and during each of the stages in the manufacturing process, from the headbox to the calender. In a paper machine, each adjustment changes the characteristics of the product, whether for the worse or the better. On many occasions, the manufacturer has to decide to sacrifice one property to meet client requirements for another property of the paper that is of greater importance to them. It is therefore necessary to be aware of the most important characteristics of each product and how these can be attained during the manufacturing process, and to understand the relationship between these different properties.

As a general rule, in the MAP countries paper and cardboard consumption is greater than production, and these are considerably lower than average European consumption, which means growth in these sectors can be assumed in the coming years, with the installation of new machines in the region.

4.2. RAW MATERIALS

Paper is a substance obtained from vegetable cellulose fibres, which are intertwined, forming a resistant, flexible sheet. The production of pulp is a process of separation of the fibres, while the manufacture of paper is a process of consolidation of the individual fibres of the pulp into an integrated structure in the form of a resistant, flexible sheet.

The main raw material for the manufacture of paper products is cellulose fibre, either virgin fibre or secondary fibre, although other auxiliary raw materials are used to reduce costs (such as in the case of mineral fillers), to improve the manufacturing process (such as in the case of processing additives), or to improve the properties of the final product (such as in the case of pigments, sizing agents, coating agents, etc).

4.2.1. Cellulosic raw materials

The fundamental raw material for obtaining cellulose fibres is wood, although it can also be obtained from other sources such as flax, hemp, ramie, chaff from cereal crops, sugar cane bagasse, bamboo, esparto grass, cotton, etc. Agricultural fibres are an important alternative source of cellulose, as the plants from which they come usually provide a high yield and adapt easily to different types of soil, and have therefore been used for a very long time.

Today, non-wood fibre pulps represent approximately 7% of total global production of virgin fibre. However, in developing countries with few forest reserves, they can represent over 30% of total pulp production (*M. B. Roncero, A. L. Torres, J. F. Colom and T. Vidal, Bioresource Technology, 2003, 87, 3, 315-323; L. Paavilainen, Pulp Pap. Int., 1998, 40, 6, 61-66*). In Turkey, the use of chaff has increased in recent years to reach 9% of virgin fibre production. (*N. S. Sadawarte, Pulp Pap. Int., 1995, 37.6, 84-95*).

From a morphological point of view, the fibres of non-wood plants are as diverse as the plants from which they can be obtained. Among them can be found a wide variety of fibres, from very long fibres, longer than those obtained from conifer wood, to short fibres similar to non-coniferous tree species. The plants that have most potential as raw material alternatives to wood are bagasse, chaff and bamboo, while others, such es esparto grass, are used for the special properties they give to the paper.

The environmental benefits of the use of these alternative fibres are not entirely clear at present, and there are extremely diverse opinions on the subject. On the one hand, agricultural waste such as chaff can be used. This is especially useful as an alternative short fibre. On the other hand, however, this type of plant generates liquid waste that is very difficult to process. The main problem centres on the limited capacity that this type of industrial installation tends to have, the high silica content of these plants and the low energy value of the black liquor generated. These factors inhibit the recovery of the black liquor by traditional methods, since at present there is no treatment process that is technically and economically viable.

Wood as a raw material

The cellulose fibres are obtained mainly from the woody part of the trunk. The disposition and form of the various elements of the trunk correspond to three main functions: supporting the top, transporting the sap and storing food. There are three sections of the trunk: transversal (x), radial (r) and tangential (t).

The observation of a transversal section (figure 4.2.1.) allows us to identify easily:

- The bark or the outermost part of the plant, in general the darkest in colour, which is of no interest for making paper pulp and which is usually removed before the pulp is obtained.
- The wood or xylem, in which we can make out in woods from warm areas, the year circles. It is from this part of the trunk that the fibres used as the raw material for cellulose, for paper production, are obtained.
- In the centre of the trunk is the medulla.

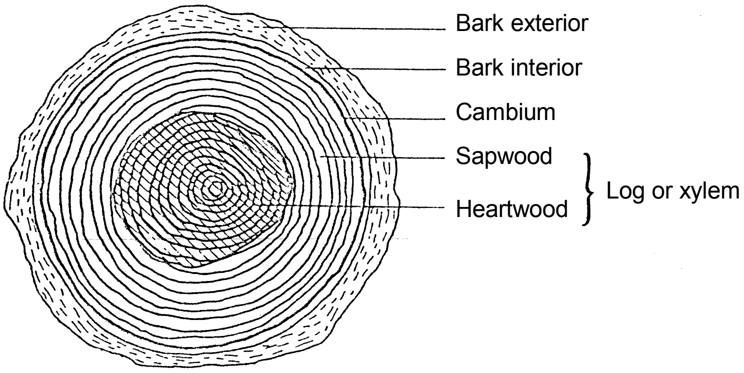


Figure 4.2.1. Cross section of a mature trunk

The most important characteristics of the fibres are the length and the thickness of the cell wall. The length is associated with the strength of the paper, and in particular with the tear length, although the final strength of the paper does not depend only on the individual strength of the fibres but also on the bond between them, which is improved by refining. Paper made from long fibres has an open structure, greater volume and permeability by the air and is of worse formation. For its part, a less thick cell wall in the fibres is positive for the number of fibre-fibre bonds.

For a long time it was thought that the best wood for the manufacture of paper was the wood with the longest fibres. Today, it has been shown that for certain classes of paper, short fibres are better, giving the paper special and useful properties such as opacity and good formation. The soft wood obtained from conifers (pine, fir, cypress, spruce, larch, redwood, araucaria, etc.) provides long fibres. Hard wood from non-coniferous trees (willow, black poplar, white poplar, birch, eucalyptus, elm, oak, holm oak, cork oak, etc.) provides short fibres. The lower limit of fibre length for a fibre to be suitable for paper production is of 0.5 mm.

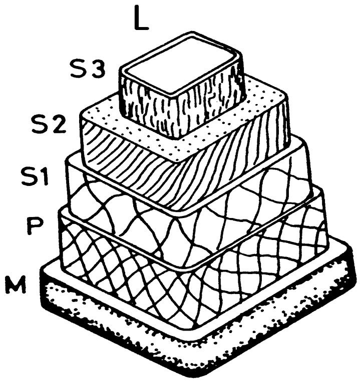
The most usual length for fibres from conifers is from 2 to 5 mm, and the average length is of 3 mm. The fibres have a strong tendency to form three dimensional networks through mechanical intertwining or flocculation of the fibres when they are suspended in water. The width of fibres varies depending on whether they are the result of spring or summer growth. Summer wood has fibres of 20 to 30 μm and spring wood has fibres of 50 to 65 μm, making the length/width ratio of approximately 100/1. From the morphological point of view, fibres obtained from conifers take the form of flat tapes with rounded edges or ending in points. Fibres from those conifers also labelled tracheids are distinguishable by the number, form and disposition of the pit-pairs that they have, which can be single or bordered.

The length of fibres from non-coniferous trees varies from 1 to 2 mm. Their diameter varies from 10 to 40 μm, which makes the length/width ratio between 100/1 and 50/1. Unlike the fibres obtained from conifers, those from non-coniferous trees contain a high level of non-fibrous constituents. Among these constituents are vessels, segments of vessels and remains of the cell wall, which affect both the manufacture of paper and the final properties of the sheet. The vessels seen in non-coniferous trees have an average length of 20 to 500 μm, which differentiates them from softwoods. The differences between the vessels are those that enable non-coniferous trees to be distinguished one from another. There are also parenchyma cells with dimensions that vary between 20 and 200 μm.

Many of the properties of the fibres and fines are the result of their chemical composition. Pulp obtained from wood fibres contain cellulose, hemicellulose and lignin, which are contained in a complex mixture in the cell wall. Cellulose is a vegetable fibre that makes up the cell walls of trees and other plants, and which represents 50% of their physical makeup. The chemical structure of cellulose is formed by the bonding of glucose molecules joined between themselves by lignin, a substance that reinforces the cells, giving them consistency and rigidity. Hemicellulose is an element that forms part of the cell wall of cellulose, being a shorter glucose chain than cellulose. The relative quantities of these components of wood are: 40-50% cellulose, 20-30% hemicellulose, 20-30% lignin and 1-10% extractive compounds, depending on the type of wood in question.

In addition, depending on the process of separating the fibres from the wood, there can also be organic compounds left, such as gum spirit of turpentine, soluble residues (above all alkalis), starches, sugars, fatty materials, and extractive substances that have not been entirely removed during the manufacture of the pulp and that will have a considerable influence on the paper manufacturing process.

Figure 4.2.2. shows a transversal cut of a fibre with the different layers that make it up. The chemical composition varies from the surface of the fibre towards the centre, and the cellulose content increases from 0% to 55%. The hemicellulose content rises from 10% to 40%, and the lignin content decreases from 90% to 5%. In this way the chemical characteristics of the surface of a fibre depend on the chemical and/or mechanical treatment process to which it has been subjected.



M: middle lamella
P: primary layer
S1: first secondary layer
S2: second secondary layer
S3: third secondary layer
L: lumen

Figure 4.2.2. Schematic transversal section of a fibre

Some of the processes for obtaining pulp can break the structure of the external wall and the predominant chemical properties are those of the layer S2. However, mechanical processes or gentle chemical processes leave a large part of the primary layer intact, which controls the surface properties of the fibres.

The cellulose chains that exist in the surface of the fibres contain hydroxyl groups that participate in the formation of fibre-fibre bonds in the paper. The cellulosic hydroxyl groups, both in the surface of the fibres and in the interior of the cell wall, also interact with water and have a major influence on the phenomenon of the swelling of the fibres associated with the refining process.

The hemicellulose content also influences the swelling of the fibres during refining due to its interaction with water, which encourages the formation of fibre-fibre bonds in the sheet of paper.

Residual lignin has a negative influence on the capacity of the fibres to form bonds between fibres, it inhibits the swelling of the fibres in the water, it produces a dark colour in the pulp and the paper, and the final products have a strong tendency to age.

Recovered paper as a raw material

Another important source of cellulose fibres is recovered paper. When speaking of recovered paper as a raw material it is important to bear in mind that there is a practical and technical limit to the recovery of paper. Firstly it must be taken into account that certain products cannot be recovered and secondly that the same fibre cannot be recycled more than 4-6 times, due to the fact that it deteriorates at each stage of recycling. As a result, the use of virgin fibre is always, and always will be, necessary, and although some countries mainly use a specific type of fibre, there must be a suitable global balance to avoid the progressive deterioration of products.

As an example, figure 4.2.3 represents the current flow of fibres in Europe. The objective for the year 2005 is to increase recovery and recycling until they constitute at least 56% of paper and cardboard products consumed in Europe. Reaching a recycling level of 56% means that the recycling of used paper must increase from the current level of 39 million tonnes to some 48 million tonnes, an increase of 25%.

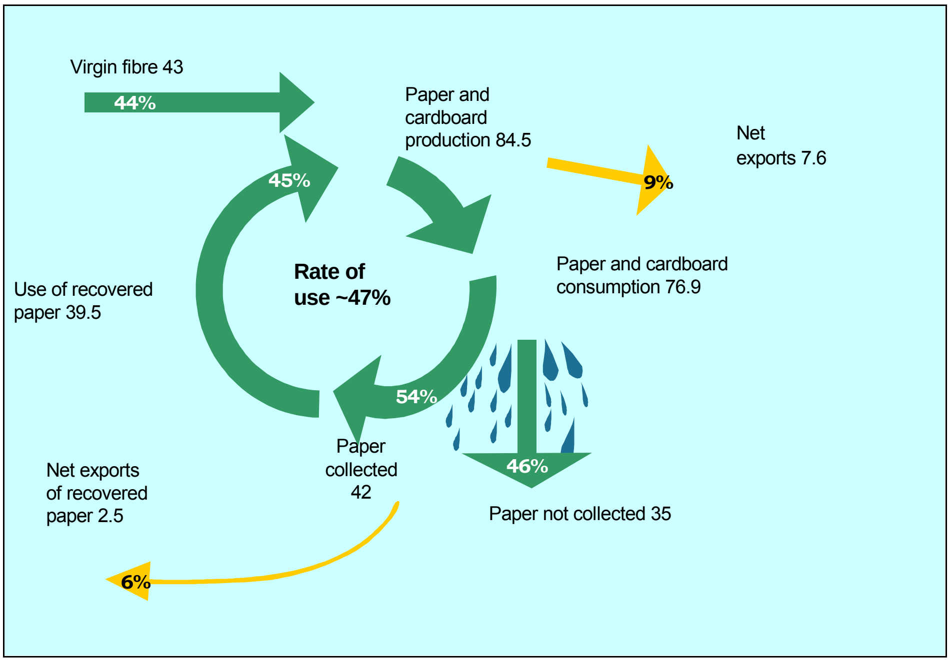


Figure 4.2.3. Fibre flow in Europe

Paper can be recovered by different means:

- Industrial collections from companies, publishing houses and printing works, and large shopping centres.
- Selective collection from designated containers and "door-to-door" collections from small businesses.
- Special collections in offices, in the buildings of public bodies and institutions, at recycling centres, etc.

Although in recent years there has been a great deal of effort made in the development of selective collecting and in achieving public collaboration, it is still necessary to increase the provision of paper banks, improve the quality of collection services, encourage their correct use, and improve the organisation and systemisation of collections from small businesses, teaching centres, offices etc.

The degree of treatment that recovered paper undergoes to obtain pulp depends on the initial quality of the recovered paper and the quality of the final product. The process of preparation in factories using this raw material is based fundamentally on the removal of contaminants that have been added to the paper during the manufacture of the final product, or during its use. In some cases the paper recovered contains over 35% inks, glues and coating compounds, the removal of which can produce large quantities of sludges, for which an appropriate destination must be found to avoid their eventual discharge. Therefore, although the use of low quality recovered paper to obtain a high quality product may be technically viable, this process is not always viable from an environmental or economic point of view. In general, recovered paper is used to obtain paper of the same grade as it was, or lower grades.

Recovered papers of low quality (mixtures, boxes, cardboards) are used in the manufacture of packaging products and cardboards. De-inked grades (newspapers, magazines, catalogues) are used to obtain newsprint and sanitary papers. High quality recovered papers (print trimmings, office paper) can be used for all types of products.

Although the maximum use of recovered paper might be made, the use of virgin fibre will always be necessary and, therefore, it is necessary to optimise the use of one or other source of cellulose, depending on the desired product, to minimise all aspects of environmental impact. When selecting the most suitable raw material for a specific product, the relationship between the properties of the fibres, the properties of the pulps and the properties of the products must be known.

4.2.2. Secondary and auxiliary materials

Although as mentioned above the fundamental raw material for the manufacture of paper is cellulosic fibre, approximately 10-15% of the materials used today for paper manufacture are non-fibrous. Among these, the most-used are mineral fillers and pigments.

Mineral fillers and pigments

Although mineral fillers have been used for over 200 years, their use has increased considerably in recent years. In Europe, the consumption of mineral fillers and pigments was 15.5 million tonnes in 2003, making up 16% of raw materials. In the Mediterranean region the percentage of fillers used is slightly less, with current consumption of 4 million tonnes, of which approximately 3.5 million tonnes are consumed in the Northern Mediterranean region, 0.4 million tonnes in the Eastern Mediterranean region, and 0.1 million tonnes in the Southern Mediterranean region.

Among the natural fillers most often used are: clays (Al_2O_3 $2SiO_2$ $2H_2O$) or kaolin, talc ($3MgO$ $4SiO_2$ H_2O), calcium carbonate ($CaCO_3$), ground or precipitate, which gives the paper greater resistance to ageing, mica ($3Al_2O_3$ K_2O $6SiO_2$ $2H_2O$) and gypsum ($CaSO_4$ $2H_2O$). The use of one or other depends on the pH at which the manufacturing process takes place, on availability, on price and on the final characteristics of the paper. For example, kaolin is used in an acid medium, while calcium carbonate is used in manufacturing when the medium is alkaline or neutral, as it is soluble in acid. The objective of the use of mineral fillers is double:

- To reduce manufacturing costs
- To improve paper quality: As these fill in the gaps left by the fibres, they reduce the roughness of the paper, which improves its formation, printing, opacity, dimensional stability, lustre and, sometimes, the level of brightness. The presence of fillers also improves the absorption of inks by the surface and decreases the penetration of the ink carriers through to the other side of the paper.

In contrast, pigments are relatively new additives. They are more expensive than fillers and are used in small proportions to improve the properties of the paper, mainly the level of brightness and the print quality. The pigments most often used are: structured kaolin, synthetic silicone, titanium dioxide, aluminium hydroxide, etc.

The correct functioning of the fillers and pigments during the manufacturing process depends on their capacity to disperse and form a stable solution, on their retention level and on their effect on the properties of the paper. This functioning depends on the following characteristics:

- **Optical properties:** this is related to the chemical composition, refraction index, distribution of particle size and particle shape.
- **Particle size and shape:** The optimum size is between 0.2 and 0.5 μm, although the size is usually greater than this. Porous or bound particles behave better than large particles.
- **Specific surface:** This is related to the size, distribution of sizes and shape of the particles. It influences the consumption of additives during manufacture and the print characteristics of the paper.
- **Abrasiveness:** This depends on the hardness, the size and the shape of the particles.
- **Solubility:** In a neutral or alkaline medium the majority of fillers have very low solubility. At pH < 7 the solubility of calcium carbonate increases greatly.
- **pH:** This depends on the surface groups of the particles in suspension and on the compounds that have dissolved.
- **Surface energy:** this determines the level of water penetration.
- **Purity:** this influences the abrasiveness, solubility, brightness, surface properties...
- **Availability and price.**

Table 4.2.1. shows how the proportion of fillers used varies depending on the type of product. In general, fillers are added in proportions of up to 20-35% and pigments in proportions of 5-10%.

Table 4.2.1. Proportion of fillers used depending on the product

PAPER TYPE	FILLER TYPE	CONTENT (%)
Newsprint From virgin fibre From secondary fibre	 -- kaolin / carbonate	 -- 5-15
Printing paper	kaolin / talc	15-35
Coated paper	kaolin / carbonate	10-30
Fine paper	carbonate	20-25

The disadvantage of a high use of mineral fillers is that the bonding between fibres is reduced, the resistance of the paper decreases, as does the sizing, and abrasion in the machine increases. In addition, there is an increase in the consumption of chemical products and, if retention is low, there can be a "double sided" effect in the paper when a Fourdrinier machine is used, as explained below. An increase in fillers leads not only to the decreased strength of the paper, but there is also an increased tendency for dust to be formed during printing, due to the fact that there are a lower number of fibres per unit of grammage and a lower number of fibre-fibre bonds in the sheet of paper.

The problem created by filler particles that are not retained in the formation fabric is that they are passed on into the white water circuit, resulting in an increase in fine particles when these waters are recirculated to the paper machine headbox.

The fillers also tend to be deposited in the pulp storage vats and decanting pipes; it is important to ensure sufficient movement of the vats and an appropriate flow speed in the pipes to be able to solve this problem.

Additives

Finally, a series of chemicals are added to the pulp suspension, formed generally by cellulosic fibres, mineral fillers and pigments. These can be divided into two broad categories: functional additives and processing additives. The objective of functional additives is to improve a specific property that already exists in the paper, or to bring a new property to it. Processing additives help the functional additives to work, help to keep the paper machine clean or improve its working order, reducing the number of stops and increasing productivity.

Table 4.2.2. shows a summary of the main functional additives and processing additives used today and describes their principal applications.

Table 4.2.2. Main functional and processing additives

	ADDITIVES	APPLICATION
FUNCTIONAL ADDITIVES	Sizing agents: resin glue+$Al_2(SO_4)_3$, alkylene succinic anhydride (ASA), alkylketene dimer (AKD)	Resistance to water penetration of the paper
	Dry strengthening agents: Cationic starch, polyacrylamides (PAM)	These increase strength
	Wet strength resins: Urea-formaldehyde, polyamines, polyamides	These increase the strength of paper when saturated with water
	Colorant agents and inks	These produce the desired colour
PROCESSING ADDITIVES	Pitch control agents Talc, aluminium, dispersants	These prevent pitch deposits
	Draining agents: PAM, polyamines, cationic starch	These increase dewatering in the formation wire
	Formation agents: Anionic polymers of high molecular weight	These improve the formation of the sheet, reducing mechanical flocculation
	Retention agents: Cationic and anionic PAM, cationic starch	These improve retention by chemical flocculation
	Anti-foam agents	These reduce foam formation
	Fungicides and biocides	These prevent the growth of microorganisms

Among the chemical additives used, the important role of flocculants in the wet end of the paper machine should be highlighted, although they are used in small quantities, because they affect the productivity of the machine and the quality of the final product. As their name indicates, flocculants are used to control the degree of flocculation of the different fractions present in the pulp suspension. From this point of view, differentiation should be made between three different applications: the flocculation of fibres, the flocculation of fines and fillers and the flocculation of colloidal and dissolved materials.

The flocculation of fibres negatively affects the formation of the sheet and can be controlled by the use of anionic polyelectrolytes. The flocculation of fines and fillers determines the degree of retention and drainage reached in the wet end of the machine and is carried out by the addition of cationic polyelectrolytes of medium or high molecular weight, or of dual systems. However, the fixing of dissolved and colloidal materials to the fibres to avoid their accumulation in the water circuits is achieved by the use of coagulants and cationic flocculants of low molecular weight.

4.3. DESCRIPTION OF PRODUCTIVE PROCESSES

4.3.1. Preparation of raw materials

As indicated in previous sections, the main raw material from which paper is obtained is cellulosic fibre from wood. The process of cellulose pulp production is a process of separating the fibres from the non-fibrous material of the wood, which can be done by mechanical, chemical or semi-chemical methods. In addition, the papers used can be recycled, providing in this case the group of recycled pulp, the preparation of which consists mainly in separating the contaminants which are brought with the secondary fibres.

Depending on the type of process used to obtain paper pulp, different prior preparation operations must be carried out on the raw material in order to obtain logs or chips, depending on the manufacturing process.

In the wood preparation area, various basic tasks are carried out: reception of the wood; preparation of the wood; and the collection of all the materials discarded in the abovementioned operations, in order to send them for final disposal. Regardless of the process of obtaining pulp, it is necessary to wash the wood, remove the bark and cut the wood into pieces.

After the wood is received, the first operation to be carried out is the washing of the logs, in order to remove sand and dirt. Following this, the bark is removed, as the bark contains very little fibre, has high levels of extractive substances, is dark in colour and often contains large quantities of soil.

There are various types of debarking machines. One of the most common is the mechanical debarking machine, which consists of a sloping, rotating cylindrical drum with open ends, into which the logs are fed, bumping and rubbing against each other, until the bark is separated. The bark falls out of the drum and is collected for later processing. Usually it is used as fuel. Debarking can also be done hydraulically, using high pressure water jets; this produces wastewater which must then be treated.

Once the bark has been removed, the logs are cut into small segments, these logs then being the raw material for obtaining mechanical pulp by grinding them. In mechanical refining, or for obtaining chemical pulp, another stage is necessary - the production of wood chips.

The chippers produce chips of varying sizes, but the preparation of pulp requires these to be of specific dimensions to ensure a constant flow through the refiners and a uniform reaction level in the digesters. To achieve this, the wood chips pass through a series of screens where they are classified by length and thickness, returning the chips that are too large to the chippers, while the smaller ones are used as combustible waste.

4.3.2. Production of paper pulp

The objectives of the pulping processes (pulp is an intermediate product in the manufacture of paper and cardboard) is the separation of the cellulose fibres in the wood.

The properties of finished products, papers and cardboards, will depend on the properties of the pulps used in their manufacture. These themselves vary depending on the type of wood used and the process used to obtain it.

The separation of cellulose fibres from the wood can be done using mechanical, chemical or semi-chemical methods, resulting in different types of paper pulps. In addition, recycled pulps can be obtained using de-inked pulp (DIP) processes, as will be outlined in section 4.3.5 of this manual.

Mechanical methods involve a de-fibring process using the mechanical action of a grindstone (SGW pulps) or a disc refiner (RMP pulps). In this process, the wood only changes physically, as chemical products are not used. The pulp obtained by these methods is more economical due, on the one hand, to the simplicity of the manufacturing process and, on the other, to the high return on the process (around 97%). The major disadvantage of these pulps is their quality, as they have little strength and yellow easily with time.

In order to maintain the advantages of the process (mainly high productivity) and to improve its defects (mechanical strength), new manufacturing methods have been developed, such as those obtaining Thermomechanical Pulps (TMP), Chemical Mechanical pulps (CMP) or Chemical Thermomechanical Pulps (CTMP) in which the chips are heat-treated before and during refining and/or a pre-treatment of the chips is carried out using chemical reactions. The production of these types of pulps is gradually increasing.

Chemical pulp, as name the suggests, is differentiated from the other types of paper pulp by the fact that the cellulose is separated from the wood using chemical processes. In this case, when the cellulose is separated from the other components of the wood, the yield is much lower than from mechanical pulps, but the pulp obtained is of high quality. There are two fundamental procedures used for obtaining chemical pulp: acid sulphite or bisulphite and Kraft (alkaline). This type of pulp represents 71% of the pulp produced on a global scale and 65% of pulp produced in the Mediterranean countries; the Kraft process is the most used (over 90% of chemical pulp is Kraft pulp).

The choice of one process or another is dependent on the desired final characteristics of the product in question.

Each of these processes of obtaining pulp for paper is explained below in more detail.

Unbleached kraft cellulose

Bleached kraft cellulose

MECHANICAL PULPS

As has been shown, the manufacture of mechanical pulps consists of the fiberisation of the wood using mechanical methods, and then the further treatment of the freed fibres. The lignin, which bonds the cellulose to the hemicellulose, does not dissolve but simply softens, allowing the fibres to move outside the structure of the wood. The yield from this, expressed as a proportion of the initial wood remaining in the pulp, is usually over 95% in purely mechanical processes (SGW pulp) and between 80 and 95% when high temperatures are used and a chemical agent is incorporated to facilitate the process (TMP, CMP or CTMP pulps).

Papers made from mechanical pulp are usually characterised by low density, high rigidity, high opacity, good absorption of inks and general suitability for printing. They are too weak for use in packaging, but their rigidity is good for the interior layers of multi-layer boxes. The manufacture of newsprint, paper for magazines and the inside layers of boxboard are the most important uses for this type of pulp.

In recent years, participation in the manufacture of paper from this type of pulp has been on the increase, and this tendency will continue in the future due to the high yield from the process and the technological advances made to increase purity and mechanical strength.

Mechanical processes can be classified in two broad groups: those using trunks or logs in which the mechanical action is due to a large cylindrical stone or "mill" that turns at high speed (figure 4.3.1.a) and those using wood chips in which defiberisation takes place in a disc refiner (figure 4.3.1.b).

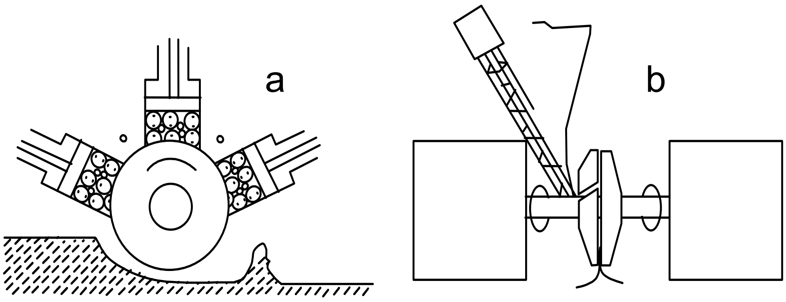


Figure 4.3.1: Mechanical processing of wood

The most suitable raw materials for the manufacture of mechanical pulp are soft woods, the most-used being the fir, as the fibres are longer than in non-coniferous hard woods. However, with the different modifications that have been made to increase the strength of mechanical pulps introduced in recent years, it is also possible to obtain mechanical pulp from hard woods. The number of industrial installations in this case is much lower.

Stone groundwood pulp (SGW)

Stone groundwood pulp is obtained from the debarked trunks. A cylindrical grindstone with an abrasive surface is used (ceramic, granite, etc.) which is dampened using sprinklers and revolves at high speed. The trunks are pressed against the surface and the rubbing of the grindstone, during several cycles of compression-decompression and with the help of an increase in temperature, results in the fiberisation of the wood.

The degree of fiberisation can be regulated depending on the turn speed and the type of surface, the pressure of the wood against the grinder, the flow and temperature of the water in the sprinklers, etc. It is important to sharpen and condition the grindstone periodically in order to obtain pulps of a sufficient quality.

The friction between the wood and the grindstone generates heat, which causes the softening of the lignin and the easier separation of the fibres. During fiberisation, water is added to soften the friction and to drag out the separated fibres, in order to absorb the heat produced and to prevent the wood from burning. more water is added later to form an easily manageable pulp.

Pulps obtained in this way are very strongly coloured. To reduce this, they are bleached with reactive oxidising chemicals. This operation (analysed in point 4.3.4) results in pulps of a light enough colour, suitable for the manufacture of newsprint or cardboard, its most usual uses.

Papers obtained from this pulp have a major disadvantage in their relatively low strength and their tendency to yellow with time. However, the brightness and the strength can be increased by mixing these pulps with chemical pulps.

The major advantage of this manufacturing process is its high yield, in some cases of over 97%.

In order to improve the process, different modifications have been introduced, such as pressurisation, obtaining PGW type pulps. When the pressure of the logs on the grinders is increased, the temperature increases to over 100 ºC, which improves the process and leads to pulps with more mechanical strength being obtained, as there is less breakdown of the cellulose in the fiberisation process. The other variation is the incorporation of a column of hot water, resulting in TGW pulps.

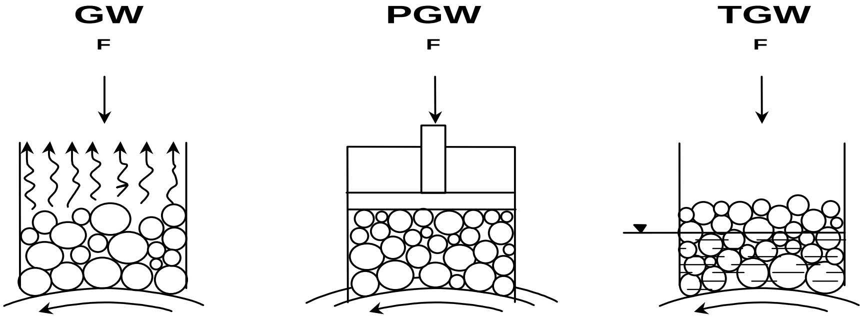


Figure 4.3.2. Processes for obtaining mechanical pulps

Refiner mechanical pulp (RMP)

Processes for obtaining refiner pulps came about from the need to improve traditional mechanical grinder pulps and improve the quality of the pulps obtained. In this type of process, wood chips are used. These are first washed to remove stones, sand and impurities that could damage the discs. The chips separate as a result of the mechanical action of refining discs. The fiberisation process can be controlled by a larger number of variables in the process, and therefore the breakdown of the cellulose during fiberisation can be avoided, resulting in more resistant pulps.

The main equipment in this process is the refiner, of which there are many designs, consisting of plates that spin at high speeds, through which the chips pass in order to be fiberised. Of the possible designs, almost 100% of installations use disc refiners, which can be of two basic types: single or double disc. The refiners are very powerful and energy consumption can vary from 1,500 to over 3,000 kWh per tonne.

In this type of process, there are more control variables, and therefore pulps of different qualities can be obtained depending on the power used, the distance between discs, the supply flow, the turn speed, the type and design of the discs, the type of feed and output, etc.

The process involves a significant increase in the temperature, and steam is produced that in some cases is used to generate energy (cogeneration).

Thermomechanical pulp (TMP)

Although it was originally thought that pre-heating the chips improved the fiberisation process, the importance of reaching a high temperature in the actual refining process was later discovered. This led to the development of TMP pulps, which are today the most important of the mechanical pulps.

The process begins in most cases with the pre-heating of the chips with steam at atmospheric pressure, in order to raise the temperature and the water content of the wood chips. Then the wood chips go through a washing process to remove any contaminants that could damage the refiners or lead to impurities in the product. The washed and heated chips are pumped as a mixture of water and wood chips at a consistency of 3-4% to a drainage screw, passing through a pre-heating stage (atmospheric or pressurised), reaching temperatures of 105-120 ºC. Finally, the wood chips are fed into the refiners where fiberisation takes place in one or various stages, depending on the industrial installation.

In order to reduce energy costs, modern plants have heat recovery systems.

Chemical mechanical pulps (CMP and CTMP)

A further step in the development of mechanical pulps is the incorporation of the impregnation of the wood chips with a chemical substance in order to improve the process. These processes result in chemical mechanical pulps (CMP), when refining is done at atmospheric pressure, or chemical thermomechanical pulps if refining is done under pressure (CTMP).

The variation consists of the incorporation of a chemical treatment stage into the process. There are various alternatives, but the most used is the incorporation of a stage of chemical pre-treatment of the chips prior to fiberisation, to improve the process and to obtain pulps of greater mechanical strength. Of the possible chemical treatments, the most-used is the use of sodium sulphite for non-coniferous pulps and NaOH and/or sodium sulphite for hard pulps. Dosage varies from 1 to 20% Na_2SO_3 on dry wood, the lowest percentages of 1 to 3% being the most often used.

In the processes for obtaining mechanical pulps, the intense treatment that the fibres undergo means that the fibres are deformed by twisting, which prevents their later use in Paper manufacture. To avoid this, the pulp goes through a latency treatment stage. This process consists of maintaining the fibre suspension at a consistency of 3% and in motion, in a latency tank at a temperature of 70-80 ºC for approximately 20 minutes.

CHEMICAL PULPS

Chemical pulp is different from other pulps for paper manufacture in that the cellulose is separated from the wood by chemical processes. The components of the wood that form its structure, mainly lignins, dissolve in the chemical products used, forming the black liquors that are separated from the cellulose by washing. The incorporation of a liquor recovery stage means that the process takes place in a closed circuit and is economically and environmentally viable.

The fundamental processes for obtaining chemical pulps are classified in two broad groups.

- **Alkaline methods:** Kraft pulp is the most representative of this type of pulps.
- **Acid methods:** Sodium sulphite or bisulphite pulps are the most representative of this category.

The importance of chemical pulps is determined by the large capacity for production on a global level (150 MMt) and the important proportion they make up of total pulp produced (71%), of which 97% are obtained by the Kraft method.

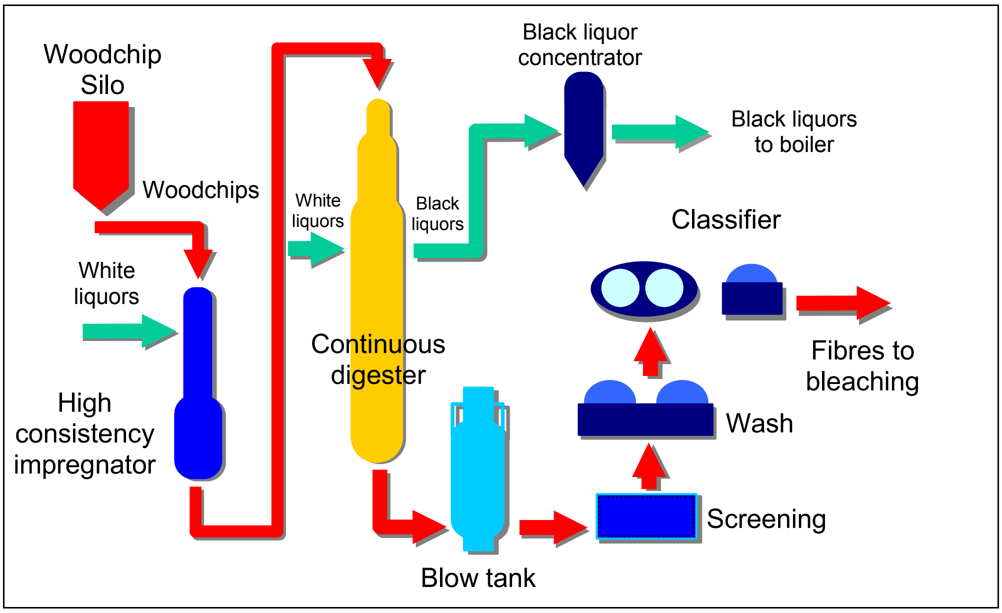


Figure 4.3.3: Diagram of cooking of chemical pulp. Source: www.papelnet.cl

The chemicals act on the middle layer of the wood, dissolving the lignin that acts as cement for the fibres. This releases them intact, unlike the mechanical process in which the freed fibres in the form of shives can be damaged. The main characteristic of chemical pulps is their high mechanical strength. In addition, as a large part of the lignin content is removed, the residual quantities and the chromophore groups can be removed by bleaching processes, resulting in pulps of high brightness.

To dissolve the lignin, in addition to chemicals, steam at medium pressure can be used. This raises the temperature, encouraging the lignin to dissolve in the chosen chemicals.

This procedure involves the cooking of wood chips and the reactives in aqueous solution in a reactor (digester) that can work by batches or continuously.

In batch cooking, the digester is loaded with chips through an opening in the top, the chemical reactives are added, and the content is cooked at high temperature and pressure. The product of the reaction is drained into a blow tank, in which the separation of the fibre agglomerations takes place as a result of expansion.

In continuous digestion, the wood chips, pre-cooked with steam, are fed into the digester continuously. The wood chips and the reactives are mixed in the impregnation zone, in the upper part of the digestor, and then move from the upper cooking zone to the lower one, and then to the washing zone, before they are pneumatically fed into the blow tank.

As mentioned above, the chemical methods are divided into *acid or alkaline*, depending on the pH at which the process is carried out. The former are more aggressive, cellulose separation is better, and they can be used for chemical purposes and to obtain high quality papers. They have the disadvantage that they cannot be used for resinous woods, as at low pH, the phenols and acids of the resin condense with the lignin, forming insoluble coloured compounds that stain the pulp. In the alkaline methods, however, these substances are removed in the residual liquors in the form of salts or soluble phenols.

Alkaline processes are the most common in the market as they result in more resistant pulps and they allow the recovery of the chemicals used.

Chemical pulps can be obtained from conifers or hardwoods, which can be unbleached or bleached.

As a large part of the non-fibrous components of the wood are removed during these processes, yields are usually low, from 35 to 60%. However, the fibres bleach better and are more resistant and of higher quality.

The most important variables for these processes are the *intensity* of the treatment (concentration, pressure and cooking temperature) and the *duration* of the treatment. Both are linked, and the quality of the fibres to be obtained is the deciding factor when setting the conditions.

Acid processes

The method using sulphite was the dominant method from the end of the 19th century until the mid-20th century, although it is limited by the types of wood that can be used and the greater difficulty in processing the residual liquors.

The cooking liquor is formed by a solution of sulphuric acid (H_2SO_3) and a bisulphite ion ($(HSO_3)^-$), which is usually prepared in situ. To do this, elemental sulphur is burned, producing sulphur dioxide (SO_2), which is passed through an absorption tower containing water and an alkaline base ($CaCO_3$ (processing the original sulphite), Na_2CO_3, $Mg(OH)_2$, or NH_4OH), which produce the acid and the ion and control their proportions.

The solutions used for digestion contain 1% combined and 4-6% free SO_2 , so that for a tonne of wood, between 125 kg and 140 kg of SO_2 are needed.

The absorption of the gas takes place by means of any of the solid-gas contact techniques. The most popular consists of limestone or dolomite towers, dampened with a counterflow of water with the gas (this is used for calcium or magnesium bisulphites).

Normally the sulphite pulp is fed into batch digesters with anti-corrosive coatings. In order to avoid undesired reactions, the digesters are heated slowly to a maximum temperature of 110 to 145 ºC, and the wood chips are cooked for 6-8 hours at a pressure of 6-7 atm. By increasing the pressure of the digestor, the sulphur dioxide is purged and mixes with the cooking acid again. When there are around 1.5 hours of cooking left, heating is stopped and the pressure is reduced, extracting gas and water vapour. The pulp is discharged into a tank and is washed and screened.

The mixture used in digestion, called red liquor, exchanges heat with the power source to recover energy, and the chemicals in all the processes are recovered later, except those processes that are based on sodium bisulphite.

For ammonium sulphite pulp, the red liquor is first allowed to cool to remove residual SO_2, and is then concentrated and burned. The gas generated contains SO_2, so it is cooled and passed through an absorption tower in which it is combined with an ammonia solution to regenerate the cooking liquor. Finally, the recovered liquor is filtered, strengthened with SO_2 and stored. The ammonia cannot be recovered as it is transformed into nitrogen and water in the recovery boiler.

In magnesium sulphite pulp, when the concentrated liquor is burned, magnesium oxide (MgO) and SO_2 are obtained, which can be recovered easily. A fairly large quantity of MgO is collected during purification of the combustion gases and the MgO ashes are dissolved in water to produce magnesium hydroxide $(Mg(OH))_2$. The SO_2 is cooled and combined with the hydroxide in an absorption tower to reconstitute the cooking liquor. The magnesium bisulphite $(Mg(HSO_3)_2)$ is strengthened with SO_2 and stored. In this case, 80-90% of the reactives can be recovered.

The recovery of residual sodium sulphite-based cooking liquor is more complicated. It is concentrated in evaporators, the concentrated cooking liquor is incinerated and approximately 50% of the sulphur is recovered by absorption as SO_2. The remaining sulphur and sodium are collected in the bottom of the recovery boiler as Na_2S and Na_2CO_3 slag. This is dissolved to produce green liquor, and after various steps, sodium bisulphite ($NaHSO_3$) is obtained. The $NaHSO_3$ is strengthened and stored. This recovery process produces some sulphurous gases, in particular hydrogen sulphide (H_2S).

The cooking liquor should be recovered as its acidity, its high BOD (due to its content in sugars from the hydrolysis of the celluloses) and the surface-active nature of the lignosulphanates, which form scum, mean that this wastewater cannot be discharged without prior treatment.

The sulphite process has been overtaken by the Kraft process for the following important reasons:

- The potential pollution from this type of process is much greater than that of the Kraft process due to the high BOD content of the wastewater and the loss of SO_2 as emissions into the atmosphere.
- The sulphite process cannot be used for all types of pulp.
- The introduction of new bleaching steps (particularly the use of chlorine dioxide) makes effective bleaching of Kraft pulp possible, resulting in more resistant pulps.

Alkali processes

The two most used methods are: the soda ash method and the sulphate method, also called Kraft, and variations of these. As indicated above, the most important method is the Kraft method and this is the method used to obtain the majority of chemical pulps at present.

Soda ash method

This method, used particularly for non-coniferous wood, is one of the oldest methods. It produces fibres that can be bleached easily.

The cooking liquor consists of a 7-8% caustic soda solution, which at 170 ºC dissolves the lignin in the wood (by the formation of sodium lignin phenolates) and some cellulose (by hydrolysis), leaving, in addition to the pulp, a dark liquid known as "black liquor", which contains the products of lignin and cellulose breakdown, sodium salts from complex organic acids, lignin phenolates and the excess soda ash.

The recovery of black liquor is particularly important to this industry. These liquors, mixed with the waters of the first pulp wash, undergo prior evaporation to obtain a solid concentration of 50 to 60%. This thick liquid is burned in a rotary furnace, and the heat released by the combustion of the organic material maintains combustion and produces the necessary heat for prior evaporation.

The ash and slag from the furnace contain the sodium in carbonate form. This ash is dissolved in water and, following the addition of sodium carbonate (which is cheaper than soda ash) to compensate for losses (approximately 10%), the solution is causticised, making it ready for a new cooking process.

The soda ash method is outlined below:

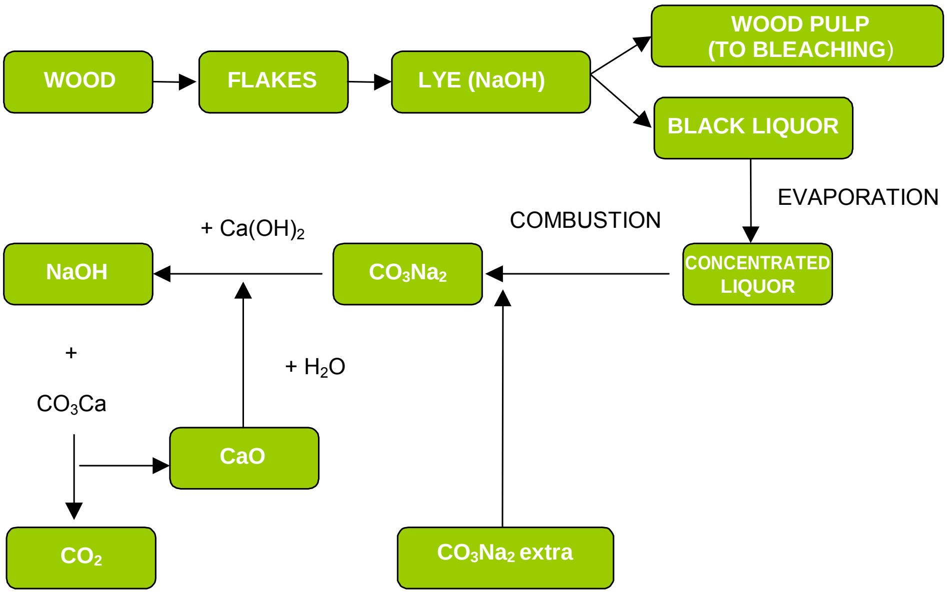


Figure 4.3.4. Outline of the pulp manufacturing process using soda ash

Source: Introduction to Industrial Chemistry Second Edition

<u>Sulphate or Kraft method</u>

Among the alkaline processes, the sulphate method, also known as "Kraft", is the most important as it produces more resistant pulps than the other processes (Kraft in German means "strength").

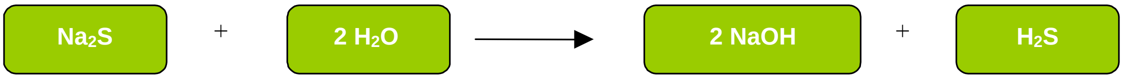
The chemical pulping agent or cooking liquor, also called white liquor, consists of a mixture of sodium hydroxide (NaOH) and sodium sulphide (Na_2S).

As a reactive, Na_2SO_4, which is cheaper than Na_2CO_3 is used, to compensate for the spent reactive. As a result of reaction with the carbon present in the products in the furnace, the Na_2SO_4, is reduced to Na_2S, so that after causticisation, the solution contains NaOH and Na_2S, reactives that dissolve lignin.

Table 4.3.1. Composition of the white liquor used to produce Kraft pulp

Component	Function
NaOH	Primary pulping agent
Na_2S	Accelerator, increases the cellulose and hemi-cellulose yield, protective action
Na_2CO_3	Present as a result of the chemical recovery system
Na_2SO_4, Na_2SO_3, $Na_2S_2O_3$	Traces

The liquors of this composition are more effective than soda ash, as they are a type of buffer solution for the OH^- content, as when OH^- are used up, when the wood is attacked more are produced, as NaOH is released by the hydrolysis of the sodium sulphide:



$$Na_2S + 2\ H_2O \longrightarrow 2\ NaOH + H_2S$$

Figure 4.3.5. Hydrolysis reaction of the sodium sulphide

Conditions of the process: 7-10 atm, 180 °C, 0.5-2 hours, depending on the temperature, the proportion of alkali and of sodium sulphide

Delignification is faster in this method than in the sulphite method, and there is little breakdown of the cellulose. A large part of the hemicellulose is retained, acting as a linking agent, which makes the fibre very strong.

The cooking process of Kraft pulp can be done in both continuous digesters (such as Kamyr digesters) and batch digesters.

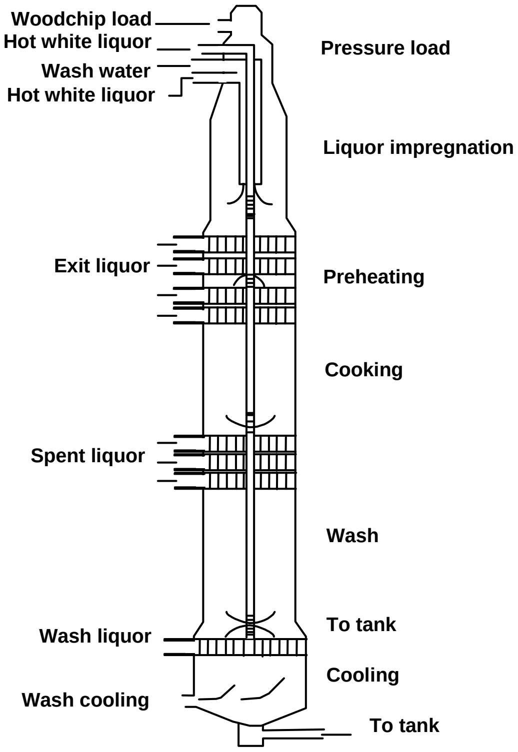


Figure 4.3.6. Kamyr digester. Source: Industrial Chemistry

In the case of batch digesters, the wood chips and the white liquor are fed into the digester, where cooking takes place at specific temperatures and pressures, depending on the degree of delignification required. When a given residual lignin value is reached (expressed as a kappa number), the content is poured into a tank and the cooking cycle is repeated with a new batch. The quantity of lignin that remains in the pulp can be determined approximately by multiplying the kappa number by the factor 0.165 (Uhlmann, 1991). Therefore a kappa number of 30 results in a residual lignin content of 4.95%.

When cooking takes place in continuous digesters, the resultant lignin content is defined by the load of wood/chemical reactive, the retention time and the cooking temperature. In this case the chips are preheated with steam before entering the digester, so that air is removed, as it interferes in the impregnation process. After entering the digester, the chips are impregnated with the cooking liquor at a temperature of 155-175 ºC. The cooking time, at maximum temperature, is around 1-2 hours. In conventional cooking processes, delignification of coniferous wood can reach a kappa number of 30-35, resulting in an acceptable pulp strength. In the case of non-coniferous woods, the kappa number can be from 14-22.

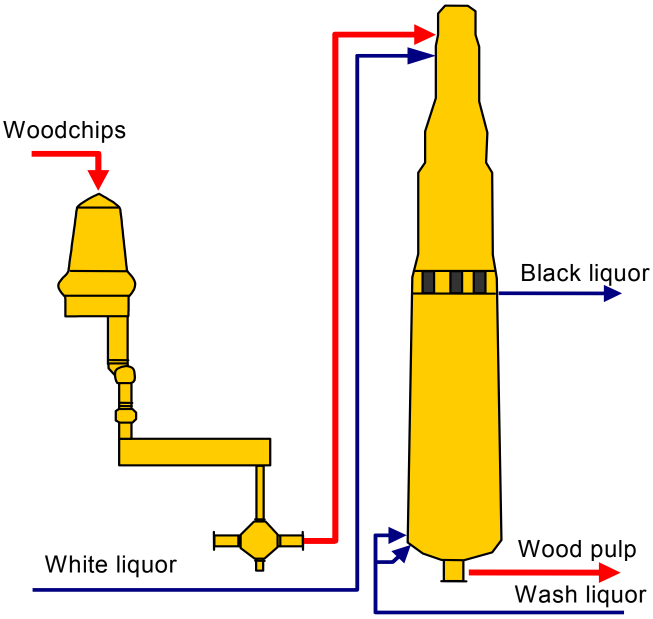


Figure 4.3.7. Kraft process continuous digester. Source: BREF

After cooking, the pulp is screened to separate the pieces of wood that have not been digested, washed, to separate the used cooking mixture (black liquors) and sent either to the bleaching process or the pulp manufacturing machine. Undigested wood is sent back to the digester or to the furnace to burn it for energy.

One of the main advantages of the Kraft method is the recovery of the black liquors, which not only allows the recovery of the chemicals, but also means the energy value of these can be used to generate the steam necessary for the process.

The recovery system in the Kraft process has three functions:

- Recovery of the chemical reactives.
- Destruction of the dissolved organic material and recovery of energy as steam or electrical energy.
- Recovery of usable organic sub-products.

The black liquor recovered from the digester contains dissolved organic substances, the exact chemical composition of which depends on the characteristics of the type of wood and the cooking conditions. Normally black liquor has a dissolved solid content of 14-18%, which must be greatly concentrated before its combustion. To do this, the black liquor is concentrated by multi-effect evaporation until the solids content is 65-75%. However, as the solids content increases, it must be remembered that the viscosity of the black liquor also increases, and this could be too high for it to be pumped. At atmospheric pressure, the limit is around 72-74% solids. The black liquor can be concentrated up to a solids content of 80% in superconcentrators, which operate at higher pressures and temperatures.

The condensates resulting from the evaporation of black liquors has different pollutant levels depending on its origins. They typically contain total reduced sulphur compounds, methanol and other volatile components. Before their use as water in the process, or their discharge, they are subject to desorption or "stripping". The vapours from this operation are sent to the bark furnace or the liquor boiler to be removed.

The concentrated black liquor, with the addition of sodium sulphate (Na_2SO_4), is sent to the recovery boiler for its later combustion, to recover the sodium and the sulphur, and to obtain energy from the combustion gases.

An increase in the solids concentration from 65-70% to 80-85% results in a change in the material and energy balances, in addition to changes to the combustion conditions in the recovery boiler. The smaller the quantity of water to the boiler, the lower the flow of combustion gases and the greater the solid content in the black liquor, which means that a larger quantity of sodium is vaporised, reacting with the sulphur and remaining in the ashes. In this way the sulphur emissions from the boiler are reduced.

The fused material from the recovery boiler is dissolved in water or weak white liquor in order to produce green liquor, consisting mainly of sodium sulphide (Na_2S) and sodium carbonate (Na_2CO_3). White liquor is clarified and causticised with calcium hydroxide, turning the sodium carbonate into sodium hydroxide to produce white liquors for digestion.

$$\boxed{Ca(OH)_2} + \boxed{Na_2CO_3} \longrightarrow \boxed{CaCO_3} + \boxed{2\ NaOH}$$

Figure 4.3.8. Causticisation

The ash and other impurities are removed from the process by the decanting of the green liquor. The calcium carbonate sludges from the causticisation process are separated by filtration of the white liquors, washed and burned in a lime kiln to regenerate the quick lime. The calcium oxide is mixed with water to obtain calcium hydroxide, which is used in the causticisation process. The burning of the sludges takes place in a rotary furnace, with added fuel (coke, coal, fuel oil or gas).

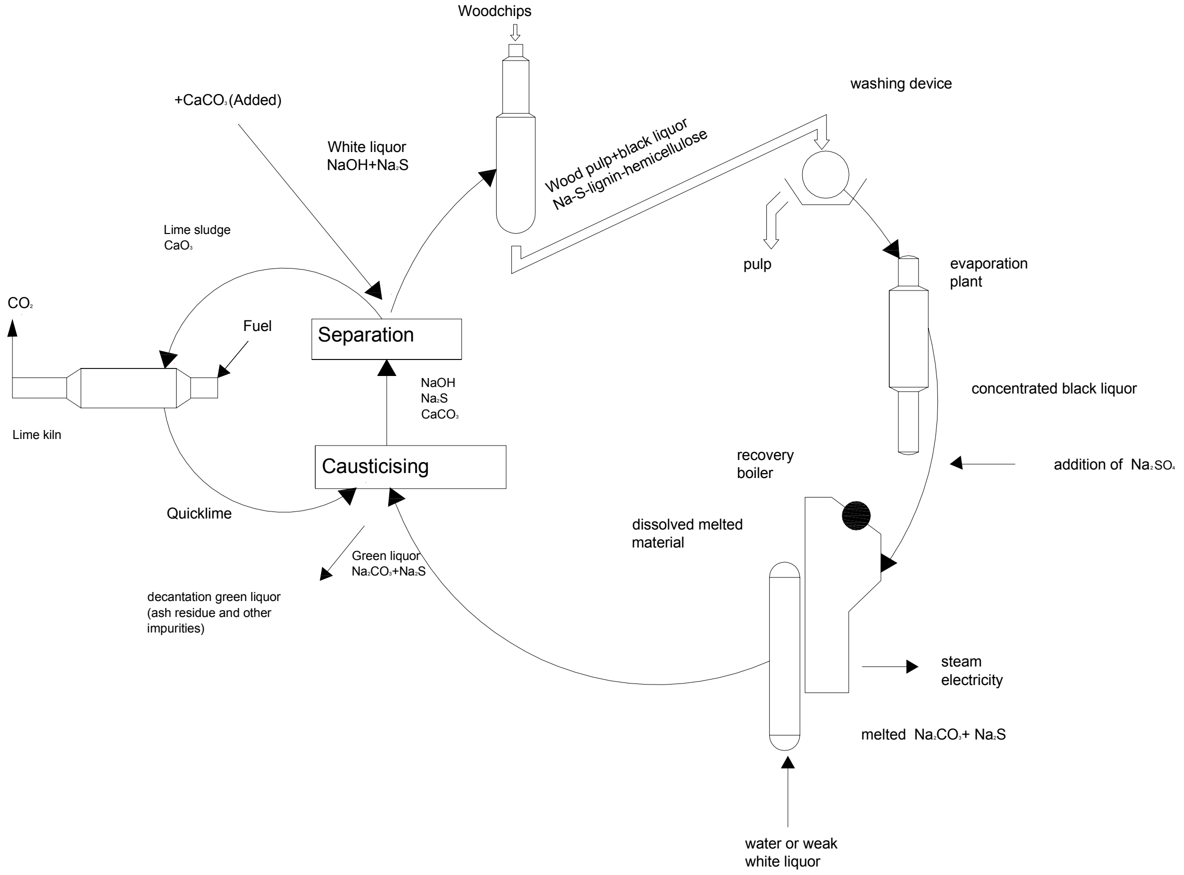


Figure 4.3.9. Kraft process

The degree of lignin removal (delignification) of each cooking is a variable that is predetermined depending on the type of wood used and the final use of the pulp manufactured, which may be to be bleached or not.

During Kraft cooking, various malodorous gases and vapours are produced. These are derivatives of sulphur (hydrogen sulphide (H_2S), methyl mercaptan (CH_3SH), dimethyl sulphide (CH_3SCH_3) and dimethyl disulphide (CH_3SSCH_3)) which must be collected and removed in suitable auxiliary installations to prevent their emission into the atmosphere (this is dealt with in a separate section).

Some advantages of the Kraft process are:

- Any type of wood can be used, which means the wood supply is very flexible.
- Chips with some amount of bark remaining are tolerated.
- Cooking times are short.
- The pulp is fairly strong.
- The recovery of the black liquors is possible.
- Usable secondary products are obtained.

Washing of the unbleached pulp

At the end of cooking, the pulp is a dark coloured mass made up of the pulp itself and a residual cooking liquor of this same dark colour, of which the main components are: water, residual chemicals from cooking and dissolved organic materials from the wood, including lignin.

The washing process consists of separating with water most of the residual chemicals and organic materials that have dissolved during the cooking of the wood, to send them to the plant chemical recovery cycle. Therefore the pulp washing process has a double objective: to remove the remaining reactive chemicals from the pulp, before its incorporation into other stages of the process, such as bleaching, and the maximum recovery of reactives in the black liquor recovery cycle.

The washing takes place in various stages, with different types of equipment: rotating filters, which are the most used; diffusers and/or washing presses. In the rotating filters, the pulp fibres deposited on the outside of the drum form an upper layer onto which successive curtains of hot water are sprayed by sprinklers along the length of the drum. The chemical in the pulp are dragged out with the washing water as it passes over the layer of pulp to the inside of the drum, which is achieved by means of the vacuum created from inside or by the pressure of the air chamber situated above the drum. The water which flows to the inside of the drum and drags out the chemicals, called weak liquor, circulates in counterflow to the advance of the pulp, finally being removed to the storage tanks for sending to the black liquor recovery plant.

The processes carried out by continuous digesters, as well as additional washing by rotational filters, use a zone of the digester as a washing zone. Nowadays washing in batch processes, like in continuous processes, begins for practical purposes in the digesters, replacing the hot black liquor with cold washing liquor.

The washing presses are especially effective for eliminating dissolved organic substances. This is one of the reasons why this type of washing press is used more and more, especially in the last stages of washing prior to bleaching, to avoid the dragging out of such substances with the pulp.

Effective washing means the reduction of transfer of the black liquor to the unbleached pulp, resulting in lower consumption of chemical bleaching agents and reducing its discharge.

Oxygen delignification

Modern cellulose plants, which produce unbleached pulps intended for bleaching, have with this stage an additional delignification process with oxygen. This consists of applying high doses of oxygen to the unbleached pulp to produce the oxidisation of the lignin, before the bleaching stages. This substantially reduces the consumption of chemical reactives in the bleaching stages.

This intermediate stage uses oxygen in an alkaline medium as its active agent, in a pressurised reactor at a temperature of around 100 ºC, to which small quantities of magnesium sulphate ($MgSO_4$) are added to preserve the quality and strength of the product.

Oxygen delignification can be carried out in one or two stages. The normal delignifying interval in pulp factories for bleaching varies between 30% and 50% in one-stage systems and is up to 70% in systems with two stages.

After conventional cooking and oxygen delignification, the kappa number is 18-22 for coniferous woods and 13-15 for non-coniferous woods, with no prolonged delignification. Depending on the type of wood, oxygen delignification, together with prolonged cooking, can result in a kappa number of 8-12.

At the end of delignification, the pulp is put through a washing process to remove the organic material and the chemicals contained in it before sending it to the bleaching process.

The advantages of this process include:

- Additional delignification after cooking with greater selectivity than prolonged cooking.
- Reduction of emissions from the bleaching plant.
- Reduction in the consumption of bleaching reactives.
- Increase in the degree of brightness in a given bleaching sequence.
- Lower uncooked content and better extractives content, maintaining the strength of the pulp.

4.3.3. Pulp screening and purification processes

Regardless of its origin, unbleached pulp inevitably contains undesired solid compounds, which are removed using screening and purifying processes. Among these undesired compounds are knots, shives or uncooked material, bark, sand, stones, coal and ash, extractives, metals, plastics etc. These compounds can damage equipment or cause quality problems in the final product, so they should be removed from the process. All these contaminants are removed from the process by screening, in the case of large contaminants, and by purifiers to remove those contaminating elements that are of different density from the cellulose (lower, as is the case of plastics, or higher, as is the case of sands).

The general aim of both operations is to remove the largest quantity of contaminants possible from the pulp suspension, with minimal rejects. The rejects, depending on their nature, are reintroduced into the process or are dealt with as waste.

The operational principles of the screens consists of passing the suspension through a strainer with holes or slots of a large enough size to allow the cellulose to pass through and to retain those contaminants of a larger size. In order to optimise the system, there are different types and designs of strainers and they worki in groups, normally operating in a cascade. At present, the most-used are pressure strainers and centrifugal strainers.

For purification, gravitational forces in hydrocyclones or centrifugal purifiers that normally work at low consistency (0.3-1.5%) are used. An installation usually has a battery of cyclones in cascade with diameters of between 50 and 300 mm, which can treat flow rates of 1 to 10 l/s.

4.3.4. Brightening

To produce good quality pulps of high levels of brightness, it is necessary to use bleaching methods that continue the delignification of the pulp, which was begun during cooking in the first stages of bleaching, and agents that remove the residual colour left from these stages. Bleaching removes those compounds that are capable of absorbing visible light or reducing their light absorption capacity.

The total bleaching process of a pulp is carried out in successive stages, using different chemicals and concentration conditions, pH, temperature, retention time, etc. These are different at each stage, always remembering the compromise between any increase in the degree of brightness and the loss of mechanical properties due to the breakdown of the cellulose fibres.

The bleaching process necessarily involves a reduced yield, as a significant amount of the lignin is removed that is still present in unbleached pulp, and moreover, some of the cellulose fibres deteriorate due to the chemical agents that are involved in the process. Normally, in the entire bleaching process, between 5 and 9% of the pulp is lost, to result in ISO brightness ratings of 87-90%.

The brightness of the pulp is measured by its capacity to reflect monochromatic light in comparison to a known standard (level 8 for the black of coal and 100 for pure magnesium oxide). While unbleached pulp has a brightness rating of approximately 30% ISO, bleached pulp has values of 88% ISO to 91% ISO. Sulphite pulps can give values as high as 94% ISO, if they are bleached, and unbleached Kraft pulp as low as 15% ISO.

The bleaching sequence used depends on the type of pulp:

- **Bleaching of mechanical pulp or chemical mechanical pulp:** As these pulps contain almost the same amount of lignin as the original wood (brightness = 50-60% ISO), treatment only raises brightness by 10-12 points, in order not to dissolve too much lignin. The residual lignin makes the products less white, and they darken with time.
- **Bleaching of chemical pulp:** In this case some partial dissolving is inevitable, with the consequent reduction in yield.

As mentioned above, bleaching takes place in a sequence of various stages, using different chemicals and conditions at each stage. The most usual chemical treatments and their abbreviated names are listed below:

Table 4.3.2. Bleaching agents

Bleaching agent	Reaction
Chlorination (C)	Reaction with elemental chlorine in an acid medium. When this combines with lignin, it forms chlorinated compounds, which can later be dissolved in water. Its use is restricted in many countries.
Alkaline extraction (E)	The dissolving of the products of an NaOH reaction. This converts the chlorinated compounds into soluble substances. This stage is usually accompanied by chemicals such as oxygen and / or oxygen peroxide. In that case, this stage is represented as Eo/Eop.
Hypochlorite (H)	Reaction with hypochlorite in an alkaline solution. Hypochlorite is a true bleaching agent, as it destroys certain chromophore groups in the lignin. It has had limited application in high-yield pulps as, following the attack on the chromophore groups, it dissolves the lignin, and unfortunately also attacks the cellulose. To ensure that it does not destroy the cellulose, there should be close pH control. Normally an excess of caustic soda is added to ensure that the final pH is greater than 9. The use of bleaching processes is being eradicated, due to their generation of chloroform and their low oxidising power.
Chlorine dioxide (D)	Reaction with chlorine dioxide in an acid medium. Its action is similar to that of chlorine, but its effect on the fibres is less harmful, and from an environmental point of view it generates less waste. This means that 1 kg of chlorine dioxide has the equivalent oxidising power of 2.63 kg of chlorine.
Peroxide (P)	Reaction with peroxides in an alkaline medium. It is used as an additional bleaching stage, or to reinforce extraction stage E. The peroxides are used in chemical pulp bleaching and high yield pulp. When it is used under relatively gentle conditions (35-55 ºC), peroxide is an effective bleaching agent which improves the brightness of mechanical pulps and other highly lignified pulps, preserving the lignin with no significant reduction in yield. The pH has a strong influence on this process and for best results, pH should be 10.5. The concentration of active perhydroxyl ions increases with the pH according to the reaction: $H_2O_2 + OH^- \Longrightarrow HOO^- + H_2O$ If the pH is over 10.5, undesirable competitive reactions are produced that diminish the bleaching action. The pH is controlled by the addition of sodium hydroxide and sodium silicate (this acts as a buffer and stabiliser in the peroxide bleaching system). Magnesium sulphate is also used, acting as a stabiliser. The silicate acts by de-activating concentrations of metallic contaminants.
Oxygen (O)	Reaction with high pressure elemental oxygen and chlorine dioxide. This is used both at the delignification stage and to reinforce step E of the extraction. Its oxidising power is 4.4 times that of chlorine.
Ozone (Z)	Reaction with ozone in an acid medium. Ozone O_3 is expensive, but offers environmental advantages by eliminating chlorinated compounds.
D_C or C_D	Mixtures of chlorine and chlorine dioxide. Mixtures of elemental chlorine are restricted in many countries.

The conditions of use of these bleaching agents are listed below:

Table 4.3.3. Bleaching agents and conditions for their use

Bleaching agent	**Concentration of the agent (%)**	**pH**	**Consistency (%)***	**Temperature (ºC)**	**Time (hours)**
Cl_2 (C)	2.5-8	2	3	20-60	0.5-1.5
Sodium Hydroxide (NaOH) (E)	1.5-4.2	11	10-12	< 80	1-2
Sodium Hypochlorite (NaOCl) (H)	1-2	9	10-12	30-50	0.5-3
Chlorine dioxide (ClO_2) (D)	~1	0-6	10-12	60-75	2-5
Hydrogen Peroxide (H_2O_2) (P)	0.25	10.5	12	35-80	4
Oxygen (O_2) (O)	1.2-1.9	7-8	25-33	90-130	0.3-1
Ozone (O_3) (Z)	0.5-3.5	2-3	35-55	20-40	< 0.1
Sulphur Dioxide (SO_2) (A)	4-6	1.8-5	1.5	30-50	0.25
Sodium Dithiosulphate (NaS_2O_4) (Y)	1-2	5.5-8	4-8	60-65	1-2

*Fibre concentration in water solution. Source: Paper and Pulp Industry Encyclopedia of Occupational Health and Safety

The existence of many different bleaching stages has resulted in a norm being established for their nomenclature.

- A "total bleaching" sequence can be obtained in 5-6 stages with the sequences CEDED (Chlorination, Alkaline extraction, chlorine dioxide, alkaline extraction and chlorine dioxide); CEHDED; OCEDED
- When two or more bleaching agents are used as a mixture or simultaneously, the agent of which the larger proportion is used is written first, in brackets: (C+D)EDED chlorine+dioxide (a larger proportion of chlorine), Alkaline extraction, etc.
- When two reactives are added in sequence, they are shown in order and in brackets (DC)EDED
- If the relation between them is to be expressed, it is shown as follows (D70C30): Sequential addition of 70% chlorine dioxide and 30% chlorine.

For many qualities of paper with lower brightness levels, short bleaching sequences can be used. The most common are: CED, DED, OCED, CEHH, CEHD and CEHP.

The global trend in bleaching sequences, since the 1990s, has been towards elemental chlorine free (ECF) bleaching and totally chlorine free (TCF) bleaching. However, there are still countries that do not use this bleaching sequence. In general, the evolution of the most-used bleaching sequences has been:

- Until the 1960s: CEHDED and CEDED
- From the 1970s (D+C)(E+O)DED y O(D+C)(E+O)D
- From the 1990s ECF, TCF

In the past, the most commonly used bleaching system was based on the five steps of the CEDED system, using chlorine gas in the first stage of acidic treatment, followed by an alkaline extraction phase with caustic soda and then a third phase of acidic treatment with chlorine dioxide, which can be followed by a fourth phase of extraction and a fifth of dioxide, until the five steps are completed.

However, due to the environmental conditioners in reference to organochlorine substances in waste from paper plants, there is less and less use of Cl_2, with it being substituted by chlorine dioxide (ClO_2) (C_DEDED), using a preliminary oxygen treatment (O_2) during the first alkaline extraction (C_DE_ODED). Traditional chlorine bleaching is used less and less, due to its pollutant nature with the formation of organochlorine compounds (AOX). In 1986, bleached paper production processes were identified as one of the contributors to dioxin and dibenzofuran emissions, with chlorine bleaching cited as the main culprit of these compounds. This led to the substitution of chlorine with chlorine dioxide and the manufacture of pulps free from elemental chlorine, **ECF** (**E**lemental **C**hlorine **F**ree) pulps and later **TCF** (**T**otally **C**hlorine **F**ree) pulps. The current global trend is for the total substitution of elemental chlorine with ClO_2 (ECF pulps) or the elimination of both (TCF pulps).

The bleaching of TCF pulps substitutes all chlorinated components for other products such as ozone, hydrogen peroxide or a combination of both. In this way new chlorine-free bleaching sequences have been developed using enzymes, O_2, ozone (O_3), hydrogen peroxide (H_2O_2), peracids and chelating agents (Q), such as ethylenediamine tetra-acetic acid (EDTA). Examples of these sequences are: OAZQP, OQPZP, where Q=Chelation. As these new processes remove the acid bleaching phases, an acid wash should be added for the removal of the metals present in the cellulose pulp.

ECF pulps allow the bleaching of pulps with higher kappa numbers. TCF bleaching necessitates low kappa numbers (10-12) in the pulps to be bleached to reach acceptable brightness levels with good strength properties, due to the breakdown of the fibres during bleaching; in this way, brightness values of 89% ISO can be attained with no loss in yield. Higher levels of lignin remain in TCF pulps than in ECF pulps. However, TCF pulps with the same brightness as ECF pulps can be obtained, although at higher cost.

The majority of factories use counterflow towers to provide the necessary retention time for the bleaching reactions followed by washers with rotating disc filters to remove the residual chemicals between the different stages. This means that all of the bleaching stages can act simultaneously, as the pulp is exuded from the upper part of the tower at the same speed as it is fed into the lower part. As a result, the feeding of the first tower automatically establishes the speed of the pulp in all the subsequent towers.

The recovery and/or treatment of the residue of each bleaching stage is the environmental objective of these processes.

4.3.5. Pulps from recovered paper

The use of recovered paper as a raw material is an important saving in natural resources (wood, water and energy), as its manufacture needs fewer chemical substances than paper made from virgin fibres.

The development of the use of recycled fibres in the paper industry increased exponentially in the second half of the 20th century, and they have become an essential raw material for sustainable development.

Encouraging the use of recovered fibres also leads to the recovery of waste and means that thousands of tonnes of paper waste does not end up destroyed in landfill sites and incinerators.

By means of the combination of chemical and mechanical processes, it is possible to obtain recycled fibres for the production of paper and cardboard. These processes use different qualities of recovered paper that contain chemical or mechanical fibres, or often an undefined mix of both. Some qualities of paper and cardboard can be manufactured exclusively from recycled fibres.

The following figure shows an example of the savings in raw materials, decrease in waste generated and occupation of space in landfill sites resulting from the manufacture of paper from recycled fibres from recovered paper:

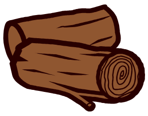
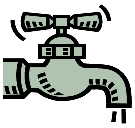
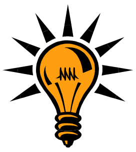
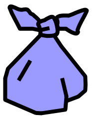
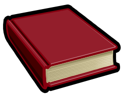
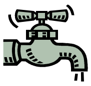
To manufacture one tonne of paper	**Raw material** kg m^3 woodtrees	**Water consumption** litres	**Energy consumption** kWh Tep	**Generation of waste** kg
Paper from virgin fibre, chemical pulp	 3.5 m^3 14 trees 2,300 kg	 15 m^3	 9,600 kWh 0.4 tep	 1.500 kg
Recycled paper	 1,250-1,400 kg used paper	 8 m^3	 3,600 kWh 0.15 tep	 100 kg

Figure 4.3.10. Typical consumption in paper manufacture from virgin or recovered pulps.
Toe: Tonnes oil equivalent

Source: Reciclapapel.org. Papelera Peninsular/Equipo Mandrágora

The first stage in the manufacture of paper and cardboard from recovered paper is the classification of the raw material, which is often done manually. This classification will depend on the product to be manufactured. Different types of qualities will be sorted, depending on the type of fibre in the waste and the quantity and intensity of the ink in the used paper.

- **Ordinary qualities (group A):** these include mixed paper and cardboard, cardboard trimmings, corrugated cardboard trimmings, packaging from shopping centres, mixed magazines and printed paper, and mixed newspapers and printed paper.
- **Medium qualities (group B):** these include used newspapers, unsold newspapers, trimmings of magazines and other similar materials, trimmings of white boxboard and trimmings of unglued bindings.
- **High qualities (group C):** computer printer paper, automated office paper, unprinted white boxboard, trimmings of white paper and white printing paper.
- **Kraft qualities (group D):** sacks, corrugated cardboard from Kraft paper, and Kraft paper trimmings.

The importance of separating the paper depending on these qualities is due to the necessity for raw material not to contain types of paper that cannot be recycled, or other foreign material that could negatively affect the recycling process.

Once the raw material is separated depending on the qualities above, inappropriate material, undesirable and contaminating substances that are present in the recovered paper and that must be removed, are removed.

The removal of these elements is carried out by physical mechanical processes using specialised equipment. These can distinguish between undesired elements that can damage the machinery or reduce the quality of the final product, and damaging materials that cause problems in the process or reduce product quality. The most usual undesired elements accompanying the raw material are:

- Crystals and sand,
- Staples and other metallic objects,

- Cables, fabric, string, laminated paper, plastic bags,
- Textiles,
- Coloured fibres,
- Offset printing inks.

And the damaging materials are:

- Asphalt-treated cardboard,
- Carbon paper,
- Greaseproof paper,
- Waterproof paper,
- Waxed paper.

Once the raw material has been selected and mixed to the desired conditions, in order to obtain an appropriate distribution of fibre sizes, the recovered paper must be immersed in large quantities of water. The pulp preparation plant consists of equipment placed in series, through which the diluted pulp passes and in which the removal of the undesired components takes place, along with the selection of fibres suitable for the manufacture of the final product.

The processes for recycling paper can be divided into two groups:

- **Pulping, cleaning and filtering:** for de-inked pulps intended for the manufacture of paper and cardboard for packaging.
- **Pulping, cleaning, filtering and de-inking:** for the de-inked pulps for newsprint, magazines, tissue or other printing and writing papers. There are also plants intended for the production of pulps for sale (DIP pulps).

Pulping

Once the raw material is separated according to the qualities listed, the paper, together with the water is poured into the pulper or grinder, where it is ground to separate the cellulose fibres from the ink that accompanies them. To do this, reactive chemicals can be added, such as caustic soda, sodium silicate or hydrogen peroxide. In the case of the manufacture of cardboard and derivatives, reactives are not usually added at the pulping stage. NaOH may be used at a later stage to improve the overall yield of the process.

The breakdown of the raw material takes place in pulpers that are usually either continuous, of low consistency, or batch of high consistency.

Those of low consistency generally operate at 3-6% consistency. They can be vertical or horizontal and their use is less widespread in the industry due to their high energy requirements. These machines usually incorporate a cleaning cycle to remove the waste that can remain in the pulper screen.

High consistency machines work at between 5 and 18%. This higher consistency is important as it uses less water and a higher concentration of the chemical agents used, which are therefore more effective.

Non-fibrous waste and pieces of metal are separated, following the pulping stage, in a separator. Dilution in the pulper takes place with process waters, recirculated from the pulp manufacturing process.

Purification and de-inking

The total purification of the recycled fibre is impossible in a single step. The main principle is to remove contaminants as soon as possible, prevent them reducing in size and avoid fibre loss. Depending on the desired quality, more or fewer purification stages are carried out, with recirculation, for the best fibre recovery. The size of the particles removed in each of the steps can be seen in figure 4.3.11.

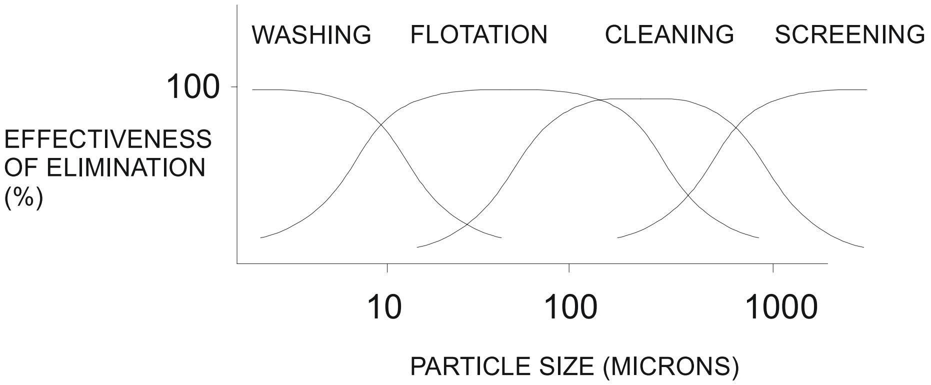


Figure 4.3.11. Effectiveness of separation of the systems used in pulp purification

Source: B. Carré and G. Galland. Overview of de-inking technology

The ground pulp goes through a first basic purification step, for which purifiers with holes of between 8 and 10 mm in diameter are used, which removes aluminium foil, white cork from packaging, waterproof papers, product samples, large plastics, strings, hoops, wires, wood, etc.

The next stage is cyclonic purification at high consistency, in which centrifugal force is used to separate materials that are heavier than the fibres, such as stones, sand, crystals, staples, different sizes of metals, etc; and a high consistency purification, in which rotating purifiers with holes or slots are used to separate particles of between 3 and 0.2 mm, mainly plastics.

In the case of de-inked pulps, the inks are removed by flotation. This is a separation method based on the surface properties of the particles. The particles, which are naturally hydrophobic, join to the air bubbles and float to the surface, where they are mechanically removed by overflow or by vacuum extraction. Flotation removes fillers and pigments to a certain extent, resulting in a scum with a high proportion of ash, and nearly 50% of the stickies or sticky organic contaminants that come with recovered paper (adhesives, latex, coating agents etc.).

Finally, using cyclonic purifiers at low consistency, the contaminants that are heavier and smaller than the fibres, which have passed though all the previous purifiers, are separated using centrifugal force; then small contaminants of a lower density than the fibres are separated by screening through low consistency purifiers. These are mainly small ink particles, plastics and stickies.

Thickening

The pulp that results from purification (classification), which must take place at low consistency to ensure effectiveness, must be concentrated for its later treatment by dispersion. Therefore there is a thickening stage at high consistency in a disc filter. In this phase, a large part of the water added during the previous phases is removed, which removes those contaminants that were not previously separated and allows the recovery of the residual chemicals. The resulting water can be re-used in the circuit, thus closing the circuit. Current pulp manufacture lines are designed with separate water loops, so that at the end of each line, through the use of disc filters and/or screw presses, the pulp is thickened and large quantities of water are recovered to be re-used in the previous stages. Disc filters extract waters of two types, known as cloudy filtrate and clear filtrate. The operation of a disc filter is summarised in figure 4.3.12.

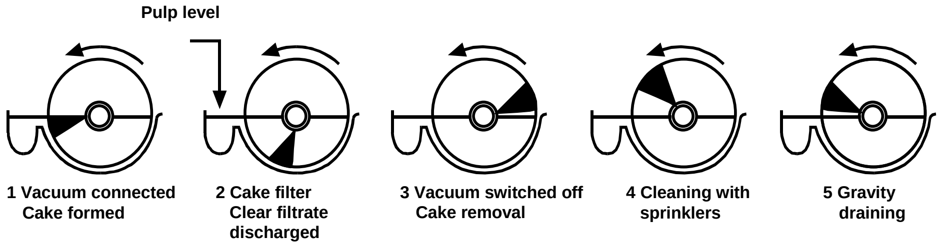


Figure 4.3.12. Diagram of the typical operation of a disc filter

The screw presses extract the cloudy filtrate which mixes with the filtrate from the disc filters. Both types of water are re-used in the process, such as in the dilution of the recovered paper used as a raw material for pulp production, and in many other stages of the process. This technique, considered a BAT in the BREF, leads to important savings of water during the process.

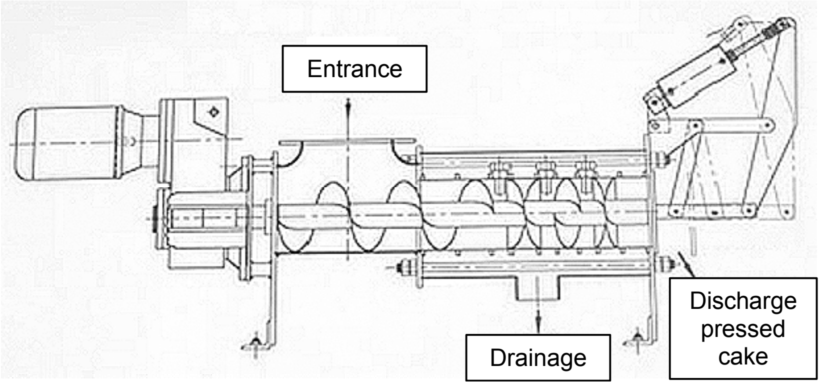


Figure 4.3.13. Diagram of the typical operation of a screw press

Dispersion

There are some substances that cannot be removed by any of the processes outlined above and that appear with the fibres in the finished paper. Although the elimination of these substances is not possible, systems have been developed that mean that they can be atomised and dispersed among the fibres, which leads to greater uniformity of the finished product. This operation takes place during a dispersion stage, in which the pulp undergoes an intensive mechanical treatment by friction. The most common dispersion systems consist of discs that spin at extremely high speeds, reducing the size of the contaminating particles such as stickies or waxes. This step takes place at high temperatures, which minimises the loss of physical properties and encourages the dispersion of the contaminants.

Brightening

Depending on the quality of the desired final product, such as in the case of supercalendered paper, office or hygienic papers, the production of pulp from recovered paper is usually completed with one or various bleaching phases. Bleaching usually takes place in tanks with a relatively high residence time, into which is added a bleaching reactive that encourages the removal of residual ink. Bleaching treatments can be oxidant or reductor. Of the oxidant products, the most common is hydrogen peroxide, which is complemented with sodium hydroxide, sodium silicate and certain chelating agents. Oxygen and ozone can also be used. Of the reductors, the most commonly-used is sodium hydrosulphite. The final brightness level depends both on the original brightness of the papers used and on the preparation process of the pulp used, along with the bleaching phases, with brightness of up to 84% ISO being reached.

Treatment of the water for re-use

The water collected in the earlier phases drag out contaminants that can be removed in dissolved air flotation (DAF) units. These units are cells in which the current of residual water is mixed with a current of water saturated with air, in such a way that small bubbles form spontaneously, resulting in the removal of contaminants of between 0.1 and 10 µm. This effect is often complemented by the addition of a coagulant or flocculant compound to encourage the removal of dissolved and colloidal material. The scum formed is removed by a simple mechanical method, while the clarified water is removed from the lower part of the DAF and reused again in the process. This technique, which is considered to be a BAT, leads to significant savings of process water due to the re-use that it enables.

Figure 3.3.14. shows an operational flow chart of a dissolved air flotation unit.

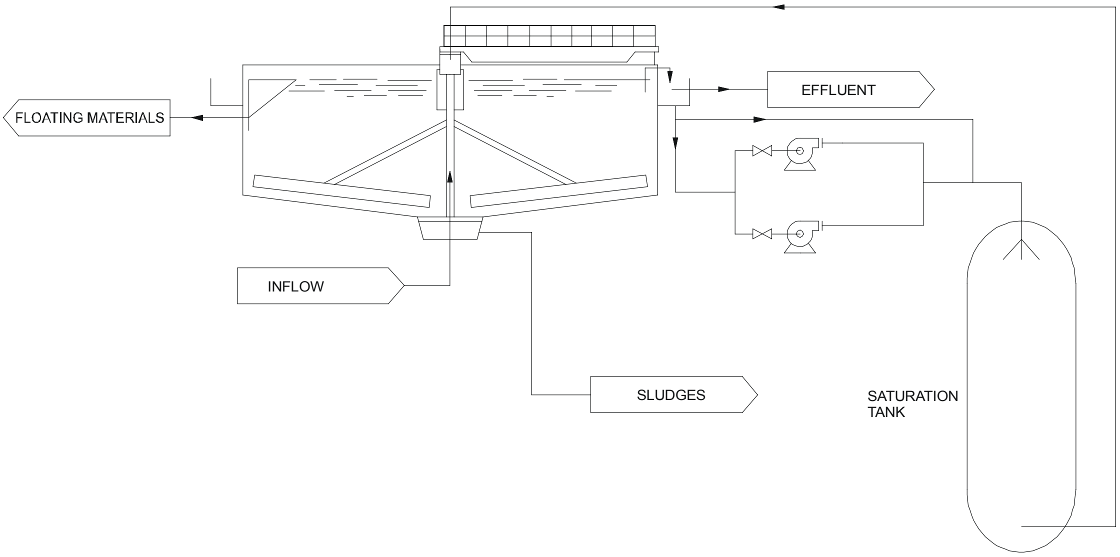


Figure 4.3.14. Basic diagram of a dissolved air flotation unit

Manufacture process block diagrams

Figure 4.3.15. shows a block diagram of a de-inked pulp manufacturing process and figure 4.3.16. shows the block diagram for the manufacture of pulp to manufacture corrugated cardboard.

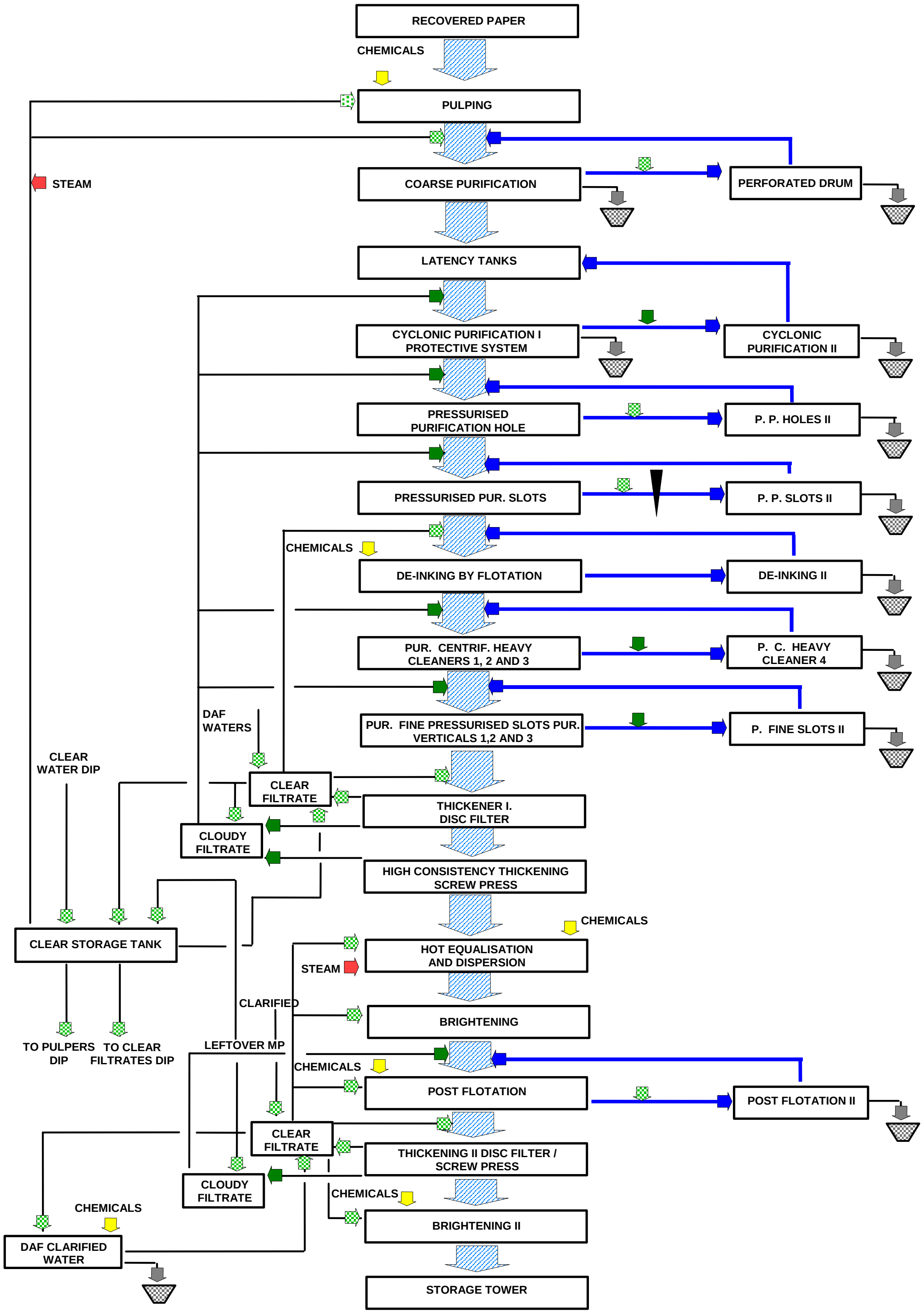


Figure 4.3.15. Block diagram of the manufacture process of de-inked pulp

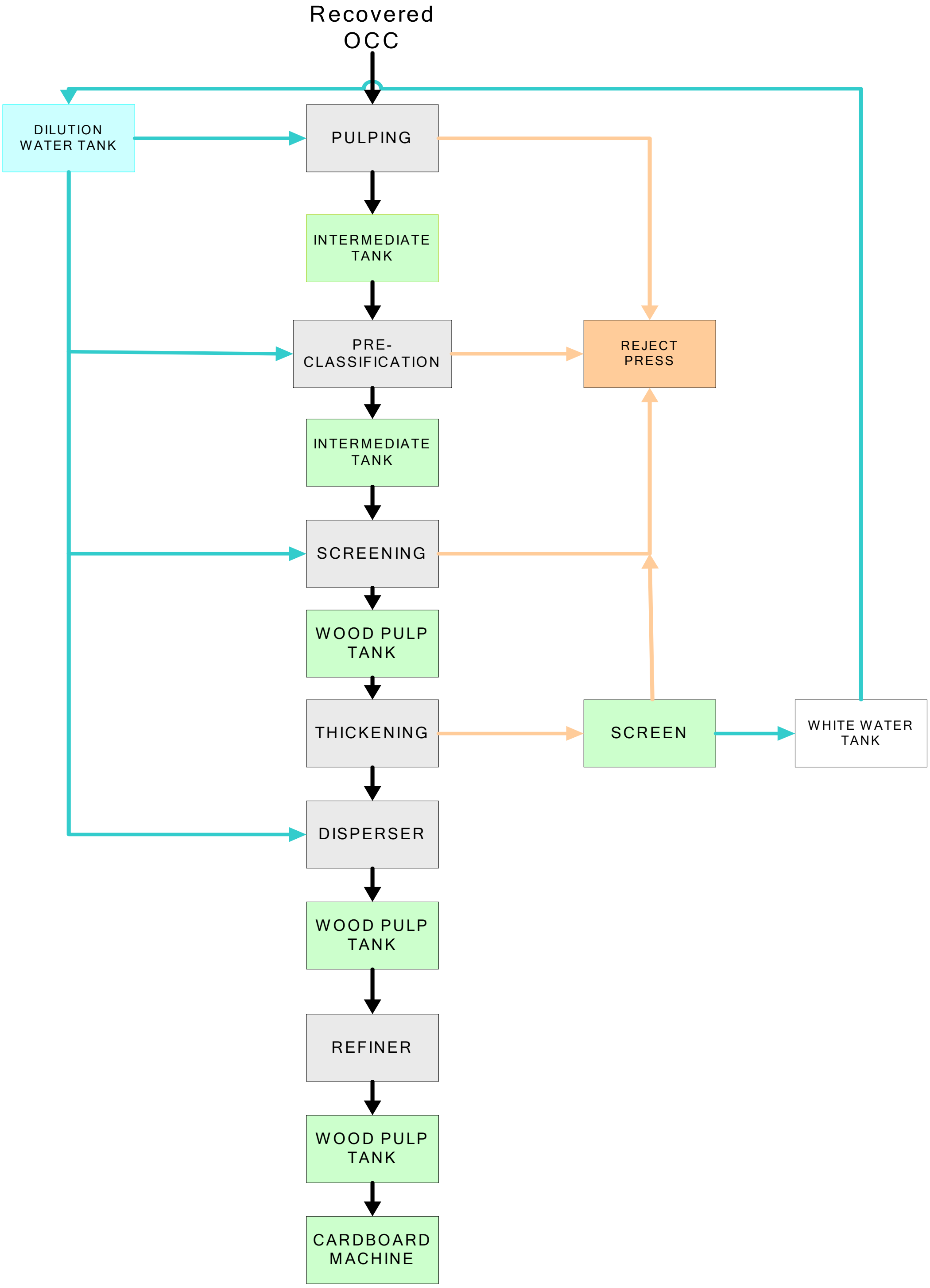


Figure 4.3.16. Block diagram of the manufacture process of pulp for corrugated cardboard

4.3.6. Paper manufacturing

Paper manufacturing, regardless of the type of machine used, consists of the forming of the sheet from a diluted paper pulp suspension. The paper machine is the main, most characteristic unit of this process. In it, the continuous sheet of paper that will be rolled up in the last sections of the machine is formed, drained, pressed and dried.

The procedures for the production of recycled paper or paper from virgin pulp are very similar, so only one outline of the process is given. The steps common to all production lines for paper or cardboard are: preparation of the pulp suspension, forming section, pressing section, drying section and finishing and manipulating section. The finishing section is not necessary for all products and in many cases this takes place separately.

Although there are various types of machines, traditionally the most used is the Fourdrinier machines, as shown in figure 4.3.17.

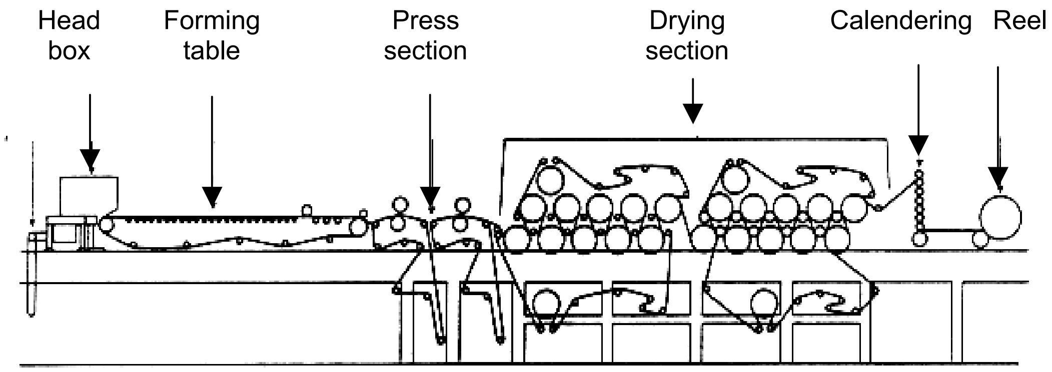


Figure 4.3.17. Paper production line with a Fourdrinier machine

The pulp, suitably purified using the processes outlined above, enters the paper machine, which can be divided into two main sections:

- **Wet end** Here, the sheet is formed and proceeds to the drying stage, first by means of gravity and then by vacuum action.
- **Dry end:** Here the paper is dried by pressing and high temperature drying, to remove any residual water. In this process, up to 70% of the water contained in the sheet is removed.

All paper manufacturers have a double objective: firstly, to obtain a product of the highest quality at the lowest cost possible, within the previously-defined specifications depending on its use, and to achieve maximum productivity, which means working at the maximum machine speed possible, without pause.

To attain these objectives, the manufacturer should optimise the paper manufacturing process depending on the quality of the final product desired. To do so, it is necessary to control all the processes involved in the forming of the sheet.

Wet end of the paper machine

Regardless of the different machines that might be used, the basic variables to be considered are: the composition of the raw material (% virgin fibre, coniferous and non-coniferous, % of recovered paper), the percentage of mineral fillers and pigments, the speed of the machine, and, most importantly, the chemicals in the wet end of the paper machine.

The objective of optimisation of the chemicals in the wet end of the paper machine is to control the state of flocculation of the pulp suspension during the process of forming the sheet. Flocculation, a complex phenomenon that is difficult to control, is of great importance as the level of flocculation of the suspension affects the efficiency of the process and the quality of the final product. Although the presence of flocs is important to improve the retention level and the drainage speed and therefore the speed of the machine, the size and the characteristics of these must be controlled in order not to alter the final quality of the product from the point of view of formation, porousness and strength.

Once the pulp suspension is prepared, this is pumped into the headbox, the function of which is to distribute homogenously the diluted suspension of fibres and additives (0.05-1%) on the forming table through the slice. To do this, microturbulence is created in the headbox to break up the flocs of fibres. The suspension is accelerated to match the speed of the machine.

There are three main types of headboxes:

- Cylinder headboxes, either open or closed.
- Conventional hydraulic headboxes.
- Hydraulic headboxes with dilution control.

The forming table, which can be up to 10 m wide and 35 m long, consists of a plastic wire conveyor, which acts as a filter. Under the wire there are different elements to help drainage. When the suspension is deposited on the wire, the water drains through it, first due to gravity and then by vacuum, while the solids in the suspension are mainly retained, forming a wet web on the wire. The different drainage elements lead to different drainage speeds and the distribution must be optimum in order to ensure progressive dewatering of the pulp and to avoid the sealing of the sheet. There are usually two sections, a filtering section, using hydrofoils and vacuum foils, and a consolidation section, using suction boxes and a suction cylinder. The drainage water or white water is collected and re-used for pulp preparation.

In paper-making terms, forming is understood to be the distribution of the particles in suspension to form the sheet of paper. The forming of the sheet is the result of three hydrodynamic processes: drainage, streamline flow and turbulent flow, which occur simultaneously. Good formation requires the even distribution of the fibres, fines and mineral fillers in the sheet. From this point of view, one of the most important phenomena that takes place in the wet end of the paper machine, which has a negative effect on formation, is the tendency of the suspensions to form stable three-dimensional structures as a result of the mechanical flocculation of the fibres.

The retention of fibres is aided by their mechanical interweaving, while the retention of fines and mineral fillers is the result of electro-static interaction between the particles in suspension and the chemical additives. Therefore mechanical flocculation principally influences the formation of the sheet, while chemical flocculation has most effect on retention. Lastly, the adhesion and occlusion of fines and mineral fillers on the inside of the flocs formed by the interweaving of fibres mainly affects the drainage process.

Another variable to be taken into account is the nature of the surface of the fibres. The surface properties of the fibres are determined by the raw materials (type of wood, process of obtaining pulp, degree of digestion, etc) and by the refining level. The refining level is of particular importance in the flocculation of fines and mineral fillers for two reasons: firstly because it determines the degree of fibrillation, which aids the occlusion process of particles; and secondly because it determines the number, type and distribution of loaded groups on the surface of the fibres, which enable the chemical flocculation of the particles in suspension when there are retention agents.

Flocculants are divided into three broad groups, depending on their chemical nature:

- Inorganic substances or electrolyte. The objective of these is to reduce the electrokinetic potential of the particles in suspension. The most commonly used of these in the paper industry are aluminium derivatives.
- Natural products and their derivatives. These are organic compounds formed of polysaccharides, the most common representatives being starch and vegetable gums.

- Synthetic or polyelectrolyte organic polymers. These are water-soluble synthetic flocculants that are effective at very low concentrations. They have different active groups distributed along their chains. The most-used are ionic, such as polyacrylamides and polyethyleneimines.

The effect of flocculants is determined by their action mechanism, which depends mainly on the characteristics of the flocculant: molecular weight and load density; the characteristics of the particles with which it is interacting: load density, surface morphology; and the process variables: time, turbulence, conductivity and pH of the medium, etc. To destabilise the suspension there are two possibilities:

- Reducing the negative forces, thus allowing the particles to draw closer until the Van der Waals force acts on them.
- Increasing the attractive forces between the particles.

As mentioned above, the chemical additives produce different effects depending on the nature of the product used. Some encourage flocculation, while others reduce it, such as in the case of the formation additives. Those agents that improve retention and drainage encourage flocculation and the stability of the flocs formed, due to the modification of the electrical charge of the suspension and the surface of the fibres, encouraging bonding between particles.

To summarise, flocculation depends on the characteristics of the raw material, the physical and chemical properties of the suspension and the degree of turbulence created in the machine. Flocculation control is complex, as the optimisation of the formation, retention and drainage processes requires different floc characteristics, which means that the process must be optimised globally, seeking a compromise between all the processes mentioned.

An inherent characteristic of the manufacturing process using a Fourdrinier machine is that all of the water is removed through one side of the sheet, the side that is in contact with the forming wire, which leads to different characteristics of the sides. This effect is accentuated by increased speed. To avoid this problem, machines with twin or several wire conveyors can be used.

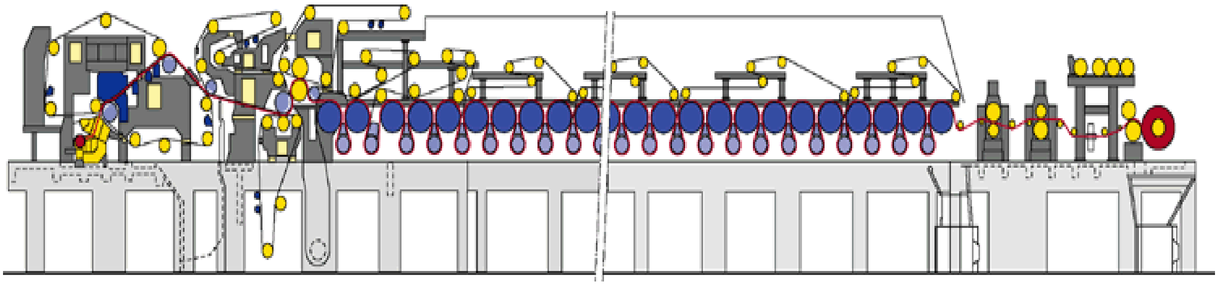


Figure 4.3.18. Twin wire machine

Pressing and drying section

At the end of the forming table, the layer has acquired 20% consistency and is considered to be a wet sheet with low strength. When no more water can be extracted by vacuum, the wet sheet proceeds to the pressing section, the objective of which is to increase consistency to 35-45%, consolidate the sheet and reduce wrinkles. Although the sheet appears dry, the fibres still contain large quantities of water inside them, interstitial water, which can only be removed in the drying section. This stage encourages bonding between fibres, modifies the surface properties of the sheet and dries the paper to 94-97% solids. The final moisture content of the reel must be controlled, as if the paper is too dry it becomes fragile.

Approximately 90% of the cost of water removal comes from the pressing and drying sections, mainly from the drying section. Therefore in order to reduce costs, drainage in the first steps of the machine must be optimised. The drainage capacity of a pulp depends on the type of pulp and the level of refinement and can on occasion limit the speed of the machine. The use of drainage additives and the optimisation of the types of flocs formed are therefore extremely important.

Figure 4.3.19 shows the drainage profile of a Fourdrinier machine.

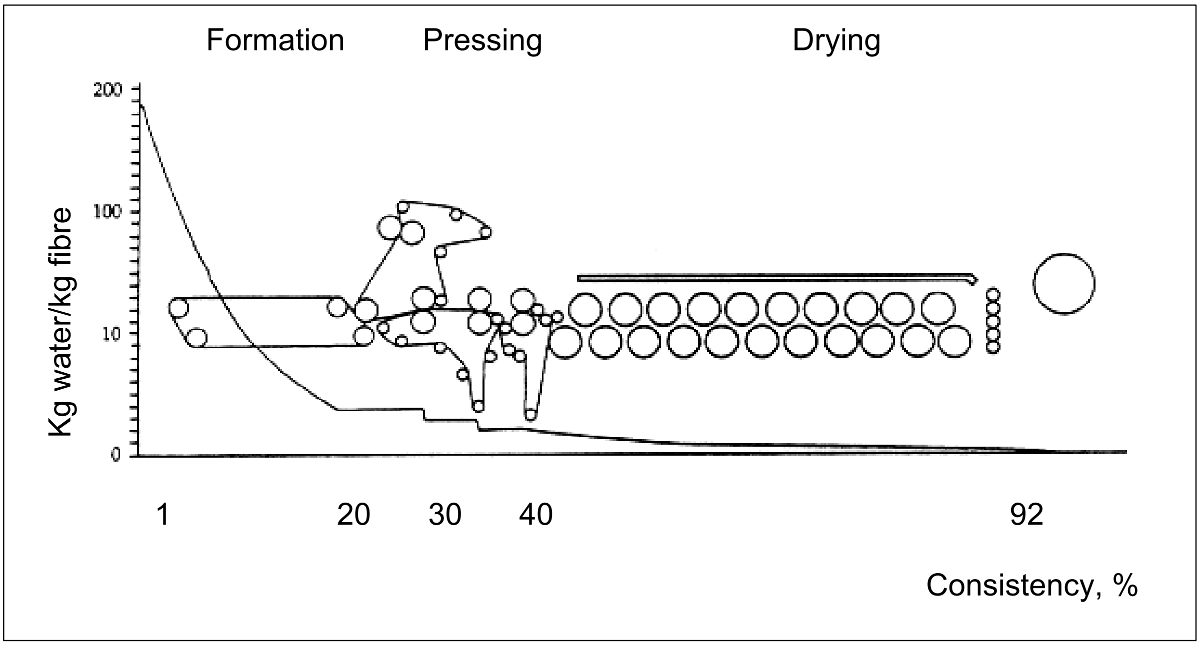


Figure 4.3.19. Drainage profile of a Fourdrinier machine

Finishing section

Depending on the quality of the final product, the finishing section can incorporate different processes such as sizing, coating and/or calendering.

When the paper is nearly dry, surface sizing can take place. This consists of adding a starch solution to the surface of the paper to control the penetration of liquid into the sheet and therefore improve its surface properties during printing. The sizing agents that are used most frequently are alkyl ketene dimer and anhydrous succinic acid

The sizing agent fills the pores and the capillaries of the sheet, making it more resistant to fluid flow through the paper. This also indirectly improves surface strength, as the starch solution encourages the bonding between fibres, reducing the possibility of defects during printing. On many occasions sizing is of the stock and not simply the surface. In general, the only papers for which sizing does not take place are hygienic papers.

The variables affecting surface sizing are:

- **Sheet characteristics:** wetness, level of stock sizing, nature of the surface of the paper, etc.
- **Variables in the sizing suspension:** solids content, temperature, viscosity, composition etc.
- **Design and operation variables:** speed of the machine, configuration of the sizing cylinders, pressure, etc.

On a microscopic scale, paper has a wrinkled surface, making printing inks tend to be distributed in a non-uniform fashion on the surface of the sheet, depending on the sheet's fibre and capillary distribution. Printing paper therefore undergoes a coating process, during which the surface of the paper is covered with a fine layer of pigments (kaolin, calcium carbonate, titanium dioxide, etc.). These are applied to the surface using an adhesive substance (starches, gums, latex, polyvinyl acetate, etc.).

In this way, high-quality printing papers are obtained, making the paper more opaque, more uniform and with more lustre, although there are also matte coatings.

Following this, the paper is dried again, and if desired can proceed to the calendering section to homogenise and reduce the thickness, to increase the density of the sheet and improve the surface appearance of the paper, increasing its lustre and smoothness. This step can also take place independently from the paper machine.

Lastly, in the paper handling section, the reel is unwound and wound up again when all defects have been removed, depending on the sizes required by clients. In some factories, the entire manipulation of the reels takes place at this stage until the final, packaged product is obtained.

Manufacturing process of multi-layer cardboard

The machines that manufacture cardboard are characterised by the fact that, in general, they have various wet ends that produce different sheets of paper, that are joined in the forming section to produce a multi-layer product. The grammage of the cardboards can be up to 500 g/m^2 whereas writing and printing products have a value of between 40 and 120 g/m^2.

Multi-layer board can be manufactured in different ways, depending on the number of layers and the material used in the mixture. The main characteristics required of this type of material are strength and resistance to compression for a not very high grammage. Often, good printing capacity is also required.

Boards usually have 3 or 4 layers, of which one may be coated on the surface. A multi-layer board manufactured from recycled fibres could consist, for example, of:

- Surface layer, formed from bleached pulp, of virgin or de-inked fibre.
- Remaining layers of more or less treated recycled fibres.
- The lower layers, depending on use, may be treated in the same way as the surface layer.

Figure 4.3.20. shows a block diagram of an integrated multi-layer board plant. The pulp dilution and screening stages are similar to those described above.

In this case, the formation of the sheet consists of a multi-layer system which has, therefore, several headboxes, one for each sheet. The felt passes through each of the headboxes and collects one of the layers, removing the water by gravity and the vacuum boxes. The sheet dries by up to approximately 20%. The excess water is run-off water that is recirculated to each of the run-off water tanks in the pulp production process.

Following this, the wet sheet is pressed and dried. Today, corrugating and surface treatment stages can be carried out, depending on the desired final product.

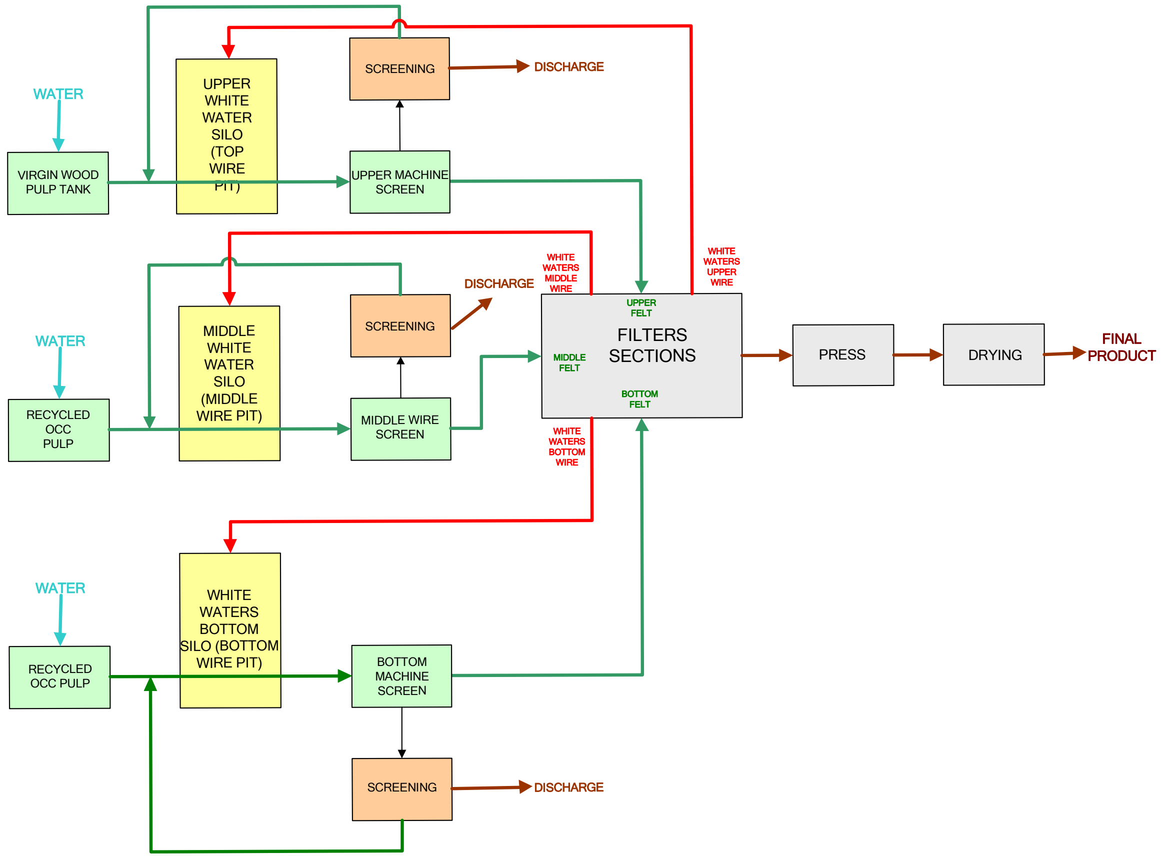


Figure 4.3.20. Block diagram of the manufacture of multi-layer board

Auxiliary equipment for the paper machine

Electric drive

The movement of the paper machine is obtained by the use of electric motors running with an alternating current. The power of these motors varies between 5 and 2000 kW and their speed is regulated by frequency variations.

The use of frequency variation in the machines, mainly in pumps and fans, means the adjustment of the energy demand needed at any time. This is therefore considered a BAT due to the energy saving it offers.

Control systems

The paper machine is controlled entirely automatically, both in the process variables and the quality variables, from the operation rooms using the most modernised computer and control systems.

Vacuum systems

This system consists of liquid ring vacuum cylinders that offer different levels of vacuum in the different sections of the paper machine, to encourage the drainage of the water of the drying of the felts in the pressing section.

Compressed air systems

Formed by rotating compressors that generate compressed air, which is used for the movement of the sheet and to feed the pneumatic equipment.

Steam system

This system is formed by a group of deposits, pumps, separators and injectors that feed the driers in the drying section with steam at a pressure of 2.5 bar, which becomes condensate, which must be removed from the paper machine to be sent to the boilers and then turned back into steam.

Ventilation system

This system consists of large fans and heat exchangers that enable the extraction of the hot, humid air from the evaporation of water in the drying section, replacing it with cold, dry air from the atmosphere.

The energy of the extracted air is transferred to the inlet air in the heat exchangers. Part of this heat is also used to heat the building where the machine is housed.

Lubrication and greasing systems

These mean that all the parts of the paper machine are lubricated and greased safely and automatically.

Tear circuit

When a sheet is torn in the paper machine, this sheet must be disintegrated in order to recover the fibres. This disintegration takes place in pulpers located below the different sections of the machine. For 2000 kW disintegration, water from the run-off water tanks is used and the pulp is sent to the mixing tank to be re-used, first passing through a thickening system to adjust the consistency.

The interconnection between machines takes place with tubes, valves and control equipment, all of which are made from stainless steel.

White waters circuit

The water removed in the paper machine, known as white water, is used to dilute the pulp to be fed into the headbox. This water from the machine is collected in a deposit known as a "silo" from where it is pumped through large speed-controlled pumps to the deaeration and purification system. The excess water is sent to a disc filter to recover the fibres, which, following thickening, are sent to a mixing tank.

Water systems for sprinklers

The paper machine and its elements must always be kept clean and lubricated. High-pressure water sprinklers are used for this. The water system consists of all the deposits, pumps, tubes and valves involved.

This is the system requiring the highest consumption of fresh water in the machine and the mill as a whole. This is the point at which the water quality has to be highest to maintain the quality standards of the product and the correct operation of the different sections.

A large part of the measures currently in place or at the research and development phase to reduce water consumption lean towards replacing the clean water in the system with clarified waters in those sprinklers that this is possible, or to establish purification treatments (ultrafiltration) which would improve the characteristics of the clarified water in order for it to be suitable for use in the most demanding sprinklers.

Roller heating systems

For this, a boiler-burner is used to heat oil to heat the calender rollers. The fuel used in this boiler is natural gas.

Dosing systems for chemical products and additives

As outlined above, some chemical products must be used in the paper machine. These are chemicals necessary for cleaning the felts, bactericide agents to prevent the formation of bacteria and biofilms or "slime", anti-foaming agents to prevent the formation of scum, retention agents to encourage the formation of fibre flocs, and mineral fillers such as calcium carbonate to control the porousness, smoothness, permeability etc. of the sheet of paper.

5. ENVIRONMENTAL PROBLEMS PULP AND PAPER MANUFACTURE; WASTE FLOWS AND CONSUMPTION

Various environmental problems arise from the manufacture of pulp and paper that depend to a large extent both on the raw materials used, fillers, additives and pigments, and on the processes carried out in the industry.

This chapter outlines the various sources of air pollution, liquid waste, and solid waste for the main processes used in pulp and paper manufacture. In some cases, specific management options are suggested, which in all cases should be compared in particular to the management obligations for waste flows established in each country with which manufacturers must comply.

In order to make it easier to understand the descriptions in this chapter, a number of general schemes of waste flow generation are given below, according to the processes described in chapter 4.

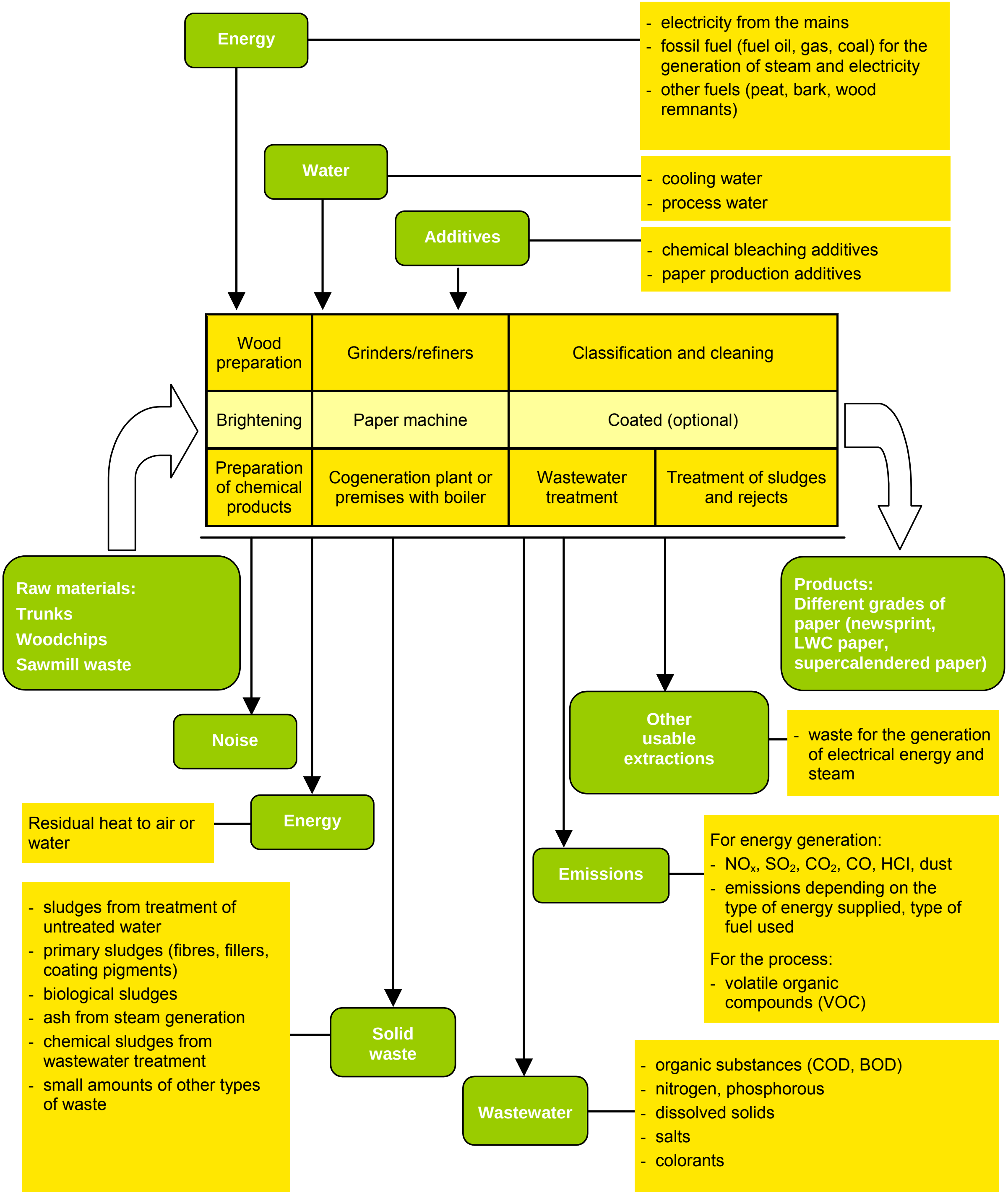


Figure 5.1 Mechanical wood pulp manufacturing

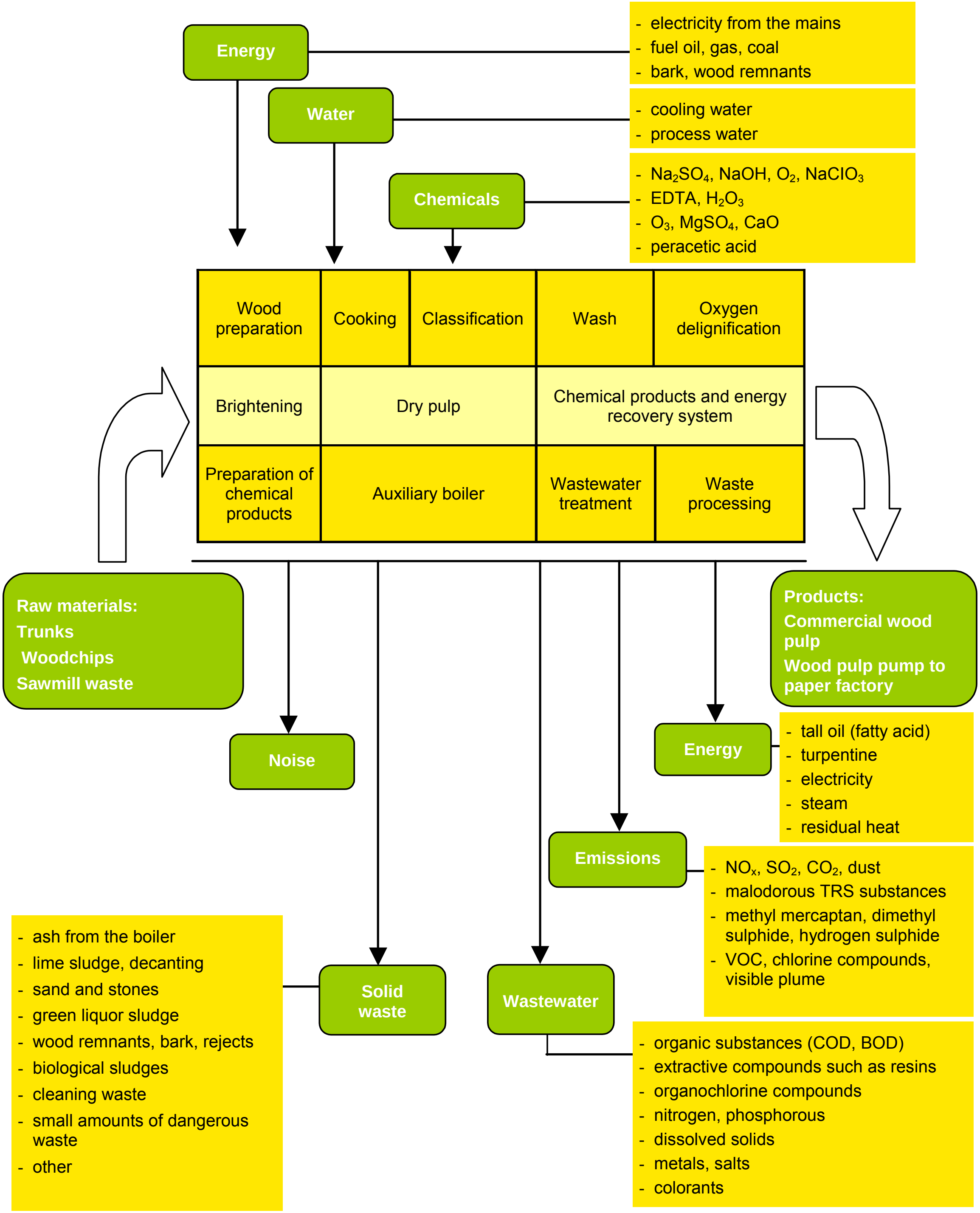


Figure 5.2 Kraft pulp process

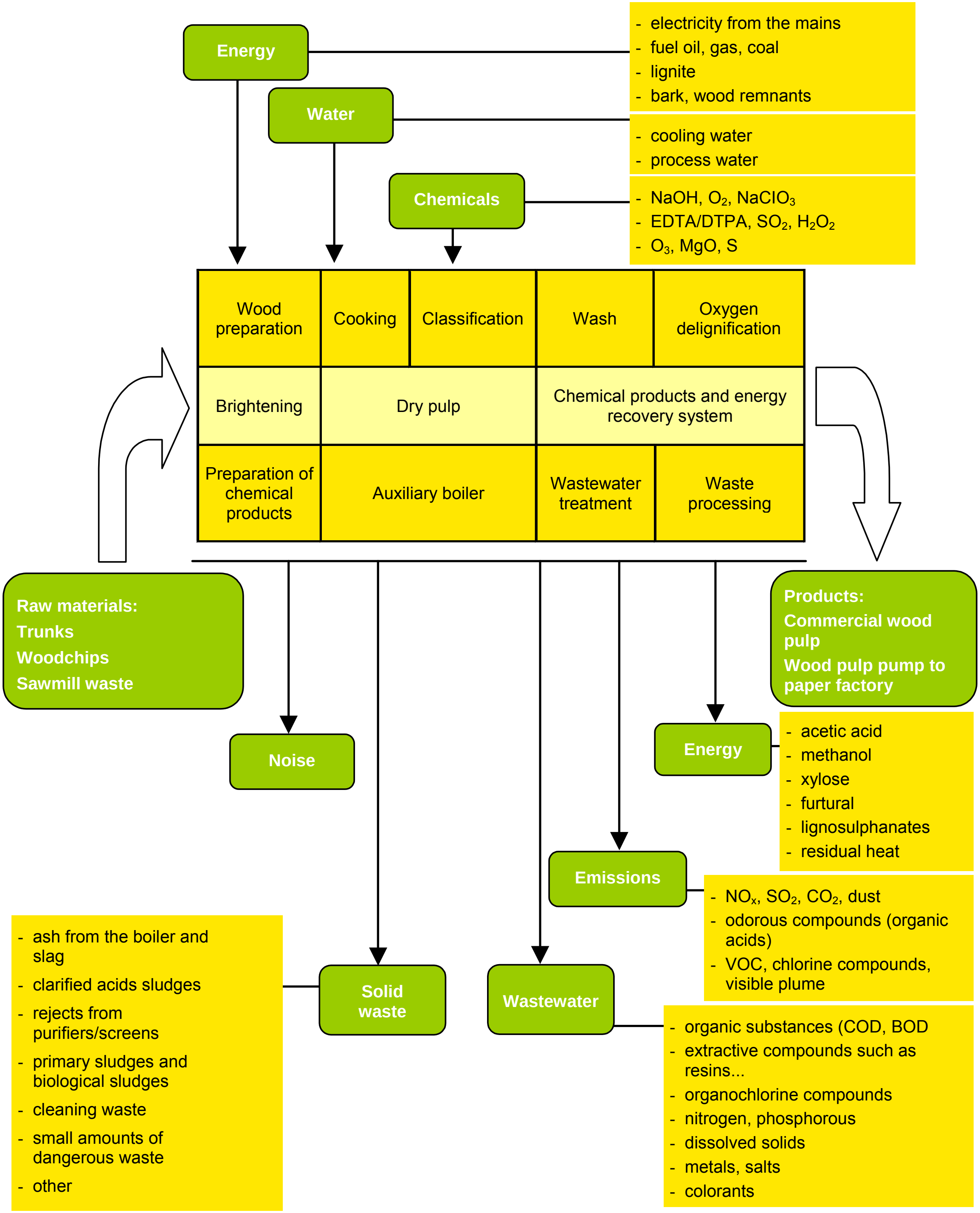


Figure 5.3 Sulphite pulp process

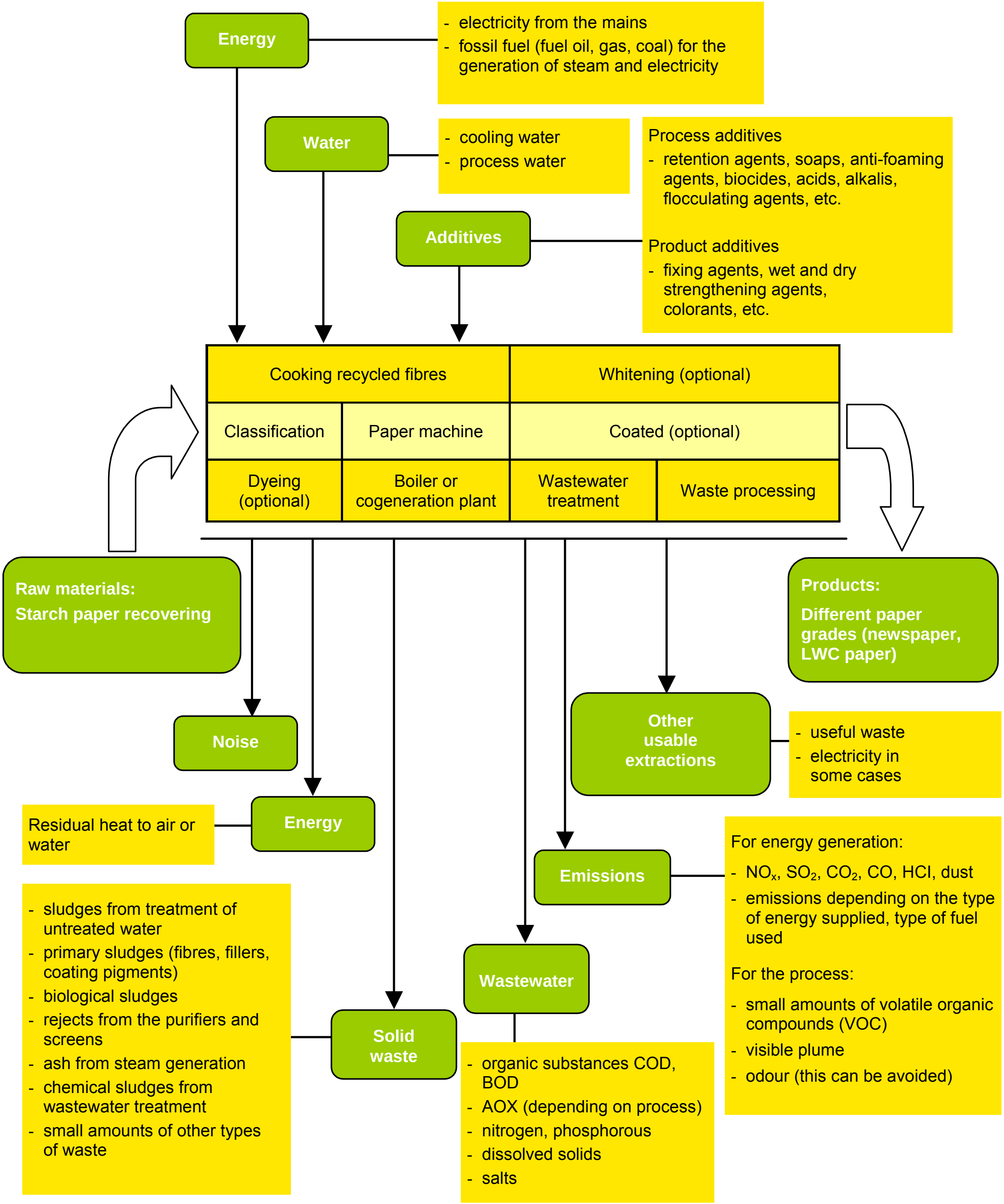


Figure 5.4 Manufacturing of recycled paper

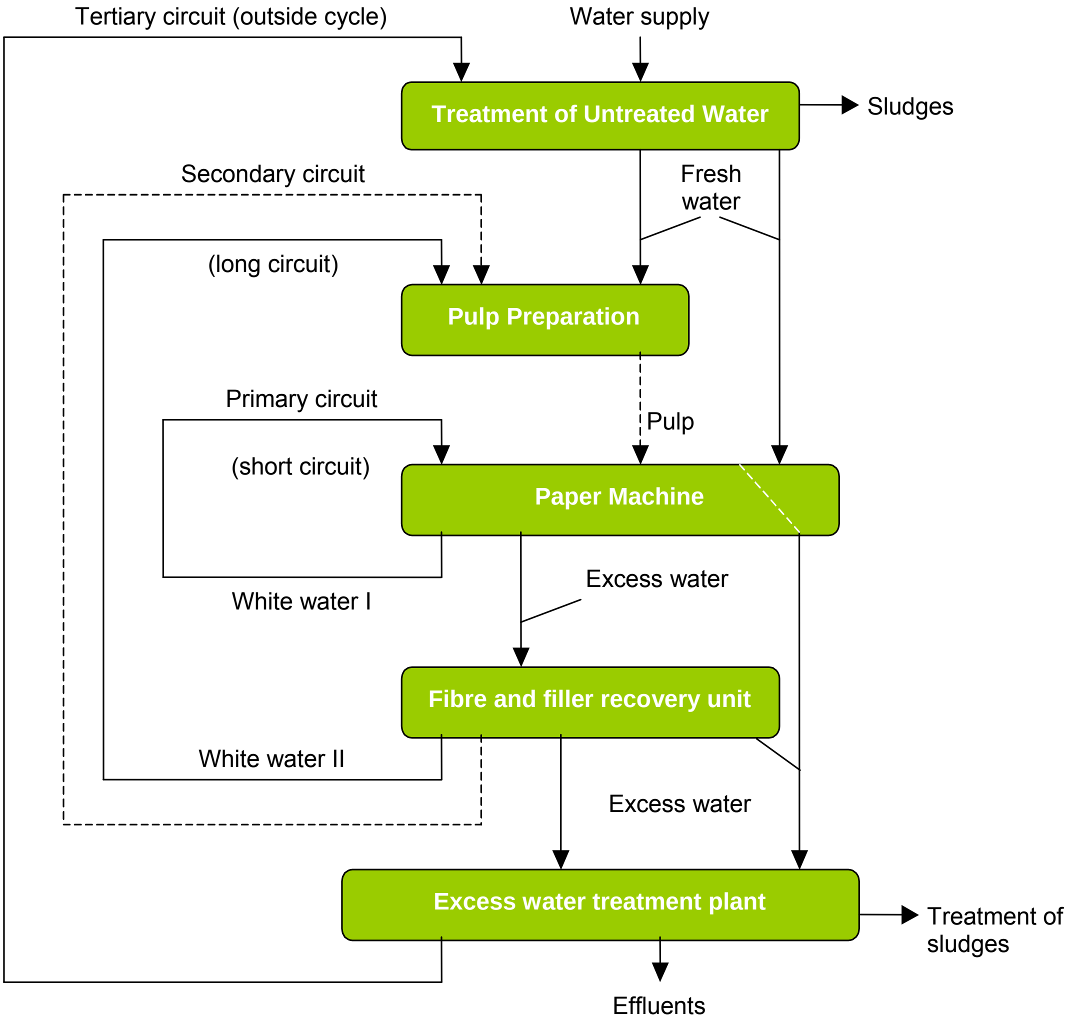


Figure 5.5. Pulp, water and waste flows in a paper mill. *Source: IHOBE*

5.1. POTENTIAL SOURCES OF AIR POLLUTION AND THEIR CONTROL

One of the environmental effects of the pulp and paper industry is air pollution resulting from the generation of volatile organic compounds, malodorous compounds, particles, etc., depending on the production process that is carried out.

These emissions are described below, according to the pulp and paper manufacturing processes.

5.1.1. Preparation of the raw material

In this phase, emissions into the atmosphere are of low volume and concentration, and can be attributed only to the emission of volatile organic compounds from the storage of the wood and wood chips.

5.1.2. Obtaining pulps

Atmospheric emissions may be generated throughout the process of obtaining cellulose pulp from wood, in the form of particles and gases from the chemical cooking stage of the wood. The composition of these depends on the processes followed. Gases are generated in the combustion of black liquor, and contain particles and volatile compounds of sulphur. These sulphur compounds are responsible for the bad smells that are characteristic of this industry. The emission of particles originates in the recovery boilers of the black liquors.

In comparison with chemical processes, mechanical processes do not emit sulphurous substances into the atmosphere, and therefore their use is not accompanied by bad smells. Atmospheric emissions from the manufacture of mechanical pulp s are low in volume and concentration, and can be attributed solely to emissions of volatile compounds from the storage of wood and wood chips, and their treatment with steam in the case of thermomechanical pulps.

In the case of the preparation of pulps from recovered paper, there is no major source of air pollution. Emissions come mainly from the fuel used in the generation of the necessary vapour to dry the paper. Some factories have sludge incineration plants, which produce the vapour used in the drying process of the final product. This incineration generates emissions into the air that are treated with filtration sequences and gas condensation processes.

The Kraft process for obtaining chemical pulps is an example of the reduction of the volume of waste generated per tonne of pulpobtained in recent decades, which in combination with the economy of the reactives used and the recovery of reactives and energy, has meant that this process has been used for a century and a half, and is today still the main process of chemical pulpmanufacture. Given the widespread use of this model, the comments given below refer exclusively to this process.

Figure 5.1.1. shows a general overview of the sources and nature of emissions in the manufacturing process for Kraft pulp.

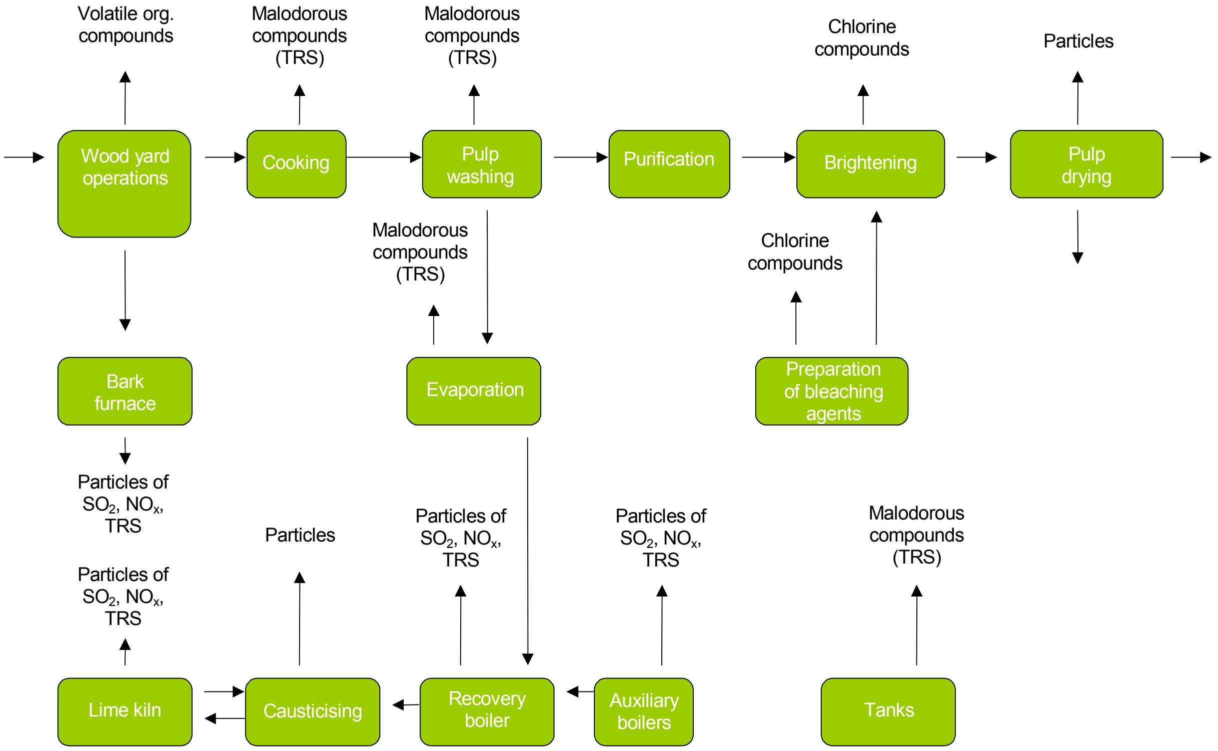


Figure 5.1.1. Atmospheric emissions from a Kraft pulp mill. Source: BREF

The majority of these emissions consist of sulphur compounds, including sulphur dioxide and total reduced sulphur (TRS) compounds, such as methyl mercaptan, dimethyl sulphide, hydrogen sulphide, etc. These compounds are characteristically malodorous, even in very small concentrations (ppb). The reactions giving methyl mercaptan and dimethyl sulphide are shown below:

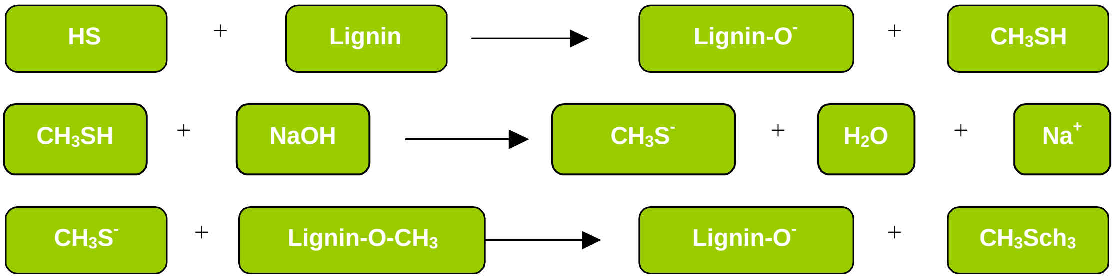


Figure 5.1.2. Methyl mercaptan and dimethyl sulphide formation

The chimneys of the steam boilers are also the source of emissions of nitrous oxides and carbon oxides, as well as dust particles. In the bleaching plant and the plants for the manufacture of chlorinated compounds, occasional leaks of chlorine into the air may occur.

Total Reduced Sulphur (TRS) compounds

Those gases containing TRS, which are produced during the manufacture of Kraft pulp, are classified as LVCH (Low Volume High Concentration) gases and HVLC (High Volume Low Concentration) gases. The high concentration gases are those in which the sulphur concentration is greater than 0.5g S/Nm^3, while low concentration gases are those with a concentration below this value.

LVHC gases result from the cooking process, the evaporation process, and the condensate "stripping" process. The sum of all of these represents a volume of approximately 25 Nm^3/t of pulp, with a sulphur content that is generally between 1-3 kg S/t of pulp, a concentration that is greater in the manufacture of pulp from non-coniferous wood than in pulp from coniferous wood, due to the different lignin structure.

These gases can be collected and burned in the lime kiln or in independent incinerators installed for this purpose in auxiliary boilers.

Low concentration HVLC gases come from the treatment of wood chips with steam, the purification of pulp, washing, recovery boilers, causticising, lime kilns and black liquor storage tanks. These represent a volume of 2,000-3,000 Nm^3/t of pulp at a concentration of 0.2-0.5 kg S/t of pulp. These diluted gases can be collected and burned in the recovery boiler, in the auxiliary boilers or in the lime kiln, provided that they are not mixed with the LVHC high concentration gases due to the high risk of explosion that such a mixture would involve. The treatment of low concentration gases can also take place in absorption towers (scrubbers).

Chlorinated components from the bleaching process and the preparation of chemicals

Due to the environmental problems generated by the use of elemental chlorine in pulpbleaching processes, this reactive has gradually been replaced with chlorine dioxide, and then others such as hydrogen peroxide and ozone, which also result in a final brightness level suitable for market demand. In this way, today ECF and TCF pulps are obtained, as described above. While the change from bleaching with elemental chlorine to ECF bleaching was an important advance in terms of environmental protection, the change from ECF bleaching to TCF bleaching has been subject to permanent debate. In the case of ECF pulps, AOX emissions are <0.4 kg/t of pulp, if the first washing stage after chlorine bleaching is removed, while in the case of TCF pulps, AOX emissions are < 0.25 kg/t of pulp. The debate arises because TCF bleaching results in lower levels of emissions, but the pulps are more expensive, while ECF pulps have a slightly higher AOX content, but at such low levels the contaminants are biodegradable and can be purified using biological treatments.

In those Kraft pulp factories where chlorine is used as a bleaching agent, a certain quantity of chlorinated compounds is released into the atmosphere from the bleaching plant and from the chlorine dioxide preparation section.

Non-condensed elements from digester purge

The purge vapours from the digesters contain volatile substances that have not been contained in the condensers: sulphur dioxide, hydrogen sulphide, methyl mercaptan, dimethyl sulphide, dimethyl disulphide. Together with these, in lower concentrations, there are vapours of some light organic compounds such as ethanol and acetone.

Emissions from the recovery boiler

The recovery boiler is one of the main sources of gaseous emissions in the Kraft pulp mill (figure 5.1.3).

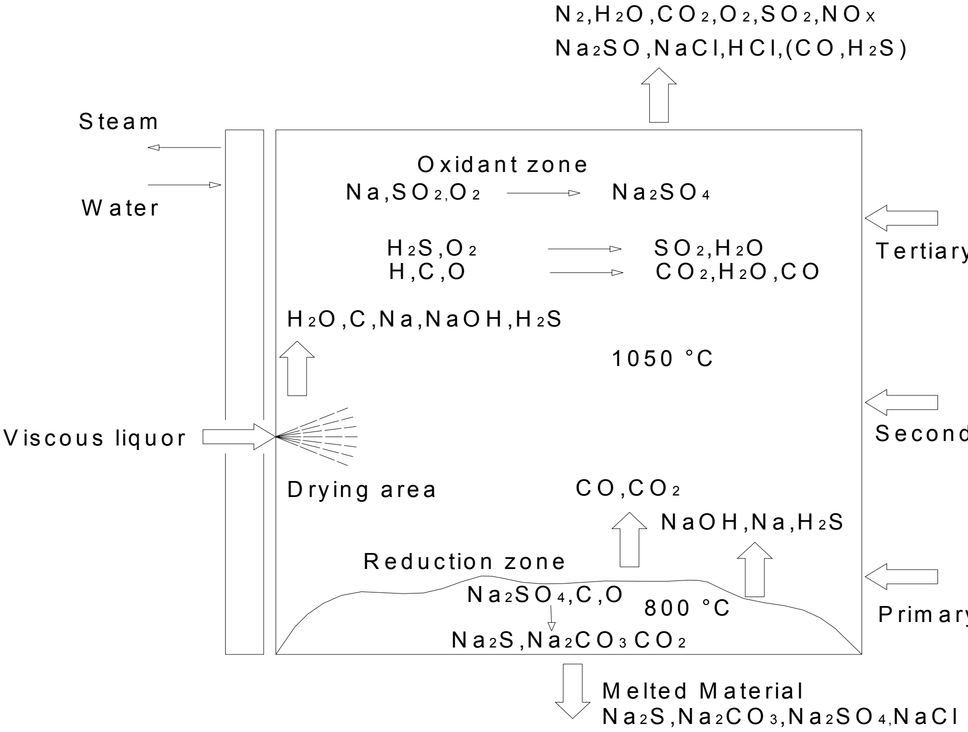


Figure 5.1.3. Recovery boiler

The recovery boiler is fed with concentrated black liquors and has a triple function:

- To remove, by means of combustion, the black liquors, which are the main potential source of pollution.
- To recover the reactives and transform the sodium sulphate for re-use (the name sulphate process comes from this, when the reactives are caustic soda and sodium sulphide).
- To recover energy in the form of steam for the electrical turbine and processing steam.

The main pollutant in emissions is sulphur dioxide, which comes from the partial reduction of incorporated sulphate to compensate for the losses in sodium and sulphur in the process and from the partial oxidation of the sulphur content of the concentrated black liquor. Other emissions are particles of the inorganic constituents, nitrous oxides and other malodorous gases derived from sulphur, hydrogen sulphate and mercaptan traces. On their release into the atmosphere, these gases also drag with them solid particles of sodium sulphate and carbonate that have not been captured by the electrofilters.

The thermal process of combustion in the boiler is determined by the calorific value of the fuel used, that is, of the black liquors. The composition of the liquors when dry is one third inorganic material and two thirds organic materials. At greater concentrations of organic material, a higher temperature is reached in the boiler and better conditions are obtained for the reduction of sulphur compound emissions, although at a higher temperature the concentration of nitrous oxides in the combustion gases is increased.

Emissions of sulphur dioxide in the recovery boiler are reduced by 80% when the initial solid concentration of the black liquors increases from 65% to 78%, as a result of the higher temperature attained in the boiler.

The reactions in the furnace are complex. Three zones are formed, characterised by the different oxygen concentration and the temperature: the lower zone of the boiler takes on a reducing atmosphere and an approximate temperature of 800 ºC. In this zone the sulphates are transformed into sulphides; in the intermediate zone, where the temperature is around 1,050 ºC, the reduction of sulphites and SO_2 takes place; and in the upper zone, with an oxidising atmosphere, the particles dragged out by the gaseous waste form sulphates.

The yield from vapour generation in an advanced recovery boiler for high solid content is 75%. The superconcentrated black liquors have a calorific energy of 21.0 GJ/t.

The boiler gases are purified of the particles, which are dragged out by an electrostatic precipitator. The flying particles, consisting mainly of sodium sulphate, are incorporated into the liquors before they are fed into the boiler.

In addition, the recovery boilers can be equipped with scrubbers, to reduce sulphur emissions. The pH of the solution is maintained at between 6 and 7 by the controlled addition of soda ash.

Table 5.1.1. includes the typical concentration values and the typical emissions in the black liquor recovery boiler.

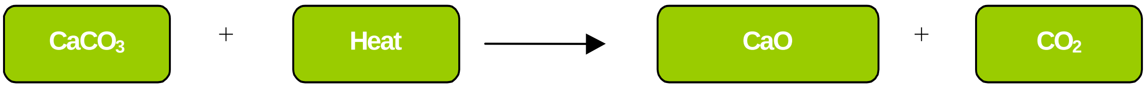
Table 5.1.1. Typical emission values of a recovery boiler

Sulphur dioxide	
Without scrubber (gas absorption) and 63-65% dissolved solids in the black liquor	100-800 mg/Nm^3
With scrubber and 63-65% dissolved solids in the black liquor	20-80 mg/Nm^3
Without scrubber and 72-80% dissolved solids in the black liquor	10-100 mg/Nm^3
Hydrogen sulphide	
90% of the time	< 10 mg/Nm^3
Nitrous oxides	
Such as NO_2	100-260 mg/Nm^3
Particles	
After the electrostatic precipitator	10-200 mg/Nm^3

DS (Dissolved Solids). Source: IHOBE

Emissions from the lime kiln

The calcium carbonate sludge generated in the causticising process is roasted in the lime kiln at high temperatures, in order to regenerate the calcium oxide according to the reaction:



Regeneration of calcium oxide in the lime kiln

As mentioned above, the emissions from the lime kiln consist mainly of carbon dioxide, sulphur dioxide, nitrous oxides and reduced sulphur compounds.

Table 5.1.2. Typical emission values of a lime kiln

Sulphur dioxide	
Burning fuel oil without non-condensable gases	5-30 mg/Nm^3
Burning fuel oil with non-condensable gases	150-900 mg/Nm^3
Hydrogen sulphide	
Normally	< 50 mg/Nm^3
Nitrous oxides (such as NO_2)	
Burning fuel oil	240-380 mg/Nm^3
Burning gas	380-600 mg/Nm^3
Particles	
After the electrostatic precipitator	20-150 mg/Nm^3
After the absorption of the gases in the scrubber	200-600 mg/Nm^3

Source: IHOBE

The sulphur dioxide emissions from the lime kiln are mainly the product of the fuel oil that is burned and the HVLC when the furnace is used for the incineration of these gases, while the sulphur that enters the lime kiln with the calcium carbonate sludge is of secondary importance.

The emissions of malodorous total reduced sulphur (TRS) compounds from the lime kiln consist mainly of hydrogen sulphide.

The emissions of nitrous oxides depend on the nitrogen content of the fuel and also on the temperature of combustion. When the HVLC gases are burned, biogas and methanol increase the emission of nitrous oxides.

Emissions from auxiliary boilers

The bark from the debarking of the wood can be used as a fuel to provide energy. The thermal yield of bark furnaces is related to the water content of this fuel. Dry debarking and the pressing of the bark can noticeably reduce the water content in the bark, as can storage in dry areas, where the relative humidity of the air allows air drying, resulting in a fuel with 45% water content and a calorific value of between 7 and 8 GJ/t.

Emissions from the bark furnace are exempt from or contain only very small amounts of sulphur dioxide, as bark contains practically no sulphur. Another reason that the emission of sulphur dioxide is low is the low temperature of combustion in comparison to those reached when other fuels are burned.

Table 5.1.3. Emissions into the air from bark furnaces

Unit	S	NOx	Particles
kg/t	0.1-0.2	0.3-0.7	0.1-0.6
mg/MJ	5-15	40-100	20-200

Source: IHOBE

The emission of particles when electrostatic precipitators are used is of 20-40 mg/Nm^3, and is around 200 mg/Nm^3 when cyclones are used. For small installations, multicyclones are usually used. These are more effective than cyclones, but much less effective than electrofilters.

Mills initially used coal as fuel in the auxiliary boilers. This has gradually been replaced with fuel oil or gas. Today, fuel oil or gas are used to supplement the insufficient energy supplied by bark.

Typical emissions values in auxiliary boilers burning fuel oil are given below.

Table 5.1.4. Emissions into the air from bark furnaces

Fuel type	mg NOx/MJ	mg S/MJ	Particles(mg/m^3)
Fuel oil	60-250	25-250	20-200

Source: IHOBE

5.1.3. Paper manufacture

Emissions into the atmosphere from paper and cardboard manufacturing processes come almost exclusively from the generation of steam and electrical energy that takes place in the mill. This means that levels of atmospheric emissions are directly related to the production of steam and electricity. The only emissions to be taken into account are those resulting from the smoke produced in the generation of steam and the evaporation mists released by the drying hoods in the paper machine. It has been shown that these mists contain low levels of VOC emissions and practically no other pollutants.

The use of natural gas as fuel in combined cycle centres, with generation of electrical energy in gas turbines and heat recovery from the turbine exhaust gases for steam generation, which is in turn used to generate electricity in steam turbines, and the counterflow steam in the turbines covering the heat requirements in the drying section of the paper machine, is a very effective use of energy, in which the pollution caused by one unit of energy produced (electricity and steam) is lower than in most conventional systems for the generation of electrical and thermal energy.

The combustion of natural gas, with very low sulphur content, avoids problems from SO_2 emissions and the emission of particles from unburned residues. The concentration of nitrous oxides in the combustion gases can be reduced by changes to the design of the combustion chamber of the gas turbine, in order to avoid there being zones known as high-temperature oxidising zones, which are necessary for the chemical combination of the gases in the air, and/or resorting to the use of systems of catalytic reduction of the nitrous oxides in the burnt gases from the turbines.

5.1.4. Carbon dioxide emissions

The Kyoto Protocol (1997), which develops the United Nations Framework Convention on Climate Change (1992) is an important international challenge to stabilise the atmospheric concentration of greenhouse gases in order to prevent climate change.

The paper manufacturing sector is responsible for the generation of some greenhouse gases (CO_2). However, the use of renewable energies, energy efficiency and cogeneration contributes to reducing the levels of greenhouse gas emissions originating from the sector.

The most significant source of CO_2 emissions from the pulp and paper industry is the use of energy in its three dimensions: energy production (electricity and heat) in the plant itself or in connected cogeneration plants, purchases of energy (electricity) from external suppliers and the use of fuels to produce heat during the process.

The following diagram shows the integration of the production of pulp-paper-energy and the sources of CO_2 emissions. It is worth noting that the production of energy in the paper manufacturing sector is based on cogeneration:

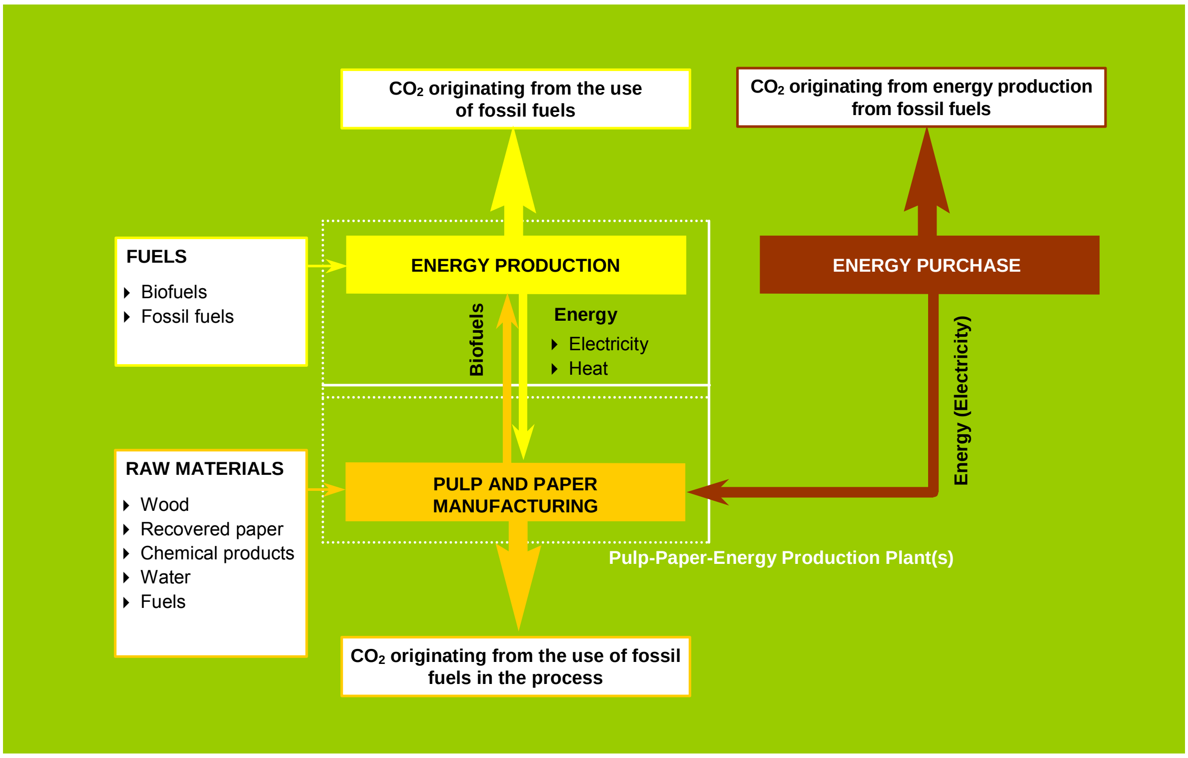


Figure 5.1.4. Integration of the production of pulp-paper-energy and the sources of CO_2 emissions.
Source: ASPAPEL, National Association of Pulp, Paper and Cardboard Manufacturers (Spain)

Energy production plants in the pulpand paper sector consist of the following installations (see description in section 5.5):

- Bark and wood remnant combustion furnaces.
- Recovery boilers using black liquors as their main fuel.
- Lime kiln.
- Cogeneration Stations in their different combinations (combined cycles, single cycles, motors, etc.).
- Steam generation boilers.

A large part of the energy generated in the manufacturing industry comes from biomass: bark furnaces, fines, screening residues and black liquor boilers; the oxidising of these materials produces carbon dioxide (CO_2).

However, the pulpand paper industry, as it has a high demand for electricity and thermal energy in the form of steam, has made a great effort to integrate cogeneration technologies into its productive processes. Different combinations, all of them linked to the combined production of electricity and steam, can be the basis for cogeneration plants, depending on the type of plant: gas turbines in single cycle with heat recovery boilers, combined cycles with gas and steam turbines, internal combustion engines with heat recovery, etc.

Conventional boilers for generating water vapour will be used in the processes of drying the pulp and paper using fossil fuels; nevertheless, in those factories where there are cogeneration plants, their main function is to provide support as auxiliary boilers in cogeneration installations.

The type of fuel used depends to a great extent on the internalisation of environmental costs into the cost of the fuel, and on availability. The evolution of the paper industry in the last decade, with the widespread use of renewable fuels, biomass and natural gas, leaves only a small margin for changing fuels to reduce CO_2 emissions.

Some of the measures that the paper manufacturing sector could take to lessen climate change are outlined below:

- A protocol for the attribution of direct and indirect emissions (the latter being those associated with electrical activities) applicable to the Paper Industry.
- The encouragement of Cogeneration in the Pulp and Paper Sector.
- A Sectorial Plan for Energy Efficiency in the Pulp and Paper Sector.
- A Plan for Fuel Substitution in the Pulp and Paper Sector.
- Increased levels of paper recovery and recycling.
- Encouraging the use of rapid growth sustainable forest sinks linked to the Pulp and Paper industry.

These measures would contribute to the reduction of emissions originating from paper-related activities in the installations of the manufacturers (direct) and also in other locations (indirect). In some cases these are potential measures which will become reality when the necessary instruments and incentives are put in place.

The following table shows by way of example an evaluation of the decrease in greenhouse gas emissions in the case of Spain. This decrease is associated with the implementation of some of the measures outlined above.

Table 5.1.5. Reductions of emissions of kt CO_2/year in Spain.

Measures	Reductions
Sectorial Fostering of Cogeneration	630-885
Energy Efficiency Plan	60-80
Fuel Substitution Plan	191-250
Increased recovery levels	134-173
TOTAL MEASURES IMPLEMENTED	**1,015-1,388 kt CO_2/year**

Source: ASPAPEL, National Association of Pulp, Paper and Cardboard Manufacturers (Spain)

It can be seen that cogeneration has a great effect in terms of decreasing emissions Table 5.1.6. shows an approximate ratio of the reduction of CO_2 emissions per year achieved by means of the use of cogeneration.

Table 5.1.6. Reduction in emissions in Spain in kt CO_2/year

Measures	Effect
Introduction of cogeneration in the sector	-1,600 kt CO_2/year

Source: ASPAPEL, National Association of Pulp, Paper and Cardboard Manufacturers (Spain)

The proportions of the reduction in CO_2 emissions as a result of cogeneration can be established in terms of heat yield. An increase in thermal yield of 12%, for the same production, results in a reduction equivalent to 12% in the emission of greenhouse gases.

In the same way, a significant reduction in CO_2 emissions can be achieved by applying energy efficiency measures such as: the substitution of the exterior lighting of the mill, the renovation and testing of lighting points, the substitution of incandescent lamps for fluorescents, the replacement of transformers and cables, the installation of economisers in the boilers, changing and adjustment of boiler burners, improved isolation of steam and condensate lines, etc.

The substitution of fuels such as coal, fuel and diesel oil with natural gas also contributes in large measure to the reduction of CO_2 emissions.

Lastly, the rapid growth tree species used in Paper manufacture from forests managed according to sustainable development criteria act as CO_2 sinks. One hectare of crops of these species can fix up to 40 tonnes of CO_2 per year, which is four times as much as slow-growth species (beech, oak etc.). Recent studies show that carbon dioxide fixing no longer takes place when the wood reaches maturity, which makes plantation with these species an environmental opportunity.

An approximate ratio of potential CO_2 reductions from the sustainable management of forest plantations is shown below:

Table 5.1.7. Reduction of emissions in Spain in kt Co_2/year

Measures	Reductions
Increase in sustainable rapid-growth forest plantations linked to the wood pulp and paper industry	4,000 kt CO_2/year

Source: ASPAPEL, National Association of Pulp, Paper and Cardboard Manufacturers (Spain)

Lastly, it is considered that the decomposition of each tonne of paper disposed of in landfill sites directly causes greenhouse gas emissions equivalent to the some 200 kg CO_2/t of paper. The recycling of paper therefore provides the largest proportional reduction of greenhouse gases, which can be avoided by recycling urban waste. This means that by increasing levels of paper recovery and recycling, the emission of greenhouse gases produced in landfill sites by non-recovered paper waste is avoided.

5.2. SOURCES OF WASTEWATER DUMPING AND ITS CONTROL

Large quantities of wastewater are generated in pulp and paper factories; the volume of this wastewater is approximately equal to the volume of water consumed, minus that which is emitted as drying steam, lost in vaporisation and vapour purges and the water content that remains in the final paper sheet.

The reduction of water consumption by means of the use of internal closed circuits, with the staggered reuse of water flow from some stages of the process to others that have less demanding requirements for the water they use, means that the wastewater discharge rate can be reduced, which in turn results in an important saving when the factories plan for the final treatment of wastewater.

Water pollution depends mainly on the raw materials used, the water reduction criteria followed in the design of the installation, the operating conditions of each stage of the process in which the highest levels of wastewater and highest level of contaminant loads in wastewater are generated, and the level of integration of water circuits in the process, in order to operate with closed circuits, in order to reach *zero emissions*.

The parameters used most often to measure the pollution level of effluent are: Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Carbon (TC), Total Organic Carbon

(TOC), salinity, Electrical Conductivity (EC), Total Suspended Solids (TSS), nutrients such as total nitrogen and total phosphorous, and in the specific case of the pulp industry, Absorbable Organic Halides (AOX).

BOD (Biochemical Oxygen Demand): This measures the oxygen consumption necessary for the aerobic breakdown of the organic material in the waters. The BOD of discharged wastewater determines the oxygen consumption in the destination riverbed. When oxygen consumption is higher than the river's capacity for regeneration, this can result in anoxic conditions, which are negative for aquatic life. The length of the test is usually 5 days (BOD_5). It is expressed in mg/l or ppm.

COD (Chemical Oxygen Demand): This is the quantity of oxygen (expressed in mg/l or ppm) consumed during the total chemical oxidation of the material present in wastewater. It determines the capacity of the wastewater to consume oxygen when discharged in the receiving waters. Excessive oxygen consumption is harmful to the environment, as it reduces the concentration of oxygen dissolved in the water, which means that aquatic life cannot develop.

TSS (Total Suspended Solids): This measures the quantity of particles found in suspension in the water. Too high a load of SS results in the disappearance of aquatic life due to the obstruction of the fishes' gills or the suppression of photosynthesis, in the case of plant life, as it prevents the sun's rays from passing through.

AOX Absorbable Organic Halides: Understood to be the total quantity of chlorine joined to organic compounds in wastewater. These compounds exist naturally, but are also formed during the bleaching of chemical pulp. Excess AOX should be limited to levels that do not have any environmental impact, as the AOX compounds such as: dioxins, chloroform and chlorophenolics (the latter includes chlorophenols, chlorocatechols and chloroguaiacoles) are extremely dangerous, being liposoluble, that is, they accumulate in the fatty tissues of animals and are therefore highly toxic and difficult to break down.

5.2.1. Preparation of raw materials

Receipt and storage

Rainwater that comes into contact with the wood in the wood storage yard can drag solid particles with it, in addition to dissolving some of the components that make up the wood.

The compounds leached into water during the storage of the wood depend on numerous different factors: precipitation, temperature, type of wood, time in storage and the action of saprophytes.

Table 5.2.1 shows the composition of the soluble pollutants from three samples taken from a yard in which coniferous wood is processed, showing the extensive variations in the pollution parameters:

Table 5.2.1. Parameters of the liquid effluent from a wood yard processing conifers.

Parameter	Runoff 1	Runoff 2	Runoff 3
BOD_5 mg/l	150	310	740
COD MG/L	765	3150	3250
Toxicity (% v/v) Microtox	20	10	8

Source: Industrial Environmental Control. Pulp and Paper; M. Springer. Ed. TAPPI, 3rd edition, 2002

The runoff water from the wood storage yard is collected in the storm basin and incorporated into the general treatment system for wastewater in the plant, following a prior process to remove solids (sand, earth, bark fragments and wood chips). The inflow to the storm basin is determined by levels of precipitation. As an estimate of dimensions, a volume of 300 m^3 is assumed for a wood yard of 1 hectare, with average precipitation of 30 mm.

Flow (m^3/h) = precipitation (mm/hour) x 10^{-3} x Surface area (m^2) x runoff coefficient

With the runoff coefficient equal to 1 in surface areas with no logs, which are paved and with a slope down towards the collectors. This criterion can be applied throughout the yard, without taking into account the absorption and evaporation of the water into the piles of logs.

After a determined level of precipitation per hour is reached, estimated from the maximum precipitation figures, the excess water is discharged directly, as this runoff consists of clean rainwater.

Annual plants are more sensitive to damage caused by the combined action of atmospheric agents and microorganisms, so these raw materials are generally stored piled up in covered warehouses.

Unloading and internal transport

The unloading of trunks from the piles to the feeding system of the washing and debarking systems is carried out by tractors with claws or pincers that unload down sloping ramps, from which they unload the trunks onto horizontal transporters which then supply the transport channel or the lineal mechanical transporters.

When transport channels are used, the circulation water, which flows through the channel in a closed circuit, propelled by pumps which create the current in the channel, acquires over time a pollutant load similar to that of runoff water. In these, together with extracts from the wood, there is a high proportion of suspended solids: earth, bark fragments, wood chips, etc.; therefore the water drained from the channels has to be treated before it is discharged.

Debarking

Bark has an important effect on bleaching and, in general, on the quality of the paper. For this reason, before the processing of the wood for the manufacture of cellulose pulps, debarking must take place. The debarking plant is one of the largest polluting areas in the pre-preparation of the raw material. This plant consumes water and generates wastewater that is toxic for aquatic life, with high levels of nutrients, fibres, and organic compounds that consume oxygen, such as resinous acids, fatty acids, etc.

There are different debarking techniques in use, which are classified according to their use of water:

- **Wet debarking,** in which the rotating cylinders or drums are partially submerged in water. Water from this is partially recycled, with a certain proportion drained off in order to drag out the bark and avoid a high concentration of solids in suspension and organic material in the circuit. Water consumption depends on the level of recirculation in operation, with values varying between 0.6 and 2 m^3 of water per 1 m^3 of apparent volume of wood or between 3 and 10 m^3 of water per tonne of pulp produced.
- **Semi-wet debarking,** in which internal showers or sprinklers are used. The water drags out bark and any impurities that appear through the slots in the machine.
- **Dry debarking,** water is only used hot, at a temperature of around 40 ºC, to defrost the trunks in cold climates, and is recirculated with the minimum generation of wastewater and water pollution. This produces bark with a lower water content which therefore has a higher calorific value when used in the bark furnace.

As at the debarking stage, the pressing of the bark (in order to remove the water prior to burning in the bark furnace) generates effluent that is toxic for aquatic life. Table 5.2.2 shows the toxicity levels of effluents depending on the type of debarking used.

Table 5.2.2. Ecological toxicity of the effluent from wet debarking

Parameter	Wet debarking and bark pressing	Dry debarking and bark pressing
BOD_5 mg/l	3,500	250
COD MG/L	6,500	600
Toxicity (% v/v) Microtox	4	10
Toxicity (ATU) Microtox	25	10

Source: BREF, Reference Document on Best Available Techniques in the Pulp and Paper Industry

Among the measures to reduce water consumption and water discharge, it has been suggested that wet debarking could be substituted with dry debarking, a measure already implemented in numerous paper plants in the EU. In wet debarking, around 0.6-2 m^3 of water is used per m^3 of wood, while this value is of 0.1 to 0.5 m^3 in dry debarking.

It has been shown that biological treatments are very efficient at eliminating the toxicity of this type of wastewater.

The typical pollutant load of wastewater from the debarking plant prior to biological treatment is summarised in table 5.2.3.

Table 5.2.3. Pollutant load of wastewater from the debarking plant without biological treatment.

Debarking technique	Wastewater volume (m^3/m^3 of wood) (m^3/t of pulp)	BOD_5 (kg/m^3 of wood) (kg/t of pulp)	COD (kg/m^3 of wood) (kg/t pulp)	Total phosphorous (kg/m^3 of wood) (g/t of pulp)
Wet debarking and bark pressing	0.6-2 3-10	0.9-2.6 5-15	4-6 20-30	5-7 25-35
Dry debarking and bark pressing	0.1-0.5 0.5-2.5	0.1-0.4 0.5-2.5	0.2-2 1-10	2-4 10-20

Source: BREF, Reference Document on Best Available Techniques in the Pulp and Paper Industry

5.2.2. Pulp production

Mechanical pulps

Water is involved in the manufacturing processes of mechanical and thermomechanical pulps in a closed circuit in order to maintain the temperature. The main operations that generate effluent in this type of process are the preparation of raw materials, washing and bleaching.

The typical pollutant load of these discharged liquids, measured as BOD_5 and COD is summarised below:

Table 5.2.4. Range of COD and BOD_5 values for liquid waste in the manufacture of mechanical pulps.

Type of pulp	COD (kg/t AD)	BOD_5 (kg/t AD)
Traditional mechanical pulp (SGW)	20 - 30	8 - 10
Refiner mechanical pulp (RMP)	40 - 60	10 - 15
Thermomechanical pulp (TMP)	50 - 80	13 - 22

Source: Sociedad Pública de Gestión Ambiental IHOBE, S.A., Basque Government

Chemical pulp

Water consumption and the characteristics of wastewater discharged by chemical pulp factories are an environmental problem that grows more important each day.

As for the previous example, the generation of liquid waste in a Kraft pulp mill are described below, as this is the most commonly used method for the manufacture of chemical pulp.

Figure 5.2.1 shows the sources of wastewater discharge from a bleached Kraft pulp mill, including accidental spillages.

The problematic issues of wastewater discharged from this type of plant are dominated by the oxygen consumption of the dissolved organic compounds, measured as COD and BOD. Wastewater from bleaching plants in which chemicals derived from chlorine are used also contain organochlorine compounds measured as AOX.

This type of wastewater also contains extractives and resinous acids and even low concentrations of metals from the stored wood, nitrous or phosphorous compounds, and on occasion coloured substances.

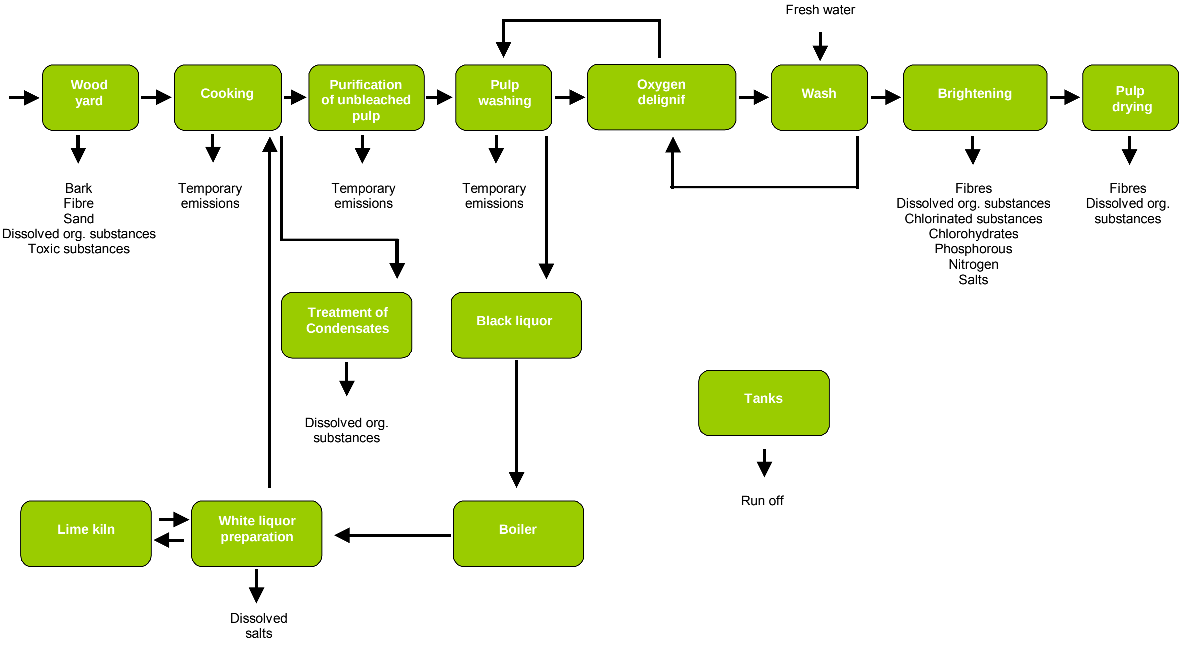


Figure 5.2.1. Block diagram of the generation of discharged wastewater in a Kraft pulp mill

Following the sequence of the manufacturing process of Kraft pulp, the main sources of wastewater generated correspond to:

- Spillages and overflows from the process and water from the cleaning of equipment and installations
- Diluted liquors from the washing of unbleached pulp
- Condensates
- Discharges from the bleaching plant

Spillages and overflows from the process and water from the cleaning of equipment and installations

Between approximately a third and half of the BOD and the TSS present in the discharged wastewater are attributable to these causes.

These losses can be attributed to a wide variety of factors, such as broken machinery, routine maintenance, programmed stops and starts, failures in the electricity supply and changes in the process or type of pulp.

The spillages and overflows from the process occur accidentally and are difficult to evaluate. Some can have a very high pollutant load, which means that although their volume is usually small, they can contribute significantly to the increase in concentration of pollutants in the plant's wastewater.

Losses resulting from overflows of fibres and black liquors can occur in the digesters, screeners and during the washing process. Losses of white liquors, green liquors and diluted liquors occur in the causticising plant. Losses during the processes due to overflows are quantified as between 2 and 10 kg per tonne of pulp.

The installation of a system of spillage collection, spillage storage, the characterisation and reintegration of spillages at different points of the process, depending on their composition or the extent to which they have contaminated and mixed with each other, is a practice that contributes to the reduction of the pollution of the flow sent to the water purification plant.

The reduction of losses, improving the control and maintenance of the installations, and the reintegration into the process of those losses that still inevitably occur, improves the yield of fibres and reactives, reduces the cost of wastewater treatment, and improves the quality of effluent from the mill.

Among the techniques applied, the following are noteworthy:

- Periodic cleaning of the evaporators to avoid the forming of encrustations. This procedure consists of circulating hot, clean water through the evaporators. Following the cleaning, this water is collected in an accumulation tank in order to be incorporated into the evaporators over time.
- Regulation storage for concentrated black liquors, diluted black liquors, and a recovery plant for chemicals, in order to prevent overflows.
- The compartmentalising of the different units, to avoid overflow, if it cannot be avoided by any other means.
- The installation of conductive leakage sensors to monitor specific critical areas.
- The training of personnel to avoid spillages and the adoption of action plans if spillages should occur.
- The installation of a safety pool to collect accidental leaks that occur before biological treatment.
- Bringing the monitoring of processes up to date to increase the operativity of the plant and to avoid overflows.

To minimise losses, the mill must develop a separate collection system for leakages and spillage losses. Industrial spillages in Kraft plants can be divided into three categories: spillages containing low concentration of solids in suspension (such as cooling water, bleaching water and condensate effluent from the evaporators), which do not need to be clarified; spillages containing high concentration of solids in suspension (such as effluent from the washing filters, effluent from the paper machine in integrated plants and effluent from the wood yard), and this type does need to be clarified; and lastly, concentrated spillages (such as overflow of concentrated black liquors, which should be collected in a deposit in order to be gradually integrated into the process).

Diluted liquors from the washing of unbleached pulp

The washing of the pulp is carried out in order to recover the highest possible amount of chemicals and organic substances dissolved in the residual cooking liquor.

The washing waters from the pulp are one of the main wastewater flows from the process and are the cause of significant pollutant discharge when the effluent from the last stages of the washing cannot be integrated into the system of concentration by multiple evaporators and black liquor concentrators. The concentration by evaporation of the washing waters is limited by the excessive energy consumption of the process and the high investment levels necessary. As a result, since washing is not an operation with 100% yield, a certain quantity of chemicals and pollutant compounds are eventually discharged.

The use of hot water (50-60 ºC) improves the efficiency of the washing in the rotating cleaners and press due to the reduction in viscosity of the filtrate and the increased solubility of the compounds removed in the waters. Nevertheless, a higher temperature excessively increases the water vapour pressure and leads to problems in obtaining a vacuum in the pulp drainage systems.

Washing takes place by means of the contact of the pulp and a counterflow of water, incorporating clean water during the last step. The water from the first step is mixed with the black liquors from the digestion process, and proceeds to the black liquor recovery system with them.

The effectiveness of the washing is defined by the displacement ratio of each step:

$$\boxed{DR = (Sv-Se)/(Sv-Sw)}$$

Where:

DR: displacement ratio.

Sv: fraction of dissolved solids in the liquor entering with the pulp.

Se: fraction of dissolved solids in the liquor that leave with the washed pulp at the last stage.

SW: fraction of dissolved solids in the wash water that enters into the stage.

Evidently a displacement factor of 1 is obtained when the concentration of solids in the waters contained by the washed pulp is equal to the concentration of the wash water.

For the comparison of different wash schemes, the Norden efficiency factor is used. This compares the number of mixing stages that provide the same result as the washer or the washing sequence considered. To compare wash efficiency, the consistency of the pulp is taken to be 10%.

Table 5.2.5. Norden efficiency factor of various wash systems

Equipment	**Norden efficiency factor**
Single drum washer	2.5-4
Filter drum washers	2-2.5
One stage diffusers	3-5
Two stage diffusers	6-10
Wash zone of Kamyr continuous digesters:	
1 hour 30 minutes	4-6
3 hours	7-11
4 hours	9-14
Diffusion/extraction	1.5-2

Source: Water management in Paper Mills, F. Zippel, Voith Paper 1999

The washing of pulp plays a decisive role in the quality of the final unbleached pulp and the suitability for bleaching of the pulp which is destined for this process. The correct washing of the pulp reduces consumption of bleaching reactives and improves the quality of bleaching plant effluent.

Condensates

Vapour condensates are obtained at different stages of the Kraft pulp manufacturing process. The most important condensates are listed below:

- Condensate from steam blowdown in the Kraft process digesters is condensed, resulting in an organic phase and a watery phase that is highly contaminated by volatile materials in the digester, which are water soluble or emulsified.
- Condensate of vapours from the concentration process of the black liquors, vapours of organic substances are generated and there is a watery phase that is contaminated by the soluble or emulsified substances.
- Vapour condensates given off by the dump tank (blow tank) of the pulps and cooking liquors from the continuous digesters, resulting in a flow of wastewater containing dissolved volatile material and an organic phase consisting primarily of terpenes and turpentine (in the case of conifers).
- Condensates of the vapours generated during the stage of unloading of the digesters, when the digested material proceeds from the operational pressure of the system to the atmospheric pressure of unloading.

These condensates consist mainly of methanol, ethanol, organic acids derived from sulphur (TRS), turpentine (only in the case of coniferous woods as raw material) and in smaller quantities, terpenes, resinous acids and fatty acids, along with nitrogen compounds.

The following table shows the typical composition of the condensates:

Table 5.2.6. Typical condensate composition

Pollutant	**Condensate of the digester vent**	**Condensate of the blow tank**	**Condensate from the Flash tank of the continuous digester**	**Condensate from the black liquor evaporators**
H_2S (ppm)	30-270	10-250	250	1-90
CH_3SH (ppm)	20-5,300	40-340	70	1-30
(CH_3) 2S (ppm)	15-7,400	40-190		1-10
(CH_3) $2S_2$ (ppm)	5-4,100	2-210		1-50
Methanol (ppm)	1,300-12,000	250-9,100	670-8,900	180-700
Ethanol (ppm)	90-3,200	20-900		1-190
Acetone (ppm)	8-420	5-95		1-15
Methyl-ethyl ketone (ppm)	27			1-3
Terpenes (ppm)	0.1-5,500	0.1-1,100	100-25,000	0.1-150
Phenols (ppm)	12			
Guayacol (ppm)				1-10
Resinic acids (ppm)				28-230
BOD_5 (ppm)	800-11500	720-9200	9.2-9.6	6-1100
pH	9.5			
Suspended solids (ppm)				30-70
Sodium (ppm)				4-20

Source: Water management in Paper Mills, F. Zippel, Voith Paper 1999

This highlights the extremely variable nature of the values. Organic extractives depend to a large extent on the type of wood, high for conifers and lower for non-coniferous wood.

Waste unloading from the bleaching plant

The bleaching plant is the area with the highest proportion of pollutant material discharge in the pulp mill. The volume and concentration of this material depends on various factors, the most important being the type of wood, the Kappa number of the pulp (lignin content), losses from the bleaching wash, the sequence and dose of chemicals, the final brightness level desired, and the closure of circuits in the plant itself.
The volume of water consumed in the bleaching plant varies between 20-40 m^3/t.

ECF (elemental chlorine free) bleaching and TCF (totally chlorine free) bleaching are conducive to a greater degree of re-use of the filtrates from the bleaching plant, with a reduction in water consumption and the closure of circuits, which is technically unadvisable when elemental chlorine is used, due to its highly corrosive nature.

In addition, bearing in mind that one Kappa unit represents 2 kg COD/t of pulp, modern techniques of extended delignification during cooking and oxygen delignification or bleaching, which enable substantial reductions in the Kappa number of the pulp, represent an important advance in the reduction of the COD load on entry to the bleaching plant, which results in a saving in chemical bleaching products and lower quantities of AOX generated.

Typical unloading values from the bleaching plant measured as COD, vary between 15 and 65 kg COD per tonne of pulp.

Table 5.2.7. Dumped wastewater measurements following biological treatment

Cooking method	Delig. Oxygen / ozone bleaching	Non-coniferous pulp		Coniferous pulp	
		Kappa	COD (kg/t AD)	Kappa	COD (kg/t AD)
Conventional cooking	---	15-18	30-38	28-30	60-63
Conventional cooking	Delig. Oxygen	8-10	20-25	14-15	30-32
Modified cooking	---	14-16	30-34	20-24	42-48
Modified cooking	Delig. Oxygen	9-10	13-15	12-13	25-28
Extended delignification	---	12-13	23-26	15-16	30-32
Extended delignification	Delig. Oxygen	8-10	12-15	10-12	15-18
Conventional cooking	Delig. Oxygen + Ozone bleaching	N.I.	3	N.I.	6

N.I. Information not available. Source: BREF, Reference Document on Best Available Techniques in the Pulp and Paper Industry

The AOX values for plants with no consumption of elemental chlorine bleach can vary between 0 and 2 kg AOX/t of pulp.

The following tables show examples of unloading of organic chloride substances, measured as AOX, for different bleaching sequences, depending on whether the raw material is coniferous (table 5.2.8) or hardwood (table 5.2.9).

Table 5.2.8. Examples of different bleaching sequences for coniferous pulps and the corresponding unloading of organic chloride substances measured as AOX.

Cooking method	Bleaching sequences	Kappa	ClO_2 (kg/t)	AOX (kg/t)
Conventional cooking	D(EOP)DED	30	95	2
Conv. cooking + Oxygen delignification	D(EOP)DED	15	60	0.8
Modif. cooking + Oxygen delignification	D(EOP)D(EP)D	12	30	0.3
Conv. cooking + Oxygen delig.	ZD	N.I.	10	0.1
Modif. cooking + Oxygen delig.	ZP	N.I.	0	0

N.I. Information not available. Source: BREF, Reference Document on Best Available Techniques in the Pulp and Paper Industry

NB: "D" Chlorine dioxide; “E” Extraction; “O” Oxygen; “P” Peroxide; “Z” Ozone

Table 5.2.9. Examples of different bleaching sequences for hardwood pulps and the corresponding unloading of organic chloride substances measured as AOX.

Cooking method	Bleaching sequences	Kappa	ClO_2 (kg/t)	AOX (kg/t)
Conv. cooking + Oxygen delig.	D(EO)DED	13	40	0.5
Modif. cooking + Oxygen delig.	D(EO)DED	10	30	0.3
Conv. cooking + Oxygen delig.	ZD	N.I.	5	0.1
Modif. cooking + Oxygen delig.	ZP	N.I.	0	0

N.I. Information not available. Source: BREF, Reference Document on Best Available Techniques in the Pulp and Paper Industry

NB: "D" Chlorine dioxide “E” Extraction; “O” Oxygen; “P” Peroxide; “Z” Ozone

Pulps from recovered paper

The volume of discharge from pulps from recovered paper is strongly linked to the type of paper or cardboard that is recovered, the requirements of the final product (class and quality of the paper), the technology used and the conditions of the mill. The additives used and the control of the process are also influential.

Water pollution occurs during the stages of purification, de-inking/flotation (as applicable) and recovery of the fibres. Dumped waters therefore come from:

- Purification rejects
- Filtrates from washing and thickening
- Leftover white waters

This contaminated water, once it has been sedimented and clarified in the mill itself, will be discharged directly into the river following preliminary treatment (primary and biological) or discharged through a public water treatment plant.

The pollutant load of this effluent is measured according to the following parameters:

- **COD** (Chemical Oxygen Demand): Emissions of this type originate with raw materials and additives. De-inking and bleaching result in a large proportion of the COD.
- **BOD** (Biochemical Oxygen Demand): this comes from the same source as Chemical Oxygen Demand.
- **Nutrients:** For the biological treatment to be effective, nutrients must be added in the form of nitrogen and phosphates, which means that there will be traces of these nutrients in discharged wastewater.
- **Heavy metals:** Concentration of these is minimal. The possible presence of copper and zinc is due to printing inks in recovered paper.

Below are a number of tables of measurements from discharged wastewater from a recovered paper pulp mill following preliminary treatment and biological treatment.

Table 5.2.10. Measurements of water discharged from a mill following primary treatment

Test parameter	Recovered pulp Without de-inking		Recovered pulp De-inked	
	mg/l	Min/max	mg/l	Min/max
BOD_5	1900		550	
COD	3800	(570/9,000)	1100	(440-1,900)
Kj-N	16	(10/40)	20	(13-25)
Flow	3,6 m^3/t	(0,4-6,6)m^3/t	15 m^3/t	(9-39) m^3/t

* Kj-N is the sum of organic nitrogen minus ammoniacal nitrogen. Source: Sociedad Pública de Gestión Ambiental IHOBE, S.A., Basque Government

Table 5.2.11. Measurements from discharged wastewater following biological treatment

Test parameter	Recovered pulp Without de-inking		Recovered pulp De-inked	
	mg/l	Min/max	mg/l	Min/max
BOD_5 prior to treatment*	1800		770	
BOD_5 after treatment	10	(3-28)	9	
COD prior to treatment*	3200		1900	
COD after treatment	150	(60-270)	290	
Kj-N	5.6	(3-13)	7.8	
TSS	25	(17-40)		
Flow	5.7 m^3/t	(3.1-11) m^3/t		11 m^3/t

*Data for BOD and COD for incoming effluent was not available, so the data for incoming effluent is calculated based on the load of wastewater from a mill without de-inking and another where pulp is de-inked. Source: IHOBE

Water pollution control in pulp manufacture

Besides the reduction of wash waters in the Kraft process and of spillages in the other operations, the main elements of which have already been outlined, there are other flows to be considered, of which the re-use contributes to the reduction of final effluent levels.

The following table shows a summary of effluent that can be reintegrated into the process, along with the intervals of the volume of water recovered per tonne of pulp. The figures given are only indicative, as the incorporation of each of the water flows requires a preliminary analytical study, together with the study of its influence throughout the process, in order to detect problems, especially those related to long-term accumulation in the process water circuits.

Table 5.2.12. Re-use of effluent from the different units of the Kraft process

Type of effluent	m^3/t	Place of use
Condensate from blow tank vapour, direct	3.7-22.4 Mean 8.6	Unbleached pulp wash Wash sieves or drums Hot water supply Sludge washing Dissolving of additives
Condensate from blow tank vapour, indirect	1.3-1.5	Not useable
Refrigeration water from the blow tank vapour condenser	3.7-22.4 Mean 8.6	Unbleached pulp wash Bleached pulp wash Wash sieves or drums Hot water supply Sludge washing Dissolving of additives
Turpentine decantation apparatus	0.04-0.65 Mean 0.2	Sprinklers on knot separation sieves Sprinklers on unbleached pulp washers
Cooling water from the turpentine condenser	2.5-9	Hot water supply Sieve washing
Condensate evaporators	2.5-100 Mean between 5-7.5	Unbleached pulp wash Lime kiln gas scrubber Liquor preparation Wood yard cleaning
Effluent from the barometric evaporator	30-57	Transportation of the fly ash from the bark furnace Recycling through the cooling tower
Closure of the evaporator, unloading to surface condensers	1.5-5.5	Unbleached pulp wash

Source: Handbook on pollution prevention opportunities for bleached Kraft pulp and paper mills, U.S. Environmental Protection Agency

5.2.3. Paper manufacture

Liquid discharge from paper factories comes mainly from pulp purification and the removal of white water from the process.

Paper pulp is purified before reaching the headbox of the paper machine. The effluent from purification usually contains sand, mineral fillers, uncooked particles and even uncooked fibres. This is taken to the wastewater treatment point or unloaded with the sludges without drying out.

The fibrous solution that reaches the paper machine is drained at the table and the pressing section. Fresh or clarified water from the wire and felt sprinklers is added to all of the drained white water. This addition results in an overflow of white water that is discharged into the wastewater, first passing through a fibre recovery step.

The surplus depends on the level of closure of the circuit and contains colloidal and dissolved matter. The matter consists mainly of suspended solids, dissolved organic matter, calcium salts and other salts.

There is currently a certain tendency to establish the mass load of a pollutant as the discharge limit, rather than a maximum pollutant concentration; This means that installations with lower specific water consumption are at an advantage.

Table 5.2.13. Final discharge limits for paper factories in France. Maximum values of monthly average in kg/tAD

Final product	New plants			Existing plants		
	TSS	DBO_5	DQO	TSS	DBO_5	DQO
Plants with a capacity of below 60 tAD/day				2.0	4.0	8.0
Paper without filler, with over 90% virgin fibre	0.7	0.7	2.5	1.5	1.0	4
Paper with filler or coating, with over 90% virgin fibre	0.7	0.7	3.0	1.5	2.0	8.0
Paper without filler, with over 90% recycled paper	0.7	0.7	3.0	1.5	1.5	6.0
Paper with filler or coating, with over 90% recycled paper	0.7	0.7	4.0	1.5	2.0	8.0
Fluting				1.9	1.9	8.0

Source: BREF, Reference Document on Best Available Techniques in the Pulp and Paper Industry

Contamination control in water used for paper manufacture

The tendency towards closed water circuits produces different problems, depending on the raw materials used, the characteristics of the mill and the quality of the products to be obtained. In practice, there is a specific level of contamination in the water circuits that is acceptable for the machines without causing unacceptable defects. When this level of contaminants is exceeded, this can be detected in the form of machines that do not operate well, and an additional water treatment procedure should be applied in order to reach an acceptable level again and to reduce the level of contamination.

The closure of the circuits or the reduction of the purge flow in them results in the accumulation of contaminants, such as dissolved and colloidal material, in the process waters.

In low quality products, the problem appears as increased salinity, which can reach high levels. In products of a higher quality, the accumulation of contaminant substances leads to problems of deposits of sticky material, holes, stains or dirtiness.

In such cases, an equal quantity of water must be removed from the circuit as that added, either through discharge or internal treatment, which acts in a similar way to the human kidney, eliminating from the treated flow those materials that have reached an unacceptable level in relation to the process or the product.

The methods used as internal treatments are filtration, sedimentation and dissolved air flotation (DAF), together with the use of chemical treatment agents.

One step further to encourage saving water is the incorporation, usually as the final stage of treatment of the process waters prior to discharge, of membrane technology ranging from microfiltering to reverse osmosis, in order to achieve maximum reduction in the removal of dissolved and colloidal material in these flows.

Total water management

The objective of total water management is maximum recycling in the water circuits. This does not imply total closure of circuits, but a balance between the quality of the product, the correct operation of the machines and the quality of process water, using the best available technology. The challenge is to recycle all the useful material in the manufacturing process, to re-use the water in the circulation of process waters and to minimise environmental impact.

At the same time, this results in significant savings: the reduction in water consumption and gross water costs, the reduction in investment and operational maintenance costs of wastewater treatment, improved operation of the paper/cardboard machine and fewer quality problems in the final product.

5.3. SOURCES OF SOLID WASTE GENERATION AND ITS CONTROL

In the pulp and paper manufacturing industry, solid waste is generated in most of the processes involved; for example, the generation of solid waste in the preparation of raw materials (wood and bark fragments from the wood storage yard, debarking and wood chip production), in the obtaining of pulp (process fibres, de-inking sludge, ash from combustion, etc.), in the manufacture of the paper, and in the biological treatments used in water purification plants.

The characteristics of the solid waste in pulp and paper manufacture vary considerably from one mill to another. For the average plant, the total distribution of solid waste would be:

• Wastewater sludges	45%
• Ashes	25%
• Bark, wood fragments	15%
• Paper, rubbish	10%
• Miscellaneous (mixed)	5%

The type of solid waste generation for each of the processes used in the manufacture of pulp and paper are described below.

5.3.1. Preparation of raw material

As outlined in previous sections, regardless of the procedure used to obtain cellulosic pulp from forest species, the sequence of preliminary operations to be carried out in the wood yard is as follows: receipt of the raw material, storage, debarking and chipping.

This type of procedure results in the production of wood and bark waste. This waste can be used in the bark furnace, except when the sand content is a major limiting factor. In this case, the waste can be screened in a vibrating sieve, to separate the bark and chip fragments that are larger in size than the sand. The quantity of waste generated is variable and ranges from 1 to 20 kg per tonne of pulp produced.

5.3.2. Obtaining pulps

Mechanical pulps

Waste from the manufacture of mechanical pulps, in addition to the bark and wood fragments, consists of fibres from the process itself, ash from the combustion of fuel oil or solid organic waste, as well as the organic sludges resulting from the biological treatment in the process water purification plant in the mill.

Chemical pulps

This section again describes the waste generated in the Kraft process, as this is the most-used process for the manufacture of chemical pulps.

In addition to the bark and wood rejects resulting from prior preparation processes of the raw material, the production of Kraft pulp generates various types of solid waste such as inorganic sludge from the recovery of chemicals, sludge from the treatment of liquid industrial effluent (inorganic material, fibres, and biological sludge) and dust from furnaces and ovens. Many organic substances, considered to be solid waste, can be used to recover energy. These usually include bark and wood fragments, in addition to sludges from the water treatment plant.

Sludges from the water treatment plant are one of the main groups of potential waste. A large quantity of sludge is generated during primary and biological treatment with the activated sludge method. The aeration lagoons generate only small quantities of excess sludge, and the quantity of sludges from anaerobic treatment is also small. Chemical flocculation produces a large quantity of sludges.

Biological and chemical sludges have properties preventing their removal with water; As a result, chemical or organic compounds are used to form flocs and improve this property.

If the solid content of the sludges is under 40%, or if there is a large quantity of inorganic material, net energy production is zero or negative. To maintain good conditions for combustion, additional fuel should be added if bark or other wood waste is not used. Combustion reduces the volume of waste, and the inorganic waste content is left as ash, which is normally transported to a controlled landfill site.

Sludges from chemical precipitation cannot be burned without the use of extra fuel due to their high content in inorganic materials and water. They are therefore usually transported to controlled landfill sites. Sludges from flocculation using only polyelectrolytes can be taken for incineration.

The decantation of green liquors (solution of melted material from the recovery boiler) generates solid waste such as ashes and other impurities. The quantity and composition of these depends on the type of management that is used and the content of insoluble silicon compounds and other salts of the black liquors.

Waste from the green liquors is usually combined with the sludges from the preparation of the milk of lime (lime sludge), in which calcium hydroxide (slaked lime) forms a suspension and produces a residue of nodules of larger size than the particles in suspension, so that they are retained in the screening process.

The following tables show the composition of some mixtures of sludges from the combination of green liquors with calcium sludges.

Table 5.3.1. Composition of sludges from the mixing of green liquors with calcium sludges

Calcium sludges %	Solids %	Ashes %	Organic material %	Total N g/kg dry material	Total P g/kg dry material	Total Pg/kg dry material g/kg dry material
< 2	45	62	20	0.4	0.6	23
75	59	62	6.5	<0.4	2.8	6.3

Source: Industrial Environmental Control. Pulp and Paper; A.M. Springer. Ed. TAPPI 3rd edition, 2002

Table 5.3.2. Metal content of the sludges from the combining of green liquors.

Calcium sludges %	Ba	Cd	Co	Cr	Cu	Hg	Ni	Pb	Sr	Zn
< 2	430	16	9.2	75	90	0.07	60	18	330	2300
75	310	11	5.3	85	96	<0.1	29	11	290	1000

Source: Industrial Environmental Control. Pulp and Paper; A.M. Springer. Ed. TAPPI 3rd edition, 2002

Recovered paper pulp

In terms of the manufacture of recovered paper, it is worth mentioning that the majority of impurities and contaminants from the processing of recovered paper end up as waste. These are rejected matter generated by the preparation of the pulp, and sludges produced both in the clarification of white water and in the treatment of excess white water. If in addition to this, waste is burned in situ, ash is generated. Waste should be thickened and dehydrated in order to attain a high dry solid content.

Depending on the different types of paper that is recovered and the class of paper to be obtained, determined quantities of waste are generated:

Table 5.3.3. Quantities of waste with reference to the input of raw materials (%) depending on the qualities of use of the recycled paper and the quality of the paper produced.

			Rejects		Sludges	
Product	Class of recovered paper	% total losses	course / heavy	fine / light	de-inking	Clarification of white water
Graphics (writing/printing and newsprint)	Newspapers, magazines, higher qualities	15-20 10-20	1-2 <1	3-5 <3	8-13 7-16	2-5 1-5
Tissue	Office, archive, medium quality	28-40	1-2	3-5	8-13	15-25
DIP (commercial)	Stationary and office	32-40	<1	4-5	12-15	15-25
Packaging	Corrugated cardboard boxes sacks, storage, shops, domestic	4-9 3-6	1-2 <1	3-6 2-4	-- --	0-1 0-1

Source: BREF, Reference Document on Best Available Techniques in the Pulp and Paper Industry

Rejects make up around 6.5% of total recovered paper incorporated and are unsuitable for recycling. They are therefore taken to landfill sites or incinerated, producing ashes.

Table 5.3.4. Overview by percentages of typical rejects from a packaging plant

Test parameter	%
Water content	45
Plastics	25.9
Paper	27
Crystals-Stones	0.1
Metals	0.9
Organic substances	1.1

Source: Sociedad Pública de Gestión Ambiental IHOBE, S.A., Basque Government

Those sludges generated during the recovery of fibres from white waters, and the mechanical treatment of excess white waters, consist of short fibres (fines) and fillers, with approximately 50% of each, depending on the class of recovered paper that is used. These sludges are not suitable for recycling for use in high quality paper and in this case they are incinerated or taken to landfill sites. The recovery of fibres contributes to reducing the quantity of waste.

Sludges from de-inking also contain fines, fillers, binders or other additives and inks. The latter can result in the presence of small quantities of heavy metals (mainly Cr and Zn) in the sludges, which can be incinerated, used in the manufacture of construction materials or taken to landfill sites (although in some countries this is prohibited).

Those sludges generated from the biological treatment of excess water in some cases are recycled in the product (this is the case of some packaging papers) or thickened, dehydrated, and then incinerated or transported to landfill sites.

5.3.3. Paper manufacture

Paper factories produce various types of solid waste during the manufacturing process:

Rejects from the pulp purification stage

Cyclonic and centrifugal purification result in rejects of which the solid content can vary. This flow is normally taken for treatment as effluent to then be mixed with the non dehydrated sludges.

Sludges generated by the treatment of feed waters and white waters from the discharge of excess white water

The systems resulting in these are

- The treatment of water supplied to the industry by means of precipitation / flocculation to obtain process water.
- Primary clarification of wastewater.
- Biological treatment. These sludges contain a high proportion of organic material.
- Chemical treatment (flocculation) of the tertiary treatment.

The sludges obtained from biological and chemical treatments are difficult to dehydrate and are usually mixed with primary sludges prior to dehydration.

Remaining starch from the dispersion preparation installations

In the majority of cases, starch suspensions with variable solid content that is not usually greater than 10% are used in these, and leakages or losses go directly to the effluent. Starch is the most important compound in this waste, resulting in increased BOD and COD.

Effluent from the coating stations

Here, losses occur during the preparation of the coating slip or as a result of the continual filtering to which this is subject. When this effluent is to be unloaded, it goes directly to the treatment plant. The water from the washing of tanks and pipes can cause problems during biological treatment due to the high one-off concentration of this wastewater. In this case, a recovery treatment can be applied to the products of the coating slip using filtration membranes, or they can be collected in a tank to be added gradually to wastewater for treatment prior to discharge.

Chemical additives

On average, 1% of the materials used to produce paper are chemicals known as additives. In addition to the positive effects these have on the efficiency of production and the improvement of quality, they can occasionally contaminate discharged wastewater.

5.4. WATER CONSUMPTION

5.4.1. Introduction

The main use of water in the manufacturing of paper and cardboard is its use as a dispersion and transporting medium for the fibrous raw materials and additives throughout the stages of the production process, which go from pulping to forming. Water is also used as a heat exchanger fluid, as a sealant in the vacuum systems, for the production of steam, as a lubricant agent, etc. The following table shows the main uses of water in this industry.

Table 5.4.1. Uses, functions and examples of water consumption

Uses	Function	Examples
Process water	Transport	Transportation of fibres, additives, fillers, etc.
	Dilution	Consistency adjustment, additive preparation
Water for sprinklers and water jets	Dampening	Dampening the formation wire
	Lubricant	Head cylinder, wire return, tensioner, conductor, etc.
	Cutting	Trimming the sides of the paper web
	Cleaning	Cleaning of the formation wire, the cylinders, etc.
	Dilution	Headbox
	Cooling	Guide cylinders, upper cylinder, mechanical parts
	Anti foaming agent	Floating cells, headbox, etc.
Cooling water	Cooling	Pump systems, machine operating systems, lubricating fluids, etc.
Water for the boiler	Steam production	Drying cylinders
Sealing water	Sealing	Vacuum boxes, pumps, etc.
Cleaning water	Transport	Cleaning machines, pipes, tanks, etc.

Due to the high levels of water consumption in manufacturing, waters with a wide range of specifications can be used, depending on their availability and the cost of their treatment. In general, surface waters have more variable properties and depend on the location of the mill, while well water has a more stable composition and fundamentally contains a large quantity of mineral salts.

The quality of the water entering the circuit of the paper machine is critical, as it defines the majority of chemical processes that will take place during the manufacturing of the paper, influencing the efficiency of the chemical retention and drainage system, determining the level of white water recirculation and the level of retention on the wire of the raw materials and additives used.

The pH of the feed water is more important in the manufacture of neutral and alkaline papers than in the case of manufacture in an acid medium. The pH of the medium determines the level of ionisation of the functional groups in solution and affects the balance between the dissolved ions and between these ions and the fillers in suspension.

In acid processes, the level of hardness of the water determines the levels of aluminium and sulphuric acid necessary to condition the water, which increases its conductivity. In other processes, it is the conductivity of the water added that has a direct influence on flocculation. The presence of salts influences the chemistry of the wet end of the paper machine due to their interaction with the charged groups on the surface of the suspended particles and the polymers present.

Lastly, the presence of organic compounds in the feed waters is of much less importance than the presence of inorganic salts. This is due to the low concentration of inorganic materials present in the feed waters with respect to the organic material present in the process waters.

The volume of water consumed depends on numerous factors, among which three are noteworthy: The type of fibre used as raw material, the product to be manufactured and the technology of the production process.

5.4.2. Obtaining pulps

Mechanical pulps

Typical water consumption in the manufacture of mechanical pulps is listed below:

Table 5.4.2. Typical water consumption in the manufacture of mechanical pulps

Type of pulp	Water consumption (m^3/t AD)
Traditional mechanical pulp (SGW)	10-15
Thermomechanical pulp (TMP)	4-10

Source: Sociedad Pública de Gestión Ambiental IHOBE, S.A., Basque Government

Chemical pulps

Water consumption in the obtaining of chemical pulps varies a great deal between factories. Values of over 50 m^3 water/t of pulp are normal if the mill has a water refrigeration tower on site.

Recovered paper pulp

Specific water consumption for different processes in the manufacture of pulp and paper from recovered paper is outlined in the following table:

Table 5.4.3. Specific consumption of water during different processes in the manufacture of pulp and paper from recovered paper

Process		**Consumption m^3/t**
Manufacture processing recovered pulp	Without de-inking	1.5 – 10
	De-inked	5 – 20
Manufacture of paper with recovered pulp	Packaging	1.5 – 10
	Newsprint	10 – 20
	Tissue	5 – 100
	Printing / Writing	7 – 20

Source: BREF, Reference Document on Best Available Techniques in the Pulp and Paper Industry

5.4.3. Paper manufacture

Depending on the products manufactured, water consumption in factories with current technology is between the following intervals:

- Cardboard and boxboard: 1-20 m^3/t of the product.
- Newsprint: 6-20 m^3/t of the product.
- Tissue paper: 10-50 m^3/t of the product.
- Printing and writing paper: 5-50 m^3/t of the product.
- Special papers: 10-300 m^3/t of the product.

There are some factories operating at higher consumption levels, due to factors such as the use of old machines, the non-existence of water clarification processes, low levels of closure of the water system, etc. Consumption can on occasion reach the following levels:

- Newsprint: 30 m^3/t of the product.
- Tissue paper: 60 m^3/t of the product.
- Printing and writing paper: 200 m^3/t of the product.

5.4.4. Total water management

If the water that is used in the manufacture of paper were in totally open circuits, water consumption would be technically, economically and ecologically unacceptable today. As a result, all factories to a greater or lesser extent use some type of water recycling in the manufacturing process. The most frequently used alternatives in the paper industry to reduce water consumption are:

- Reuse of white waters as process waters.
- Reuse of clarified water for different applications.
- Use of water in cascade systems depending on quality-use requirements.
- Use of water for technical purposes in closed systems.
- Reuse of effluent after treatment as feed water.

The objective of total water management is maximum recycling in the water circuits (as seen in the figure). This does not imply total closure of circuits, but a balance between the quality of the product, the correct operation of the machines and the quality of process water, using the best available technology. The challenge is to recycle all useful materials in the manufacturing process, re-use the water in the circulation of process water, and minimise environmental impact.

At the same time, this results in significant savings: the reduction in water consumption and gross water costs, the reduction in investment and operational maintenance costs of wastewater treatment, improved operation of the paper/cardboard machine and fewer quality problems in the final product.

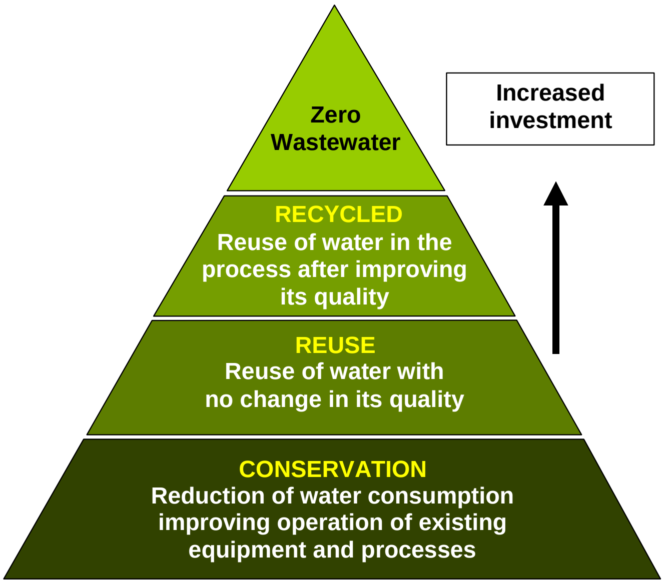


Figure 5.4.1. Total water management

5.5. ENERGY CONSUMPTION

5.5.1. Introduction

The paper industry consumes energy in the following forms and areas:

- Electrical energy:
    - Operation of machinery: debarking machines, chipping machines, refiners, transporters, etc.
    - Operation of machinery: paper machine.
    - Mechanical systems of disintegration, dispersion, stirring and mixing.
    - Pumps and fluid transportation.
    - General and auxiliary services.

- Steam:
    - Digester heating.
    - Pulp drying.
    - Paper drying.

These energy needs are covered in the following way: electricity is co-generated in the plant itself, or is bought from external suppliers, while steam is always produced in the plant itself by means of the cogeneration process or in conventional boilers. Cogeneration is the production in one single process of electricity and heat. The most is made of the residual heat produced in the generation of electricity by means of an industrial process that uses it as useful thermal energy in the form of steam. Therefore the installation of a cogeneration plant is intrinsically linked to the existence of an industry that demands useful heat, as in the case of the pulp and paper industry.

Energy production plants in the sector consist of the following installations:

- Bark combustion furnaces: During the processing of wood for the obtaining of cellulose, the bark, chips and silt with fibrous content, which are renewable biomass, are burned in furnaces for energy.
- Black liquor recovery boilers: Black liquor is a biofuel that is generated during the production of chemical pulp and consists of a mixture of inorganic chemicals used in the cooking of the wood, with lignin and other organic compounds. These liquors are concentrated and burned in recovery boilers to produce water vapour, which is cogenerated for use in the production process and, in addition, to produce electricity. The resulting waste is used to recover chemical reactives that will again be reused in the process of obtaining pulp.
- Steam producing boilers: In these boilers, by means of the use of fossil fuels, the water vapour is generated that is used in the drying process of the pulp and paper. In those plants that have a cogeneration system, these boilers are used only as auxiliary boilers.
- Central cogeneration boilers: Due to the intense demand for electricity and thermal energy in the form of steam in the pulp and paper industry, there has been widespread integration of cogeneration technologies into the production processes.

The following figure shows the different systems which cover the energy needs of a pulp and paper production plant.

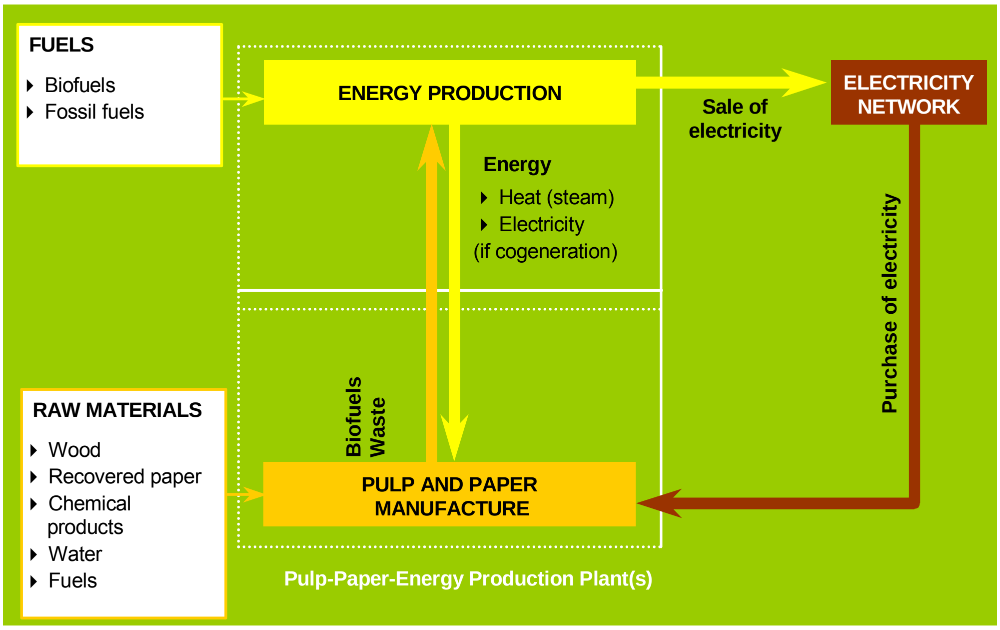


Figure 5.5.1. Means of covering the energy needs of a pulp and paper production plant

Source: ASPAPEL, National Association of Pulp, Paper and Cardboard Manufacturers (Spain)

Energy needs are linked to the type of product, the volume of production and the size of the production centres.

Improved energy costs is one of the keys to competitiveness in the pulp and paper industry. There are three factors of significant importance: energy efficiency, cogeneration and fuel mixtures, including the use of recycling waste for energy valuation purposes.

Keys for energy efficiency
Energy efficiency
Cogeneration
Fuel mixture and use of process waste for energy valuation

The concept of energy efficiency refers to those processes that enable the same production of goods and services, using less energy. Source: ASPAPEL, National Association of Pulp, Paper and Cardboard Manufacturers (Spain)

In recent years, the paper industry has identified and is in the process of applying a whole variety of energy efficiency measures both in horizontal technologies (non-specific technology in a sector) and process technology (technology that is specific to one process), measures that range from the external lighting of the mill to the operation of the different elements of the machinery, and that have led to competitive advantages.

Cogeneration saves primary energy and contributes to improved energy efficiency, as it is thermally the most effective way of generating electricity and heat. In addition, since this is a decentralised means of producing electricity, meaning that the electricity is produced nearer to its point of consumption, it avoids losses and investment in transport networks and electricity distribution, improving the quality of the system. It also improves the energy efficiency, the productivity and the quality of the electricity supply of the associated industries, avoiding interruptions in production due to power cuts or microshorts.

Below is a diagram showing the energy savings in a pulp and paper production plant by means of such an installation.

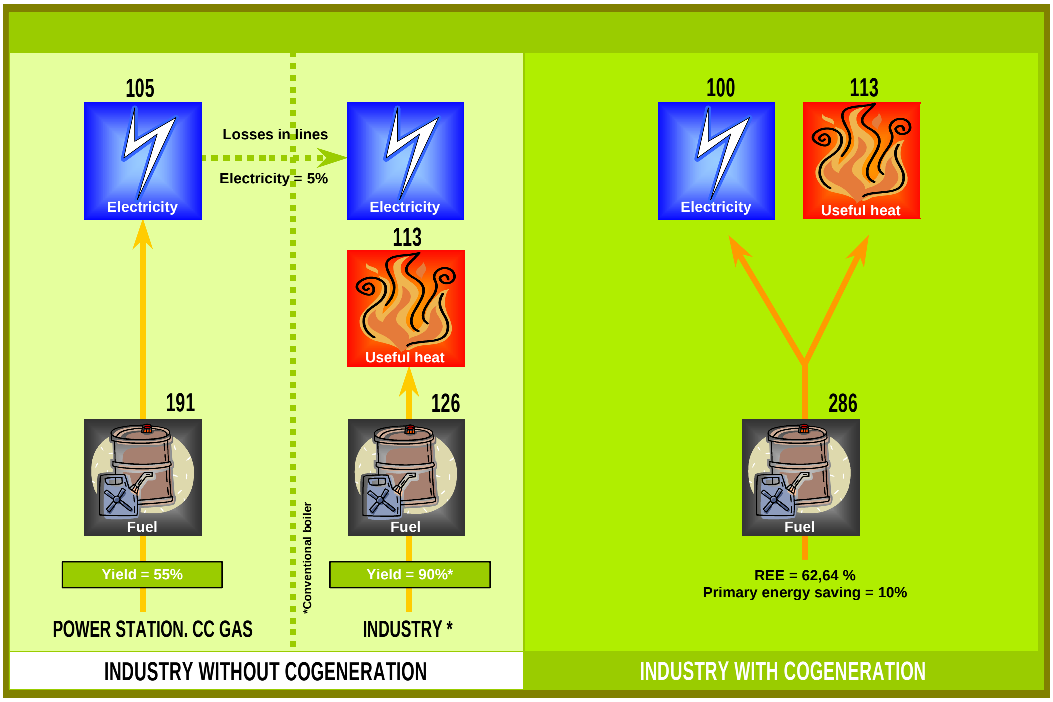


Figure 5.5.2. Energy savings made in a pulp and paper plant as a result of the installation of cogeneration

Source: ASPAPEL, National Association of Pulp, Paper and Cardboard Manufacturers (Spain)

Cogeneration technology in the pulp, paper and cardboard production sector is recognised as a Best Available Technique according to the definition of the Council Directive 96/61/EC regarding Integrated Pollution Prevention and Control (IPPC). Such technology is without doubt supported by the European Commission in relation to emissions trading, through Communication 2003/830, given that cogeneration is an energy efficient, clean technology.

Norms concerning the environment emerging today definitively show the important role that cogeneration is taking on in the paper manufacturing sector. For example, in the case of the countries of the European Union, Directive 2004/8/EC of the European Parliament and of the Council on the promotion of cogeneration based on a useful heat demand in the internal energy market was passed recently, and in countries such as Egypt cogeneration is accepted as an important technique in the field of the environment in the “National Strategy for Improving Energy Efficiency” and benefits from financial contributions from the government and international development agencies within the framework of the "United Nations Development Programme".

With respect to fuels, the evolution of fuel use in the paper sector has moved in the last decade towards the substitution of fuel and coal for natural gas, accompanied at the same time by extensive use of biomass.

Within the strategy of energy optimisation that is being developed in the Spanish paper industry, the reuse of recycling waste for energy valuation purposes is seen as a key opportunity to advance in the improvement of the structure of fuels used in the sector.

Process waste management consists firstly of waste minimisation by means of quality control of the raw material used and improvements in the manufacturing process, and secondly in the recycling of waste or its use for energy valuation. Sufficient utilisation of recycling waste for energy valuation is expressly defined as a Best Available Technique in the paper sector within the framework of Directive 96/61 on IPPC.

Recovered paper, even after undergoing a process of selection for paper for recovery, arrives at the paper mill mixed with up to 10% inappropriate materials from the collection process: plastics, bags, staples, sand, organic material, etc. These materials are rejected during the paper recycling process, generating non-dangerous waste, which has traditionally been sent to landfill.

However, this waste has a high potential for valuation and utilisation as energy in the paper manufacturing process, thus avoiding around 90% of discharge in landfill sites.

5.5.2. Obtaining pulps

Mechanical pulps

Specific energy consumption in obtaining mechanical pulp varies depending on the manufacturing process used and on the final degree of refinement of the pulp produced.

Table 5.5.1. Specific energy consumption in the manufacture of mechanical pulps

Type of pulp	kWh/t AD	Degree of refinement
Traditional mechanical pulp (SGW)	1,100-2,000	350-40
Refiner mechanical pulp (RMP)	1,500-3,000	350-30
Thermomechanical pulp (TMP)	1,800-3,000	400-30

Source: Sociedad Pública de Gestión Ambiental IHOBE, S.A., Basque Government

Calorific energy consumption is much lower than electrical energy consumption and depends mainly on the process used and the level of integration in the mill.

Chemical pulps

In the manufacture of chemical pulps, the majority of energy consumed is used to heat different fluids and for the evaporation of water. Calorific energy is also used to accelerate or control chemical reactions. Electrical energy is consumed mainly in the transportation of materials.

The manufacture of bleached pulp consumes around 10-14 GJ/t AD (excluding the steam from electrical energy production). Electrical energy consumption is 600-800 kWh/t, including the drying of the pulp. The consumption of energy from the drying of the pulp corresponds to 25% of the calorific energy and between 15 and 20% of the electrical energy. Approximately 50% of the electrical energy is used to operate pumps.

Energy consumption depends on the configuration of the productive process, the equipment installed and the control of the process. For example, electricity consumption in an integrated unbleached Kraft pulp mill is approximately 50% that of a non-integrated bleached Kraft pulp mill.

The energy self-sufficiency in a Kraft pulp mill depends mainly on an efficient energy recovery system, with the burning of organic materials dissolved in the cooking liquor in the black liquor boiler; secondary energy can also be recovered in the burning of solid organic waste, the optimisation of the cooking system, the recovery of hot water from evaporation and gas cooling, etc.

Recovered paper pulps

In terms of thermal energy, the main consumption corresponds to the operation of hot dispersion, which is not always part of the installations.

In terms of electrical energy, the following table shows an example of electrical energy consumption.

Table 5.5.2. Consumption of electrical energy in various recovered paper pulp plants

Type of plant	Electricity consumption
De-inked Tissue Production 40,000 t/year	400 kWh/t
De-inked Newsprint Production 90,000 t/year	250 kWh/t

Source: ASPAPEL, National Association of Pulp, Paper and Cardboard Manufacturers (Spain)

5.5.3. Paper manufacture

The paper industry can de described as energy-intensive, and energy is an important element of the costs involved.

Table 5.5.3. Energy consumed in heat and electricity in a non-integrated fine paper mill

Type of plant	Heat (GJ/t)	Electricity (kWh/t)
Pulp preparation	--	202
Paper machine	8	350
Wastewater treatment	--	4
TOTAL	8	556

Source: ASPAPEL, National Association of Pulp, Paper and Cardboard Manufacturers (Spain)

6. OPPORTUNITIES FOR POLLUTION PREVENTION AT SOURCE

The objective of this chapter is to provide a certain degree of reflection for technicians and management in the paper sector on their own processes and alternative technologies that may be more respectful of the environment, in addition to providing a guide for the competent authorities for the establishment of concrete policies to act as a motor for environmental improvement. To do this, the chapter describes numerous alternatives that permit a reduction in the environmental impact of pulp and paper mills, considering two complementary objectives:

1. To minimise the generation of pollutants, waste flows and the consumption of resources during the production process.
2. To reduce the ultimate environmental impact of these things.

The technological alternatives proposed vary from modifications in traditional production systems, proposing in some cases alternative systems for specific production processes or unitary operations, to alternatives for the control of the final emissions from these installations. The proposed technological alternatives are complementary to other general measures based on good practice and on the motivation of personnel who, as a group, enable the optimisation of each industrial installation.

The criteria followed for the development of this chapter consists of presenting a table for each of the processes described in chapter 4, which shows specific technological alternatives for pollution prevention.

All of these alternatives are defined below and a data sheet is provided for those requiring a more detailed explanation, either due to their technological relevance or because their greater complexity requires a more specific description of the process; those alternatives that do not require such a detailed description of the process are not represented in a data sheet, either due to their technical simplicity, their more theoretical nature, their easy application or because they are very specific.

The alternatives presented are not exclusive, nor are they the only possible alternatives. Rather, in general mills adopt various measures simultaneously, as described in the practical examples.

The economic data given is taken from the reference document (BREF, Reference Document on Best Available Techniques in the Pulp and Paper Industry). These figures are only indicative and are provided as a reference for the order of size of the different alternatives, and they are normally expressed in millions of euros (M euros).

6.1. SELECTION OF TECHNOLOGICAL ALTERNATIVES, DEPENDING ON THE PRODUCTION PROCESS

The tables shown below provide a general vision of those preventative technological alternatives for the reduction of emissions, waste, discharge, and water and energy consumption. In this section, the presentation of the different alternatives is based on the most important production processes in the pulp and paper sector, and to do this five tables have been produced, which correspond to:

- Alternatives for pollution prevention at source (APPS) in mechanical pulp production and their environmental impact (table 6.1.1).
- Alternatives for pollution prevention at source (APPS) in sulphite pulp production and their environmental impact (table 6.1.2).

- Alternatives for pollution prevention at source (APPS) in Kraft pulp production and their environmental impact (table 6.1.3).
- Alternatives for pollution prevention at source (APPS) in recovered paper pulp production and their environmental impact (table 6.1.4).
- Alternatives for pollution prevention at source (APPS) in paper production and their environmental impact (table 6.1.5).

The rows show the available techniques, highlighting the effects that these would have on consumption levels of resources and on emissions (columns). The effects of each alternative are indicated qualitatively using arrows (↑ or ↓). The downward pointing arrows indicate a reduction of the consumption of chemicals, water or energy, and a reduction in the pollutant load of emissions, waste and/or discharge. The upward pointing arrows show an increase in pollutant generation, in the consumption of resources, or an improvement in the production process.

The information shown in the tables is based on the reference document (BREF, Reference Document on Best Available Techniques in the Pulp and Paper Industry). The effects these have on consumption and emissions, depending on the alternative, should not be considered as imperative information, but rather as a departure point to understand a possible source of pollution. Moreover, the effects will depend on the specific conditions of each mill.

Alternatives for pollution prevention at source (APPS) in mechanical pulp production

Table 6.1.1. APPS in mechanical pulp production

APPS	**Effects on emission and consumption levels (crossed effects)**					
	Consumption of chemicals	**Consumption of energy (E) and water (A)**	**Wastewater effluent**	**Atmospheric emissions**	**Solid waste**	**Remarks**
6.3.1. Dry debarking	n.e.	↑ E in debarking ↓ A	↓ COD ↓ TSS ↓ flow	n.e.	n.e.	--
6.3.2. The use of storage tanks with sufficient volume to optimise water consumption	n.e.	n.e.	↓ Flow ↓ Pollutant load	n.e.	n.e.	--
6.2.2. Water recirculation	n.e.	↓ A	↓ Flow	n.e.	n.e.	--
6.3.5. Efficient washing	↓ brightening ↓ cooking	↑ E washing (electric) ↓ A	↓ BOD ↓ COD ↓ AOX ↓ Flow	n.e.	n.e.	↓ brightening
6.4.1. New energy efficient pulping processes	n.e.	↓ E	n.e.	n.e.	n.e.	--
6.4.2. Closing of the water circuits with evaporation and concentrate incineration	n.e.	↓ A ↑ E	↓ Flow ↓ Pollutant load	↑	↓	BAT for CTMP
6.4.5. Membrane bioreactor	n.e.	n.e.	↓ Pollutant load	n.e.	↑ sludges	Treatment of sludges
6.3.13. Control of emissions from the wood yard	n.e.	n.e.	↓	n.e.	n.e.	Fibre recovery
6.2.14. Application of steam and energy cogeneration	n.e.	↓ E	↓ Suspended solids	↓	n.e.	--
6.3.17. Minimising loss from rejects	n.e.	↓ E	↓	n.e.	↓	--

↑ *= increase;* ↓ *= decrease;* ***n.e.*** *= no (or negligible) effect;* ***(↑/↓)*** *= this may or may not produce an effect, with its impact depending on conditions;* ***CTMP****: Chemical thermomechanical pulps;* ***MTD****: Best Available Technique*

Alternatives for pollution prevention at source (APPS) in sulphite pulp production

Table 6.1.2. APPS in sulphite pulp production and their environmental impact

APPS	Effects on emission and consumption levels (crossed effects)					
	Consumption of chemicals	**Consumption of energy (E) and water (A)**	**Wastewater effluent**	**Atmospheric emissions**	**Solid waste**	**Remarks**
6.3.1. Dry debarking	n.e.	↑ E in debarking ↓ A	↓ COD ↓ TSS ↓ flow	n.e.	n.e.	↑ energy production in the bark furnace
6.3.2. The use of storage tanks with sufficient volume to optimise water consumption	n.e.	n.e.	↓ Flow ↓ Pollutant load	n.e.	n.e.	Avoiding alterations in the wastewater treatment plant
6.3.3. Control and recovery of leaks and escapes	n.e.	↑ E evaporation	↓ Flow ↓ COD ↓ BOD	n.e.	n.e.	n.e.
6.3.4. Unbleached pulp screening in a closed water circuit	n.e.	↓ A ↑ E evapor.	↓ Flow ↓ COD	n.e.	n.e.	Increased recovery of organic material. The plant's recovery capacity should be considered
6.3.5. Efficient washing	↓ brightening ↓ cooking	↑ E washing (electrical) ↓ A	↓ BOD ↓ COD ↓ AOX ↓ Flow	n.e.	n.e.	↑ quality
6.3.6. Extended modified cooking	↓ brightening	(↑ /↓) E cooking ↑ E evapor.	↓ COD ↓ AOX	↑ odour	n.e.	↑ Improved brightness (↑/↓) final pulp yield. Better recovery of organic material
6.2.3. Oxygen delignification	↑ oxygen ↓ brightening	↑ E oxygenation stage ↑ E oxygenation of white liquors ↑ E recovery boilers and lime kilns	↓ COD ↓ AOX	↑ NO_x in the recovery boiler	↑ decantation sludges	↑ energy production ↓ bleaching costs
6.2.5.TCF bleaching	(↑/↓)	(↑/↓)	↓ ↓ AOX ↑ N (chelating agents)	n.e.	n.e.	↑ Bleaching costs ↑ Encrustation problems
6.4.3. Removal of chelating agents	↓	n.e.	↓ BOD ↓ COD ↓ EDTA	n.e.	n.e.	For the removal of chelating agents, the bleaching system has to be changed to a system without peroxide or ozone or metals must be removed by precipitation

Table 6.1.2. APPS in sulphite pulp production and their environmental impact

APPS	**Effects on emission and consumption levels (crossed effects)**					
	Consumption of chemicals	**Consumption of energy (E) and water (A)**	**Wastewater effluent**	**Atmospheric emissions**	**Solid waste**	**Remarks**
6.2.6. Closing the circuit in the bleaching plant	↑ brightening	↑ E evaporation	↓ BOD ↓ COD ↓ Flow	n.e.	↓ decantation sludges	↓ water consumption
6.2.8. Water clarification with membrane systems	↑	↑	↓ Suspended solids ↓ Dissolved Colloidal Material ↓ Water nutrients	n.e.	↑ sludges	Permeation rejects Treatment of sludges
6.4.5. Membrane bioreactor	n.e.	n.e.	↓ Pollutant load	n.e.	↑ sludges	Treatment of sludges
6.2.10. Purification of the gases from the recovery boiler by scrubbing	n.e.	↑	n.e.	↓ SO_2	n.e.	(↑/↓) energy balance
6.2.11. Purification and reuse of condensates from the evaporating plant	↓ brightening ↓ In the treatment of wastewater	↓ E Aeration ↓ A ↑ steam	↓ COD ↓ Flow ↓ TRS	↓ odour	n.e.	Improving the efficiency of the wastewater treatment plant
6.3.14. Increased concentration of the black liquor	n.e.	↑ E evaporation	n.e.	↓ SO_2 ↑ NO_x ↑ particles	n.e.	↑ capac. of evaporation necessary ↑ energy prod. boiler ↑ production capacity Necessity for electrostatic precipitators
6.2.12. Treatment of boiler and furnace gases with an electrostatic precipitator	n.e.	↑ electricity	n.e.	↓ SO_2 particles	n.e.	--
6.4.4. Selective non-catalytic reduction	↑ urea/NH_3	↑ manipulation system	n.e.	↓ NO_x ↑ NH_3	n.e.	--
6.2.13. Improved pulp preparation with a decrease in energy consumption and emissions	n.e.	↓ E	n.e.	↓	n.e.	--

↑ = increase; ↓ = decrease; ***n.e.*** *= no (or negligible) effect;* ***(↑/↓)*** *= this may or may not produce an effect, with its impact depending on conditions*

Alternatives for pollution prevention at source (APPS) in Kraft pulp production

Table 6.1.3. APPS in Kraft pulp production and their environmental impact

APPS	Effects on emission and consumption levels (crossed effects)					
	Consumption of chemicals	Consumption of energy (E) and water (A)	Wastewater effluent	Atmospheric emissions	Solid waste	Remarks
6.3.1. Dry debarking	n.e.	↑ E in debarking ↓ A	↓ COD ↓ TSS ↓ flow	n.e.	n.e.	↑ energy production in the debarking furnace
6.3.2. The use of storage tanks with sufficient volume to optimise water consumption	n.e.	n.e.	↓ Flow ↓ Pollutant load	n.e.	n.e.	Avoiding alterations in the wastewater treatment plant
6.3.3. Control and recovery of leaks and escapes	n.e.	↑ evapor.	↓ Flow ↓ COD ↓ BOD	n.e.	n.e.	--
6.3.4. Unbleached pulp screening in a closed water circuit	n.e.	↓ A ↑ evapor.	↓ Flow ↓ COD	n.e.	n.e.	Better recovery of organic material. The plant's recovery capacity should be considered
6.3.5. Efficient washing	↓ brightening ↓ cooking	↑ E washing (electrical) ↓ A	↓ BOD ↓ COD ↓ AOX ↓ Flow	n.e.	n.e.	↑ quality
6.3.6. Extended modified cooking	↓ brightening	(↑ /↓) E cooking ↑ E evapor.	↓ COD ↓ AOX	↑ odour	n.e.	↑ Improved brightness (↑/↓) final pulp yield. Better recovery of organic material
6.2.3. Oxygen delignification	↑ oxygenat. ↓ brightening	↑ E oxygenation stage ↑ E oxygenation of white liquors ↑ E recovery boiler and lime kiln	↓ COD ↓ AOX	↑ NO_x in the recovery boiler	↑ decantation sludges	↑ energy production ↓ bleaching costs
6.3.7. Ozone bleaching	↑ oxygenat. ↓ brightening	↑ E oxygenat. ↓ E bleaching	↓ AOX	n.e.	n.e.	↑ Cost
6.2.4. ECF bleaching	(↑/↓)	(↑/↓)	↓ AOX ↓ Dioxins ↓ ClO_3^-	n.e.	n.e.	Improved closure of circuits
6.2.5. TCF bleaching	(↑/↓)	(↑/↓)	↓ ↓ AOX ↑ N (chelating agents)	n.e.	n.e.	↑ Bleaching costs ↑ Encrustation problems
6.4.3. Removal of chelating agents	↓	n.e.	↓ BOD ↓ COD ↓ EDTA	n.e.	n.e.	--
6.2.6. Closing the circuit in the bleaching plant	↑ brightening	↑ E evaporation	↓ BOD ↓ COD ↓ Flow	n.e.	↓ decantation sludges	↓ water consumption

Table 6.1.3. APPS in Kraft pulp production and their environmental impact

APPS	**Effects on emission and consumption levels (crossed effects)**					
	Consumption of chemicals	**Consumption of energy (E) and water (A)**	**Wastewater effluent**	**Atmospheric emissions**	**Solid waste**	**Remarks**
6.2.8. Water clarification with a membrane system	n.e.	↑	↓ Suspended solids ↓ Dissolved Colloidal Material ↓ Water nutrients	n.e.	↑ sludges	Treatment of sludges
6.4.5. Membrane bioreactor	n.e.	n.e.	↓ Pollutant load	n.e.	↑ sludges	Treatment of sludges
6.3.14. Increased concentration of the black liquor	n.e.	↑ evaporation	n.e.	↓ SO_2 ↑ NO_x ↑ particles	n.e.	↑ capac. of evaporation necessary ↑ energy prod. boiler ↑ production capacity Necessity for electrostatic precipitators
6.2.10. Purification of the gases from the recovery boiler by scrubbing	n.e.	↑	n.e.	↓ SO_2	n.e.	(↑/↓) energy balance
6.2.11. Purification and reuse of condensates from the evaporating plant	↓ brightening ↓ In the treatment of wastewater	↓ E Aeration ↓ A ↑ steam	↓ COD ↓ Flow ↓ TRS	↓ odour	n.e.	Improving the efficiency of the wastewater treatment plant
6.4.4. Selective non-catalytic reduction	↑ urea/NH_3	↑ manipulation system	n.e.	↓ NO_x ↑ NH_3	n.e.	--
6.3.15. Improved washing of calcination waste	n.e.	n.e.	n.e.	↓ TRS	n.e.	--
6.2.12. Treatment of boiler and furnace gases with an electrostatic precipitator	n.e.	↑ electricity	n.e.	↓ particles	n.e.	--

↑ = increase; ↓ = decrease; ***n.e.*** *= no (or negligible) effect;* ***(↑/↓)*** *= this may or may not produce an effect, with its impact depending on conditions*

Alternatives for pollution prevention at source (APPS) in recovered paper pulp production

Table 6.1.4. APPS in recovered paper pulp production and their environmental impact

APPS	**Effects on emission and consumption levels (crossed effects)**					
	Consumption of chemicals	**Consumption of energy (E) and water (A)**	**Wastewater effluent**	**Atmospheric emissions**	**Solid waste**	**Applicability**
6.2.9. Optimum water management. Reduction of freshwater consumption by means of the separation of water circuits and the counterflow	↓	↓ E ↓ A	↓ Flow ↓ Pollutant load	n.e.	n.e.	↓ Fresh water consumption
6.3.8. Closing the water circuit with the biological treatment of effluent integrated into the process	n.e.	↓ A	↓ BOD ↓ COD ↓ Flow	↓ Odour	↑ sludges	BAT for brown grades Total closure of circuits
6.2.7. Clarification of waters by dissolved air flotation in de-inking plants	↑ flocculants	↑ E ↓ A	↓ MDC ↓ COD ↓ Flow	n.e.	↑ sludges	BAT for de-inked grades This allows circuit closure
6.2.8. Water clarification with membrane systems	n.e.	↑	↓ Suspended solids ↓ Dissolved Colloidal Material ↓ Water nutrients	n.e.	↑ sludges	Treatment of sludges
6.2.13. Improvements in pulp preparation to reduce energy consumption and emissions	n.e.	↓ E	n.e.	↓ atmospheric emissions because ↓ consumption of E	(↑/↓)	BAT for brown grades Improved quality
6.2.14. Application of steam and energy cogeneration	n.e.	↓ E	↓ Suspended solids	↓	n.e.	--
6.3.17. Separate collection of non-fibrous materials	n.e.	↑/↓	n.e.	n.e.	↓	--
6.3.23. Updated designs of facilities	n.e.	↓ E	n.e.	n.e.	n.e.	Increases yield

↑ = increase; ↓ = decrease; ***n.e.*** *= no (or negligible) effect;* ***(↑/↓)*** *= this may or may not produce an effect, with its impact depending on conditions;* ***MTD****: Best Available Technique*

Alternatives for pollution prevention at source (APPS) in paper production

Table 6.1.5. Alternatives for pollution prevention at source in paper production and their environmental impact

Alternatives	Effects on emission and consumption levels (crossed effects)					
	Consumption of chemicals	**Consumption of energy (E) and water (A)**	**Wastewater effluent**	**Atmospheric emissions**	**Solid waste**	**Applicability**
6.2.8. Water clarification with membrane systems	n.e.	↑ E ↓ A	↓ Flow ↓ Pollutant load	n.e.	↑	For all levels of pollution
6.2.9. Optimum water management. Reduction of freshwater consumption by means of the separation of water circuits and the counterflow	n.e.	↓ E ↓ A	↓	n.e.	n.e.	For all levels of pollution
6.3.9. Reduction of fibre and mineral filler losses	↓	↓ A	↓ Suspended solids	n.e.	n.e.	↓ Cost
6.3.10. Recovery and recycling of coating products contained in wastewater	↓	↓ A	↓ Flow ↓ Pollutant load	n.e.	↓	Improved processing in the treatment plant of wastewater in supercalendering or coating waters
6.3.11. Independent pre-treatment of wastewaters from coating processes	↑	n.e.	↓ Flow ↓ Solids in suspension	n.e.	↑	In supercalendering or coating waters. ↓ Alterations in the wastewater treatment plant
6.3.21. Removal of accidental or occasional discharge	n.e.	n.e.	↓ One-off discharge	n.e.	n.e.	For all levels of pollution. ↓ Alterations in the wastewater treatment plant
6.3.12. Substitution of potentially harmful substances with other less polluting alternatives	n.e.	n.e.	↓ Toxicity	n.e.	↓ Toxicity	For all levels of pollution. Improved biological treatment.
6.2.14. Application of steam and energy cogeneration	n.e.	↓ E	↓ Suspended solids	↓	n.e.	--
6.3.16. The use of low sulphur fuels or renewable fuels	↓	↓ E	n.e.	↓ SO_2 ↓ CO_2	n.e.	--
6.3.20. The use of energy-efficient technologies	n.e.	↓ E	n.e.	n.e.	n.e.	For all grades
6.2.15. Optimisation of dewatering in the pressing section of the paper machine	n.e.	↓ E	n.e.	n.e.	n.e.	For all grades

↑ = increase; ↓ = decrease; ***n.e.*** *= no (or negligible) effect;* ***(↑/↓)*** *= this may or may not produce an effect, with its impact depending on conditions*

6.2. DATA SHEETS FOR SELECTED TECHNOLOGICAL ALTERNATIVES FOR POLLUTION PREVENTION AT SOURCE (APPS)

This section outlines the technologically most relevant alternatives for pollution prevention at source and presents alternatives for the main production processes in the sector and for all types of waste (wastewater, atmospheric pollution and solid waste).

The theoretical data sheet (6.2.1) is a tool for the correct interpretation of the other data sheets. It contains the description and objectives of each of the sections that make up the data sheets.

Alternatives for pollution prevention at source (APPS)	**6.2.1. Theoretical data sheet**
Process and Action	- <u>Production:</u> process in which the APPS is applicable. - <u>Key action:</u> on which the APPS is based (substitution of raw materials, recycling at source, technological changes or Good Housekeeping Practices).
Stage / Operation	Stage or operation which is changed, included or removed to implement the APPS.
Environmental problem	Most important implications for the environment in the original production process, which are minimised or reduced with the application of the APPS.
Potential benefits of the alternative	Main benefits obtained from the application of the APPS.
Description	Scientific and technological bases of the APPS, and a description of its operation.
Procedure	Description of the most used process/es for the integration of the APPS into the production process.
Comments	Additional information which is complementary to the information provided in previous sections.
Economic aspects	Where possible, the economic orientation of the implementation and operating costs of the APPS will be given. The figures provided are taken from the reference document: BREF, Reference Document on Best Available Techniques in the Pulp and Paper Industry (2001).

Alternative for Pollution Prevention at Source (APPS)	**6.2.2. Water recirculation**
Process and Action	Process: Pulp and paper production (example of a mill producing mechanical pulp). Action: Technological changes, recycling at source.
Stage / Operation	Minimising and reuse of process waters.
Environmental problem	High water consumption, processing costs of wastewater are high. Bad water management in the industry.
Potential benefits of the CP alternative	The main benefits of the application of this alternative are: • Reduction in fresh water costs. • Reduction in fresh water treatment costs. • Lower flow of wastewater to be treated. • Reduction in losses of raw materials. • Lower energy consumption. • Quicker drainage speed in the paper machine.
Description	Once the necessary water consumption is known for each stage of the process and the water qualities of the effluent from each of the different processes is assessed, the use of water can be optimised by the reuse of those flows of which the quality allows their reuse in other processes. Today, all mills work to a greater or lesser extent with water recirculation. The degree of recirculation depends on the level of pollutants that can accumulate in the circuit without affecting the quality of the product or the manufacturing process. Some fresh water is necessary in all cases, even in entirely closed circuits, due mainly to losses through evaporation. In non-integrated mills, where the final product is usually paper pulp, the water added is fresh water, while in integrated mills, the final product is paper, and fresh water may be used in the paper machine and white water in the pulp plant.

In each case, the critical pollutants for each process must be established. For example, in pulp plants the level of extractives and elements foreign to the process, such as chlorides, metals, Ca, etc. are critical, while in recycled paper plants the level of salts, anionic trash (understanding by this dissolved and colloidal material that is anionic in character) or stickies are more critical, and in plants producing coloured papers the colour of the water can determine the level of closure of the circuit.

The most immediate effects of the closure of water circuits on water quality are: An increase in solids in suspension, dissolved and colloidal material and temperature. These alterations could produce numerous problems both in the manufacturing process and the quality of final products, affecting the plant's productivity. An example of this is the reduced efficiency of chemicals, problems with corrosion and abrasion, the formation of deposits and encrustations, blockages of sprinklers, wires and felts, etc.

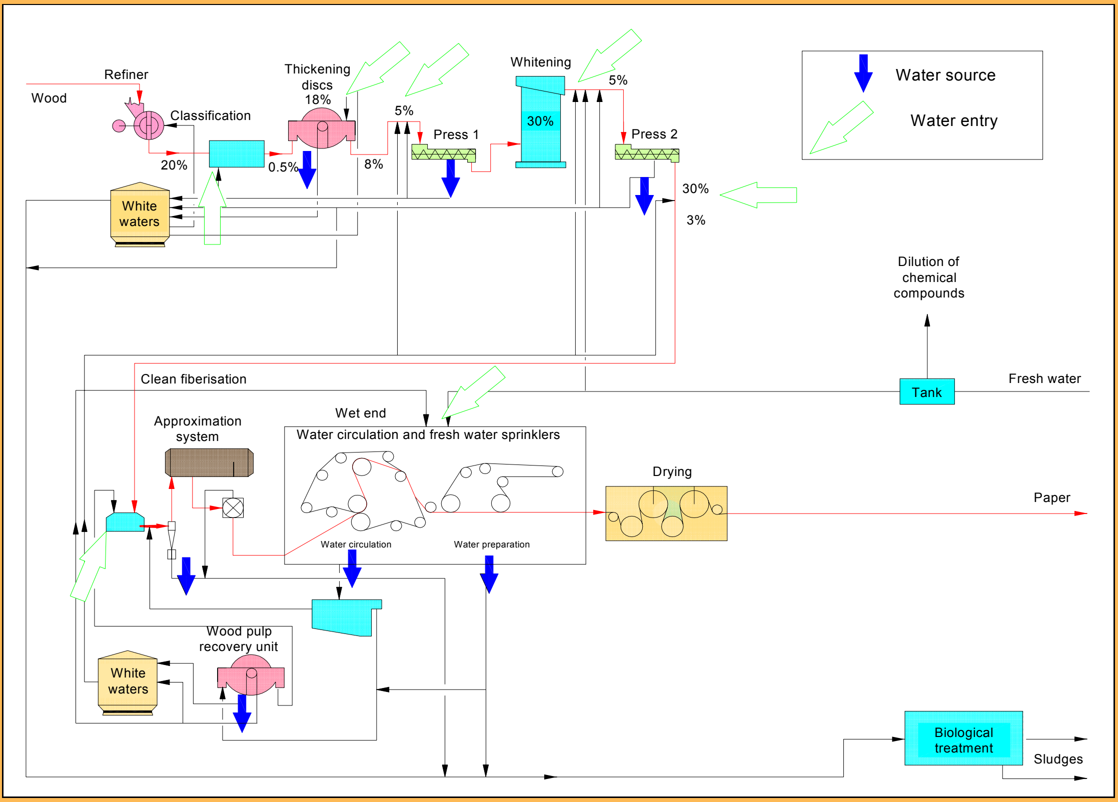


Figure 6.2.1. Main water sources and drains in an integrated pulp and paper mill

Procedure

There are various alternatives for circuit closure. Among the most used are:

- The separation of water circuits depending on their pollutant load.
- The use of water in cascade systems and in counterflow depending on the quality-use requirements. One example of the use of the cascade system is the pulp washing process.
- The use of water for technical purposes in closed systems: Sealing waters, cooling waters, vacuum system waters, etc.
- Sufficient water storage capacity to deal with fluctuations in the process.
- Thickening of the pulp before sending it to the paper plant.
- Reduction of fresh water consumption by recirculating white water, depending on the quality of water required for the different processes.
- The reuse of white waters in sprinklers, where possible.
- Generation of clarified water from the white water and its reuse.
- Reuse of the plant's final effluent as feed water, following filtration.
- Measures to balance the negative effects of the recirculation of process water.

The closing of circuits of water for technical use enables a reduction in cooling water of 10-15 m^3/t of product and the consumption of sealing water can be reduced by at least 1 m^3/t. At the same time it is possible to recover part of the energy, if heat exchangers are used. In general, good water management, without applying any specific treatment, enables a 20% reduction in fresh water consumption (5-8 m^3/t) (these figures depend on the initial situation).

Comments

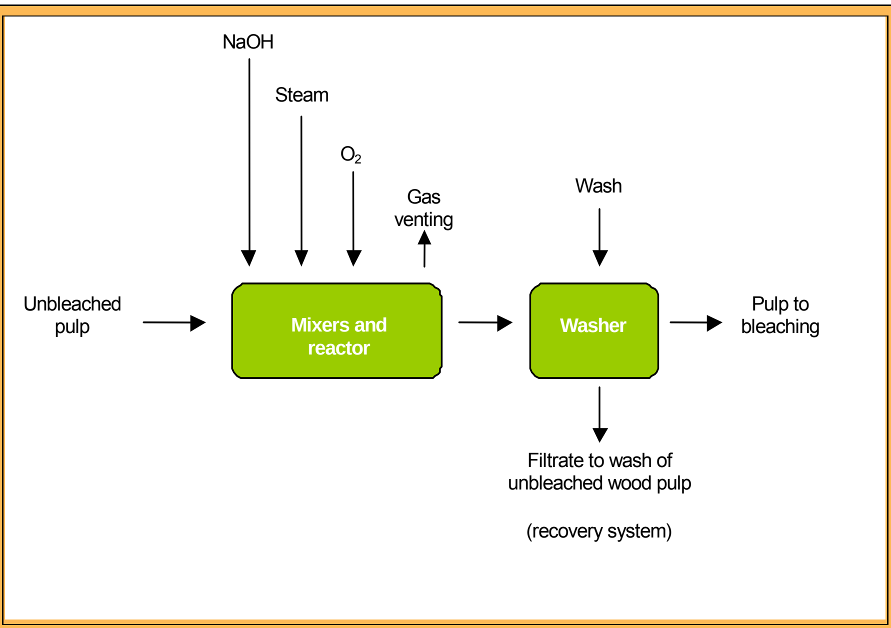
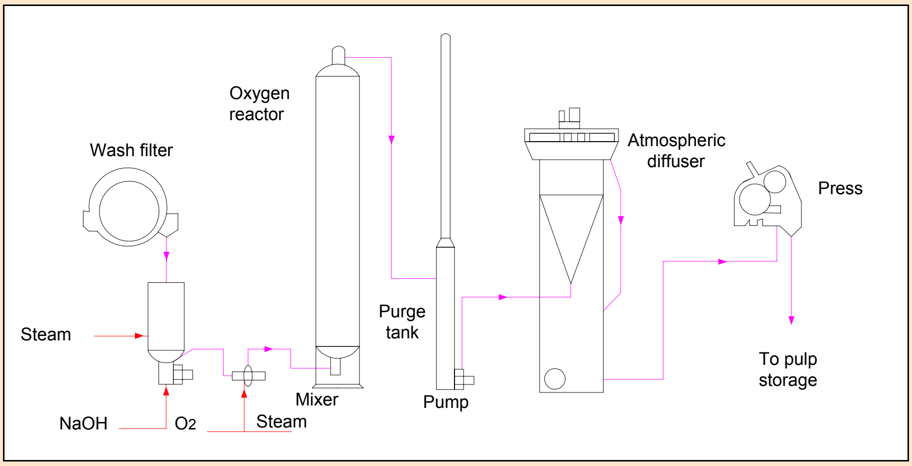
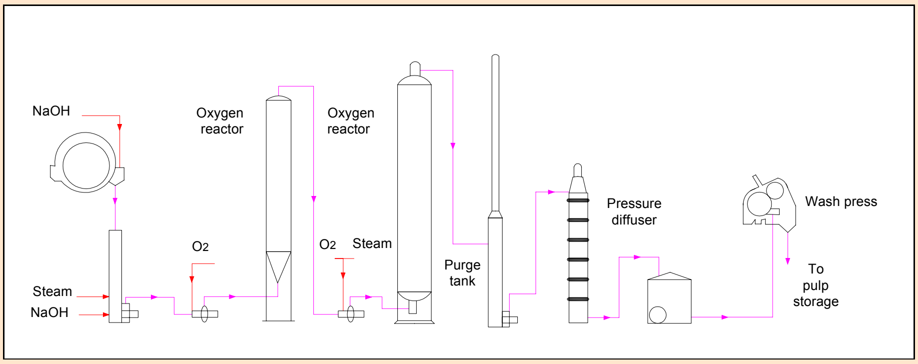
This measure can be applied both in new mills and existing mills. The balance of water has to take place in conjunction with the balance of energy.

Economic aspects	The investment costs for an integrated mill with production of 700 t/year and a reduction in water consumption of 20 m^3/t to 10 m^3/t, is estimated to be around 10-12 M euros. This figure can vary a great deal depending on the quality of the final product. The recirculation of cooling and sealing water requires additional investment for pipes, pumps and water filters. The increase in the capacity for water storage necessitates the installation of new tanks. There are no figures available for specific costs. This technique enables a reduction in the costs of raw materials and energy consumption.

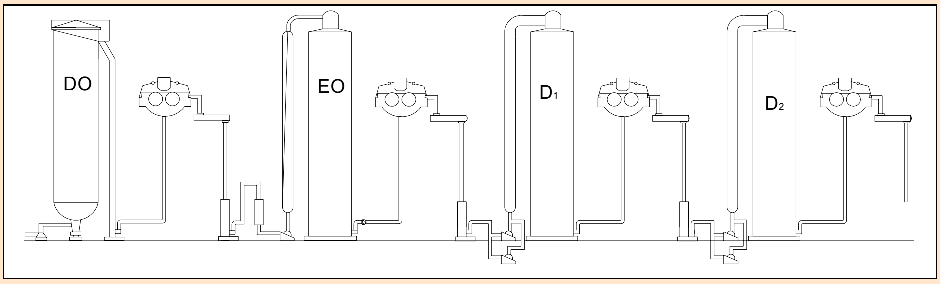
<table>
<tr><td>Alternatives for pollution prevention at source (APPS)</td><td>6.2.3. Oxygen delignification</td></tr>
<tr><td>Process and Action</td><td>Process: Chemical pulp production
Action: Technological changes, recycling at source</td></tr>
<tr><td>Stage / Operation</td><td>Delignification as a step prior to bleaching.</td></tr>
<tr><td>Environmental problem</td><td>Dumping of water with a high organic material content.</td></tr>
<tr><td>Potential benefits of the CP alternative</td><td>

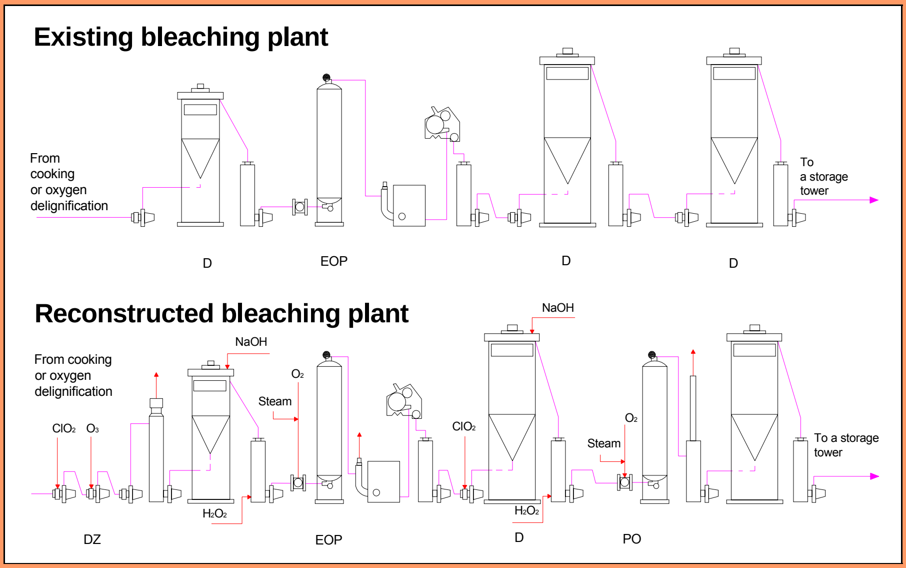
Reduction of the pollutant load of the bleaching effluent: COD and AOX (if agents containing chlorine are used).
Lower consumption of bleaching agents.
Lower bleaching costs.

Table 6.2.1. Characteristics of delignification technology
<table>
<tr><th rowspan="2">Delignification technology</th><th rowspan="2">Kappa for non-coniferous wood</th><th rowspan="2">Kappa for coniferous wood</th><th colspan="2">COD load of bleaching effluent (kg/t)</th></tr>
<tr><th>Non-coniferous wood</th><th>Non-coniferous wood</th></tr>
<tr><td>Conventional cooking</td><td>14 – 22</td><td>30 – 35</td><td>28 – 44</td><td>60 – 70</td></tr>
<tr><td>Conventional cooking + oxygen delignification</td><td>13 – 15</td><td>18 – 20</td><td>26 – 30</td><td>36 – 40</td></tr>
<tr><td>Modified / extended cooking</td><td>14 – 16</td><td>18 – 22</td><td>28 – 32</td><td>36 – 44</td></tr>
<tr><td>Extended cooking + oxygen delignification</td><td>8 – 10</td><td>8 – 12</td><td>16 – 20</td><td>16 – 24</td></tr>
</table>
</td></tr>
<tr><td>Description</td><td>Treatment of the pulp with oxygen in an alkaline medium, at a pressure of 4-5 atm and a temperature of 100ºC, to remove between 40 and 60% of the residual lignin present in unbleached pulp, depending on whether the process takes place in one or two steps.
Oxygen delignification can be carried out at low consistencies (10-15%) or medium consistency (25-30%).
The residual liquors are used in counterflow as wash water for the unbleached pulp and finally, are sent to the recovery boiler.</td></tr>
</table>

	 Figure 6.2.2. Diagram of oxygen delignification
Procedure	 Figure 6.2.3. One stage delignification  Figure 6.2.4. Two stage delignification
Comments / Examples of application	The most modern mills combine modified cooking and oxygen delignification. The advantages mentioned are only attained with an effective pulp washing system. The integration of a delignification stage in existing plants runs a risk of loss of production if the recovery system does not have sufficient capacity to deal with the additional load of organic material generated (70 kg/t for coniferous woods and 45 kg/t for non-coniferous woods, which means 4-6%). In addition, extra

	capacity at the evaporation stage of 0-4% for high consistency systems and 4-10% for medium consistency systems is required. This measure generates an increase in energy recovery from dissolved organic material, but also a reduction in the calorific energy of the black liquors due to the high content in inorganic compounds. The viscosity of an oxygen delignified pulp is less than that of a pulp obtained with a conventional bleaching system. However, there are no significant differences in the final strength properties of the pulp.
Economic aspects	This technique is widely used and could be adopted both by new mills and existing mills, but not in the same way nor for the same cost. Investment costs for an oxygen delignification plant is 35-40 M euros for production of bleached pulp of 1,500 t/d. Operating costs are 2.5-3.5 M euros/year but the reduction of the cost of chemical product consumption in bleaching compensates for these costs.

Alternatives for pollution prevention at source (APPS)	**6.2.4. ECF bleaching**
Process and Action	Process: Kraft pulp production Action: Substitution of raw materials, technological changes
Stage / Operation	Brightening.
Environmental problem	Dumping of waters with high organochlorine compound content.
Potential benefits of the CP alternative	• Reduction of the AOX pollutant load in the bleaching effluent (< 0.3 kg AOX/t of pulp). • Reduction in the formation of organic chlorine compounds and dioxins (2,3,7,8-TCDD and 2,3,7,8-TCDF). • Dioxin reduction depends on the kappa index of the pulp and the ClO_2 impurities.
Description	In ECF bleaching, chlorine gas is substituted with chlorine dioxide as the main bleaching agent, which reduces the formation of organic chlorine compounds and dioxins. ECF bleaching takes place in several stages, which differ depending on the kappa number of the pulp on entry to the bleaching plant, the final degree of brightness desired, and the species of wood that is being processed. Hard woods usually require fewer bleaching stages. The substitution of Cl_2 increases consumption of ClO_2, O_2 and H_2O_2.
Procedure	Possible bleaching sequences are: Soft woods: D(EP)D DPDP D(EOP)DD D(EO)DD D(EO)D(EP)D DQ(PO) D(EOP)DED D(EO)D(OP) D(EOP)D(OP) (OP)DQ(PO) Hard woods: D(EOP)D(EP)D D(EO)D(EP)D D(EOP)DD D(EO)DD QDPZP The approximate consumption of reactives necessary for a D(EO)DD process for a kilogram of pine Kraft pulp following oxygen delignification is: 44 kg of ClO_2, 15 kg of NaOH, 4 kg of O_2 and 1,5 kg of SO_2. In the bleaching of hard pulp, the second stage of chlorine dioxide can on occasion be removed.  Figure 6.2.5. Example bleaching sequence

	D stages are usually carried out at a consistency of 10% for 30 minutes, at a temperature of 60ºC and a final pH of 3.5. The stages of alkaline extraction take place at a consistency of 10-12% for 60 minutes, at a temperature of 60-70ºC and an alkali load of 10-20 kg/t of pulp. Generally an EOP stage takes place, with the presence of oxygen (3-6 kg/tAD) and oxygen peroxide (2-4 kg/t).
Comments / Examples of application	Treatment with peroxide enables a gentle initial treatment with oxygen and the alkaline extractions. In addition, it enables the adjustment of the final brightness in high consistency storage towers. A stage with peroxide allows for the separation of the delignification and bleaching stages. Finally, a PO stage at the end of the bleaching line enables the production of ECF pulp without the need to increase the plant's ClO_2 capacity. Figure 6.2.6. shows an ECF plant without and with the modification of a Z and PO stage.  Figure 6.2.6. Comparison between an ECF plant without the modification with a Z and PO stage, and with the modification At the concentrations of AOX reached in the process waters in an ECF plant, the organochlorine compounds are relatively biodegradable and can be removed in the biological treatment of wastewater. This measure has been adopted in the majority of mills in Europe. The conversion of existing mills to ECF plants requires considerable modifications in the pulp and chlorine dioxide production line and involves an increase in bleaching costs (2-3%).
Economic aspects	Investment costs for the production of 1,500 t/d of bleached pulp are some 8-10 M euros in new mills and 3-5 M euros in existing mills. Operational costs are 10-12 M euros per year. These costs include the need to increase production of chlorine dioxide.

Alternatives for pollution prevention at source (APPS)	**6.2.5. TCF bleaching**
Process and Action	Process: Chemical pulp production Action: Substitution of raw materials, technological changes
Stage / Operation	Brightening.
Environmental problem	Dumping of water with high organochlorine compound content.
Potential benefits of the CP alternative	Removal of the AOX pollutant load in bleaching effluent.
Description	TCF bleaching is carried out using agents that are entirely free from chlorine. To obtain a bleaching standard of 88/90 º ISO, the kappa number of the pulp at the start of bleaching must be under 9, with this depending on the final value of the raw material used and the bleaching sequence chosen. TCF bleaching takes place in several stages, which differ depending on the kappa number of the pulp on entering the bleaching process, the final brightness required, and the type of wood used. The

commonly used bleaching agents are: hydrogen peroxide and ozone and, on occasion, peracetic acid.

Hydrogen peroxide is the most commonly used bleaching agent for TCF sequences, in particular when the wood used is non-coniferous, particularly eucalyptus. To bleach pulps from coniferous wood, ozone bleaching must be used (see alternative 6.3.7). Peracetic acid is not in frequent use. Due to the higher cost of hydrogen peroxide and its lesser bleaching power, in TCF processes the kappa number of the pulp on entry to the bleaching plant is significantly less than that used in ECF bleaching processes. Therefore in this case the pulp undergoes extended modified cooking (see alternative 6.3.6) and one or two oxygen delignification stages (see Data Sheet 6.2.2), in particular when it is coniferous wood that is used.

Before bleaching takes place, heavy and transition metals (Mn^{2+}, Fe^{2+}, ...) must be removed using chelating agents in an acid stage to avoid the rapid decomposition of the perhydroxyl ion.

Procedure

Possible bleaching stages are:

- Q(EP)(EP)(EP) for coniferous wood
- QPZP for non-coniferous wood
- Q(OP)(ZQ)(PO)
- Q(EOP)Q(PO)
- Q(OP)ZQ(PO)

The most usual treatments per tonne of pulp are:

- STAGE Q: 1-2 kg EDTA; pH 5.7 to 6.2; 10% consistency, reaction time 1h; temperature 90ºC.
- EOP STAGE: 10-30 kg NaOH; 3-6 kg O2; 2-4 kg H2O2; pH 11; 1 h; temperature 60-70ºC.
- STAGE P: 20-40 kg H2O2; pH 11-11.5, retention time 4h; temperature 90ºC.
- STAGE Z: 5kg O3; pH 2-3; medium or high consistencies; temperatures below 70ºC; low pressure.

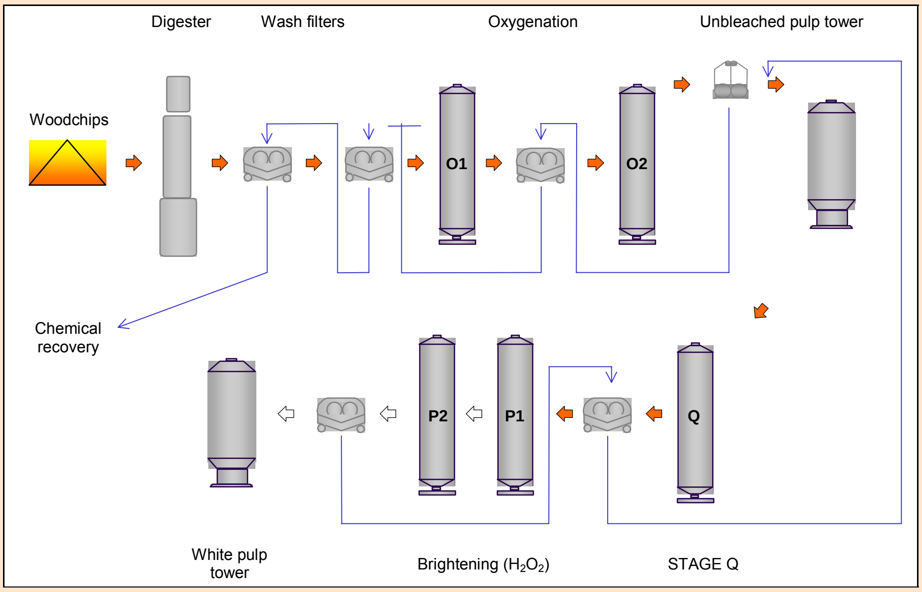
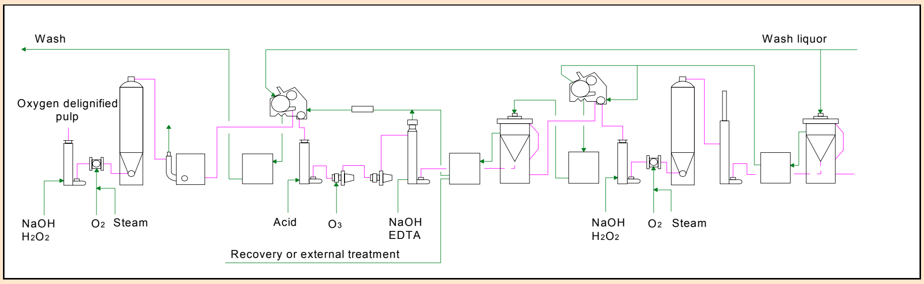
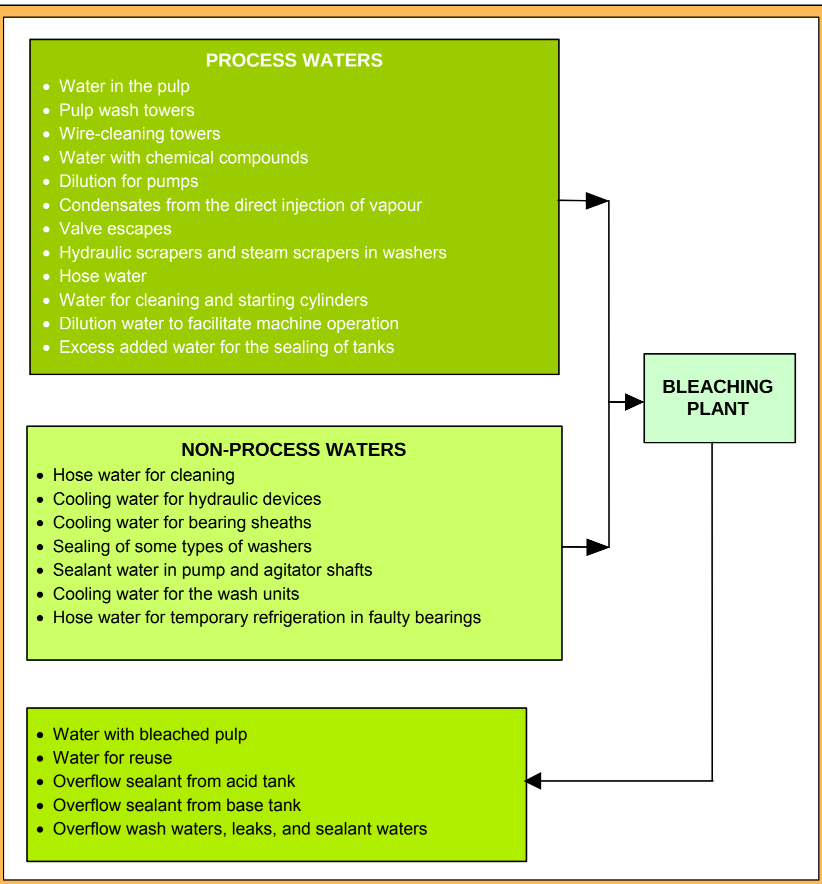


Figure 6.2.7. Example of a TCF process for eucalyptus pulp

	 Figure 6.2.8. Example of a TCF process for resinous pulps
Comments / Examples of application	ECF and TCF pulps can have the same final quality. TCF pulp production costs are higher. Today, ECF sequences are used more frequently. There are companies that produce ECF or TCF pulps in different batches, depending on demand. As in the case of ECF, treatment with peroxide enables a gentle initial treatment with oxygen and the alkaline extractions. In addition, it enables the adjustment of the final brightness in the high consistency storage towers. A peroxide stage enables the separation of the delignification and bleaching stages. Using only H_2O_2 the desired brightness can be obtained but this process is difficult to control on an industrial scale and requires heavy peroxide consumption. This is why oxygen treatment was introduced, which also "activates the fibres", helping the peroxide to act. Treatment with ozone should not be very strong, as it is not a very selective agent and can attack the cellulose fibres. Ozone should be generated in the mill, due to its rapid decomposition, which makes its storage and transportation difficult. This technique can be used in both existing and new mills. Existing mills require a new oxygen and wash stage to convert ECF bleaching into TCF bleaching. If hydrogen peroxide or ozone are used, two new bleaching towers will be required, and the bleaching filters will require reconstruction. Ozone bleaching requires ozone generators and a reactor. In the case of peracetic acid, a bleaching tower is required.
Economic aspects	Investment costs for peroxide bleaching in new mill with production of 1,500 t/d of pulp is 7-8 M euros; in existing mills, the cost is 2-5 M euros, depending on the material of the bleaching equipment. If the materials tolerate hydrogen peroxide, the cost is 2-3 M euros. The additional operating costs of TCF bleaching are considerably higher, of 18-21 M euros/year, due to the high cost of the chemicals.

Alternatives for pollution prevention at source (APPS)	**6.2.6. Closing circuits in the bleaching plant**
Process and Action	Process: Chemical pulp production Action: Technological changes, recycling at source
Stage / Operation	Brightening.
Environmental problem	Wastewater with a high dissolved organic compounds content. Toxicity of wastewater.
Potential benefits of the CP alternative	• Reduction of wastewater at the bleaching stage. • Reduction of the pollutant load of the water. • Reduction of its toxicity.

Description	 Figure 6.2.9. Example of the water balance in the bleaching plant Water consumption can be reduced with the improvement of the different individual operations and the increased reuse of water between the different parts of the process. The first step for closing the water circuit is to make a detailed balance of the water in the bleaching plant. Water in auxiliary circuits that are not considered part of the process are also considered in this balance. These waters should not be mixed with process waters and, if possible, they should work in a closed circuit, such as the sealing water and the cooling water.
Procedure	There are different alternatives for closing the circuits, based on: • Separate recovery of the bleaching effluent and the cooking liquors. The waters are evaporated and reused, and the solids generated are burned in the recovery boiler. Due to the corrosive nature of the liquors, special materials are required for the evaporators. Evaporation requires heavy energy consumption. • Recirculation of only the alkaline effluent in the recovery cycle of the cooking liquors. This minimises corrosion problems, and the acidic effluent can be treated in the biological treatment of the purification station. This effluent can be recirculated both at the wash stage of the unbleached pulp and during the causticising cycle. The latter is the most used alternative, to avoid higher consumption of bleaching agents. Recirculation is limited by the available capacity in the evaporators. As a preliminary step, membrane filtration can be carried out to concentrate the solids, although this technique presents numerous operating problems.

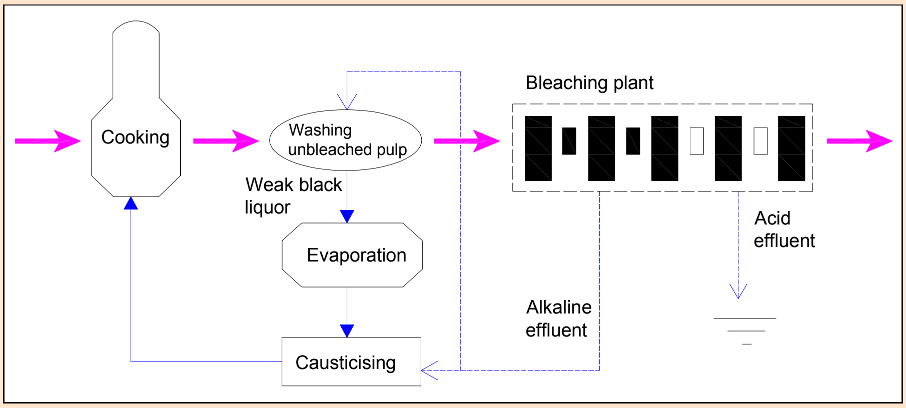


Figure 6.2.10. Recirculation diagram of the alkaline effluent in the recovery of cooking liquors

- Recirculation of both bleaching effluents in the liquor recovery cycle. This presents problems of corrosion, an increase in consumption of chemicals, the formation of deposits, high evaporation costs of the white liquor, the need to purge the chlorides and metals, etc.

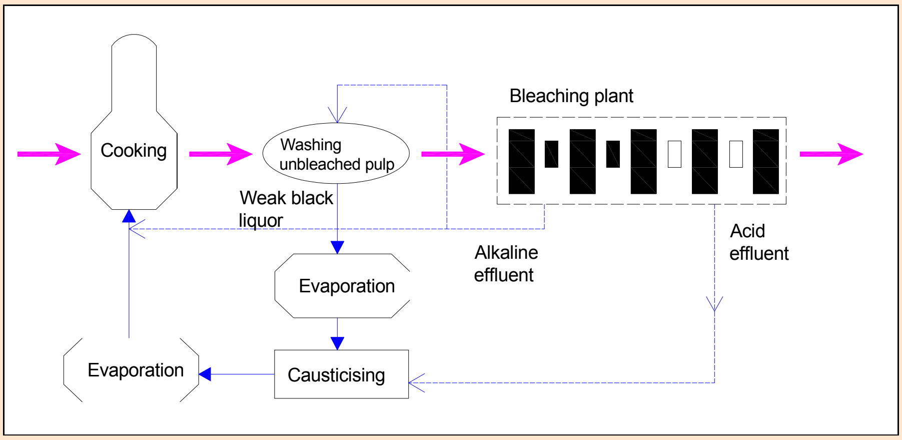


Figure 6.2.11. Recirculation diagram of the acid and alkaline bleaching effluent in the recovery of liquors

In practice, only the partial closure has been obtained, applying for example the concept of BFR® (Bleach Filtrate Recycle). Treatment is also considered for the removal of chlorides, CRP® (Chloride Removal Process) and a system for the removal of metals, MRP® (Metal Removal Process).

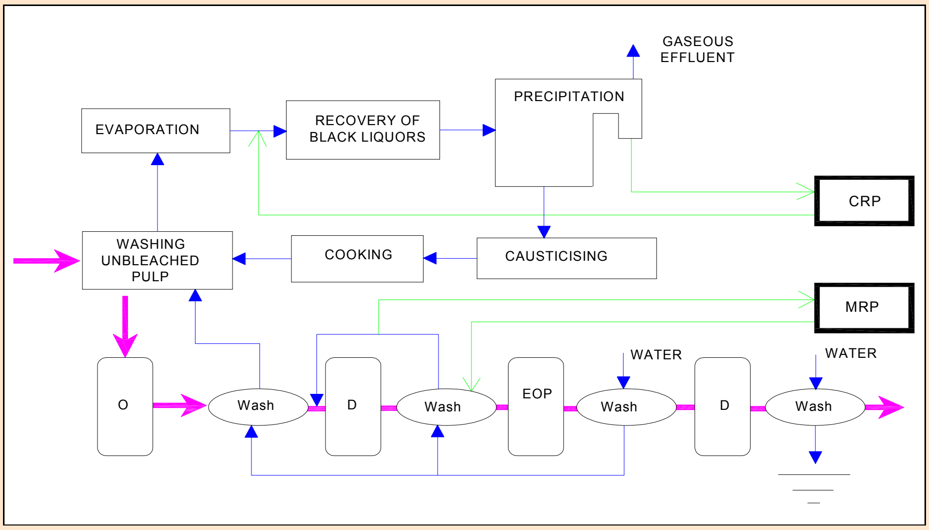


Figure 6.2.12. Treatment diagram for the removal of chlorides, CRP® and a system for the removal of metals, MRP®

Examples of the water circuit in a plant with 4 and 3 washers is shown below. The fresh water or white waters are fed into the lower sprinklers of the last washer and are used in counterflow, which means that they end up for the most part in the wastewater. The hot water is used in the upper sprinklers of the washers and leaves the plant with the pulp.

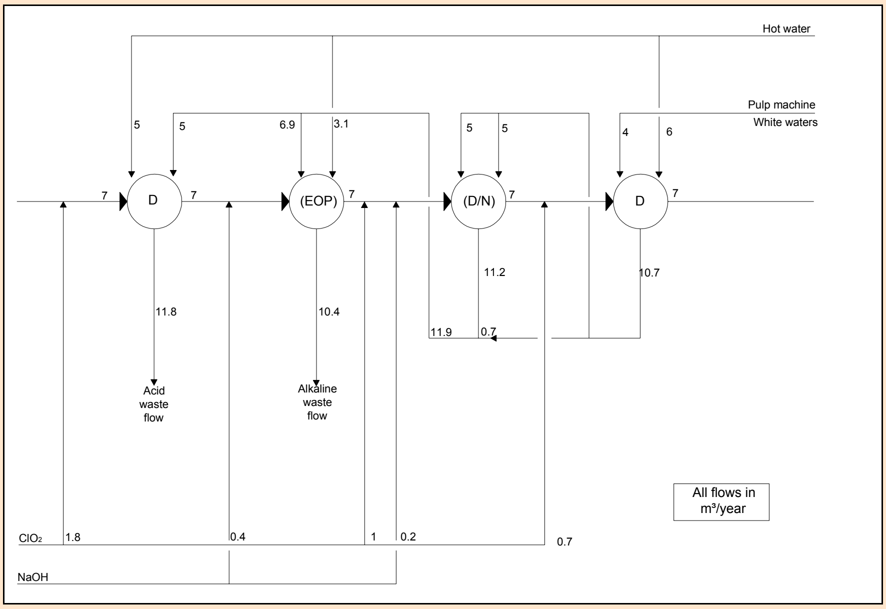


Figure 6.2.13. Diagram of a water circuit in a plant with 4 washers

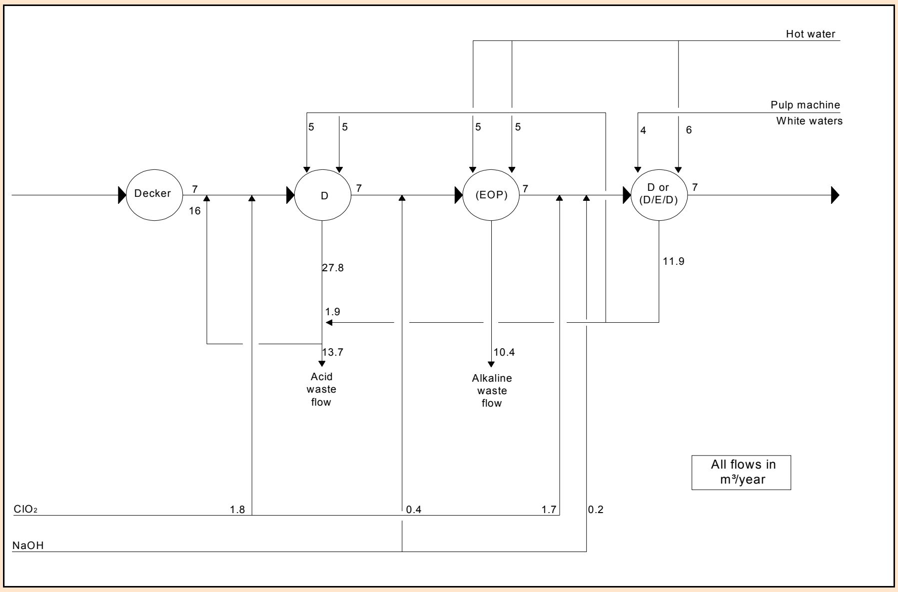


Figure 6.2.14. Diagram of a water circuit in a plant with 3 washers

In order to close the water circuits and avoid the dragging out of bleaching products with the pulp to the paper machine, it is imperative that the water be separated from the pulp. To do this, presses are used in the final bleaching stage. These allow the consistency of the pulp to be increased on exit from bleaching from 10-15% to 25-35%.

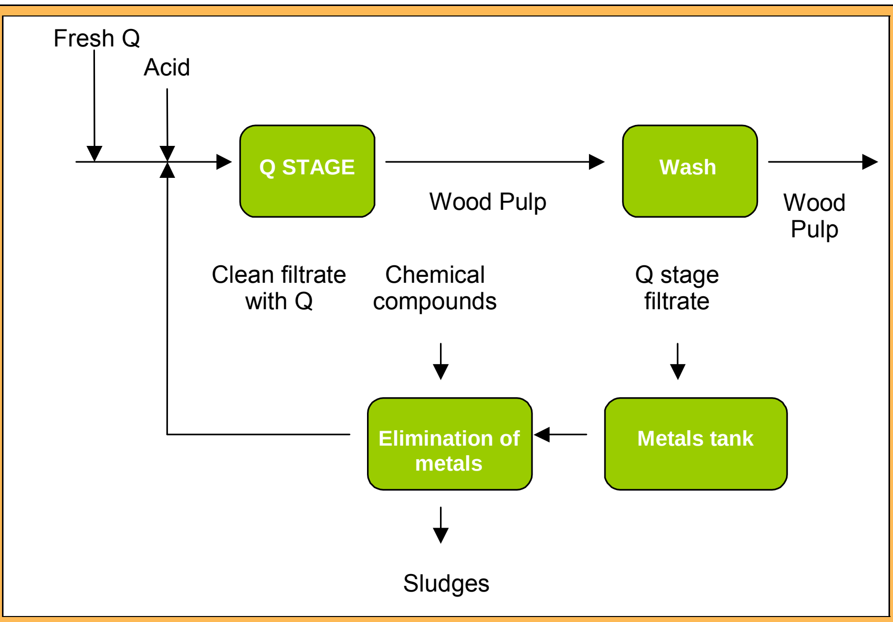
Comments / Examples of application

The wastewater from bleaching constitutes around 50-70% of total wastewater in the pulp producing mill. The partial closure of the bleaching waters circuit would therefore have a direct impact on the mill's overall wastewater.

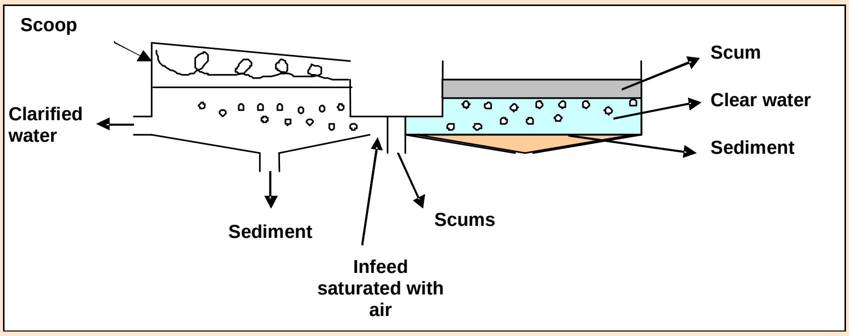
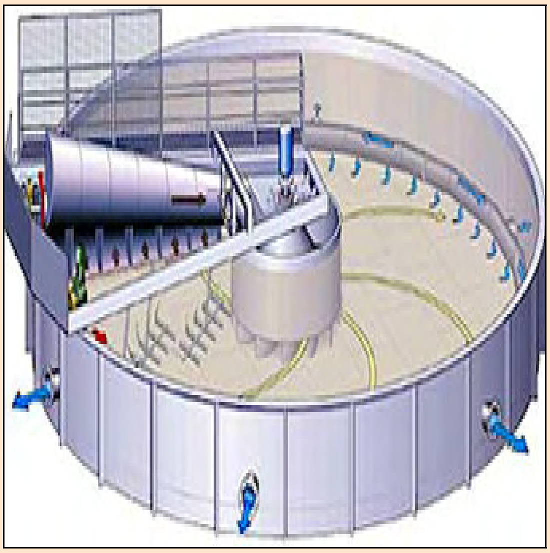
The factors determining water reuse are: The design of the washers, the load of pulp used, the number of washers used, the design of the filter water storage tanks, etc.

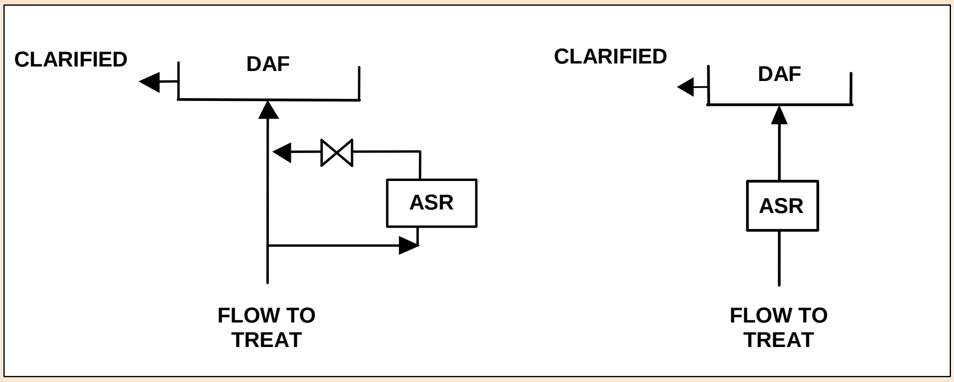
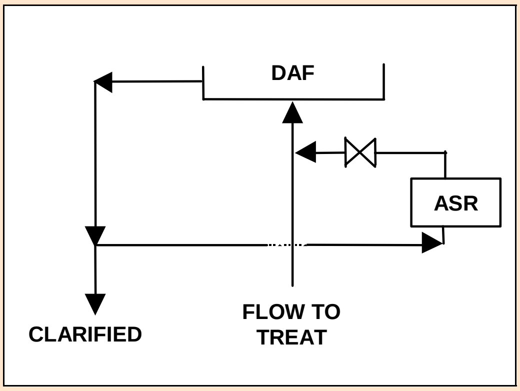
Optimum pH control is essential at each stage of bleaching to avoid negative effects from residual chemicals that diminish the effectiveness of other bleaching agents and can reduce the final brightness level of the pulp.

	The problems associated with the closure of water circuits are: - Chloride accumulation: problems of corrosion in the evaporators and in the recovery boiler. This problem is particularly serious in plants using chlorine compounds for bleaching. - Accumulation of elements foreign to the process: These are usually inorganic elements which are soluble in an acid medium and which precipitate in a basic environment. They cause encrustations and deposits (Al, Si, Ca, Ba); corrosion (Cl, K, Mg); blockages in the recovery furnace (Cl, K); accumulation of inert elements in the lime cycle (P, Mg, Al, Si); these reduce the effectiveness of the oxidant bleaching agents H_2O_2 and O_3 (Mn, Fe, Cu); they have an environmental impact on the waters (N, P, Cd, Pb), etc. - Modification in the Na/S relationship: the recirculation of bleaching effluent can vary the sulphur levels of the cooking medium. In general there are more Na losses that S losses, which means that sulphur must be purged from the system periodically. - Accumulation of organic material: this can affect the pulp quality, the consumption of bleaching agents and can lead to the formation of deposits. There are different possibilities to minimise water consumption during bleaching. Some examples are: - Minimising the use of fresh water. Using it only in the washer sprinklers in the last two stages. - Control of the flow of the washer sprinklers depending on production. Improving the distribution of water in the sprinklers. - Control of the consistency on leaving the washers. Maintaining the maximum consistency while attaining a good wash ratio. - Control of the ratio of the water-pulp relationship at the different stages (optimising water consumption in relation to the brightness desired). - Control of the air present in the filter waters. - Optimising the number of washers: for example a washer after the H, D_1 and E_2 stages is not entirely necessary. - Optimising the operation of the washers. - Using filtrate water to clean the wires. - Substituting fresh water with white water in integrated mills. - Carrying out the first stage of bleaching at medium consistency. - Reusing filtered bleaching water to wash the unbleached pulp.
Additional alternatives	In the effluent of TCF processes there is a concentration of chelating agents (EDTA and DTPA) of 10-15 mg/l when 2 kg chelating agent per tonne of pulp is used. Although these compounds are not toxic in themselves, the worry is that they will mobilise metals in the sediments, and therefore an alternative for their removal is considered. - Although in conventional biological treatment only 10% of the EDTA is removed from the waters, a change in the processing pH from 7 to 8 or 9 would enable 50% to be removed. This reduces EDTA concentration in the water to 2-4 mg/l. When the process is optimised, the breakdown of organic material would not be affected. - Separate treatment of effluent from the chelating stages to separate the metals from the chelating agents and remove them from the system, while the treated effluent is recirculated. This can reduce chelating agent consumption by over 50%. The separation of the metals is achieved in an alkaline medium and following this they must be destabilised and precipitated, using the appropriate chemical agents (such as in the PEO/phenolic resin system). It is estimated that removal of Ca, Mn ph enolic Fe is of 80%, although this alternative is still not in widespread use and not much industrial data is available.

	 Figure 6.2.15. Diagram of the separate treatment process of effluent from the chelating stages
Economic aspects	It is difficult to estimate the economic costs. The application of some good housekeeping practices in water management can be carried out at low cost. However, considerable investment is called for in order to close the circuits: the total reconstruction of the water distribution system in the bleaching plant; storage tanks for filtrate water; the implementation of the strategic control of the water system, etc.

Alternative for pollution prevention at source (APPS)	**6.2.7. Water clarification by dissolved air flotation**
Process and Action	Process: Production of recovered paper pulp and paper. Action: Technological changes, recycling at source.
Stage / Operation	Recycling process waters in pulp or paper plants. This is used extensively to recycle the waters in recovered paper plants with de-inking.
Environmental problem	The paper sector consumes large quantities of water, which means that it is necessary to increase the level of closure of the circuits. To close the circuits, avoiding the accumulation os pollutants, it is necessary to clarify the process waters before their reuse. The best available technique today for the removal of suspended solids and dissolved and colloidal material is through dissolved air flotation (DAF).
Potential benefits of the CP alternative	• Reduction of the water's content in solids and dissolved and colloidal materials. • Adjustment of water quality to reuse it in a closed circuit (determined level of closure). • The saturation with air (oxygen) of the process water prevents the formation of anaerobic bacteria. The main advantage of DAF is that in addition to eliminating suspended solids, part of the colloidal material present in the waters can be removed. This amount is relatively high in plants with de-inking. Using the DAF technique for the treatment of the appropriate flows, the degree of closure of the circuits in the water system can be constantly adjusted, achieving the quality of water required for its reuse in different parts of the process, depending on the concentration of anionic trash in the circuit, the consumption of additives and the required quality of the product.
Description	Dissolved Air Flotation (DAF) is a process to remove fine materials from an aqueous solution. The energy necessary for effective flotation is brought in the form extremely small air bubbles, which join to the material in suspension. The attraction between the microbubbles and the particles is the result of forces of adsorption, which are a function of the characteristics of the particle surface, and the physical attraction in the particle. The joining of bubbles to the particle reduce its density, resulting in increasing flotation, which leads to these aggregates rising to the surface, forming scum. The floating sludges are separated, drained and discharged with the solid waste from the plant. Generally, coagulants and/or flocculants are used to encourage the destabilisation of the dissolved and colloidal material, forming flocs that join with the bubbles more easily.

	The optimum efficiency of the system is good, but it depends on various factors that should be monitored and controlled: pH, flow, size of the air bubbles, consistency of the waters, dosage of flocculants, etc.
Procedure	The suspension to be treated, resulting from the process, is totally or partially saturated with air, and is introduced into the lower part of the flotation cell, where it expands, resulting in the emission of the air bubbles that were absorbed in the liquid. The bubbles formed trap the solid particles and rise to the surface, forming scums that will be collected by mechanical means, by a scoop, which is a cone that turns on the surface of the water, collecting the scum that forms. The scoop has a spiral on its inside to break down the scum, so that it will be collected more easily by the inner deposit of the cell. There is also a phenomenon of sedimentation of the particles and the aggregates. This sediment is waste that is collected by scrapers at the bottom of the tank and is removed through the bottom part of the cell. The clarified waters are obtained from the side of the cell, where scum formation is less.  Figure 6.2.16. Obtaining clarified water using the DAF process  Figure 6.2.17. DAF operational principles This equipment can work in three different operational modes, depending on the fraction of water that is saturated with air in the air saturation tank: • Partial flow mode, in which part of the infeed goes through the saturation tank and is then mixed with the main flow again. • Total flow mode, in which all of the infeed is saturated with air. • Recycling mode, in which the flow that is saturated is not the main infeed flow, but rather part of the clarified water obtained in the flotation machine itself, which is recirculated through the saturation tank.

	 Figure 6.2.18. Diagrams of Partial Flow Mode and Total Flow Mode respectively  Figure 6.2.19. Diagram of Recycling Mode
Comments	In paper manufacture, the use of dissolved air flotation cells is fairly widespread, particularly in the treatment of wastewater flows for the removal of pollutants and the recirculation of these flows. These can be used in the main loops of the process, both in the manufacture of pulp and of paper. One possible location is for the treatment of the clear filtered water from the disc filters. Another option is their incorporation into the treatment of sludges, for the treatment of waters from the gravity table and from the screw presses. Sometimes improvements to the water clarification system is combined with improvements in the water circuits. These can be implemented both in existing recovered paper mills and in new ones.
Operational experiences	The efficiency of the system depends on the following parameters: • Level of liquid in the cell; depending on the level of scum removal desired, a higher level of liquid results in a higher quantity of rejects collected by the scoop, but also a reduction in certain cases of the yield from the process. This level is controlled by the discharge tube. • Turn speed around the axis of the cell. The higher the speed at which the scoop circles the scum, the greater its total collection capacity, but this can result in turbulence that decreases the yield from the process. • Turn speed of the scoop around its own axis. This determines the quantity of scum removed and the state of the scum. If the speed is too great, the scoop can overflow, with the consequent lack of effectiveness of the process. • Air pressure in the reactor, which determines the quantity of air dissolved in the liquid and therefore the quantity and size of the bubbles formed. It should be remembered that the solubility of the air decreases as the temperature increases. • Relationship between the pressurisation flow and the flotation flow. It is also important to consider the possible incorporation of an additive to encourage particle removal. Usually, flocculants or coagulants are added at relatively low levels (2-5 mg/l). These compounds produce aggregates of particles that are easily dragged out by the bubbles. Aggregates that are large in size rise immediately and are collected in the part nearest the centre of the cell, while smaller aggregates are projected to the outer edge by centrifugal force, where the larger-sized bubbles can drag them to the surface. By optimising the dose of chemicals, effectiveness of over 98% can be achieved in the reduction of turbidity and suspended solids. The removal of COD depends on the characteristics of each process.

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Reductions of 5-15% have been obtained. It has also been observed that microstickies and secondary stickies can be removed with this technique.

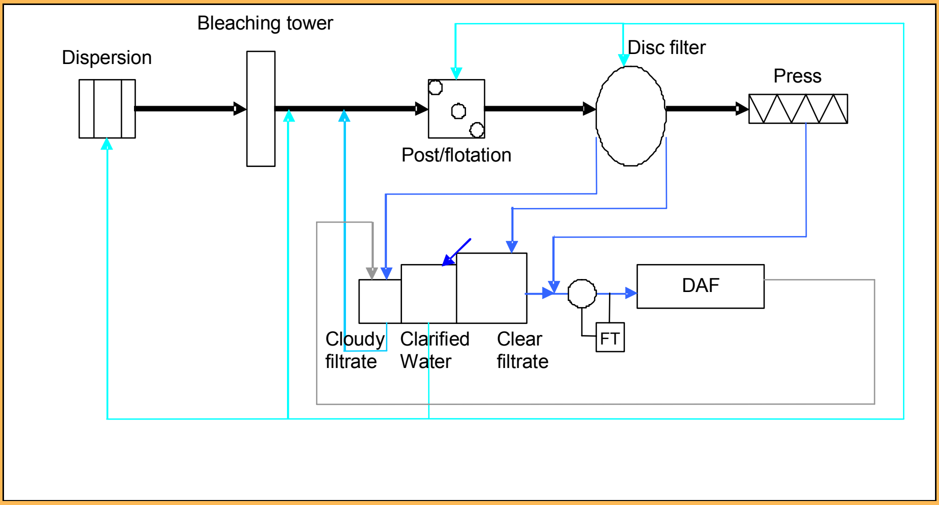

Figure 6.2.20. Example 1: Treatment of process waters in a de-inking plant

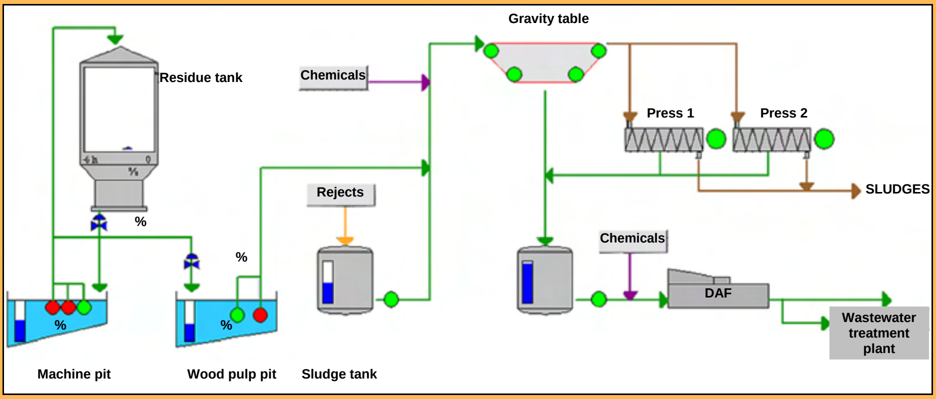

Figure 6.2.21. Example 2: Treatment of sludge dewatering waters
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Alternative for pollution prevention at source (APPS)	**6.2.8. Water clarification with membrane systems**
Process and Action	Process: Paper production. Action: Technological changes, recycling at source.
Stage / Operation	Recycling process waters in pulp or paper plants. This can also be used to recycle the waters in recovered paper plants with de-inking.
Environmental problem	The paper sector consumes large quantities of water, which makes it necessary to increase circuit closure levels. To increase circuit closure avoiding the accumulation of pollutants, it is necessary to clarify the process waters before their reuse. Conventional filtration cannot effectively remove the solid and colloidal material that is under 1 µm in size. An alternative for this clarification is the flocculation of colloidal material and its filtration with membranes.
Potential benefits of the CP alternative	• Removal of nearly 100% of organic and suspended matter (suspended solids, colloidal materials, anionic trash, organic compounds with high molecular weight) without the introduction of undesirable compounds into the water circuits. • Membrane filters with small pore size (Nano Filtration (NF) and Reverse Osmosis (RO)) can reduce the quantity of inorganic material; however, the energy/pressure requirements of these systems increases exponentially with the degree of removal of salts or organic compounds of low molecular weight.

- Reduction in the nutrient load (N and P) of the discharged waters, produced indirectly by a reduction in the quantity of water consumed and biologically treated.

Description

Membrane filtering is a technique that separates molecules depending on their size. The filtered water is known as permeate, and the concentrate as retentate. The mode of operation is shown in figure 6.2.22. The usual means is to use a pressure gradient to produce separation.

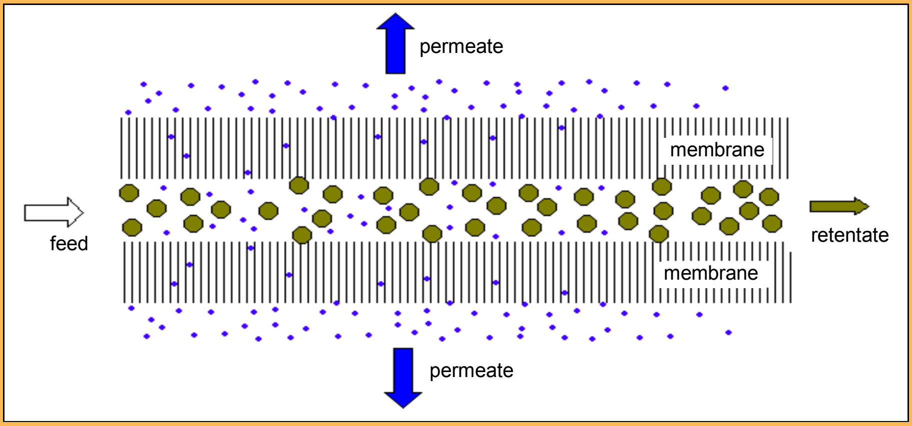


Figure 6.2.22. The principle of membrane filtering

Depending on pore sizes, different membrane processes can be distinguished:

- *Microfiltration*, which operates at a pressure of under 1 atm, and uses membranes with pore size of 0.1-0.2 µm, can be used when a quantity of 1-5 mg/l of very fine solids can be permitted after the process.
- *Ultrafiltration* (UF), operates at a pressure of 1-2 atm and is considered to be a possible solution for the removal of 100% of the total suspended solids, 99% of bacteria, 100% of turbidity (all of the colloidal material is removed) and 45-70% of anionicity. COD decreases by around 10-20%. This means that UF allows organic substances (organic compounds of low molecular weight) and soluble inorganic material to pass through. It should be considered that the UF of white waters improves the quality of recirculated water, which can be used in sprinklers (of low and high pressure), in the wire section, in the dilution of chemical compounds, as water for the lubrication of the pressing section, and other uses for washing and cleaning. However, the efficiency of removal of the membranes in UF depends on the permitted levels of pollutants in the paper machine, as does the specific uses of the recycled water.
- *Nanofiltration* (NF) or *reverse osmosis* (RO), operate at pressures of 15-25 atm. These methods have still not been considered in the paper industry for their application in the treatment of white waters.

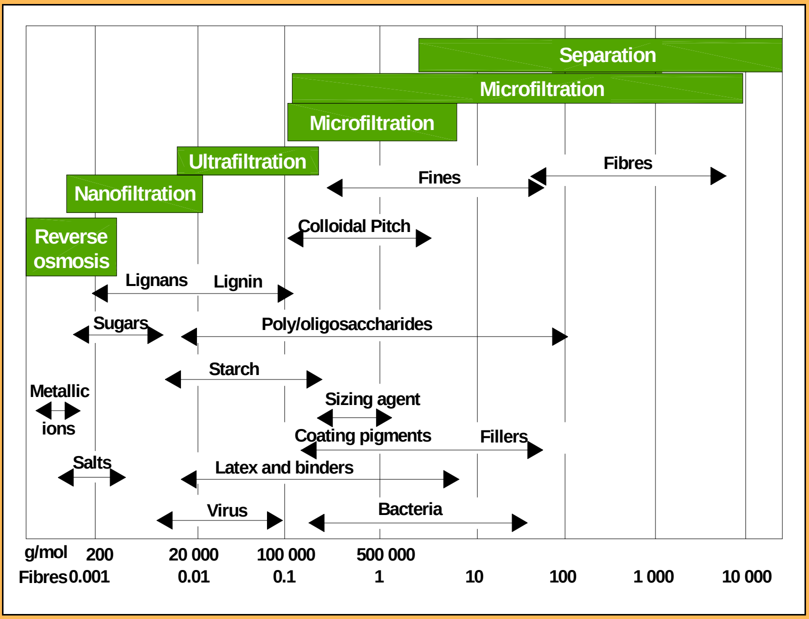
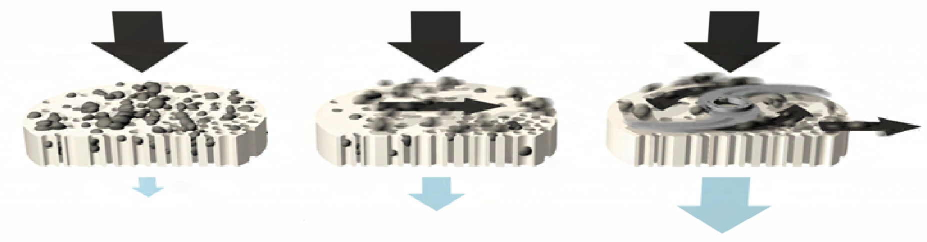
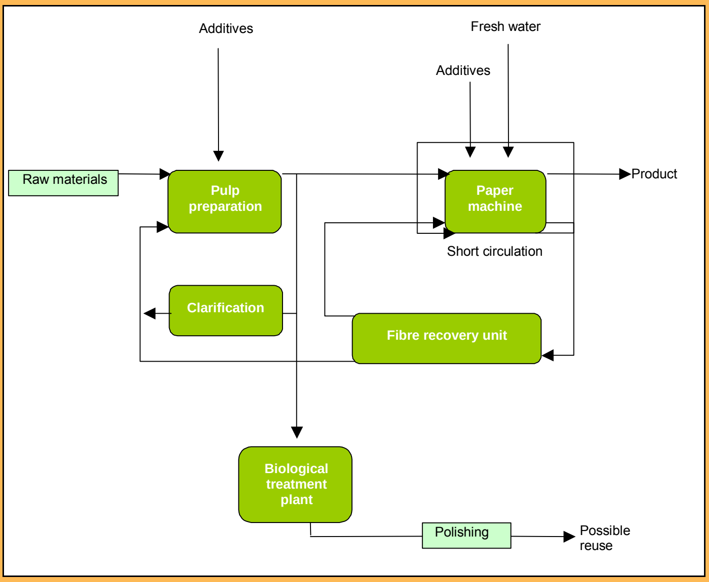


Figure 6.2.23. Separation of pollutants by different membranes

	The concentrate resulting from the filtration membrane (3-5% of the load) is taken to a biological treatment plant or incinerated. The latter case requires an initial concentration stage prior to combustion. Today there are studies being carried out on the possible reuse of the permeate in other areas to replace fresh water.
Procedure	Some aspects affecting the selection of membrane technology are outlined below. • Input flow, its composition and hydraulic load. • The flow of clarified water and the quality required. • Filtering at high pressure produces highly clarified waters, but consumes more electricity and should be equipped with efficient treatment systems to avoid the filters becoming blocked. • Maintenance requirements (symmetrical or asymmetrical membrane structures, acid or alkali wash, space capacity, automatic or continuous cleaning). Symmetrical membranes have more of a tendency to get dirty. Blockages can be avoided by using pre-filters and maintaining conditions of high turbulence, but this requires greater energy consumption.  Pre-filter · Tubular filtration Cross-flow · CR Filtration Improved cross-flow Figure 6.2.24. • Final treatment and disposal of sludges and concentrates. Liquid waste can be sufficiently concentrated as to cause toxic effects, which means it may require further concentration and absorption in order for it to be removed as solid fuel by incineration. After they have been clarified in the disc filter and the filtration system, white waters can be clarified using UF. The number of filters in the operation regulates the capacity of permeation of the UF.
Operational experiences	This process has only been implemented in its complete form in a small number of mills. One of the practical limitations of membrane filters is the material of the membrane itself, as it is sensitive to blocking if it is not furnished with a pre-treatment system for the removal of solids, or cleaning treatments, or if strong turbulence is not maintained near the surface of the membrane. Where appropriate, the filters must be washed using acid or alkaline solutions (NaOH, detergents, etc.), generating small quantities of liquid waste. The membranes should be changed after a certain length of time, the average lifespan of a membrane being around 15 months. This technique can be used in cases where water is scarce.
Economic aspects	Investment in a UF process is 1.1 M euros for a flow of 1,500 m^3/d. It is estimated that the payback period for the investment is approximately 5 years. The cost of filtering white waters with membranes is around 0.3-0.4 euros/m^3. Maintenance and service costs are around 0.05 euros/m^3, energy costs are around 0.07 euros/m^3 and cleaning the membranes with chemical compounds is around 0.02 euros/m^3. Total operational costs are approximately 0.14 euros/m^3.

Alternative for pollution prevention at source (APPS)	**6.2.9. Optimum water management. The reduction of fresh water consumption by means of the separation of water circuits and counterflow**
Process and Action	Process: Paper production Action: Technological changes, recycling at source
Stage / Operation	Water circuit.
Environmental problem	High water consumption and wastewater treatment costs. Bad water management within the industry.

Potential benefits of the CP alternative	Reduction of fresh water consumption without increasing the concentration of pollutants in the water circuit of the paper machine, so that this does not affect the quality of the final product nor the machine's productivity. Reduction in wastewater flows, improvement of the efficiency of treatment in operating wastewater plants. The separation of the water circuits enables the complementary application of other pollution reducing alternatives based on the internal treatment of the most contaminated flows and their recirculation.
Description	The objectives of optimum water management are to minimise water consumption at each stage of the process, to recirculate water directly at those points that this is possible, to clarify some flows for their reuse, to close water circuits without affecting the quality of the product or the productivity of the machine, and to minimise the environmental impact of the final effluent. A widely used alternative in integrated pulp and paper mills is the separation of the different water circuits and the counterflow of the white waters from the paper machine to the pulp plant. The excess white waters, once cleaned in the fibre recovery units, are used instead of fresh water in the bleaching plant, and the excess water from the bleaching plant is used, instead of fresh water, in the production of pulp. This recirculation system allows a substantial reduction in water consumption, so that the consumption of fresh water is only necessary in the paper machine's system, where the demand for quality is higher (generally it is used for the preparation of chemicals and for specific sprinklers). Water consumption depends on the quality of the product to be manufactured. For example, in the case of tissue paper, large quantities of fresh water are required to maintain efficiency in the washing of the formation wire.  Figure 6.2.25. Diagram of the water circuit in a paper mill
Procedure	It is important to minimise the flow of water in the direction of the product in order to avoid the dragging out of pollutants to the circuits of higher quality water. To do so it is necessary to increase the consistency of the pulp fed into the bleaching plant and the pulp sent to the paper machine as much as possible. The separation of water circuits is done using thickeners, for example with dewatering screws or presses, which increase the consistency of the pulp to 30-35%.

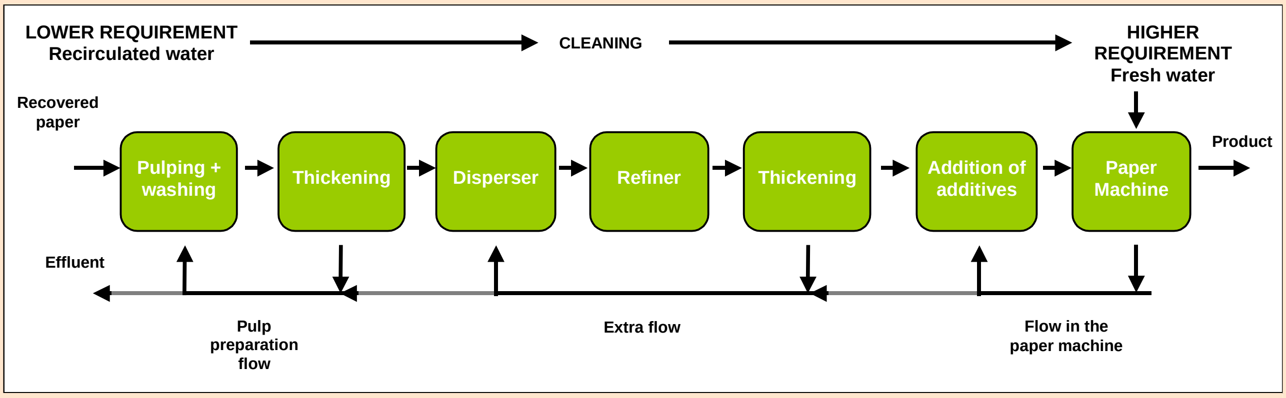


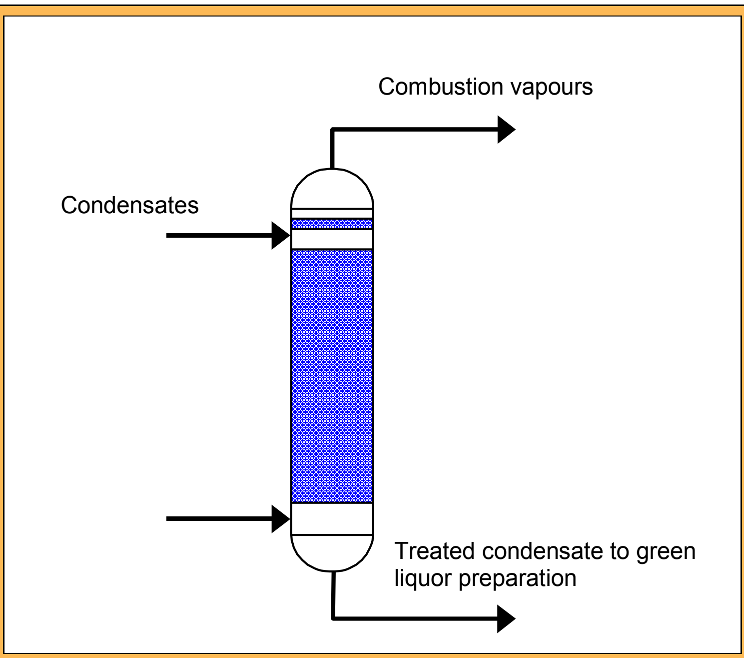
Figure 6.2.26. Water recirculation in paper mills with effluent separation and counterflow circulation

Comments	This integrated process technique can be applied in both new and existing mills. The principle described of recycling white waters through a counterflow is used mainly in integrated plants and paper plants where recovered paper is used as a raw material. In this case white waters are used in the pulp preparation plant, which can have 1 or 2 separate water circuits. The dirtiest water is that used in the pulper for the disintegration of the scrap paper.
Economic aspects	The costs of this measure depend on the reordering that is necessary for the water system and on the additional facilities required.

Alternative for pollution prevention at source (APPS)	**6.2.10. Purification by scrubbing of the gases from the recovery boiler**
Process and Action	Process: Chemical pulp production. Action: Technological changes.
Stage / Operation	Combustion of the black liquors.
Environmental problem	High levels of SO_2 emissions.
Potential benefits of the CP alternative	• The installation of a scrubber at the gas outlet of the recovery boiler reduces SO_2 and TRS emissions by over 95%. This means that emissions are reduced from 0.5-2 kg S/t to 0.1-0.3 kg S/t. • Energy recovery: hot water production. This technique is an alternative to measure 6.3.18. of incrementing the concentration of the black liquor and is complementary to alternative 6.2.14. in which combustion gases are treated in an electrostatic precipitator. The combination of both alternatives enables the reduction of acid gas emissions by over 95% and of particles that are not retained in the electrostatic precipitator by 90%.
Description	Wet gas desulphuring procedure based on the use of an alkaline solution as absorption system, given the acid nature of the gas to be removed (SO_2).
Procedure	The scrubber generally consists of two stages: previous contact with the scrubbing solution, in which the hot gases are cooled by saturation with the evaporated water, and a second stage in which the cold scrubbing solution is recirculated. The SO_2 and the particles are removed in the scrubbing zone. The scrubber requires alkali in the form of oxidised white liquor, weak liquor or sodium hydroxide, to maintain the pH level at 6-7. A higher pH fosters the removal of H_2S, but also results in the absorption of CO_2, making the alkali consumption excessive. The used scrubbing solution is used for the preparation of white liquors, meaning that the scrubber operates with no water discharge. Before the gases are released, they pass through a mist eliminator.  Figure 6.2.27. Image of the mist eliminator
Comments / Examples of application	The use of scrubbers has the following disadvantages: • Energy consumption in the circulation of gas and of the scrubbing solution.

	• Loss of floating capacity of the steam-laden emissions from the chimney, due to the cooling of the gases. • The emission gases are saturated with steam, making the plume visible, especially in cold countries. The installation of scrubbers can be implemented with no problem both in existing boilers and new ones, although the cost in the former case is greater. The investment cost for a bleached Kraft pulp plant with a production capacity of 250,000 and 500,000 tonnes/year is of around 7.2 M euros and 10.4 M euros respectively. This cost includes the scrubber, the necessary pumps, the electrification and the instrumentation. Operating costs are around 0.6 and 1.0 M euros/year respectively.
Economic aspects	The investment cost for a bleached Kraft pulp plant with a production capacity of 250,000 and 500,000 tonnes/year is of around 7.2 M euros and 10.4 M euros respectively. This cost includes the scrubber, the necessary pumps, the electrification and the instrumentation. Operating costs are around 0.6 and 1.0 M euros/year respectively.

Alternative for pollution prevention at source (APPS)	**6.2.11. Purification and reuse of the most-contaminated condensates from the evaporation plant**
Process and Action	Process: Chemical pulp production. Action: Technological changes, recycling at source.
Stage / Operation	Evaporation plant and cooking stage.
Environmental problem	High water consumption. Dumping of water with a high volatile organic material (methanol, acetone, terpenes...) and TRS content. For the reuse of the condensates from multiple evaporators, it is necessary to remove the volatile compounds by stripping. Then the stripping vapours have to be condensed for their reuse as process water, or incinerated.
Potential benefits of the CP alternative	• Reduction of the pollutant load and the odour from condensates produced in the Kraft process. Reduction of COD in wastewater. • Savings in fresh water by reusing condensates. • The stripping of condensates together with the incineration of non-condensable gases reduces the emission of TRS compounds, malodorous substances and VOC emissions.
Description	The contaminated condensates from evaporation and cooking, together with the weak liquors from overflows and losses in the manufacturing circuit, are suitable for treatment in a stripper, where the clean condensates will be separated from the non-condensable gases. The stripping operation takes place in a tower with steam, which can be integrated into the evaporation plant, or separate. The clean condensates obtained by stripping can be reused in several stages of the process, for example as wash water in the unbleached pulp washing plants and the bleaching plants. The stripping vapours are condensed, adjusted to recover organic products or sent for combustion in the bark furnace, the lime kiln or in the auxiliary boilers.

	 Figure 6.2.28. Steam stripping column where the stripping operation takes place
Comments / Examples of application	In general, only 1 m^3 of the 8-10m^3 of condensates produced per tonne of pulp is very concentrated, with a COD of 10-20 kg/m^3. The level is higher in condensates from hard woods than from soft. On occasion condensates with medium pollutant loads are also treated. The removal of pollutants in the stripper is 90%, although this depends on the pH, and COD values of 1.0-1.5 kg/m^3 can be reached. TRS removal is 97% and methanol removal, 92%. Up to between 6 and 9 m^3 of water/t of pulp can be reused, which also results in an energy saving. An alternative to this process is reverse osmosis, in which the permeate is used as process water, and the rejects from osmosis are separated by rectifying in order to obtain the organic compounds.
Economic aspects	Investment costs for the stripper system for the manufacture of 1,500 t/d of Kraft pulp are around 2.0 - 2.5 M euros. Additional investments can be necessary to increase evaporation capacity, but this depends to a large extent on existing configuration. Costs for bringing materials up to date can vary from 1-4 M euros. Usage costs consist mainly of the costs of the steam used for stripping, and maintenance costs. If the stripper operates separately from the evaporation plant, the usage costs are noticeably higher, due to the demand for fresh steam. Costs are around 0.6-0.7 M euros/year. If the distillation column is connected between the evaporation stages, the usage costs are lower, varying from 0.3-0.4 M euros/year.

Alternative for pollution prevention at source (APPS)	**6.2.12. Treatment of the boiler and furnace gases with an electrostatic precipitator.**
Process and Action	Process: Chemical pulp production. Action: Technological changes, recycling at source.
Stage / Operation	Recovery boiler of the reactives and energy of the black liquors. Bark furnace. Lime kiln.
Environmental problem	High levels of particle emissions that can reach over 2,000 mg/Nm^3.
Potential benefits of the CP alternative	Reduction in particle emissions, recovery of reactives as fly ash. Among the advantages of electrostatic precipitators is the capacity to treat large flows of gas, with small load losses, in the order of 0.25-1.25 mbar. They can also work at high temperatures, of up to 650 ºC.

	The energy consumption of electrostatic precipitation is lower than other particle purification systems of similar effectiveness, because the energy acts on the particles, not on the gas carrying them, which means they can operate with electricity consumption of around 0.03 to 0.3 kW for every 1,000 m^3/h of gas flow, although the majority of this energy is consumed in its more costly form, as continuous high-voltage electrical current.
Description	The installation of a two chamber electrostatic precipitator (ESP) reduces emissions to under 50 mg/Nm^3, while one with three chambers reduces emissions to under 20 mg/Nm^3. The installation of an electrostatic precipitator (ESP) reduces particle emissions from the lime kiln by over 99%.
Procedure	The dry purification of particles allows them to be recovered as fly ash, which will be used in the causticising of the green liquors. Over 2 t/hour of fly ash is collected. Many bark furnaces operate with a multicyclone system in order to retain fly ash. The effectiveness of purification is over 99.5%, especially of fine particles, when an electrofilter is used. The use of an electrofilter has the following advantages: high efficiency in small particle purification, very low load losses in relation to efficiency, which results in energy savings for gas pumping, it enables the treatment of hot gases, etc. However, investments are high. The costs resulting from the electrical energy consumed are comparatively low. There are three particle generation mechanisms in the black liquor recovery boilers: • Particles of melted black liquor or partially-burned particles that are dragged out by the gas. • Aerosol particles (ejected) which form from drops of black liquor and then dry and burn in the gas flow. • Submicrometer smoke, which forms when inorganic compounds are vaporised in the lower zone of the boiler and condense when the gases cool in the upper area of the furnace or boiler. The particles dragged out and the large ejected particles tend to be deposited in the boiler, in such a way that their proportion decreases in accordance with the gases passing through the boiler while the proportion of inorganic smoke and smaller ejected particles increases. The proportion of alkaline chlorides, such as Cl/(Na + K), which can result in sticky deposits on the surfaces of the heat exchanger, is related to the furnace operating temperature and increases when these concentrations are over 5% greater than the ash in moles. The accumulation of ash on the surfaces of the heat exchanger leads to a reduction in heat transmission speed. As the deposits increase, and the amount of heat transferred decreases, the temperature of the gases increases and therefore so does the vaporisation of inorganic material in the furnace, a situation that quickly leads to conditions in which the furnace cannot operate. To reduce the chloride content, different processes have been suggested, including the reduction of the chlorides from the cooking reactives and other chemical substancess. In addition to this measure, the solution to the problems of adhesive ash on the heat exchange surfaces in the recovery boiler includes the control of chloride content of the ash collected in the electrofilter, in which the chloride particles concentrate, vaporised as inorganic smoke. The simplest alternative is the purging of some of the ash retained in the electrostatic precipitator, eliminating from the ash leaching tank a proportion of the fly ash collected in the electrofilter, which is conditioned for the chloride content introduced into the liquors from chemicals and wood. Other chloride reduction processes include the selective leaching of fly ash (from which mainly the chlorides that are more soluble than the other constituents are dissolved), followed by crystallisation sequences to separate them. The most effective processes, but with the highest investment costs and energy consumption, are based on the total solution of the ash and the separation of compounds by fractional crystallisation, in which the first steps separate the least soluble particles and the last steps separate the most soluble particles (chlorides).
Comments / Examples of application	Purging in a Kraft pulp mill using pine wood with 10 to 12% of the fly ash caught in the electrostatic precipitator, together with the use of products with low chlorine content, enables the chloride content to be reduced by up to 1.5%. ESP purification of the black liquor recovery boiler gases requires an average energy consumption of some 50 kWh/hour for a gas flow of 500,000 m^3/h with a particle concentration of between 1.1 and 4.5 g/ m^3 before purification.

Table 6.2.2. Examples of parameters of the potassium chloride removal system

Parameters of the potassium chloride removal system for the Oji Paper Kasuagi Mill in the ash of the electrostatic precipitator (ESP)	
Boiler capacity	2,400 t dry solids/day
Steam pressure	10.8 Mpa
Steam temperature	515 ºC
Ash treated	1.8 t/h (approximately ¼ of the total retained in the ESP)
Suspension tank temperature	40 ºC
Precipitation tank temperature	15 ºC
Water-ash relations in the ESP	2.3 to 2.6
Potassium removal	75%
Chloride removal	90%
Sodium recovery	70%

A technique that is complementary to ESP purification is the washing of the gases with a neutral or weak alkaline solution, to avoid carbonation.

Alternative for pollution prevention at source (APPS)	**6.2.13. Improved pulp preparation with reductions in energy consumption and emissions**
Process and Action	Process: Production of pulp from recovered paper without de-inking, and of sulphite pulp. Action: Technological changes, Good Housekeeping Practices, recycling at source.
Stage / Operation	Pulp preparation.
Environmental problem	High energy consumption. High levels of atmospheric emissions. The use of a larger number of machines than the necessary minimum.
Potential benefits of the CP alternative	• Reduced energy consumption. • Reduction of atmospheric emissions. • Improved quality of the paper manufactured. • The use of the different types of rejects generated. The demand for electricity for the preparation of pulps and the pulp flow system is between 20 and 40% of total energy demand in a recovered paper plant without de-inking. The optimisation of pulp preparation reduces energy consumption, resulting in less air pollution. Improving the quality of the recovered fibres and the cleaning of the recovered pulp results in improved quality of the paper made. Rejects from different stages of the process are collected and used for other purposes. For example, rejects containing large quantities of plastic can be incinerated with the benefit of the consequent recovery of energy. Rejects with a high organic material content can be used for compost. Rejects with high levels of inorganic materials can be used in other industrial sectors for the production of bricks, cement, etc.; otherwise, they are taken to landfill sites.
Description	Different objectives are achieved with the improvement of the pulp preparation plant. Therefore the first step is the definition of the objective to be attained, depending on the company's priorities. For example, greater removal of small impurities and pollutants to improve the quality and the efficiency of the paper machine, increased yield from the plant with a reduction of fibres in the rejects, or energy savings. Another objective might be the simplification of the pulp preparation process, resulting in lower energy consumption, less loss of raw materials and the need for less space. In this case, the dispersion and purification stages can be removed for "brown grade products".
Procedure	The paper recovery process begins with the removal of non-fibrous components (plastics, metals, wood, sand, etc.) and the removal of damaging substances such as stickies, wax or pieces of non-disintegrated paper. The screening and cleaning processes should take place in various stages (2 to 4) in order to reduce the loss of fibres in the final stage of each process.

	Following this the fibres are treated in such a way that the quality of the final product is controlled, for example the fibres can be divided into long and short fibres and/or refining and dispersion processes can take place. This pollution prevention alternative is based on the selection and optimisation of the most appropriate processing system depending on the quality of the final product, reaching a balance between the cleanness of the pulp, fibre losses, energy requirements and operating costs.
Comments	Improvements to the pulp preparation plant and the pulp flow system can be carried out in existing plants. A standard pulp preparation plant uses more machines than the necessary minimum, and it is therefore easy to close some systems, provided that the pipe system is redefined. In the case where pulp quality is to be improved, normally the strainers are the bottleneck when mesh of 0.15 mm or less is installed, and in this case an investment should be made in pressurised strainers. Many configurations of the pulp preparation plant have been developed, whether to improve the treatment of the pulps or to achieve lower energy consumption, without there being a single commonly accepted configuration. For example, in the manufacture of brown quality paper, different configurations can be suggested to reduce energy consumption or to improve pulp quality. Energy consumption decreases if the pulp is divided after coarse screening and only the long fibres are dispersed, since this is one of the stages requiring the greatest energy consumption (30-80 kWh/t). If pulp quality requirements allow it, the dispersion stage can be entirely removed, resulting in significant energy savings (approximately 30%), but the level of stains and stickies in the final product would increase and the efficiency of the paper machine could be adversely affected.
Economic aspects	Increased investment costs for the improvement in the pulp preparation plant should be evaluated along with the improvement in efficiency of the paper machine.

Alternatives for pollution prevention at source (APPS)	**6.2.14. Application of steam and energy cogeneration**
Process and Action	Process: Paper manufacture. Action: Technological changes, recycling at source.
Stage / Operation	Manufacturing Processes of Pulp and Paper.
Environmental problem	High energy consumption in the manufacture of pulp and paper.
Potential benefits of the CP alternative	Cogeneration saves primary energy and contributes to improved energy efficiency, as it is the most effective thermal form of generating electricity and heat. Emissions are decreased as a result of increased energy efficiency, since fuel consumption is also reduced. One aspect to be considered in energy production is the production of greenhouse gases. The use of more effective processes such as this reduce carbon dioxide emissions per unit of energy produced or per product unit.
Description	Cogeneration is the production of electricity and heat in the same process. The residual heat produced in the generation of electricity is taken advantage of by its use in an industrial process that consumes it as useful thermal energy in the form of steam. As this takes place in decentralised electricity production, near the centres of consumption, it prevents losses and investment in transport and electricity generation networks, improving the quality of the system. Cogeneration plants in the sector, depending on the type of plant, can contain different combinations, all linked to the joint production of electricity and steam: gas turbines in a single cycle with heat recovery boilers, combined cycles with gas and steam turbines, internal combustion engines with heat recovery, etc.
Procedure	An example of the most modern and efficient cogeneration, the combined gas/steam cycle, is given below: as in conventional gas turbine technologies, the air is compressed prior to its entry into the combustion chamber, where the fuel and the air are mixed and combustion takes place. Following combustion, the gas fuel expands in the gas turbine, producing mechanical energy which is transformed into electrical energy by a generator. In this type of plant, the residual thermal energy contained in the exit gases from the gas turbine is used to generate steam in a steam recovery boiler, which is used to generate additional electrical energy through a steam turbine. In turn, this steam turbine can operate to condensation, which means that the steam from the turbine passes through a condenser, eliminating the latent residual heat, or at counterpressure, using this steam for thermal uses and therefore recovering the heat. The use of steam at lower pressures, for mechanical or thermodynamic recompression, constitutes an energy saving technique that should be considered in the energy optimisation of the mill as a whole, as it

	enables operations such as sludge or waste drying, which cannot be carried out economically without the use of residual heat.
Comments / Examples of application	This integrated process technique is a well-known and developed technique. It can be carried out in both new and existing mills.
Economic aspects	The specific cost of transformation in combined cycle plants is around 1,000 euros/kW. The economic benefits are associated with fuel costs and the price of electrical energy exported to the grid, and it is considered in general to be an economically viable option.

Cleaner Production (CP) Alternative	**6.2.15. Optimisation of dewatering in the press section of the paper machine**
Process and Action	Process: Paper manufacture. Action: Technological changes.
Stage / Operation	Paper machine.
Environmental problem	Increased moisture with the resulting need for higher energy consumption in the drying section.
Potential benefits of the CP alternative	Savings in the calorific energy required to dry the paper. This technique can result in a saving of between 20 and 30% of the energy necessary to dry the paper.
Description	After the headbox, the paper machine is a drainage system in which retention and drainage should be optimised throughout the different stages: • Formation and dewatering section, first by gravity and then by vacuum, up to 20% solids. • Press section to increase dewatering to 40-50% solids. • Drying section to achieve the final drying of the paper to 94-97% by evaporation. The further on in the paper machine, the more expensive it is to remove the water. Likewise, if dewatering is very rapid in the first stage, the leaf will be sealed and less water will be removed in the press section. Therefore the dewatering curve throughout the machine must be carefully optimised, enabling gradual dewatering. In a paper machine, the largest energy consumption is required to dry the paper (steam 572 kWh/t). Electrical energy is needed to move the rollers and the conductor cylinders (100 kWh/t electrical) and to create the vacuum (67 kWh/t electrical). The drier the paper web following the press section, the less thermal energy required in the final drying section. With a 1% increase in the dryness of the paper web when entering the drier, an energy saving of approximately 4% is made (in terms of low pressure steam, approximately 2 atm). It is therefore important to adopt all possible measures to ensure the highest dryness levels possible on exit from the press section. When the pressure limit is reached in a traditional roller press, this can be replaced by a shoe press, which can exert greater pressure, encouraging dewatering. When dewatering speed is increased, the speed of the machine can be increased, and therefore productivity can also be increased.
Comments / Examples of application	Dryness can be increased by some 3-15% with the installation of new shoe presses in packaging paper and cardboard machines. This increase depends on the operation of the reconstructed press section and the new type of presses selected. Technique integrated into the process. Both new and existing paper machines can be adapted for the majority of types of paper (except tissue), with the only requirements being sufficient free space in the press section and the structure of the mill being strong enough to take the extra weight. Good foundations are useful to support the weight of the machinery.
Economic aspects	Investment costs for a paper machine of 5 m in width is around 10 M euros. These costs include felts, new rollers and installation. The energy consumed by the new press is approximately the same as costs for a conventional press. Savings for steam for drying the paper vary between 10 and 15 euros/t of steam, with specific steam consumption being 2 tonnes of steam per tonne of paper and savings being between 20 and 30 euros/t of paper. For the substitution of presses, the investment return period is approximately 2.5 years, if no other aspects exist to limit the increase in speed of the machine, which can be of up to 30%.

6.3. OTHER TECHNOLOGICAL ALTERNATIVES TO CONSIDER

6.3.1. Dry debarking

Definition

Dry debarking is an alternative to wet debarking and reduces water consumption by over 80%. In this process, water is only used to remove ice from the trunks in cold climates, and the water is recirculated within the process. As a result, dry debarking produces bark with lower water content and therefore higher calorific value when it is used in the auxiliary boilers, a fact that is positive for the energy balance of the mill, although energy consumption during dry debarking can increase. For easier debarking, the wood used should be fresh.

Applicability

This technique involves a technological change and can be applied both in new mills and in existing mills. Dry debarking is widely used and is overtaking wet debarking techniques.

Environmental aspects

Dry debarking reduces water consumption and leads to lower organic material, solids and colorant material content in the effluent. Likewise, the dissolved organic compounds content in the water decreases, as does the content in resinous acids, fatty acids and other extractives, which reduces the toxicity of the waters.

Table 6.3.1 Pollutant load in the effluent from different debarking processes, prior to biological treatment

Debarking technique	Effluent volume (m^3/t pulp)	BOD_5 (kg/t pulp)	COD (kg/t pulp)	total P (g/t pulp)
Wet debarking and bark press	3-10	5-15	20-30	25-35
Dry debarking and bark press	0.5-2.5	0.5-2.5	1-10	10-20

Source: BREF

Economic aspects

The cost of dry debarking machines is not significantly different to the cost of wet debarking machines. Typical investment cost in a new dry debarking machine is around 15 M euros for a capacity of 1,500 t/d of pulp. The conversion of a wet debarking plant to a dry debarking plant has a cost of approximately 4-6 M euros. This cost only includes equipment and installation.

Operating costs vary between 0.25-0.35 M euros/year.

6.3.2. Use of storage tanks with a sufficient volume to optimise water consumption

Definition

This measure is of a general nature and can be used in any pulp and paper manufacturing plant. It is normally complemented by measure 6.3.3. It therefore contributes to a reduction in the volume of wastewater in the plant, the pollutant load of this wastewater and the negative effects of one-off tipping of highly polluted wastewater on the operation of the water treatment plant. The storage tanks should be able to avoid overflows during the starting-up and stopping of the plant or when there is an alteration in the process. In general, their capacity should be sufficient to store the flow produced over several hours if there is a problem at any stage of the process. Clean flows should be diverted from the area where there could potentially be leaks to avoid their possible contamination or dilution.

Applicability

The optimisation of the necessary capacity of the process water storage tanks is a good housekeeping technique which can be applied in new and existing plants. These measures help not only to conserve valuable chemicals from the process and to make the process more economical, but also have a profound effect on the environmental operation of the mill. In existing facilities, the most effective alternative is to apply this alternative in conjunction with measures to avoid overflows and leaks, making the storage tanks compatible with the overflow collection system. Likewise the possibility of using other complementary improvements to improve economic viability should be looked into. For example, in the case of chemical pulp plants, this technique could be used in combination with improvements in the washing and the screening of the pulp, or in the evaporation and filtering process of the liquors.

In the case of chemical pulp plants, it is important to prevent spillages of liquors, both strong and weak, of condensates and of green liquor. Therefore a storage capacity of at least 30% above normal operational volume is necessary. The volume of the tanks is determined by the concentration of the liquors. The storage capacity in old plants, in plants with little wash efficiency or without a black liquor concentration stage before evaporation is much greater than in modern plants, because the liquors are more diluted (8 and 60% for weak and strong liquors respectively, compared to 16 and 75% for modern plants).

In the process of market CTMP pulp production, there is less need for process water storage than in a chemical pulp plant, as once water consumption is minimised, the water balance shows that there is excess water that has to be treated in the wastewater treatment plant. As a result, in this case a process water storage tank with the capacity to ensure the necessary water for the whole plant when the mill is operating in unstable conditions or one of the stages is interrupted, is sufficient.

In integrated mechanical and thermomechanical pulp mills, most of the water used in the pulp production process is received as excess white water from the paper or cardboard machine. The solution is therefore a white water storage tank of sufficient capacity. On some occasions, the storage tanks are also used for the cooling of process waters.

In paper and cardboard mills it is necessary to have white water storage tanks that allow for white water to be stored during short pauses, the starting up and irregular operation of the plant. It is also necessary to have tanks for broke and, in the case of coated paper, to have an additional tank for the storage of coated broke.

Environmental aspects

This pollution control method is related to containing and reusing leaks and spillages. The environmental improvements in the process require a combination of both techniques. These measures reduce the flow of wastewater produced in the plants, along with their pollutant load. In addition, they reduce the risks of alterations to the operation of the wastewater treatment plant by avoiding accidental tipping with high organic loads, sometimes toxic, or with extreme pH values.

In the specific case of mechanical pulp, the impact on the environment is less than for chemical pulp, but the treatment of wastewater improves with the reduction of the frequency of overflows and spillages.

In addition, the safety values represented by the control of spillages in these plants must be taken into consideration.

Economic aspects

For a plant producing approximately 1,000 tonnes of pulp per day, at least two tanks with a storage capacity of 2,000 m^3 are considered necessary. Approximate investment costs for each tank, together with the necessary auxiliary equipment, is estimated to be 0.5-0.8 M euros.

In the case of a paper mill with production of 1,000 t/day, 2 or 3 storage tanks are considered necessary, depending on whether the paper is coated or not. For white waters, a tank of 3,000 m^3 is considered necessary (0.6-0.7 M euros) and for non-coated or coated brokes, a tank in each case of 2,000 m^3 (0.4-0.5 M euros).

The operational cost is very low and corresponds fundamentally to maintenance costs.

6.3.3. Control and recovery of leaks and escapes

Definition

Measures should be taken to reduce wastewater generated in all plants, along with the pollutant load of these wastewaters. This measure will enable the reduction in size of the wastewater treatment plant, treatment costs and the final discharge flow. In addition, it is important to avoid one-off pollutant tipping, especially if this is toxic, to avoid the wastewater treatment station not operating correctly.

Accidental internal overflows and spillages are relatively frequent within the manufacturing processes of pulp and paper. The most frequent internal spillage points are: pump closures, valves, washers, purifiers and mechanical equipment in general, tank overflows, mechanical faults and operational errors, in addition to overflows during the maintenance operations, starting and stopping of the mill.

Overflows with a solid content of over 2-3% should be contained, collected (avoiding their dilution) stored and reused at the appropriate stages of the process. It is therefore important to consider the following things in the plants:

- The collection of internal overflows and spillages with the highest concentration of dissolved solids possible.
- Storage tanks for filtrates and water that are of a sufficiently large capacity.
- Returning liquors and fibres from overflows to the process.
- Control of pH, conductivity, turbidity, etc. at strategic points, which enables the rapid tracing of leaks or overflows. Alarm system.
- Restraint and control of critical process areas in order to avoid high concentrations or dangerous spillages of the mill's general effluent, for example black liquor and waste liquor, condensates produced in the evaporators, etc.

Applicability

The control and recovery of spillages and leaks is considered a Good Housekeeping Practice, which requires the suitable design of the plant. The control of collection, storage, processing or reuse of internal spillages and overflow is easier to apply in newly designed mills than in those that are older in design. In existing plants, the key to an efficient solution is mainly in the equipment itself, installing the adequate means to contain overflows and leaks.

This measure, although it can be applied to any process, is most important where the spillages have a higher pollutant load, as in the case of chemical pulp plants. In this case it is necessary to foresee, with this in mind, an excess capacity of the evaporation plant of approximately 10%.

Environmental aspects

This measure is related to the use of storage tanks with sufficient capacity for optimum water management (measure 6.3.2). The environmental improvement is based on the combination of both techniques.

It is estimated that in Kraft pulp plants, good process management and a properly designed system of containing and recovery of spillages, together with a 5-10% increase in the plant's evaporation capacity, lead to a reduction of 3-8 kg COD/t in the final wastewater flow.

The risk of alterations in the wastewater treatment plant are reduced when accidental tipping of wastewater with high organic content, toxic pollutants and/or with extreme pH is avoided.

Economic aspects

The control and reuse measures for spillages and leaks, along with process control in the sector, are beneficial and necessary from the economic and environmental point of view. This question has been effectively solved in many plants with the use of fairly simple methods. However, in some plants there are limits at the time of avoiding spillages, centring on the bottlenecks at some stages of the process (pulp washing, screening, evaporation, etc.).

The investment cost for a treatment system for leaks and spillages in a Kraft pulp plant with production of 1,500 t/d of pulp is of 0.8-1.5 M euros. If the evaporation capacity in the plant needs to be increased by 0.8 m^3/t, between 4 and 6 M euros are required in addition. The operating costs of the systems are estimated to be between 0.1 and 0.4 M euros/year, but this figure can vary considerably between newly constructed and old plants.

In the case of paper mills with a capacity of 1,000 t/d, the application of this measure would necessitate the installation of a new tank of 3,000 m^3 in capacity for the storage of white waters and a tank of 2,000 m^3 in capacity for the storage of non-coated broke, which involves a cost of 1.0-1.2 M euros. If an additional tank is required for coated broke, an additional 0.4-0.5 M euros must be added to the above cost.

6.3.4. Screening of the unbleached pulp in a closed water circuit

Definition

Operating with the water circuit entirely closed in the screening process for unbleached pulp avoids the generation of a large quantity of wastewater. This alternative contributes to a reduction in the final effluent from the plant and its pollutant load. The fibre shives and knots separated at this stage are recovered and incinerated in the recovery boiler.

Applicability

This technique of source prevention is widely used in both new and existing mills. The closure of the water circuits in the washing and screening operations can require supplementary equipment or the substitution of some units to minimise the water consumption of the washers and in order to make the equipment more resistant to corrosion. If the capacity of the evaporators and the recovery boiler is at the limit, complementary alternatives will have to be considered to increase this capacity and to be able to treat the waters with the waste from the screening stage.

Environmental aspects

The closed system contributes significantly to the reduction of organic compounds in the effluent, which are recovered and incinerated in the recovery boiler, thus reducing the wastewater flow from the pulp plant.

Energy consumption increases due to the increased need for evaporation.

Economic aspects

The investment in this type of sifting plant is of 4-6 M euros in new mills and 6-8 M euros in existing mills. Operating costs are of 0.3-0.5 M euros/year for a capacity of 1,500 t/day of pulp.

Current developments of the screening process, which means that higher consistencies can be used than were possible in the past, enable investment costs and energy consumption to be reduced, and as a result they have been adopted extensively.

6.3.5. Efficient washing

Definition

The objective of washing unbleached chemical pulp is to separate the cellulose fibres from the organic and inorganic compounds dissolved in the water, forming the residual cooking liquor. The dragging out of residual chemicals from earlier stages to a greater or lesser extent depends on the level of efficiency of the washing stage. These residual products increase the consumption of bleaching agents, increase the flow of wastewater from bleaching and the pollutant load of this wastewater. The higher the consistency of the pulp on finishing the washing stage, the lower the levels of dragging out of residual chemicals and pollutants.

Of all the mechanical pulps, this technique is particularly relevant for chemical thermomechanical pulps (CTMP). The main principle is to separate the dissolved organic material during the breakdown of the wood; in this case such high washing efficiency as in chemical pulps is not required.

To wash this pulp, a combination of successive stages of dilution and thickening of the pulp is used. The pieces of equipment used are vacuum drum filters, pressurised drum filters, Fourdrinier type flat washers, atmospheric and pressurised diffusers, and wash presses.

The washing of CTMP pulps is more difficult than of chemical pulp, and therefore larger capacity of the washing equipment is needed. With a traditional washing system, 65-75% of the organic material can be recovered, while with an improved system it is possible to reach efficiency levels of 75-80% by installing new equipment in series.

A closed washing system increases the importance of controlling overflows and accidental leaks, which is another alternative for pollution control. In this case, spillages have a high load of organic and inorganic substances, which would increase the pollutant load of the end wastewater.

Applicability

In order to implement this measure, technological change or the increase in size of some plant units is necessary. Nevertheless, this technique can be applied both in old mills and in newly-built mills. This alternative is used extensively in Kraft pulp plants, but to a lesser extent in CTMP plants, as in these it is not so important for the washing of the pulp to be so efficient.

In Kraft pulp plants, in practice, instead of carrying out modifications to the wash process, the total replacement of the wash machinery could be worthwhile.

Environmental aspects

An optimised washing system in Kraft pulp plants allows for the separation of wash waters, which are treated in the recovery system, and reduces the dragging out of pollutants with the pulp, which decreases the consumption of chemicals at later stages and even increases the quality of the pulp if this drags out fewer extractives. Modern washing facilities enable values of 2-4 kg COD/t to be reached on exit from the wash plant, while the majority of facilities produce pulps with a COD of 5-8 kg COD/t.

Wash presses provide advantages when used in the stage prior to bleaching, as they enable the consistency of the pulp to be increased from the 10-15% reached in conventional washers to 30-35%, which means that a larger quantity of wash filtrates can be recycled, with the consequent reduction in the flow of wastewater from the bleaching plant and also a reduction in the pollutant load of this wastewater: COD, BOD_5, AOX, etc.

Economic aspects

As regards chemical pulps, investment costs are typically 4-6 M euros in new plants and approximately 2-4 M euros in existing plants. The typical investment cost for a CTMP pulp plant with production of 700 t/d is of 3-5 M euros in new mills and 2-3 M euros in existing mills.

There are no relevant operational costs.

6.3.6. Extended modified cooking

Definition

From an environmental point of view, a key point in the process of obtaining pulp is the degree of delignification attained before the bleaching stage. The lower the lignin content in the pulp (lower kappa index), the lower the consumption of bleaching agents and the lower the pollutant load of effluent from the bleaching stage.

Delignification takes place in the digesters and optionally in an oxygen delignification stage (measure 6.2.2.). The lignin in the latter case is selectively removed to minimise the attacking of the cellulose fibres and to avoid losses in yield from the process. The option of modified extended cooking, either continuous or batch, enables greater amounts of lignin to be removed during cooking (35-45% more than the traditional process), resulting in pulp with 3% residual lignin (with a kappa number of 20) as opposed to the 5-10% in conventional processes (with a kappa number of 30). As a result, the unbleached pulp obtained is easier to bleach, while the content of organic substances in the liquors sent to the recovery boiler is greater.

Continuous cooking

There are three alternatives for continuous cooking: modified continuous cook (MCC). extended modified continuous cook (EMCC) and isothermic cook (ITC). In the MCC process, the cooking zone of the digester is divided into two zones, a co-current zone and a subsequent counter-current zone. The feed of white liquor is divided between the two zones. The objective of the modification is to reduce the initial alkali concentration and to maintain a homogenous alkali concentration throughout the cooking process, while maintaining a low concentration of dissolved lignin in the final part of the process. The EMCC process is a modification of the former process, the difference being that the white liquor is also added in the wash zone, in order to extend the delignification process in the digester.

Another MCC cooking operation is isothermic cooking. In ITC, the whole of the digester is used for delignification, which results in gentler conditions during cooking (lower temperatures) and therefore the pulp retains its strength characteristics.

Batch cooking

There are also three alternatives for the batch process: Rapid Displacement Heating, "Superbatch" and "Enerbatch". In the first two types, a pretreatment of impregnation with white liquor takes place, in order to reduce energy consumption and at the same time increase the initial sulphur concentration and reduce the effective alkali load. In the "Enerbatch" process, pretreatment is carried out with white liquor, followed by a pretreatment with black liquor. All of these processes result in lower energy consumption and increased quality of the pulp, reducing the kappa number by up to 35% in soft pulp and up to 20% in hard pulp.

Applicability

This is an integrated process which can be adopted in new pulp mills and with a certain degree of limitation in existing mills, as its implementation requires a change or technological extension of the plant.

In continuous digesters or if the recovery boiler is working to the limit of its capacity, there can be production losses of 4-8%. In the latter case, complementary measures would have to be adopted that would allow an increase in the quantity of liquors burned in the boiler (additional evaporation stages, the use of anthraquinone in the cooking process, etc.).

It is possible to reduce the kappa index by 6-7 units when soft woods are used as raw materials and by 4-5 units when hard woods are the raw materials, without affecting the strength of the fibres. In continuous digesters, pulp with a kappa index of 20-24 for soft woods and 14-18 for hard woods can be obtained. With continuous digesters, the values of the kappa index are reduced to 15-16 if soft wood is used and to 12 in the case of hard woods.

Main environmental aspects

The effects obtained from extended delignification are:

- An increase in the quantity of dissolved organic substances in the liquors sent to the recovery boiler.
- An increase in the energy produced by the recovery boiler.
- A reduction in the consumption of chemical bleaching products, which results in significant financial savings.
- A reduction in the discharge of pollutant loads (AOX, COD) from the bleaching plant (2-3 kg COD/t of pulp for each unit of the kappa index).
- Batch cooking processes reduce energy consumption and the consumption of cooking steam but increase the consumption of steam in the evaporation of black liquors.

Economic aspects

The investment costs of the modification of a conventional cooking plant to turn it into an extended cooking plant is 4-5 M euros in a mill producing 1,500 t/d of pulp.

6.3.7. Ozone bleaching

Definition

Ozone bleaching is related to the production of ECF and TCF. The main objective of the use of ozone is to provide greater delignification capacity to the pulp. Ozone encourages the action of oxygen peroxide, resulting in better brightness and lower peroxide consumption.

Applicability

This is a technique that is integrated into the process and can be adopted in both new and existing mills. It implies the substitution of raw materials, and technological changes.

Environmental aspects

If ozone is used to substitute chlorine dioxide in the ECF processes, AOX discharge is reduced to a great extent. In TCF processes, the use of ozone enables pulps of high brightness levels to be attained, and facilitates the closure of circuits at the bleaching stage.

Operational experiences

Ozone bleaching in an ECF plant usually results in pulp with the same properties.

Economic aspects

Ozone bleaching has high investment costs due to the expense of ozone generators and the auxiliary equipment. Investment costs for the production of 1,500 t/d of pulp are 12-15 M euros. Operating costs are approximately 1.8-2.1 M euros/year.

6.3.8. Closure of water circuits with biological treatment of effluent integrated into the process

Definition

Currently this technique is only considered an APPS in unbleached paper plants from recovered paper, although the basic principle, of purifying with physical and chemical methods part of the process water for its reuse, can be used in other types of paper mill.

This measure considers the traditional biological treatment of wastewaters at the end of the line as an internal treatment of this wastewater that enables it to be recirculated. In this way, the water circuits can be closed, avoiding the problem of the accumulation of dissolved organic and colloidal material that this closure usually implies. In this way, problems of corrosion and odours are avoided both in the product and around the paper machine. The main advantage of treatment integrated into the process is that only part of the total COD load needs to be removed in order to maintain a determined level in the water in the circuits (7,000-8,000 mg/l are equivalent to plants with a water consumption of 3-4 m^3/t). This means that the integration of the process waters purifying plant is economically attractive. There are currently various technical options enabling this, two of which are described below.

Option 1: Anaerobic treatment followed by a re-aeration and decarbonising stage.

After a preliminary stage to remove fibres from the process waters, a part of the flow is purified using an anaerobic process in a reactor with a fluidised bed, followed by a re-aeration stage in order to provoke the change of sulphides to sulphates, and a decarbonising stage, to avoid the encrustation of calcium carbonate in the reactor or other parts of the circuit. Once purified, the flow is reused in the process.

Option 2: Anaerobic treatment combined with an activated sludge system and a sand filter.

Following a cooling stage for the process waters to cool them from 55°C to 35°C, the waters are conditioned in a buffer and preacidification tank where the necessary nutrients are added. Then the waters are moved to the UASB reactor, where the anaerobic treatment takes place, and from there the waters go for aerobic treatment in two parallel aeration tanks. Following sedimentation, the clarified water is sent to the sand filters to reduce the concentration of solid substances. The biogas produced in the anaerobic reactor is sent to a scrubber, to remove the H_2S, and enable it to be used later for steam generation.

Applicability

This a technique of recycling at source that implies technological changes. The closure of water circuits by means of the integration of the biological treatment of the process waters can theoretically be applied in new and existing paper mills. However, there are various reasons why this technique is not generally considered to be a Cleaner Production alternative. The main reason is the precipitation of calcium carbonate in the water circuit and in the anaerobic and aerobic treatment reactors. The control of the concentration of calcium in the white water is extremely complex and not enough information is available on this. The technical solutions for this problem are still undeveloped.

To integrate this technique into an existing process, the entire water system would have to be optimised, and it is therefore not considered to be economically viable.

Environmental aspects

The closed water circuit with integrated treatment reduces liquid discharge practically to zero.

6.3.9. Reduction in fibre and mineral filler losses in the paper machine

Definition

This technique can be used for any type of paper, except tissue paper, given that for tissue paper the recovery of fillers and fines is not important as they cannot be reused in the process.

The management of fibre recovery in the process of paper manufacturing is a matter of great importance for cost optimisation.

When the pulp flows through the headbox onto the formation wire, the non-retained fraction of fillers and fines becomes part of the white water. The short water circuit is recirculated without prior treatment. The rest of the waters are taken to the fibre recovery equipment, usually disc filters, or for dissolved air flotation, to separate solids from the water flow. These solids are then collected in a tank and recycled in the paper machine. Clarified waters are usually collected and recirculated for different uses in the paper machine: dilution of pulp in the pulp preparation machine, water sprinklers, etc. In integrated mills, excess white water is used in the pulping process.

For the recovery of fillers and fines, the most efficient systems are based on vacuum disc filters or on flotation cells. Filtered waters with a suspended solid content on 10-20 mg/l can be obtained, compared to the 50 mg/l with conventional filters, and in addition this offers the possibility of reusing the filtered waters at different stages of manufacturing.

Other methods to avoid the loss of fibres and fillers are:

- The optimisation of purification and refining in the head of the machine.
- The correct dimensioning and operation of the broke system.
- The adequate addition of chemical additives and a good control system to optimise the retention of fines and fillers.
- The efficient control of the headbox to produce the homogenous distribution of the pulp over the formation wire.

Applicability

These techniques can be applied in both existing and new mills.

Environmental aspects

The loss of total solids generated in the paper machine, together with rejects in pulp preparation, excess of white waters taken to the purifying plant, in the press section, through overflows and leaks from pulp tanks, etc., is around 10-100 kg/t.

Economic aspects

Vacuum disc filters call for a higher investment, but involve lower operating costs due to lower energy consumption and the absence of the additives that might be necessary for flotation; nevertheless, these systems are more effective in the recovery of fillers.

For the production of 100 t/d of paper, the investment for a filtration system can reach 240,000-270,000 euros, in comparison to the 198,000-228,000 euros for flotation.

6.3.10. Recovery and recycling of coating products contained in wastewater

Membrane technologies are usually chosen due to the fact that they offer possibilities for the reuse of chemical coating products, although they call for a change or increase in the technology in the plant.

Definition

Mills that produce coated paper generate a wastewater flow in the coating section of 2-5% of the total flow, and this wastewater has a high pigment and adhesive content.

The adequate management of coating waste implies:

- Minimal discharge from the preparation sector of the coating colours by means of efficient production and and optimised inventory.
- The optimal design of the colour preparation feed system for coating.
- Recovery of the chemical compounds from coating by means of the ultrafiltration of wastewater in the coating system.

Ultrafiltration consists of a separation method of the water and chemical compounds by means of the use of a semi-permeable membrane. The pores of the membrane are so small that they only allow miniscule molecules to pass through, such as water, metallic ions, salts and starch monomers, while other compounds such as the chemical compounds from coating (pigments and binders) are retained.

Applicability

This technique of recycling at source can be applied both in existing mills and new mills.

Environmental aspects

Water emissions and the quantity of waste are reduced. There is also a reduction in water consumption due to the fact that the permeate can be reused.

Operational experiences

The application of ultrafiltration has been applied with success in many mills. The useful life of the membrane, which is of not longer than a year, should be taken into account.

Economic aspects

One UF unit can treat around 2,000 l/h of effluent with 2% solids. This type of unit can be useful in mills that use from 10 to 50 tonnes per day of chemical compounds for coating. Investment costs in this case are 0.2-0.3 M euros. Savings can be obtained by the recycling of the chemical compounds for coating (costs of deposit in controlled landfill sites, and savings in the chemical compounds for coating, which are very expensive).

6.3.11. Independent pre-treatment of wastewater from coating processes

Definition

This technique can be applied as an alternative to the technique described in point 6.3.4. Membrane technologies are usually chosen as they offer possibilities of reuse of the chemical compounds for coating.

The discharge of chemical compounds can be divided into two groups:

- Undiluted surpluses (around 50-70% dry solids) from the coating preparation system.
- Diluted compounds from the wash water.

In the typical treatment of this waste for discharge, the wastewater is collected in a neutralisation tank. Following this it is screened and pumped into the physico-chemical treatment system, where aluminium sulphate or aluminium polychloride are used as coagulants. Polyelectrolytes are also added as flocculating agents. The flocs from the wastewater flow into a clarifier, where the solids are sedimented and are collected from the bottom of the clarifier. The clean water overflow is discharged into a wastewater channel for additional treatment. The sludges collected at the bottom are taken to a sludge tank from where they are pumped to the dehydration stage. The sludges, dehydrated to a concentration of 30-40%, are finally transported to a landfill site.

In some cases, the sludges are dehydrated by using centrifugal force and are then reused as coating agents. However, this option is accompanied by additional conditioning costs.

Applicability

The pre-treatment of wastewater from coating can be applied both in existing and new mills, although existing mills will require the change or increase in technology in the plant.

In new facilities, the preferred option would probably be a system of wastewater ultrafiltration, as these usually have a shorter return time on investments.

Environmental aspects

The main achievement is the improvement in the operation of the mill and in particular in the wastewater treatment plant.

6.3.12. Substitution of potentially harmful substances for less polluting alternatives

The concentration of chemicals in the process waters is directly related to the retention of these products in the paper product. If retention is low, the chemicals are incorporated into the white waters, becoming potential pollutants when the waters are recirculated. These compounds can also be present in the plant's solid waste and can affect the quality of these if they are to be reused as compost or, if they are taken to the landfill site, they could be incorporated into leach waters.

The presence of these pollutants in discharged wastewaters depends on their initial retention, their potential for degrading and their retention in the sludges from the water purification plant. The higher the retention, the lower the discharge into effluent and the lower the potential environmental effect of the additives used. Using products with high retention is desirable both from the economic point of view (less product loss) and the environmental point of view. Product additives are designed to improve the quality of the final product, and therefore in general have good retention. However, process additives, which contribute to the improvement of different stages of the production process, usually have lower retention as in many cases their effect is on the water circuits themselves, and as a result they accumulate in the process waters. These potential pollutants contribute to an increase in the dissolved and colloidal material in the circuit and can interact among themselves, resulting in the formation of deposits that affect the quality of the product, the equipment and the processes.

This technique suggests the generalised reduction in the use of chemical additives, large proportions of which end up in effluent, and their substitution with others that are more environmentally sound. This is particularly interesting for dangerous chemical substances, for which there are less pollutant substitutes that offer the same results in the process. The use of biodegradable, non toxic and non bioaccumulable products should be encouraged. Chemicals that are thought to have dangerous effects on humans or the environment should be avoided, such as organic hydrocarbons, for example benzene (a carcinogen), toluene (toxic) and xylene (toxic) contained in the solvents and detergents used in the cleaning of wires, felts and machines, etc. These should be replaced with solvents with less toxic effects, such as esters that are partially biodegradable.

Environmental effects

The control of additives in the final waste from the plant is important to determine which are not retained, or are not degraded, and end up in this effluent. The dosage of these compounds should be minimised and where possible they should be substituted with compounds that are less problematic from an environmental point of view.

It is advised that a detailed study of active process elements be carried out, for example a balance of retention and degradability of the products used, in order to select those that should be substituted or the use of which should be minimised.

6.3.13. Control of emissions from the wood yard

This technique, considered a Good Housekeeping Practice, is more relevant in the manufacture of mechanical pulp, as the wood must be kept fresh due to the fact that the storage time of the wood and the conditions of this storage cause changes to the quality of the wood that affect the solubility of its components, which can have a significant environmental impact. These changes are due to the activation of bacteria and fungus, to the drying of the wood and its accelerated oxidation. The changes that take place differ depending on the species of wood. In general, it is thought that the most volatile compounds evaporate and the triglycerides are hydrolysed into fatty acids, which is beneficial, but the penetration of the soluble extractives of the bark into the wood also takes place. These changes can result in reduced brightness of the pulp later in the process.

There are currently two trends as regards the management of operations relating to wood:

- The shortening of the time between the cutting of the wood and its use in the plant to process the wood while it is as fresh as possible.
- The use of automated cutting machines that partially debark the wood. The removal of 30-50% of the bark means that the dissolving of the components present in the bark, mainly extractives, is reduced during debarking in the mill. This pre-debarking means that the wood dries more quickly, so any delay in the cutting and processing of the wood must be avoided.

In the wood yard, the wood is sometimes dampened with water to prevent it from drying out. This water should be collected and treated in the appropriate way, in order to avoid the pollution of the soil.

6.3.14. Increased concentration of the black liquors

Definition

In the recovery boiler, the inorganic substances are reduced and separated in their solid form (mainly as Na_2S and Na_2CO_3). These are deposited at the bottom of the boiler, while the organic material is burned, generating energy. In a conventional recovery boiler there are two different zones, the upper part where the oxidation reactions take place and the lower part, where reduction takes place. Operating conditions such as temperature, air supply, the dry solid content of the black liquor and the chemical balance must be optimised to minimise the emission of particles, nitrogen oxides and sulphur dioxide from the boiler.

A higher solid content in the black liquor implies greater energy efficiency in the boiler and higher levels of reduction, which become lower emissions of sulphur and nitrogen oxides from the chimney. It is therefore important to put the black liquors through an extra evaporation process, in order to obtain a solids content of above the 65% that was traditionally reached. The optimum solids content after evaporation, to minimise atmospheric emissions, is 72-73%. In facilities that are provided with superconcentrators, the solid content of the black liquors can be increased to up to 80%, although the final value depends on the type of wood used as raw material.

Applicability

This technique involves technological change or the increase of the plant's evaporation capacity. It can be integrated into the processes of existing and new Kraft pulp mills. The installation of a superconcentrator can be considered as a separate stage from the evaporating plant.

The maximum concentration of dry solids is limited by the increase in viscosity and the potential of the concentrated liquor to form encrustations. The limit depends on the species of wood and on the temperature. In practice, in eucalyptus pulp mills and other type of hardwood mills, it is difficult to attain a concentration of solids in the liquors of over 70%.

The increase in the concentration of black liquor provides the typical problems of high viscosity liquids, with difficulties in their decanting and problems of dirtying in the pipes.

Main environmental effects

Sulphur emissions from the recovery boiler are reduced to 5-50 mg S/Nm^3 or 0.1-0.3 kg S/t of pulp. On occasion this is reduced almost to zero because the excess sodium is vaporised and reacts with the sulphur.

On the other hand, there is an increase in particle emissions, which can be controlled with an electrostatic precipitator (measure 6.2.14.). There may also be an increase in NO_x emissions, which should be controlled.

Economic aspects

In existing Kraft pulp mills with production of 1,500 t/day, the investment costs to increase the concentration of the black liquor will be as follows:

• Increasing concentration from 63% to 70%:	1.7-2.0 M euros
• Increasing concentration from 63% to 75%:	3.5-4.0 M euros
• Increasing concentration from 63% to 80%:	8.0-9.0 M euros

There are no significant operating costs for these improvements, due to the increase in economy of energy (between 1 and 7%) and due to the increase in capacity of the recovery boiler. The increase in dry solids in the recovery boiler can even give rise to net savings.

6.3.15. Improvement in the washing of causticisation sludges

In the process of obtaining white liquor, calcium carbonate is produced as a product of precipitation during causticising.

Causticising sludges are formed for the most part by calcium carbonate precipitate.

To reduce the loss of reactives, this then proceeds to a process in which it is washed over the drum filters, usually used for its filtration.

The washed calcium carbonate with the lowest proportion of sodium and alkali is dehydrated on the filter in order to reduce its water content prior to calcination.

The improvement of washing of the filtrate using new generation filters leads to an increase in the recovery of reactives and lower emissions of sulphate compounds during calcination.

This alternative results in a higher level of recycling at source in the process, although it requires advanced technology.

6.3.16. The use of low sulphur fuels or renewable fuels

The type of fuel used depends to a great extent on the internalisation of environmental costs, on the price of these fuels and on their availability. The evolution of the paper industry in the last decade, with the extensive use of renewable fuels, biomass and natural gas, leaves a small margin for the route of fuel substitution to reduce CO_2 emissions.

The substitution of fuels such as coal, fuel and diesel with natural gas contributes to a great extent to the reduction of emissions of CO_2 and NOx. Sulphur dioxide emissions are almost negligible, as the sulphur content of natural gas is very low.

Table 6.3.2. Comparison of emissions per unit of energy produced

Centres and equipment	NO_x	SO_2	CO_2 (*)
Conventional coal	1,790	4,050	920
Conventional diesel	1,040	4,437	760
Conventional natural gas	680	0	505
Natural gas turbine in a combined cycle (NG)	282	0	369
Natural gas turbine in a combined cycle (Diesel)	557	162	562

(*) Factors expressed in g/MWh, except for CO_2, in kg/MWh

Within the energy optimisation strategy that is developing in the Mediterranean region countries, the energy valuation of recycling waste is outlined as a key opportunity for advancement in the improvement of the structure of fuels used by the sector.

6.3.17. Minimisation of reject losses in mechanical pulp mills

Definition

There are basically two methods available for the separation of pollutants from low consistency pulp:

- Centrifugal purifiers, in which the particles that are heavier than the fibres are separated out.
- Rotating pressure purifiers, with holes (1-2 mm) or slots (0.10-0.35), in which the larger-sized material is separated out.

The rejects in both cases are accompanied by a large quantity of fibres that can be recovered. For this, it is necessary to have the purifiers operating in series or cascade. Rejects with a consistency of 30-40% are treated in a process of one or two steps to separate the fibres, which are recovered. The final waste is incinerated in a boiler or removed from the plant with the solid waste.

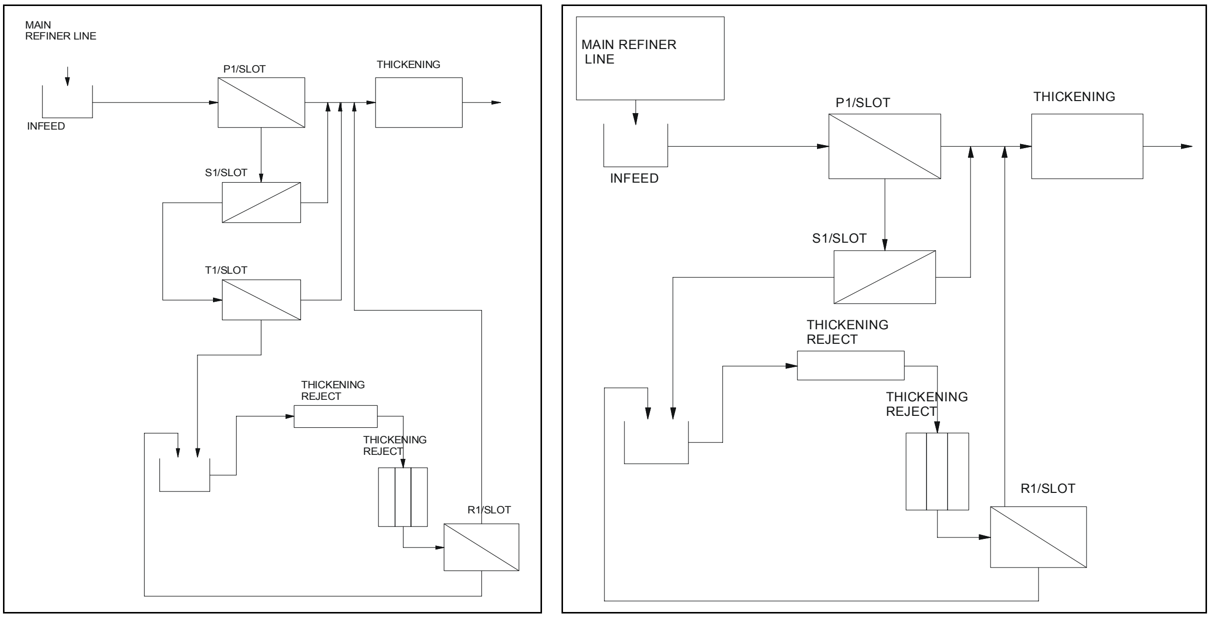


Figure 6.3.1. and 6.3.2. Alternatives 1 and 2, respectively, for the flow of a TMP process for paper and pulp

Applicability

This technique can be applied both in new and existing mechanical pulp mills.

Environmental aspects

This measure reduces fibre losses and decreases the generation of solid waste, and is therefore considered a measure of recycling at source for pollution. In addition, the energy balance is positive.

The quantities of total solids (TSS) in the effluent are also reduced.

Economic aspects

Investment costs for production of 700 t/d of pulp is 0.8-11 M euros, while operating costs are of approximately 0.3-0.5 M euros.

The economic benefit can be seen in the comparison between the economic costs of the alternative and savings through increasing the pulp yield, which are obtained by reintroducing some of the rejects back into the process.

6.3.18. Separate collection of non-fibrous materials

The non-fibrous material accompanies the recovered paper in the bales. These are foreign materials that should be removed from the pulp circuit. If this is not done, the metal materials can cause faults in the machinery, while the softer materials that could disintegrate into tiny particles as a consequence of the pulp treatment would become impurities, resulting in the lower quality of the final product.

Separation takes place in the first operations in the treatment of recovered paper:

- Feeding of the pulper: cables, springs, etc.
- Pulping to high consistency-separator: large pieces of plastic, cords, etc.
- Centrifugal purifying at high consistency: sands, staples, clips, etc.
- Pressurised purification at medium consistency: small pieces of plastic, "hot melts", etc.

The total of these materials is around 3-4% in weight of the total raw materials used.

6.3.19. Updating the design of the facilities in order to reduce energy consumption

The increasing use of recovered paper is resulting in continuous improvements in the different items of equipment that make up a complete treatment and preparation system.

It should be remembered that in all recycled pulp systems there are two objectives:

- The removal of those non-fibrous materials or components that accompany the recovered paper (plastics, glues, waxes, etc.).
- The treatment of the fibres to obtain the necessary characteristics for the paper manufactured from them.

When considering the redesigning of a system, the priorities of each facility should be set out. This should be both in terms of the removal of impurities and pollutants and in the efficiency of the paper machine itself, bearing in mind its configuration and operating conditions.

A balance considering a compromise between the cleanliness of the pulp, fibre losses, and the quality of the paper to be manufactured, enables the selection of the circuit and equipment most suitable for obtaining the most efficient energy consumption. Normally, this measure is accompanied by a technological change in the plant.

6.3.20. The use of energy-efficient technologies

There are numerous methods applicable in the manufacturing process to reduce energy consumption. Normally, these measures are linked to investments in substituting, modifying or increasing the process equipment. These measures are not applied simply to save energy, but also at the same time to increase production efficiency, to improve the quality of the product and to reduce total costs. It is therefore essential that energy saving techniques be incorporated into all aspects and levels of paper manufacturing. The majority of these are advantageous and increase productivity.

Some of these technologies and their main characteristics are outlined in the table below.

Table 6.3.3. Situations in which it is possible to apply measures for the reduction in energy consumption, and their effects

Energy efficient technology	Type of energy required, and quantity	% energy saving and quantity	Remarks
High consistency disintegration	Electricity for pumps and rotors; 60 kWh/t	33%; 20 kWh/t	Attained with the optimisation of rotor design
Best practices in refining	Electricity for motors; 100 -500 kWh/t	20%; 80 kWh/t	Depends on the properties of the product; variations between the composition of manufacturing and grades of quality
High consistency during formation	Electrical; 200 kWh/t	20%; 40 kWh/t	Applied to recovered paper
Double wire in the formation section	impulse	no data	Not applied specifically for energy saving
Optimisation of the vacuum systems	Electrical	25%	Improved drainage
Variable speed conduction system	Electrical	no data	
Highly energy efficient motors	Electrical	no data	
Good sizes of electrical engines	Electrical	no data	
Hot presses or an increase in the pressure zone	Heat in the drying section	15 - 20%	Mainly recovered fibres
Cross direction moisture profile correction with IR heaters	Heat in the drying section	1 -2%	Reduces the extent of over drying
Combustion gases humidity control	Heat	10%	Allows the adjustment and reduction of air flow
Heat recovery from combustion gases	Heat	10%	See description below
Recovery of condensates	Heat	10%	The water can be returned and used
Direct drying with combustion gases and air	Heat	40%	Used in the tissue paper machine hood
Increased solids in the sizing press	Heat for the drying section after sizing	Drying load reduced by 48%	This leads to a reduction in brokes

The technique described below is an example of one of the possibilities available for saving energy using energy efficient techniques.

Description

The objective of the heat recovery system is to reduce the consumption of primary energy in the mills, using the residual energy from the process in a way that is economically viable. Almost all of the thermal energy consumed in a paper manufacturing plant is used in the drying of paper, and therefore the drying section of the paper machine is the section that consumes the most energy. Approximately 80% of the necessary energy in the drying section comes from primary steam for the drying cylinders and the rest comes from the air and the wet web of paper.

Almost all of the energy from the drying section is lost with the vapour. Nearly 50% of this energy, that is, approximately 620 kWh/t of paper, can be recovered with an efficient heat recovery system.

The typical applications in use are air-air or air-water heat exchangers, both of plate type designs (in some cases the direct contact exchanger is used, in the form of scrubbers). The recovered heat is used mainly to supply hot air to the hood and as ventilation air in the machine room. The next most common use is to heat the circulation water and the process water respectively. These heat exchangers form part of the heat recovery towers.

Applicability

These measures can be applied in new and existing mills if in their processes these mills generate gas flows with a high energy content and if there are points with a demand for calorific energy. The heat exchangers for the supply of air to the heating hood can always be installed.

Main environmental effects

Large quantities of primary steam are saved, which means less impact in terms of the generation of steam. Achievements also depend on climactic conditions.

The majority of the heat is recovered in the circulation water, which is then normally used to heat the building's ventilation air, for heating process water (for example for the sprinklers) and for the white waters from the machine.

Economic aspects

Heat recovery systems generally have fairly short return periods on investments made. It is not always economical to recover the largest possible amount of heat, there should always be a specific analysis to maximise the benefits. The solution depends on the relative cost of energy (in kWh) for fuel, steam and electricity.

Operational experiences

The heat recovery systems that are available depend on the machinery distributor. The optimum system is specific for each paper mill and should be specially designed in each case. Generally, heat exchangers are accompanied by necessary cleaning devices to keep the surface clean and avoid it becoming silted up.

6.3.21. Elimination of accidental or occasional discharge

This discharge is not related to the process and is a result of maintenance failures or a lack of prevention or procedure. The storage and the facilities for the manipulation of potentially polluting products should be designed to avoid this type of accident.

This measure is fundamentally preventative, and is considered a Good Housekeeping Technique:

- Generally: Establishing procedures which clearly outline the repercussions on the environment and the pollutant characteristics of the different operations.
- In process facilities: Ensuring the appropriate size of white water systems and brokes to be able to absorb three hours of production in the case of continuous breakage of the paper machine. The investment for tanks for waters and pulp from brokes for a production of 100 t/d of pulp is around 140,000 euros.
- In systems of storage and decantation of fillers and auxiliary products: Installing security instruments such as leak detectors, level alarms etc, and constructing barriers or containing walls. This is normally a question of minor investments (<2% on the main investment).

6.3.22. Training, education and motivation of personnel

Mills are managed and operated by a collective of people, and therefore training is a sure way of reducing energy and water consumption and the effluent discharges that can harm the environment.

Training, education and motivation of personnel is a Good Housekeeping Practice of proven effectiveness.

6.3.23. The optimisation of process control and the effective maintenance of the facilities

The optimisation of the process and the efficient maintenance of the facilities is carried out in accordance with the initial conditions of design and operation.

Advanced process control systems maintain the process variables at the optimum set point, correcting any minor deviations that can occur during the manufacturing process.

The direct benefits of an advanced process control system in the manufacture of pulp and paper are related to the losses which occur in the process with respect to the optimum conditions. These losses include:

- Losses of product quality. These are the most important from an economic point of view, if the product does not meet specifications, and involves the consumption of raw materials, water, and energy, and the generation of effluent gases and wastewater discharge, in addition to increased general waste, without the counterweight of the production of the goods.
- Deviations from the process variables. These deviations result in a reduction in yield from operations and processes, and lead to increased consumption of raw materials, energy, and water.

The reduction in yield of the different stages also leads to increased pollutant emission due to the reduction in conversion during the chemical reaction stages, and in an analogous fashion, the reduction in efficiency of the effluent purification stage has as a consequence the increase in flow and concentration of emissions and discharge.

By means of example, the predictive control of a Kamyr type continuous digester for the production of Kraft pulp can be cited. This is based on the cooking parameters such as the viscosity of the pulp and its kappa index, along with the variables in the process such as pressure, temperature, liquors/wood relationship or hydromodule, vaporisation and preimpregnation of the wood with the process liquor, and residence time.

The control of the reactor enables the optimisation of steam consumption, the reduction in emissions of total reduced sulphur compounds, and the production of the pulp to the specified quality with lower consumption of reactives in the stages after oxygen delignification and bleaching, with the consequent saving in wash water to ensure the pulp is of a specific quality.

The advanced control of energy generation processes, along with that of the equipment for the purification of combustion gases, means that thermal and purification yields obtained are higher than those obtained through control systems based on conventional PID control links, Proportional, Integral, Derivative; this system is in turn better than all-nothing control, which is extremely outdated.

Given the cost/benefit ratio obtained by the automatic control of processes, and the fact that the return on the investment comes in a relatively short time, this technology is applied in practically all the pulp and/or paper manufacturing industries.

The efficiency of advanced process control systems in all the parameters of the machine, pressing and drying, is clearly shown in paper mills. The control of the following parameters: consistency, feeding the machine, grammage, forming and moisture in drying, permits an increase in production, the reduction in stoppages due to broken sheets and a better use of raw materials and additives. This results in economic savings and environmental improvements derived from the reduction of the pollutant load in wastewater discharge. The control of the variables of circulation of process waters is also important in terms of the reduction of water consumption.

The maintenance of the facilities, both process facilities and facilities for effluent purification, is of great importance in the pulp and paper industry. Preventative maintenance reduces breakdowns, losses, uncontrolled spillages, increases yield from raw materials, reduces emissions, discharge, the generation of waste and, in addition, it reduces emergency situations resulting from unprogrammed stops and breakages.

The maintenance programme establishes the sequence of periodic operations to be carried out on each of the machines, in addition to directions for the detection of breakdowns by means of monitoring the electrical consumption of engines, loss of charge in conduction, monitoring of thermal heat exchange temperatures, sound levels and vibrations in machines, the state of sealing joints and mechanical closures, etc. Predictive maintenance provides preferential attention to the critical points of the facility, defined in the evaluation of environmental risks.

6.3.24. Environmental management

Companies in all of the industrialised countries are adopting Environmental Management Systems (EMS) to enable them to administer the problems and opportunities on an environmental level in a more efficient and systematic manner. The integration of Environmental Management into the total management of the company is a fundamental point, as it is one of the relevant aspects affecting companies.

The name Environmental Management Systems is given to the collection of organisational responsibilities, procedures, processes and means required for the implementation of an environmental policy in a company or production centre. It is the framework or method used to enable an organisation to attain and maintain levels of operation in conformity with the established standards, and is directed towards attaining the objectives defined in the organisation's environmental policy.

The establishment of an EMS is done to obtain an improvement in environmental action. The effectiveness of an EMS is linked to an extremely detailed knowledge of those elements of its application that can significantly affect the environment. Therefore an EMS analyses the environmental behaviour of an organisation in reference to the impacts of this organisation on the soil, water, generation of waste and management of natural resources, among other things.

As indicated above, the implementation of an environmental management system always begins with the integration of environmental considerations into the overall management of the company.

The basic objectives should always be focused on improving the company's environmental results and complying with environmental legislation. This environmental improvement must be reflected in cleaner production that consists of the continuous application of an environmental protection strategy for both processes and products in order to reduce risks both for humans and the environment. Environmental improvements in processes promote the optimising of the minimum quantities of water and energy used.

There are basically two models of recognition, ISO-UNE 14001 certification and the EMAS regulations.

ISO-UNE 14001

This is a voluntary, international norm, which is applicable to all types and sizes of organisations. Its main objective is to provide organisations with those elements necessary to develop an environmental management system. It is not intended to be used to create trade barriers.

It is a tool of which the objective is to specify the requirements for an EMS, to give organisations the capacity to formulate a Policy and a number of Objectives, taking into account the legal requirements and information concerning significant environmental impacts.

The EMS provides a structured process for achieving continuous improvements, of which the rate of application and the extension will be determined by the organisation of economic factors and other circumstances.

EMAS (Regulation 761/2001)

This is a tool that also specifies the requirements for the implementation of an Environmental Management System, but it is only applicable in the countries of the European Union. The main differences between this and ISO 14001 are that this regulation stipulates the need to carry out an initial environmental revision and that an annual environmental declaration must be made.

Those organisations that have implemented an EMS improve the image of their company for the general public and for their employees, due to the fact that they are guaranteeing compliance with environmental standards.

Among the benefits of an EMS is the cost saving resulting from the minimising of consumption of resources (water, energy, etc.), the minimising of waste, the minimising of packaging, improved market image, etc. The latter is possible when the ecological awareness of consumers is raised.

6.4. EMERGING TECHNOLOGICAL ALTERNATIVES

6.4.1. New energy efficient processes of obtaining TMP pulp

Definition

TMP pulp processes consume large quantities of energy in the interval 1,600-3,200 kWh/t.

Today, large amounts of research work is being carried out with the intention of reducing energy consumption in this type of process. Since the mid-1990s, some applications of new energy efficient processes have been found (RTS and Thermoplus®).

Stage of development

These techniques, RTS and Thermoplus®, consume substantially less energy than the usual processes for obtaining TMP pulp. Thermoplus® processes were installed in the mid-1990s both in Europe and North America. The first installation of RTS took place in Switzerland in 1996. The two techniques can be considered to be available technology, but they are normally installed only in new mills or when the equipment in existing mills is being replaced.

Main environmental aspects

RTS processes reduce energy consumption in the refining of wood chips by increasing the speed of the discs. At the same time the temperature is increased. The "R" stands for Retention time, "T" is temperature and "S" is speed. The first applications of this technology show a 15% reduction in energy consumption compared to conventional TMP techniques.

Regarding the Thermoplus® process, the first stage of refining takes place at relatively low temperatures. The pressure and the temperature are raised prior to the second stage of refining, which takes place at fairly high temperatures and pressure (700 kPa and 170 ºC). Energy reductions of 10-20% have been obtained.

Economic aspects

There are no figures available.

6.4.2. Closure of water circuits with evaporation and incineration of concentrates

Definition

An alternative for the closure of the water circuits is the evaporation of wastewater and the incineration of the concentrates in a recovery boiler. This technique, considered to be an emerging technique, can be applied to all waters or those that are most contaminated, sending the rest for primary and secondary treatment.

This is an alternative that should be considered when the capacity of the production plant is to be increased and biological treatment is on too small a scale. It requires technological changes in the plant and implies an increase in recycling in the process.

It has been applied in a CTMP plant where the condensate is reused in the plant itself, reducing the consumption of fresh water. It has also been used to completely close the water circuits in a Canadian CTMP plant, as shown in figure 6.3.3. Wastewater is treated first in a Krofta clarifier to remove the suspended solids, and is then evaporated in two stages. At the first stage, solid concentration reaches 35%, and at the second it reaches 70%. The solids obtained at this stage, together with those obtained from clarification, are burned in the recovery boiler. The distillate from the first stage is separated into fractions to avoid the contamination of the purest distillate, which represents 85%. The fraction with the higher content in volatile organic compounds is treated by "stripping" to separate the organic material, which is then incinerated.

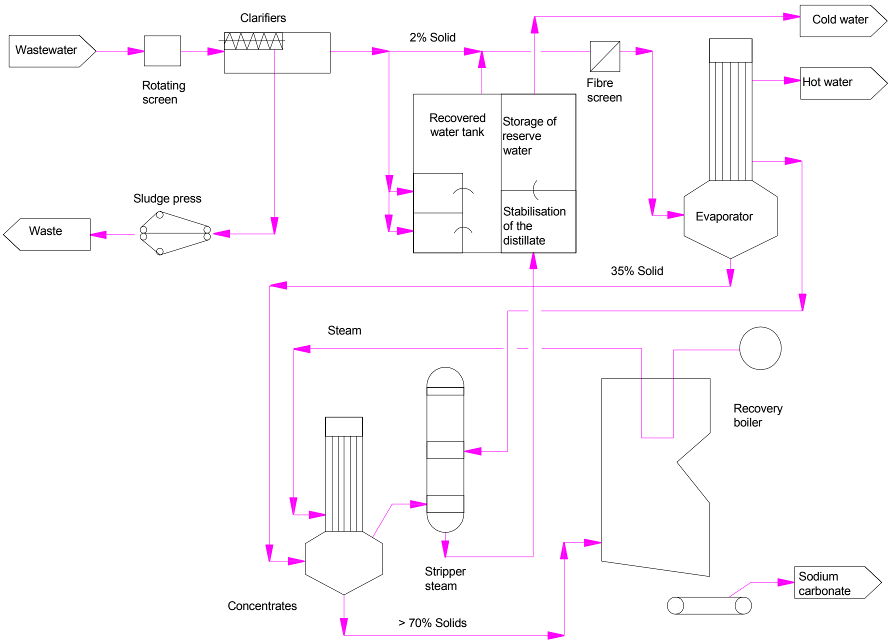


Figure 6.3.3. Diagram of the total closure of the water circuits in a Canadian CTMP plant

A new evaporator has also been developed. This has multiple effects and is known as the Zedivap^{TM}. The majority of distillates from the evaporators can be used in pulp mills directly at 65 ºC. However, some mills require the water temperature to be 20-30 ºC, and therefore a part of the distillates is refrigerated, and the majority of the organic compounds are removed in biological stabilisation tanks.

The melted material from the recovery boiler is cooled and solidifies on conveyor belts, and is then deposited in containers.

Applicability

This integrated process technique can be used both in new and existing mills. It has been used in CTMP and TMP plants, although it can be used in other processes. The limitation of this is the high cost of evaporation, the availability of capacity in the recovery plant, a high capacity for storing wastewater, the availability of space, etc.

When evaporators are used, the bleaching plant should be modified. For example, sodium silicates cannot be used as they generate encrustation problems.

Economic aspects

Energy consumption for an MVP process is estimated to be around 13 kWh/m^3 of water treated, while in the evaporators, the multiple effect is of 1.4 kWh/m^3, for a capacity in both cases of 3,600 m^3/d.

6.4.3. Removal of chelating agents

Definition

EDTA chelating agents (ethylenediaminetetraacetic acid) and DTPA chelating agents (Diethylenetriaminepentaacetic acid) have traditionally been used in the pulp and paper industry for their sequestrant properties and their capacity for suppressing the activity of dissolved transition metal ions. These metal ions are capable of acting as catalysts in the decomposition of hydrogen peroxide, used as a beaching agent, into radicals, with the consequent reduction in their bleaching capacity and increase in the costs of bleaching. Therefore in TCF pulp bleaching processes, sequences with chelating agents "Q" are used to avoid the negative influence of the metal ions on the active chemicals (hydrogen peroxide) used in TCF pulp bleaching.

However, it has been proven that in the mill's wastewaters, high concentrations of chelating agents "Q" are removed (between 25 and 40% of the total used). And despite the fact the EDTA is a substance that is considered non-toxic, there are difficulties in its total biodegradation, and therefore it is desirable that it be removed from mill waste.

Techniques have been under study recently to permit greater recovery of chelating agents "Q".

There are two processing options for the removal of EDTA.

Option 1: Biological treatment with or without activated sludge, which result in significant reductions of the COD and BOD of the effluent. However, this system cannot significantly reduce the EDTA of this effluent. It has been found that EDTA is resistant to biodegradation in activated sludge plants operating under normal conditions (pH=7). Moreover, the EDTA is not absorbed into the sludge. A recent study shows the increase in the biodegradation of EDTA in a plant with activated sludge under alkaline conditions (pH=8-9). An additional reduction in EDTA is obtained of around 50% (the reduction being 10% at pH 7).

Option 2: Another technique to reduce the consumption and discharge of Q, used prior to the hydrogen peroxide stage in TCF bleaching, is the use of membranes for the treatment of this effluent.

Option 3: Its substitution with other chemical compounds that are more easily biodegradable is currently being researched, such as: anionic modified polyamines, polyasparaginic acid salts, iminodisuccinic acid, etc.

Stage of development

The biodegradation of EDTA in activated sludge plants in alkaline conditions seems promising. The treatable nature of the EDTA contained in wastewaters from bleaching plants in activated sludge plants in moderate alkaline conditions has been confirmed in a laboratory environment [C.G. van Ginkel, 1997 a+b] and in full-scale activated sludge plants.

Detailed information is required concerning the complexities of EDTA and the influence of sludge retention time, temperature, etc, in order to improve the calculation of the removal of EDTA from the wastewater in paper mills (Fe(III)EDTA compounds are well known as the reluctant salts, those salts formed by Mn and Ca with the EDTA are more easily biodegradable). A low retention time of the activated sludge and the compound Fe(III)EDTA may be the cause of relatively low removal.

In addition, the photodegradation of the compound has also been described in the relevant literature [Kari, 1996]. FeEDTA is the only EDTA compound that can be photochemically transformed in surface waters.

The first application on an industrial scale of the Kemira NetFloc (PEO/phenolic resin) system for the recovery of EDTA from bleaching plant effluent was recently put into practice.

Main environmental effects

In an activated sludge plant on a real scale, in moderately alkaline conditions (pH 8-9), an average reduction of almost 50% of EDTA was obtained (the reduction being 10% at pH 7). The results also indicated that the adjustment of the pH to 8-9 with calcium oxide (dosage of around 90 mg CaO/l) did not interfere with the normal operation of the activated sludge plant. EDTA concentrations in the samples with accelerated biodegradation were relatively constant (2-4 ppm).

6.4.4. Use of the SNCR (Selective Non Catalytic Reduction) process

Definition

Selective non catalytic reduction (SNCR) enables a reduction in emissions of nitrous oxides $NO_{x,}$, is an industrially viable process and enables reduction effectiveness of between 50% and 80% to be reached.

The difference between selective and non-selective processes is in the reduction in oxygen: therefore in both, reduction begins with the conversion of NO_2 into NO. In non-selective processes, the following step is the reduction of oxygen, and when this has practically run out, a stage takes place which really leads to the purification of the gases, the reduction of NO to elemental nitrogen and water. The final products, therefore, are the natural constituents of air.

The NO_xOUT process is one of several processes using the technique of selective non catalytic reduction to reduce NO_x emissions by means of the conversion of ammonia to nitrogen according to the following reactions:

$$3NO_2 + 2NH_3 \rightarrow 3NO + 2N_2 + 3H_2O$$
$$6NO + 4NH_3 \rightarrow 5\ N_2 + 6H_2O$$

If urea is used, the following reaction will take place first:

$$(NH_2)_2CO + H_2O \rightarrow 2NH_3 + CO_2$$

The reducing agent used in the tests carried out on an industrial scale is a solution of urea in water with the final result of the generation of ammonia. The reaction occurs at a temperature of nearly 1,000 ºC. If the temperature increases considerably, the NO_x emissions increase, but if it is low then a larger quantity of ammonia is generated. In the NO_xOUT process, the temperature interval expands and the chemical compounds limit the formation of ammonia. The most important parameters in the optimisation of the process are the undesired production of ammonia as a result of secondary reactions, and the consumption of chemical compounds.

Stage of development

A Swedish Kraft pulp company carried out a large scale test of the patented NO_xOUT process in one of its recovery boilers. During the period of the test, the boiler operated at between 95 and 105% of the maximum continuous range. The project showed that the thermal reduction of nitrous oxides using the NO_xOUT process can successfully be applied in recovery boilers.

Main environmental effects

In comparison with other combustion processes, lower quantities of nitrous oxides are produced in the recovery boiler. The typical levels are between 50 and 80 mg NO_x/MJ. Despite the relatively low concentrations of NO_x in the recovery boiler, this is the main source of NO_x emissions in the Kraft pulp plant (due to the high flow levels of gas). As a result, the smoke treatment measures applied in the recovery boiler represent the most significant effect on total emissions. In addition, an increase in NO_x emissions from high efficiency recovery boilers is predicted, due to the demand for increased dry content of black liquor and the increased loads in the furnace.

6.4.5. Membrane bioreactor

Description

This is a combined separation and oxidising process. It consists of an intense biological oxidisation that seeks the decomposition of the organic material and the separation of solids and liquids through the use of a membrane. The membrane is submerged in the biomass in the activated sludge plant.

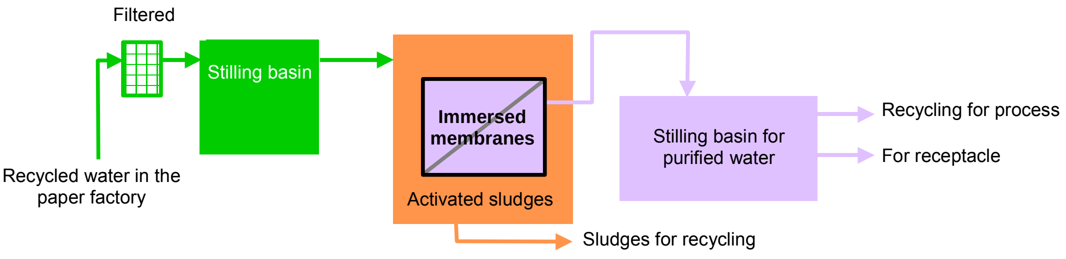


Figure 6.3.4. Membrane bioreactor using immersed membranes in an activated sludge reactor (MBR)

Stage of development

The first application on a real scale was put in place in 1999 in a French card mill (Papeterie du Rhin). The flow of the design is relatively small (900 m^3/d), although the intention is to increase progressively the fraction of water recycled in the process.

Main environmental effects

For some types of mill, which cannot solve the problem of discharge limits (for example: when their concentration or load is slightly higher) a membrane bioreactor (MBR) could enable them to comply with the discharge limit. The process could also be used as pretreatment for separation/concentration processes such as Nanofiltration (NF) or evaporation. This application can be of interest for operators of paper mills who plan to use MBR to obtain the closure of the water circuit.

Membrane bioreactors can produce lower quantities of sludge, as low as half, than a conventional biological treatment, due to the specific characteristics of the activated biomass that grows in MBR applications.

6.4.6. Recovery of ash and CO_2 from the boiler to produce mineral fillers for use in paper manufacturing

With this technology, recycled calcium carbonate precipitate is produced. The origin of this is the combustion of the de-inking sludge (alternative 6.2.21), with the main advantage for the paper manufacturer using calcium carbonate precipitate being that in the process, different particle sizes and forms can be obtained as desired, which optimises yield in paper manufacturing operations.

It has been discovered that ash from the incineration of de-inking sludge makes possible the nucleation and development of calcium carbonate precipitate. It has also been proven that this can be a substitute for the lime (CaO) that is used to produce calcium hydroxide.

This technique significantly reduces the quantity of solid residue from de-inking plants, of fuel necessary to produce CaO, and of CO_2 emissions.

6.4.7. Diagnostic systems

Definition

Due to the complexity of paper manufacturing processes, new data information systems have been developing gradually. The complexity of the processes can be illustrated by the example of water use. The increase in water recirculation results in different chemistry in the process, increases the water temperature, and leads to different water management practices, new flow rejects, changes in effluent treatment operations, increased energy consumption, etc.

The consumption of energy or electricity is also determined by the machine's production speed and by the level of development of its operation.

The different technological choices will have different effects on the energy balance of the mill. It can therefore be concluded that in the future, intelligent process solutions will try to combine the different systems - energy, water, fibres, chemical compounds - in order to ensure a good level of integration in the mill.

Stage of development

A number of computerised tools capable of analysing the complexity of the system, including the effects produced, are currently being researched.

Main environmental aspects

The key factor is how to carry out processes that emit fewer pollutants into the air and water and at the same time to reduce the generation of solid residues and the consumption of energy. The requirements for new processes are better paper qualities and greater productivity of the machine, together with better process management. This means better knowledge of the behaviour of the processes.

It is clear that the new optimisation tools are useful for the future development of paper manufacturing processes. Some computerised tools contain the following information:

- Information on the concentration of pollutants in different parts of the process.
- Models of behaviour of the pollutants.
- Methods of treatment and parameters of the separation process.
- Methods for optimising the treatment of water with regard to the concentration of pollutants and their behaviour.
- Identification of heat sources.

- Methods of optimising the use of heat through integration processes.
- Information on emissions and the formation of solid waste.
- Detailed process design based on the choices made.
- Methods for analysing and developing the operation of the process of the paper's passage through the machine.

Economic aspects

No information has been found; however, the total investment for the implementation of computerised tools would not be a very costly one.

6.5. SUMMARY TABLE FOR THE PROPOSED TECHNOLOGICAL ALTERNATIVES

All of the proposed technological alternatives are shown by means of a summary table below, with a brief outline of the alternative along with the benefits obtained from its application and the repercussions of said application on the production process.

They are classified in four categories: liquid discharge, atmospheric emissions, solid waste/sludges and energy, both for pulp manufacture (mechanical pulp "MP", Kraft pulp "KP", sulphite pulp "SP" and pulp from recovered paper "RP"), and for paper manufacture.

ENVIRONMENTAL PROBLEM 1: LIQUID DUMPING (PULP MANUFACTURE)

No.	Type of pulp	Proposed measure	Description	Benefits	Repercussions on the production process
6.3.1.	MP, KP, SP	Dry debarking.	Techniques for dry debarking of the trunks.	The flow of water is reduced, decreasing the COD and the total dissolved solids (TDS). Higher energy generation in the bark furnaces.	None.
6.2.2.	MP	Water recirculation.	Reuse of process water.	Reduction of liquid discharge.	Very closed circuits could have a negative effect on the quality of the final product.
6.3.2.	MP, KP, SP	The use of storage tanks with sufficient volume to optimise water consumption.	The storage tanks enable the avoidance of overflowing during the starting up or stopping of the plant or when there is an alteration in the process.	Lower volume of wastewater and lower pollutant load. This reduces the risk of alterations in the operation of the wastewater purifying plant, by avoiding accidental leaks with high organic loads, or with extreme pH values.	None.
6.3.3.	MP, KP, SP	Control and recovery of leaks and escapes.	Collection and treatment of internal spillages and overflows.	Minor water spillages.	This requires a slight increase in the capacity of the evaporation plant.
6.3.4.	PK, PS	Screening of the unbleached pulp in closed water circuits.	Closed circuits in the pulp purification plant.	This avoids the discharge into the effluent of organic materials dissolved in the water.	Very closed circuits could have a negative effect on the quality of the final product.

ENVIRONMENTAL PROBLEM 1: LIQUID DUMPING (PULP MANUFACTURE)

No.	Type of pulp	Proposed measure	Description	Benefits	Repercussions on the production process
6.4.2.	MP	Closure of water circuits with the evaporation and incineration of concentrates.	Closure of water circuits by means of the evaporation of wastewaters and the incineration of the concentrates in a recovery boiler.	Reduction in liquid discharge.	High cost of evaporation, availability of space, etc.
6.3.8.	RP	Closure of the water circuit with the biological treatment of effluent integrated into the process.	Closure of water circuits by means of an internal biological treatment that enables water to be recirculated.	This enables liquid discharge to be reduced practically to zero.	The calcium concentration in the white water should be monitored, as it can lead to precipitation of the calcium carbonate in the water circuit.
6.3.5.	MP, KP, SP	Efficient washing.	Efficient technique of separating the cellulose fibres from the residual cooking liquor.	Lower consumption of chemical bleaching products, along with lower residual COD, BOD5 and AOX (bleached pulps).	Higher energy generation.
6.3.6.	PK, PS	Extended modified cooking.	Obtaining pulp with a lower lignin content that is therefore easier to bleach.	Increased quantity of organic substances dissolved in the liquors that are sent to the recovery boiler. AOX and COD reduction Reduction in chemical bleaching products.	Higher energy generation.
6.2.3.	PK, PS	Oxygen delignification.	Treatment with oxygen for the removal of residual lignin.	Lower generation of residual AOX and COD in the bleaching plant. Lower consumption of bleaching agents. Lower bleaching costs.	Higher energy generation.
6.3.7.	PK	Ozone bleaching.	Pulp bleaching with ozone, with the objective of giving the pulp greater capacity for delignification.	In ECF processes, the discharge of AOX is reduced, while TCF processes enable higher brightness levels to be reached with better peroxide consumption, and also make the closure of circuits during the bleaching stage easier.	None.
6.2.4.	PK	ECF bleaching.	Pulp bleaching without the use of chlorine gas.	Less formation of chlorinated organic compounds and lower dioxin load (AOX).	None.
6.2.5.	PK, PS	TCF bleaching.	Pulp bleaching with agents that are totally free of chlorine.	There is no AOX formation.	The need for the use of chelating agents Q to capture the heavy transition metals.

ENVIRONMENTAL PROBLEM 1: LIQUID DUMPING (PULP MANUFACTURE)

No.	Type of pulp	Proposed measure	Description	Benefits	Repercussions on the production process
6.2.6.	PK, PS	Closure of circuits in the bleaching plant.	Total or partial closure of the circuits in bleaching plants.	Reduction in the quantity of organic substances, nutrients and heavy metals in the mill effluent.	Total closure could increase the consumption of chemical bleaching products and result in precipitation of calcium oxalate.
6.4.3.	PK, PS	Removal of chelating agents.	Techniques enabling greater recovery of "Q": Biological treatments with or without activated sludge, or the use of membranes, for the treatment of this effluent.	Recovery of chelating agents.	None.
6.2.7.	RP	Clarification of process waters from de-inking by means of dissolved air flotation.	The recycling of the white water from a recovered paper plant with de-inking is only possible with a prior clarification treatment of these waters. The best available technique today is dissolved air flotation (DAF).	Removal of suspended solids and dissolved colloidal material.	None if carried out in a controlled manner.
6.2.8.	RP	Internal treatment of waters by the use of filtration membranes and the recycling of process water.	Filtration with membranes of the white waters in a recovered paper plant with de-inking. Conventional filtering cannot effectively remove the solids and colloidal material of smaller than 1 microm in size. (The solutions are flocculation and filtration with membranes).	Removal of suspended solids and dissolved colloidal material.	None if carried out in a controlled manner.
6.4.5.	MP, KP, SP	Membrane bioreactor.	This is a combined process of separation and oxidation. It consists of intense biological oxidation seeking to achieve the decomposition of the organic material and the separation of solids and liquids by means of a membrane.	Reduction of the pollutant load.	None.

ENVIRONMENTAL PROBLEM 2: EMISSIONS INTO THE ATMOSPHERE (MANUFACTURING PULP)

No.	Type of pulp	Proposed measure	Description	Benefits	Effects on the production process
6.3.13.	MP	Control of emissions from the wood yard.	Control of emissions from the wood yard. Dampening the wood with water.	Reduction of emissions into the atmosphere	None.
6.3.14.	PK, PS	Increased concentration of the black liquor.	Extra evaporation process of the black liquors. The use of superconcentrators that enable a solid concentrate of up to 80% to be obtained in the black liquor.	Low SO2 emissions in the recovery boiler. More energy generated in the recovery boiler. Enables production capacity to be increased.	Requires greater capacity in the evaporation plant.
6.2.10.	PK, PS	Purification of the boiler gases by washing.	Condensate stripping, a technique for separating the clean condensates from the non condensable gases (NCG).	Reduction in TRS emissions (malodorous gases) into the atmosphere, and the COD of emissions into the water.	None.
6.2.11.	PK, PS	Purification and reuse of condensates from the evaporating plant.	Polluting condensates from evaporation and cooking, together with the weak liquors from overflows and losses in the manufacturing circuit, can be treated in a stripper, which can separate the clean condensates from the non condensable gases.	Reduction of the emission of TRS compounds, malodorous substances and VOC emissions. Saving fresh water by the reuse of condensates.	None.
6.2.12.	PK, PS	Processing the gases from boilers and furnaces with an electrostatic precipitator.	The use of electrostatic precipitators for the reduction of particle emissions.	Reduction of particle emissions, recovery of reactives as fly ash.	None.
6.4.4.	PK,PS	Selective non catalytic reduction "SNCR".	Reduction of NO_X emissions by means of selective non catalytic reduction.	Reduction of NO_X emissions.	None.
6.3.15.	PK	Improvement in the washing of causticising sludges.	Washing of the sludges in order to recover most of the chemicals they contain.	Reduction of TRS and SOx emissions into the atmosphere.	None.
6.2.13.	SP	Improvements in pulp preparation to reduce energy consumption and emissions.	Design of circuits and selection of appropriate equipment in order to improve energy consumption.	Energy savings. Reduction of atmospheric emissions. Improved quality of the paper manufactured. Reuse where possible of the different types of rejects generated.	None.
6.2.14.	RP	Application of steam and energy cogeneration.	Cogeneration of heat and electricity.	Increased global energy efficiency of the process. Reduction in greenhouse gas emissions.	None.

ENVIRONMENTAL PROBLEM 3: SOLID WASTE / SLUDGES (PULP MANUFACTURING)

No.	Type of pulp	Proposed measure	Description	Benefits	Effects on the production process
6.2.18.	MP	The installation of boilers with fluidised beds for sludge incineration.	A very versatile and effective technology resulting in lower emissions of volatile compounds into the atmosphere.	Reduction of NO_X emissions.	None.
6.3.17.	MP	Minimisation of loss through rejects in mechanical pulp mills.	The use of purification and refining systems that enable better use to be made of the raw materials.	Reduction in the loss of fibres and lower generation of solid rejects.	None.
6.3.1.	MP, KP, SP	Dry debarking.	Techniques for debarking the trunks when dry.	The flow of water is reduced, decreasing the COD and the total dissolved solids (TDS). Better energy generation in the bark furnaces.	None.
6.3.19.	RP	Separate collection of non-fibrous materials.	Separation of wires, plastics, etc. that accompany the recovered paper.	Separate storage of this waste.	None.

ENVIRONMENTAL PROBLEM 4: ENERGY (PULP MANUFACTURING)

No.	Type of pulp	Proposed measure	Description	Benefits	Effects on the production process
6.2.14.	MP, RP	Application of steam and energy cogeneration.	Cogeneration of heat and electricity.	Increases the global energy efficiency of the process. Reduces emissions of greenhouse gases.	None.
6.2.13.	SP	Improvements in pulp preparation to reduce energy consumption and emissions.	Design of circuits and selection of appropriate equipment to achieve lower energy consumption.	Energy savings.	None.
6.3.23.	RP	Updating the design of the facilities in a recovered paper plant.	Updating the design of the facilities in order to reduce energy consumption.	Reduction of energy consumption.	None.
6.3.6.	PK, PS	Extended modified cooking.	Obtaining pulp with a lower lignin content which is easier to bleach.	Increased quantity of organic substances that are sent to the recovery boiler. Reduction in AOX and COD. Reduction in the consumption of chemical bleaching products.	Greater energy generation.
6.2.3.	PK, PS	Oxygen delignification.	Processing with oxygen to remove the residual lignin.	Lower generation of residual AOX and COD in the bleaching plant.	Greater energy generation.
6.4.1.	MP	New energy efficient TMP pulp processes.	RTS and Thermoplus® techniques consume substantially less energy than the usual TMP processes.	Energy savings.	None.

ENVIRONMENTAL PROBLEM 5: LIQUID WASTE DUMPING (PAPER MANUFACTURING)

No.	Proposed measure	Description	Benefits	Effects on the production process
6.2.9.	Optimum water management. Reduction of fresh water consumption by means of the separation of water circuits and counterflow.	Circuit closure. The separation of waters and the use of exchangers or refrigeration towers enables water to be reused.	Reduction in fresh water consumption. Decreased liquid waste discharge: • Waters from refrigeration, seals and vacuum systems. • White waters from drainage. • Clarified waters from thickening to filtering.	None if carried out in a controlled manner; if this is not carried out in a controlled manner, the efficiency of the facility is reduced. It is helpful to install some kind of microfilter to remove the solids. It is possible to design closed links for the sealing water for the vacuum pumps, incorporating coolers and filters to separate the solids.
6.3.9.	Reduction in the loss of fibres and mineral fillers.	Use of disc filters or flotation units to recover fillers and fines.	Recovery of fillers and fines in the paper machine.	None; this can be somewhat limited due to the lack of space.
6.3.10.	Recovery and recycling of coating products contained in wastewater.	Ultrafiltration is used to separate the coating compounds by means of a semipermeable membrane.	Reduction in the emission of water pollutants and the quantity of waste. Reduction of water consumption, as the permeate can be reused.	None.
6.3.11.	Independent pre-treatment of wastewater from coating processes.	Chemical flotation and flocculation are carried out. An ultrafiltration system is preferred in new facilities as they normally offer a shorter return time on the original investment.	Operational benefits in the wastewater treatment plant.	None.
6.3.12.	Substitution of potentially harmful substances with other less polluting alternatives.	Removal of these substances after the treatment of wastewater for discharge. The use of alternative, non-toxic and biodegradable alternatives. Example: substitution of rosin and sodium sulphate glues which have been used for the internal gluing of papers with synthetic glues (alkylketene dimers), thus preventing the sudden pH variations that occurred.	Greater efficiency in waste processing, and therefore less environmental impact.	None.
6.3.21.	Removal of accidental or occasional discharge.	Preventative measures and training of personnel to deal with possible accidental spillages.	Avoids as far as possible accidental spillages and minimising their consequences.	None.

ENVIRONMENTAL PROBLEM 6: ATMOSPHERE (PAPER MANUFACTURING)

No.	Proposed measure	Description	Benefits	Effects on the production process
6.2.14.	Application of steam and energy cogeneration.	Energy requirements and the heat-energy ratio in the paper industry, together with the regularity of operations throughout the year, make the use of cogeneration techniques extremely appropriate.	Emissions per unit of heat or energy generated decrease substantially as a result of greater energy efficiency.	None.
6.3.16.	The use of low sulphur fuels or renewable fuels.	The use of alternative fuels such as natural gas. The use of renewable fuels such as wood or wood waste.	Reduction of CO_2 emissions into the atmosphere.	None.

ENVIRONMENTAL PROBLEM 7: SOLID WASTE / SLUDGES (PAPER MANUFACTURING)

No.	Proposed measure	Description	Benefits	Effects on the production process
6.2.15.	Optimisation of dewatering in the press section of the paper machine.	Optimisation of drainage and retention in the paper machine.	Savings of calorific energy when drying the paper.	None.
6.3.9.	Reduction of losses of fibres and mineral fillers in the paper machine.	Installation of disc filters or microfiltration units.	This improves the separation of fibres and fillers in comparison with conventional methods (sedimentation tanks).	None.

ENVIRONMENTAL PROBLEM 8: ENERGY (PAPER MANUFACTURING)

No.	Proposed measure	Description	Benefits	Effects on the production process
6.2.14.	Application of steam and energy cogeneration.	Cogeneration of heat and electricity.	Increased global energy efficiency of the process. Reduction in greenhouse gas emissions.	None.
6.3.20.	The use of energy-efficient technologies.	Energy efficient technologies such as better refining and pulping techniques, double wire forming in the paper machine, optimised vacuum systems, speed varying possibilities for fans, pumps, high performance electrical motors, recovery of condensed steam, increased concentration of sizing-press solids, heat recovery systems, etc.	Optimised energy consumption.	The implementation of some of these techniques would only be possible with the plant's reconstruction or where appropriate, during a stoppage to replace the equipment.

7. FINAL TREATMENTS FOR THE MINIMISATION OF POLLUTION (FTMP)

The objectives of the final treatments proposed in this chapter are to improve the composition (moisture content, toxicity, organic material, etc.) of waste that cannot be reused in the industry, in the receiving medium. In this way the environmental impact of the waste on different vectors of the environment (air, water and soil) is minimised.

Integrated pollution prevention is achieved by means of the efficient application of the Alternatives for Pollution Prevention at Source (APPS) outlined in the last chapter, and the final treatments for the minimisation of pollution where this is necessary.

7.1. SELECTION OF FINAL TREATMENTS ACCORDING TO THE PRODUCTION PROCESS

In this section, the presentation of the treatments is based on the most significant production processes in the pulp and paper sector. To do this, five tables have been produced, corresponding to:

- Final treatments for the minimisation of pollution (FTMP) in the production of mechanical pulp and their environmental impact (table 7.1.1).
- Final treatments for the minimisation of pollution (FTMP) in the production of sulphite pulp and their environmental impact (table 7.1.2).
- Final treatments for the minimisation of pollution (FTMP) in the production of Kraft pulp and their environmental impact (table 7.1.3).
- Final treatments for the minimisation of pollution (FTMP) in the production of recovered paper pulp and their environmental impact (table 7.1.4).
- Final treatments for the minimisation of pollution (FTMP) in the production of paper (table 7.1.5).

The rows show the available techniques, for which the effect produced on the levels of resource consumption and emissions is shown in the columns. The effects of each alternative are indicated qualitatively using arrows (↑ or ↓). Arrows pointing down indicate a reduction in the consumption of chemicals, water or energy, or a reduction in the pollutant load of emissions, waste and/or discharge. Conversely, arrows pointing up indicate an increase in the generation of pollutants or in the consumption of resources, or an improvement in the production process.

The information shown in the table with regard to the effects on consumption and emissions depending on the alternative, should not be considered as imperative information, but rather as a departure point to understand a possible source of pollution. Moreover, the effects will depend on the specific conditions of each mill.

Final treatments for the minimisation of pollution in a mechanical pulp mill

Table 7.1.1. FTMP in the production of mechanical pulp and their environmental impact

TFMC	Effects on emission and consumption levels (crossed effects)					
	Consumption of chemicals	Consumption of energy (E) and water (A)	Wastewater effluent	Atmospheric emissions	Solid waste	Remarks
7.2.2. Biological treatment of wastewater	↑	↑	↓ BOD ↓ COD ↓ AOX	↑ odour	↑ sludges	↑
7.3.1. Primary treatment of wastewater	n.e.	n.e.	↓ Suspended solids ↓ Nutrients ↓ COD	n.e.	↑ sludges	Treatment of sludges
7.3.3. Tertiary treatment of wastewater	↑	↑	↓ N ↓ P ↓ Organic Materials	n.e.	↑ sludges	Treatment of sludges
7.4.1. Effluent treatment with a combined ozonation and biofiltration process	Generation using oxygen instead of air must be considered	↑ E	↓ Colour ↓ COD ↓ AOX	n.e.	↑ sludges	Treatment of sludges
7.2.6. Minimisation of waste sent to landfill sites	n.e.	↓ E Incineration ↑ E Dehydration	n.e.	↑	↓	--

↑ = increase; ↓ = decrease; ***n.e.*** *= no (or negligible) effect;* ***(↑/↓)*** *= this may or may not produce an effect, with its impact depending on conditions*

Final treatments for the minimisation of pollution (FTMP) in the manufacture of sulphite pulp

Table 7.1.2. FTMP in the production of sulphite pulp and their environmental impact

TFMC	Effects on emission and consumption levels (crossed effects)					
	Consumption of chemicals	Consumption of energy (E) and water (A)	Wastewater effluent	Atmospheric emissions	Solid waste	Remarks
7.3.1. Primary treatment of wastewater	n.e.	n.e.	↓ Suspended solids ↓ Nutrients ↓ COD	n.e.	↑ sludges	Treatment of sludges
7.2.2. Biological treatment of wastewater	↑	↑	↓ BOD ↓ COD ↓ AOX	↑ odour	↑ sludges	Treatment of sludges
7.4.1. Treatment of effluent with a combined ozonation and biofiltration process	Generation using oxygen instead of air must be considered	↑	↓ Colour ↓ COD ↓ AOX	n.e.	↑ sludges	Treatment of sludges
7.2.2. Capture and treatment of malodorous gases	n.e.	↑ E capture and transport system	n.e.	↓ TRS ↑ NO_x ↓ odour	n.e.	↑ energy production (heat recovery)
7.2.4. Installation of low NOx emission burners	n.e.	n.e.	n.e.	↓ NO_x	n.e.	--

↑ = increase; ↓ = decrease; ***n.e.*** *= no (or negligible) effect;* ***(↑/↓)*** *= this may or may not produce an effect, with its impact depending on conditions*

Final treatment for the minimisation of pollution (FTMP) in the manufacture of Kraft pulp

Table 7.1.3. FTMP in the manufacture of Kraft pulp and their impact on the environment

TFMC	**Effects on emission and consumption levels (crossed effects)**					
	Consumption of chemicals	**Consumption of energy (E) and water (A)**	**Wastewater effluent**	**Atmospheric emissions**	**Solid waste**	**Remarks**
7.2.2. Biological treatment of wastewater	↑	↑	↓ BOD ↓ COD ↓ AOX	↑ odour	↑ sludges	Treatment of biological sludges
7.3.1. Primary treatment of wastewater	n.e.	n.e.	↓ Suspended solids ↓ Nutrients ↓ COD	n.e.	↑ sludges	Treatment of sludges
7.3.3. Tertiary processing of wastewater with chemical precipitation	↑	↑	↓ N ↓ P ↓ Organic Materials	n.e.	↑ sludges	Treatment of sludges
7.4.1. Treatment of effluent with a combined ozonation and biofiltration process	Generation using oxygen instead of air must be considered	↑ E	↓ Colour ↓ COD ↓ AOX	n.e.	↑ sludges	Treatment of sludges
7.2.2. Capture and treatment of malodorous gases	n.e.	↑ E Capture and transport system	n.e.	↓ TRS ↑ NO_x ↓ odour	n.e.	↑ energy production (heat recovery)
7.2.4. Installation of low NOx emissions burners	n.e.	n.e.	n.e.	↓ NO_x	n.e.	--

↑ = increase; ↓ = decrease; ***n.e.*** *= no (or negligible) effect;* ***(↑/↓)*** *= this may or may not produce an effect, with its impact depending on conditions*

Final treatments for the minimisation of pollution (FTMP) in the manufacture of recovered paper pulp

Table 7.1.4. FTMP in the production of recovered paper pulp and their environmental impact

TFMC	**Effects on emission and consumption levels (crossed effects)**					
	Consumption of chemicals	**Consumption of energy (E) and water (A)**	**Wastewater effluent**	**Atmospheric emissions**	**Solid waste**	**Applicability**
7.3.1. Primary treatment of wastewater	n.e.	n.e.	↓ Suspended solids ↓ Nutrients ↓ COD	n.e.	↑ sludges	Treatment of sludges
7.3.2. Anaerobic treatment as the first stage of aerobic treatment	n.e.	↓ E Biogas production	↓ COD ↓ BOD	↓	↓ sludges	BAT for brown grades facilitating aerobic treatment
7.2.2. Biological treatment of wastewater	↑	↑	↓ BOD ↓ COD ↓ AOX	↑ odour	↑ sludges	↑
7.2.7. In situ treatment of rejects and sludges: dewatering	↑	↑	↑ Flow from the wastewater treatment plant ↑ Pollutant load	n.e.	↓ sludges	For all levels of pollution

↑ = increase; ↓ = decrease; ***n.e.*** *= no (or negligible) effect;* ***(↑/↓)*** *= this may or may not produce an effect, with its impact depending on conditions;* ***MTD****: Best Available Techniques*

Final treatments for the minimisation of pollution (FTMP) in paper manufacturing

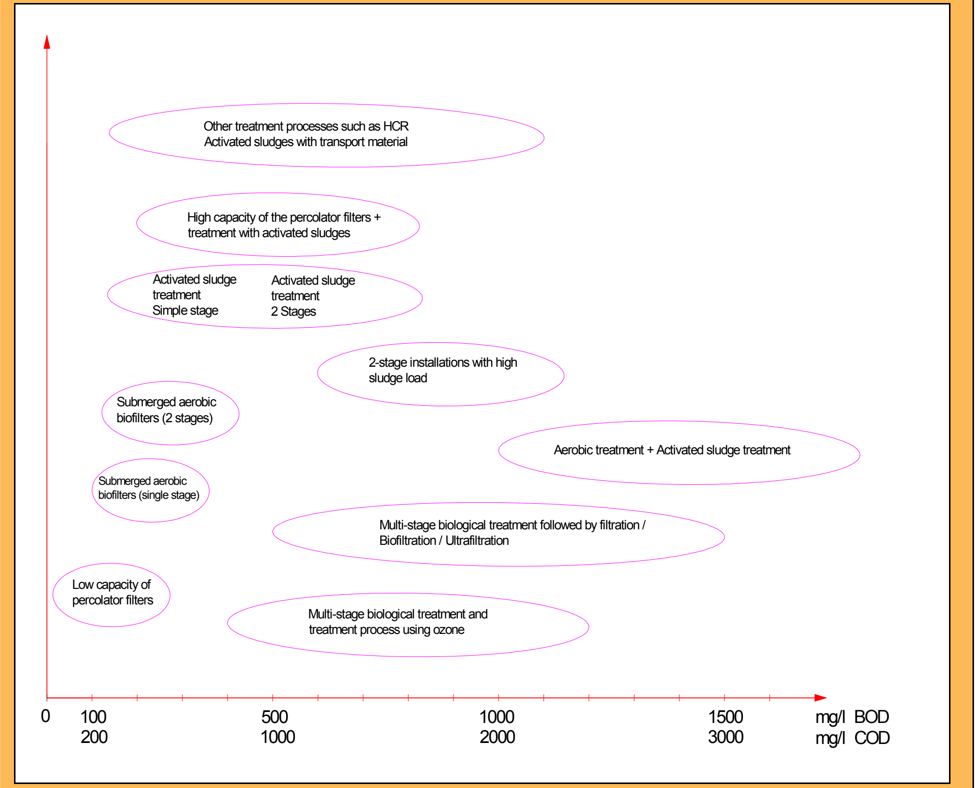
Table 7.1.5. FTMP in paper production and their environmental impact

TFMC	Effects on emission and consumption levels (crossed effects)					
	Consumption of chemicals	**Consumption of energy (E) and water (A)**	**Wastewater effluent**	**Atmospheric emissions**	**Solid waste**	**Applicability**
7.2.2. Biological treatment of wastewater	↑	↑	↓ BOD ↓ COD ↓ AOX	↑ odour	↑ sludges	↑
7.3.3. Tertiary treatment of wastewater with chemical precipitation	↑	↑	↓ N ↓ P ↓ Organic materials	n.e.	↑ sludges	Treatment of sludges
7.3.4. Control of the potential disadvantages of closing the water circuit	↑	↓ A	↓	n.e.	n.e.	This enables a reduction in the consumption of fresh water. For all levels of pollution
7.2.4. Installation of low NO$_X$ emissions burners	n.e.	n.e.	n.e.	↓	n.e.	For all levels of pollution
7.2.5. Reduction of external noise	n.e.	n.e.	n.e.	↓ Noise	n.e.	For all levels of pollution
7.2.7. In situ treatment of rejects and sludges: dewatering	↑	↑ E	n.e.	n.e.	↓ volume	For all levels of pollution
7.2.8. Combustion of de-inking sludges	n.e.	↑↓	n.e.	↑↓	↓	Recovery of E (steam)

↑ = increase; ↓ = decrease; ***n.e.*** *= no (or negligible) effect;* ***(↑/↓)*** *= this may or may not produce an effect, with its impact depending on conditions*

7.2. DATA SHEETS FOR SELECTED FINAL TREATMENTS FOR THE MINIMISATION OF POLLUTION (FTMP)

Final treatment for the minimisation of pollution (FTMP)	**7.2.1. Theoretical data sheet**
Process	Production process in which the FTMP is applicable.
Stage / Operation	Stage or operation which is modified, included or removed for the implementation of the FTMP.
Environmental problem	Most important effects on the environment resulting from the original process, which are minimised or reduced with the application of the FTMP.
Potential benefits of the FTMP	Main advantages obtained from the application of the FTMP.
Description	Scientific and technological bases on which the FTMP is based, and a description of its operation.
Procedure	Description of the most used technique(s) for the integration of the FTMP into the production process.
Comments	Additional information which is complementary to the earlier sections.
Economic aspects	Where possible, an idea will be given of the economic costs of implementation and operation of the FTMP. The figures provided have been taken from the reference document: BREF, Reference Document on Best Available Techniques in the Pulp and Paper Industry (2001).

Cleaner Production (CP) alternative	**7.2.2. Biological treatment of wastewater**
Process	Pulp and paper production.
Stage / Operation	Pulp and paper production plants.
Environmental problem	Wastewaters with a high organic compounds content.
Potential benefits of the CP alternative	Reduction of the content of organic material in the wastewater discharged from the plant.
Descripción	This is a much-used technique since the 1980s to remove degradable organic material present in the wastewater from pulp and paper plants. In most cases, aerobic treatments are used. In some specific cases, such as in pulp production plants or recovered packaging paper plants, an anaerobic treatment is used as a preliminary stage (6.3.9.). The choice of one technique or other depends fundamentally on the pollutant load of the waters to be treated.  Figure 7.2.1. Main external treatment process for wastewater from a paper plant and the appropriate range of application (HCR: High performance compact reactor) Aerated lagoons This is used for waters with a COD concentration of over 300 mg/l. Large areas are required in order to allow for a long residence time for the wastewater (3 and 20 days). The concentration of microorganisms is low (100-300 mg/l), which means that the efficiency of the treatment is also low. The most commonly used units for aeration are surface turbine aerators. Bottom aerators with induced or compressed air feed are also used. Aeration equipment provides the mixture required to maintain the solids in suspension and the microbial activity. Typical removal efficiencies for a residence time of between 15 and 30 days are: 40-85% for BOD$_5$, 30-60% for COD and 20-45% for AOX. There is no removal of nitrogen or phosphorous. The sludge or precipitated sediment is removed with a frequency of between 1 and 10 years. These are now practically unused due to the need for space, the low efficiency levels, the low energy yield in aeration and mixing, the appearance of mists, problems of scum and odours in the final effluent, etc.

Activated sludges

This is the most commonly used process. It is used for waters with a COD concentration of over 300 mg/l. The advantages of the process are the high yield obtained, the possibility of controlling the process (particularly the consumption of oxygen) and the relatively low space requirement.

The typical values of pollutant reduction are: 85-99% for BOD_5, 60-90% for COD, 40-65% for AOX, 40-85% for phosphorous and 20-50% for nitrogen. The efficiency of the removal of suspended solids achieved with a complete treatment of wastewaters (primary and secondary treatment) is 85-90%.

The disadvantages are the relatively high vulnerability to alterations resulting in operational instability of the system, the high level of production of biological sludges and the high operating costs.

There are alternatives to activated sludge treatments which are more compact and less costly, although the available experience of these facilities is limited.

Procedure

The activated sludge system consist of an activated sludge reactor where the degradation of the organic material takes place, and a clarifier to separate the sludge from the treated waters. Most of the sludges are recirculated to the reactor to maintain a high concentration of microorganisms, which means that the residence time of the wastewater in the reactor is short (15 - 48h). The oxygenation and the mix in the biological reactor is achieved using mechanical aeration equipment. The most widely used equipment is surface aerators, submerged turbines, and, with air blowers and compressors, fine bubble aerators and jet aerators.

Excess sludges are purged out (0.3-0.6 kg of sludges/kg of BOD_5 removed depending on the microorganism and pollutant loads). The sludges obtained are thickened and drained. When possible, the sludges are burned in the auxiliary bark furnaces and if not, they should be appropriately removed to landfill.

Comments / Examples of application

Table 7.2.1. Concentrations (mg/l) of effluent following a biological activated sludge treatment for different types of plants

Plant	BOD_5	COD	TSS	Total P	Total N
Kraft pulp	20-40	300-500	20-40	0.2-0.4	2-4
Paper	5-20	< 230	< 30	< 1	< 10

The energy consumption for the removal of 1 kg of BOD_5 varies between 0.3 and 3 kWh depending on the oxygen necessary for the degradation of the organic material and on the microorganism content in the system. High load systems with an optimised design and operation of the plant mean that consumption can be maintained at below 1 kWh/kg BOD_5 removed.

The nutrient content of the wastewater from paper plants is generally low, and therefore the controlled addition of phosphorous and nitrogen is necessary.

To control problems of eutrophication in the discharge flows, nutrient overdosing should be avoided, as should accidental emissions of nutrients. This is a typical case for CTMP plants.

Occasionally problems of sludge separation in the secondary sedimentation tank can arise, due to the formation of high volume sludges (bulking). These problems are due to the formation of filamentous bacteria or bacteria with a high degree of water retention in the sludge flocs, making its sedimentation difficult. The main causes of the development of filamentous sludges are the low concentration of dissolved oxygen in the aeration tank, the lack of nutrients, a low ratio BOD/microorganisms and an insufficient gradient of soluble BOD. The main causes of non-filamentous "bulking" are excessive aeration and the presence of material that is toxic to the bacteria. This cause can occur in the water from the bleaching process, in which a large part of the agents used are biocides, and the waters from paper manufacturing, if the bacterial control agents used in the white waters circuit are not chosen with enough care.

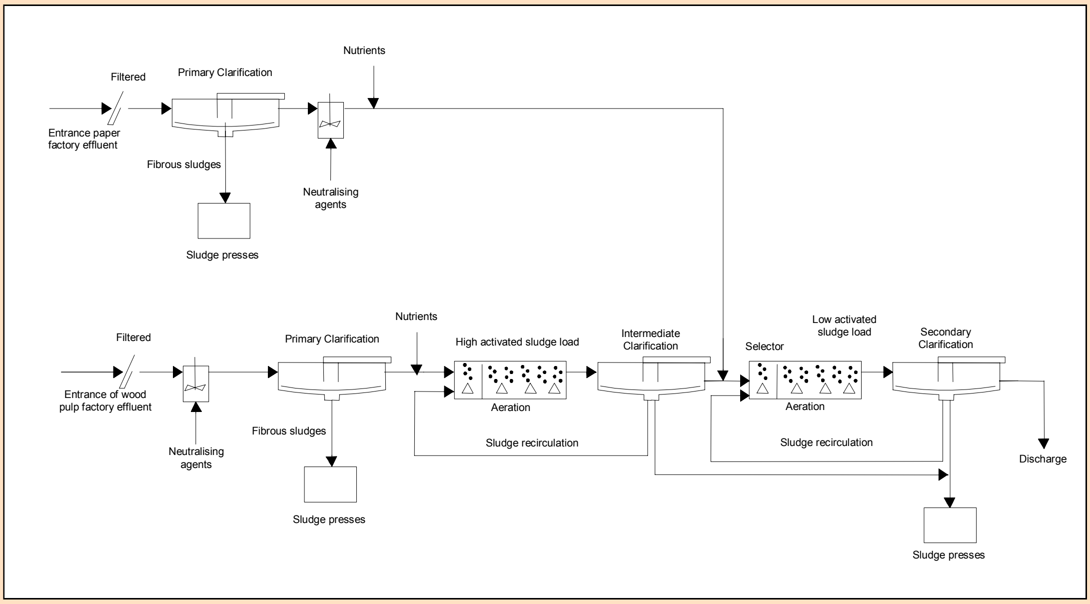
To avoid the production of bad smells when temperatures are high, the process conditions should be optimised, avoiding anoxic conditions in the bottoms of the sedimentation tanks and in the sludge thickeners.

In some situations (cardboard and paper mills) part of the effluent from biological treatment is recycled into the process waters of the plant. To do this, prior filtration of this effluent is necessary, for example by sand filtration.

Economic aspects

Aerated lagoons

The cost of this technique depends on where and how the lagoon is to be constructed. The investment costs varies substantially, and is usually between 16 and 20 M euros for a Kraft pulp mill with production of 1,500 t/d. This cost includes the primary treatment and the dehydration of the

	sludge. Operational costs come to some 1.3 - 1.7 M euros/year, which consists mainly of electrical energy, required to obtain the conditions of oxygenation and mixing in the lagoon. <u>Activated sludges</u> Investment in a new activated sludge treatment plant is approximately 19-24 M euros for a Kraft pulp mill with production of 1,500 t/d. This investment also includes the primary treatment and the later treatment of the purge sludges. Operating costs are of 2.0 to 2.6 M euros/year. For an integrated mechanical pulp mill in which production is 1,000 t/d, the investment is of approximately 13-16 M euros, including the primary treatment and the activated sludge treatment. The corresponding operating costs are 1.2-1.5 M euros/year. The estimated investment for a water treatment plant by activated sludge in a printing paper mill with a production of 200 t/d is 2 M euros and for a cardboard plant with production of 100 t/d, of 1.5 M euros. The annual cost of operation is estimated to be between 300 and 600 euros/kg COD removed per day.
Figure 7.2.2. Biological treatment of wastewater with activated sludges	

Cleaner Production (CP) alternative	**7.2.3. Capture and processing of malodorous gases**
Process	Chemical pulp production.
Stage / Operation	Gases of high volume and low concentration (4 kg S/t of pulp). These are formed during the decantation of liquors and unbleached pulps. • Reject knots, drainage deposits for knots, and auxiliary tank. • Blow tank and storage tanks for pulp. • Washers, filter tanks and strainers. • Oxygen delignification. Gases of low volume and high concentration (0.5kg S/t of pulp). These are formed during the cooking and evaporating process: • Evaporation systems for the black liquors. • Flash deposits. • Blow tank. • Vaporising of wood chips, when live steam is not used. • Accumulator of the blow heat recovery unit.

	- Condenser relief non-condensed steam. - Prehydrolysis unit. - Barometric well or condensate accumulation tank.
Environmental problem	TRS emission.
Potential benefits of the CP alternative	Reduction of TRS emissions by over 90%.
Description	This alternative can be applied to gases of low and/or high concentration, but these should be maintained in separate circuits. Gas capture by suction. Directing to the removal systems. Treatment of gases by incineration. In the case of low concentration gases, these can also be scrubbed.
Procedure	The gases are captured and directed to the treatment systems in a circuit which must meet the following prerequisites: - Negative pressure must be maintained at all of the open points. - There must be a valve system to close the capture points when these are not operational. - There must be by-pass lines with flow indicators, for the evacuation of gases to the chimney. - There must be safety valves in the by-pass lines. - The concentration of flammable compounds must be maintained below explosion level. This aspect is of particular importance for the circuit of low volume, high concentration gases. Later the gases are treated by incineration in the recovery boiler, in the lime kiln with an SO_2 scrubber, or in an auxiliary boiler equipped with an SO_2 scrubber. As an alternative to incinerating the gases, they can be processed by alkaline scrubbing or oxidant scrubbing, especially in the case of diluted gases.
Comments / Examples of application	This alternative can be applied in both new and existing plants. In the latter case, the application depends on the adaptation costs for the capture of the gases and taking them to the treatment system. Plants that work with continuous digesters and washers with diffusers instead of pressure washers produce a lower quantity of low concentration gases. The thermal conversion of non-condensed gases requires the correct control of the operating conditions in the furnace: combustion temperature, gas flows and residence times of the gases. The problems presented by this are: - Temperature and residence time control: it has been established that a residence time of 0.75 seconds, at a temperature of 875ºC, is sufficient for the total conversion of the TRS. - Emission of untreated TRS: the flow conditions should avoid preferential routes and backmixing in the furnace. - Accidental return of furnace gases through the feed line of the malodorous gases: installation of anti-return valves and flame extinguishers. - Increase in SO_2 concentration. - The presence of SO_3 from oxidation of 5 to 10% of the SO_2 formed, which shows a tendency to mist formation. The furnace gases should be purified of particles and SO_2. The application of this technique can result in crossed effects such as increased emissions of SO_2 and NO_X, in the combustion gases, if the appropriate measures are not taken, and increased energy consumption during gas suction. Another alternative that is under development for the treatment of low concentration gases is to mix them with the gases from the bleaching washers. The resulting gases go to the alkaline scrubber in the bleaching system. This proposal involves zero cost for reactives, provided that the facility has chlorine dioxide bleaching, and has alkaline scrubbing of the bleaching gases with a sufficient capacity to receive the gases with sulphur compounds.

<table>
<tr><td></td><td>
Table 7.2.2. Necessary molar reactions for the oxidation of the TRS
<table>
<tr><th>Compound</th><th>ClO_2 moles/mole of compound</th></tr>
<tr><td>H_2S</td><td>8:1</td></tr>
<tr><td>CH_3SH</td><td>2:1</td></tr>
<tr><td>$(CH_3)_2S$</td><td>1:1</td></tr>
<tr><td>$(CH_3S)_2$</td><td>1:1</td></tr>
</table>
Studies carried out by Paprican have shown reductions in emissions of between 75 and 79%, with exit concentrations of below 3 ppm of TRS
</td></tr>
<tr><td>Economic aspects</td><td>
It is estimated that the investment for this alternative, considering the capture and processing of gases for a plant with production of 1,500 t/d of wood pulp is:

Incineration in the recovery boiler: 3.6-4.5 M euros
Incineration in the lime kiln with scrubber: 4-5 M euros for new plants and 5-8 M euros for existing plants.
Incineration in an auxiliary boiler with scrubber: 7-8 M euros for new plants and 8-11 M euros for existing plants.
Operating costs are estimated to be of 0.3-0.5 M euros/year.

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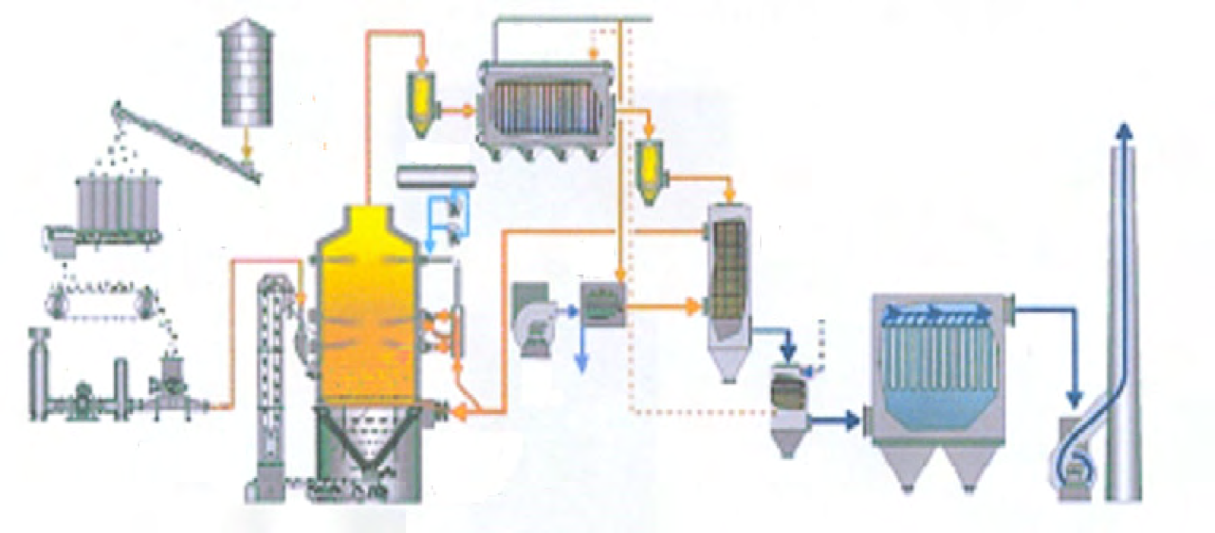
Cleaner Production (CP) alternative	**7.2.4. Installation of low NO_x emission burners**
Process	Chemical pulp production.
Stage / Operation	Auxiliary furnaces burning bark, fuel oil, coal or natural gas, with or without a combined cycle. Recovery boiler. Lime kiln.
Environmental problem	Nitrous oxide emissions.
Potential benefits of the CP alternative	Reduction of nitrous oxides emissions. The reduction depends on the type of furnace, on the fuel used and on the burner selected. Compared to conventional burners of auxiliary boilers, with emissions of 250-500 mg of NO_x/MJNO_x, low NO_X burners can reach levels of 120-140 mg NO_X / MJ. It is estimated that in the recovery boilers, there are reductions of NO_x of 10-25% but the values vary from boiler to boiler. As NO_X has the potential to acidify and can increase problems of eutrophication in surface waters, it is important to control NO_X emissions.
Description	The formation of nitrous oxides takes place, with the exception of a small proportion, in fuels that contain organic nitrogen, through chemical combination between the nitrogen and the oxygen in the air. The conditions that should be avoided to minimise the formation of NO_x are high combustion temperatures and oxidant atmospheres. NO_X reducing technologies during combustion are: • Burners with low emissions of NO_X (Low-NOx burners [LNB]) with or without Over Fire Air (OFA). • Recombustion of coal or fuel oil. The use of natural gas as a fuel in combined cycles reduces the emission of NO_x by over 50% with respect to other types of fuel. Nitrous oxide emissions in combined cycles are controlled by the use of low NO_x burners without water injection, when natural gas is burned. In the case of using secondary fuel in emergency situations (gas oil), these emissions are controlled by means of water or steam injection into the combustion chamber of the gas turbines.

	Recombustion technology consists in the first stage of the injection of coal or diesel with primary air, in smaller proportions than the stoichiometric proportions, creation a reduction zone with low NO_X formation. In the next stage of combustion, secondary and tertiary air is introduced to complete the combustion of the coal with under 3% unburned fuel in the ash. Depending on the geometry of the combustion chamber, the recombustion zone may be increased by means of the injection of air through side nozzles, located in the refractory walls of the combustion chamber, with the objective of obtaining NO_x concentrations of lower than 100 ppm in the reduction zone, without penalising this improvement with the formation of CO and an increase in unburned fuel in the ash.
Procedure	In low NO_x emission burners, the central combustion zone is lacking in air, which means that the temperature is limited by this, and the atmosphere is of reduction; combustion is completed with the introduction of secondary air into the external zone of the flame. Over fire air burners can also be used, which in contrast to the burners described above, also have tertiary air at between 10 and 25%, which is introduced over the zone of the flame, creating an oxidant external atmosphere.
Comments / Examples of application	Low NO_x burners can be used in both existing boilers and in new ones. LNB burners reduce the emission of nitrous oxides in a proportion of between 30 and 55%. The option LNB and OFA enables reductions of emissions of NO_x by between 40 and 60% of the emissions from conventional burners. The application of this technique presents a crossed effect, that is an increase in CO emissions, if not properly controlled.
Economic aspects	Investment is around 0.5-0.8 M euros for a plant producing 1,000 t/d of paper. Operating costs are from 0.1-0.2 M euros/year. In the case of a Kraft pulp plant with production of 250,000 and 500,000 t/year, investment would be 1.7 and 2.3 M euros respectively. Operational costs would not be affected.

Cleaner Production (CP) alternative	**7.2.5. Reduction of external noise**
Process	Pulp and/or paper plant.
Stage / Operation	Digesters. Recovery boiler. Chippers. Chip transporters. Debarking drums. Refiners. Paper machine. Dryers.
Environmental problem	Noise generation.
Potential benefits of the CP alternative	Reduction in noise emitted.
Description	Within a pulp or paper plant there are numerous sources of noise. Once the noisiest processes are identified, the most widely used technique to minimise noise is the containment of the processes inside soundproof booths, in order to reduce the external noise to the limits of between 80 and 85 dB.
Procedure	Containment of the pulp plant, including the trunk unloading system. Containment of the de-inking plant. Containment of the paper machine. Improvements to the mechanical systems: transmissions, streamlining. The use of elastic supports (silent blocks). Some examples of measures for the control of the noise produced in the machine itself are: hoods with reinforced soundproofing, the installation of silencers in pumps and vacuum circuits and in the interior and exterior vapour extraction fans, etc.
Comments / Examples of application	Chippers can emit powerful noise levels, reaching up to between 100 and 128 dB. By means of containment with acoustic panels, noise can be reduced to levels of 80 dB.

Cleaner Production (CP) alternative	**7.2.6. Minimisation of waste sent to landfill sites in mechanical pulp plants**
Process	Mechanical pulp manufacturing.
Stage / Operation	Pulp processing.
Environmental problem	High moisture content of the waste, resulting in leaching in landfill sites and the need for more energy for its combustion.
Potential benefits of the CP alternative	Reduction in waste volume. Energy recovery.
Description	With the exception of the bark from the debarking of the wood, the rejects, sludges and solid waste in general from mechanical pulp plants are transported in an aqueous medium to the treatment plant, where they are removed with a high moisture content to then be sent to landfill. The pressing of this waste allows a large quantity of water to be removed from it, which enables dryness levels to be reached that allow it to be burned with the consequent generation of energy.
Procedure	There is different mechanical equipment available to carry out this operation: • Belt presses. • Screw presses. • Decanter centrifuges. In terms of incineration, there are two possible options for the incineration of this type of waste: • Incineration together with the bark in the bark furnace. • The separate incineration of this type of waste. Therefore this type of waste can be burned alone or together with an auxiliary fuel to produce energy (a detailed outline of incineration with energy recovery can be seen in the alternative 6.2.18).
Comments / Examples of application	Good results of water removal from waste have been obtained with all types of press. In recent years, an increase in the use of screw presses has been observed, due to greater interest in the incineration of sludges, a process which requires drier solids. Incineration in bark furnaces is carried out in many mills. The separate incineration of this type of waste has been widely used. However, this consumes an amount of additional fuel, and normally this process does not allow for energy recovery. The technique of integrated combustion of sludges and other waste, with preliminary drying using a flow of boiler gases, considerably increases thermal yield. The combustion of this type of waste produces emissions of solid particles, nitrous oxides and sulphur, which must be monitored before their emission through the chimney. When sludges are burned, fluidised bed boilers are recommended for their very versatile nature and their greater efficiency, with lower emissions of volatile compounds into the atmosphere. The lower emissions of NOx in the fluidised bed boiler are due mainly to the lower combustion temperature, while emissions of SO_2 are controlled by means of the addition of calcium or lime, which reacts with the SO_2, depositing it in solid form with the ash from the bed of the boiler. The emission of particles should be controlled using ESP, fabric filters or Venturi scrubbers.
Economic aspects	Investment costs for new sludge incinerators are 5-7 M euros. Operational costs are of 0.5-0.6 M euros/year, corresponding to pulp production of 700 t/d. The economic benefit is worked out from the evaluation of thermal and electrical energy generated, in comparison to the investment and operational costs.

Cleaner Production (CP) alternative	**7.2.7. In situ treatment of rejects and sludges (dewatering)**
Process	This technique is directed more at paper manufacturing processes from recovered paper, although the dewatering process is an environmental concept for any pulp and paper manufacturing process.
Stage / Operation	Pulp purification, water treatment.
Environmental problem	Normally the rejects from the manufacturing of paper from recovered paper have no recycling potential and are taken to controlled landfill sites, which results in the accumulation of waste in landfill sites, and the generation of leaching.
Potential benefits of the CP alternative	• Reduction in the volume of waste deposited in landfill sites. • Production of energy from a renewable source. Depending on the type of reject and the drying system, the water content in the rejects can be reduced by between 40 and 75%. In the case of discharge of the rejects in landfill sites, prior drying reduces the volume of waste (by up to 20 times) and minimises the problem of leaching. When rejects are burned in energy production plants, or in cement manufacturing kilns, the demand for energy for the evaporation of water from the rejects is reduced. This contributes to greater energy recovery.
Description	In the processes of pulp purification, rejects and sludges are generated that should be dealt with in the appropriate manner. The rejects generated can be 4 to 8% of the recovered paper processed, depending on the quality of the recovered paper, the purification stages and the required quality of the final product. Rejects are divided into three groups: heavy-large, coarse, and light-fine. These rejects have no potential for recycling and are taken to controlled landfill sites. Sludges are also produced in the wastewater treatment process. Sludges from primary treatment can in many cases be directly reused. The excess of biological sludges and chemical treatment sludges are not easily dewatered, so they are sometimes mixed with sludges from primary treatments. If necessary, the sludges are thickened first, in gravity thickeners (up to 3-4%) before dewatering. Chemicals which produce the agglomeration of the wastes and make the removal of the water easier can also be used. Biological sludges can be reused in some cases, such as in cardboard factories. The volume of reuse of the sludges tends to be less than 1% in dry weight with respect to the recovered paper processed. This very small volume can be used as a raw material in the production of paper without affecting the process or the quality of the product. In these cases, the drying processes are not necessary. For the reuse or final discharge of these rejects and sludges, a preliminary drying process is essential, as this minimises transport costs.
Procedure	For the drying of rejects of high grammage and coarse rejects, different types of sieves and screens are used to obtain a solids content of 60-80%. The drying of fine rejects is carried out in wire presses or vibrating sieves and if necessary also in screw presses, to obtain a solid content of 50-65%. In terms of biological sludges, these can be dewatered by up to 25-50%, depending on the quantity of fibres they contain, by means of gravity, screw presses, decanter centrifuges and filter presses.
Comments / Examples of application	This technique can be applied in both new and existing mills. The drying of the rejects results in an increase in the volume of wastewater to be treated. The waters generated have a similar composition to process waters.
Economic aspects	Investment costs for the drying of the rejects to obtain a solid content of 65% is around 0.2 M euros. The annual maintenance cost is approximately 25,000 euros. These costs correspond to the annual treatment of rejects of 13,000 tonnes of dry material. The investment necessary for the dewatering of sludges in a de-inked paper plant is: • Fabric press: 1.5-1.8 M euros. • Screw press: 1.7-2.0 M euros. • Centrifuger: 0.7-0.9 M euros.

Cleaner Production (CP) alternative	**7.2.8. Combustion of de-inking sludges**
Process	Manufacture of recycled paper.
Stage / Operation	De-inking: dehydration of the dehydrated sludges.
Environmental problem	The discharge of de-inking sludges in landfill sites results in the accumulation of waste and the production of leaching and gases.
Potential benefits of the CP alternative	• Reduction in waste, reduction in the problems associated with landfill sites. • Waste minimisation. • Occasionally, the use of the ash.
Description	Combustion in a fluidised bed, with steam generation and selective non catalytic reduction of nitrous oxides, purification of gases by means of a fabric filter.
Procedure	De-inking sludges, with an ash content of 47% and an average solids content of 55%, following dehydration in the filter press and drying in a rotating drum, are sent for combustion with steam generation in a fluidised bed boiler. This technology can be applied to the combustion of material with low calorific value, with the minimum generation of dangerous atmospheric pollutants. A system of selective non catalytic reduction of oxides is used with the injection of an aqueous 19% ammonia solution, by means of peripheral pulverisers located in the fluidised bed, or solid urea is used in order to reduce emissions of NO_x. Emissions of SO_2 can also be reduced by means of the addition of calcium carbonate to the fluidised bed. The low calorific value of the sludges requires preheating of the air with the exit gases, in order to obtain a combustion temperature of around 750ºC, which is helpful for the retention of sulphur compounds in the alkaline ash, and avoids the thermal decomposition of the carbonates.
 Figure 7.2.3. Diagram of the combustion process for de-inking sludges	
Comments / Examples of Application	De-inking sludges are classified as a renewable energy source, which does not increase the emission of CO_2 into the atmosphere. The combustion gases are purified of particles by means of a bag filter. Typical emissions are:

Comments / Examples of application

Table 7.2.3. Typical constituents of the gases

Constituent	Unit	Limit (1 h)	Limit (24 h)
Particles	mg/m^{3}N at 10 % O_2	30	10
SO_2	mg/m^{3}N at 11 % O_2	50	
NO_x	mg/m^{3}N at 11 % O_2	200	
CO	mg/m^{3}N at 10 % O_2	100	50
HCl	mg/m^{3}N at 10 % O_2	30	10
HF+HBr	mg/m^{3}N at 10 % O_2	2.0	
HCN	mg/m^{3}N at 10 % O_2	0.5	
P_2O_5	mg/m^{3}N at 10 % O_2	5	
VOC	mg/m^{3}N at 10 % O_2	20	10
PCB+PCDF+PCT	mg/m^{3}N at 10 % O_2	0.1	
PAH	mg/m^{3}N at 10 % O_2	0.05	
Total metals	mg/m^{3}N at 10 % O_2	0.5	
Cd+Hg+Tl	mg/m^{3}N at 10 % O_2	0.1	
PCDD+PCDF (TEF equiv.)	ng/m^{3}N at 10 % O_2	0.1	0.1

7.3. OTHER POLLUTION MINIMISATION TREATMENTS (PMT) TO BE CONSIDERED

7.3.1. Primary treatment of wastewater

Definition

Wastewaters in pulp and paper mills have a high content in suspended solids (bark fragments, fibres, fines, mineral fillers, coating agents, etc.) and in colloidal and dissolved solids (extractives, starch, remains of chemicals, adhesives, etc.).

The removal of suspended solids by sedimentation is a practice that has been in widespread use for decades. The percentage of solids removed depends on the type of plant, that is, it depends on the quantity of sedimentable solids (80% in Kraft plants, 70% in de-inking plants, 80-95% in paper mills). In conjunction with this, organic material is also removed (20% in integrated plants and over 80% in tissue paper or packaging paper plants).

Another technique that is widely used today for the removal of suspended solids is dissolved air flotation, which is up to 98% effective (measure 6.2.7).

In order to increase the productivity of removal of suspended and colloidal solids, a coagulation-flocculation treatment can be carried out before the sedimentation or flotation processes. With the use of coagulants (aluminium salts and iron salts, aluminium polychlorides, polyamines etc) and/or flocculants (polyacrylamides, dual systems with microparticles...) it is possible to cause the destabilisation of the dissolved and colloidal material present in the waters, thus making it easier to remove this later.

On some occasions, only a basic primary treatment of screening, equalisation and/or neutralisation is used as a stage prior to biological treatment with the objective of avoiding excessive loads and shocks and improving yield.

Applicability

Primary treatment by sedimentation or flotation is very lengthy. However, the chemical destabilisation of the dispersed material in the waters is used mainly in paper mills.

Environmental aspects

This alternative allows the removal of suspended solids. Using the flocculation treatment, efficiency levels of 97-99% can be obtained in the removal of suspended solids, and 70% in the removal of total COD. However, only 10% of the dissolved organic material is removed. The COD/BOD ratio after primary treatment is 3, which shows that the majority of organic material removed is not very biodegradable, and therefore its removal is useful for later biological treatment.

It should be remembered that in this treatment, approximately 3 to 6 kg of sludges are generated per m^3 of water treated and that these have a water content of 60 to 80%. These sludges, difficult to dewater, should be treated and removed in an appropriate manner.

Economic aspects

The investment necessary for the facility of physico-chemical treatment in a paper mill producing 100 t/d is approximately 1 M euros. This facility includes an equalisation tank, the chemical product preparation and dosing equipment, a coagulation-flocculation unit and the clarifying unit.

7.3.2. Anaerobic treatment as the primary stage of aerobic treatment

Definition

In pulp and cardboard factories there is a series of specific stages during which wastewaters with a high biodegradable organic material content are generated. This alternative for pollution control is based on the anaerobic biological treatment of these flows as a stage prior to biological treatment.

In chemical pulp plants, the condensates from the evaporation of the liquors can be separated and treated, this is considered a PMT (Pollution Minimisation Treatment) for sulphite pulps. In CTMP mills, this technique is not widely used as it is very sensitive to alterations in the process. In paper mills, it is considered a PMT in manufacturing processes of "brown grade papers". It can also be applied to manufacturing processes for de-inked papers.

There are different anaerobic reactors that can be used: contact reactors, UASB reactors, fixed bed reactors and fluidised bed reactors. The most important aspect is to maintain a high concentration of the biomass in the reactor, which can be achieved by means of the recirculation of sludges after their sedimentation in the contact reactor or by using a support medium for the biomass in the reactor in other cases, which allows waters with a higher content in organic material to be treated. The most widely used of these is the UASB reactor.

Applicability

This treatment can be incorporated into new plants and existing plants. It is usually used when the capacity of the aerobic treatment plant has been surpassed. It has been implemented since the early 1990s.

If the sulphate content of the waters to be treated is very high (>1,000 mg/l) this technique cannot be used, as it would cause the formation of H_2S, which is toxic for anaerobic microorganisms. A suspended solids content of over 200 mg/l can also cause problems in the reactors.

Environmental aspects

The effectiveness of anaerobic treatment depends on the design of the plant and its operating conditions. Typical values of the efficiency of COD removal are 60 to 85% and for BOD, 85-95%.

This treatment makes later aerobic treatment easier, reducing the size of the facility and its operating costs. In addition, it reduces the production of biological sludges (70-80%) and facilitates their sedimentation.

The overall effectiveness of anaerobic + aerobic treatment is 95-97% of COD and 99.0-99.8% of BOD. Therefore the content of organic material in the effluent treated is reduced to 25-30 kg COD/t of pulp produced and 0.5-1.5 kg COD/t of paper produced. Combined treatment increases the stability of the treatment plant, enabling greater control of the quality of the final waste discharged from the mill.

The biogas generated (400-600 m^3/t COD removed), with a methane content of approximately 65-75%, can be used as fuel in the plant itself, following a desulphuring treatment. It is estimated that around 25-30% of the energy produced is needed for the anaerobic + aerobic water treatment plant, while the rest can be used in other parts of the production process.

Economic aspects

In order for the treatment to be economically viable, the initial COD concentration in the waters should be greater than 2,000 mg/l.

The investment necessary for combined anaerobic + aerobic treatment varies depending on the volume of water to be treated and the content in organic materials of the water. For a plant that treats a COD load of 25 to 35 t/d, the cost of installation is 7-12 M euros.

The operating costs, taking into consideration the later use made of the biogas, are 0.6-1.0 euros/t of paper produced.

7.3.3. Tertiary processing of wastewater with chemical precipitation

Description

In some cases, it is necessary to carry out chemical precipitation to improve the removal of suspended solids and colloidal material, or, if this is used as a tertiary treatment, for the removal of nutrients, mainly phosphorous. Dissolved and colloidal organic materials are destabilised by means of a chemical agent to produce their agglomeration and then their separation by filtration or sedimentation. The chemicals used for this precipitation are generally the following aluminium salts ($Al_2(SO4)_3$, $(Al_n(OH)_mCl_{3n-m})$, iron salts ($FeCl_3$ and $Fe_2(SO4)_3$, $FeSO_4$), lime or polyelectrolytes.

This measure can be applied in both new and existing plants.

Environmental aspects

The results of studies of the combination of biological treatment and chemical precipitation as a tertiary treatment, carried out in a pilot plant in Sweden, show that reductions in phosphorous of 80-90%, of nitrogen of 30-60%, of COD of 80-90% and of AOX of 80-90% can be obtained.

Economic aspects

The investment cost for a Kraft pulp mill with a production capacity of 250,000 t/year is 2.6 M euros, and 3.8 M euros for a mill with a production capacity of 500,000 t/year. This investment cost includes the equalisation tank, the reactives preparation and dosing equipment, the precipitation and flocculation units, and the tertiary clarifier.

The operational cost of tertiary treatment is estimated to be approximately 500,000 euros/year.

7.3.4. Control of the potential disadvantages of the closure of the water circuit of the paper machine

Definition

The closure of circuits requires knowledge, experience and appropriate control of the water system in order to avoid the disadvantages that this implies.

As shown, the closure of circuits results in the accumulation of suspended, dissolved and colloidal solids that are organic, inorganic and microbial in nature. Depending on the raw materials used, the type of fresh water and of chemical compounds used, the closure of the water circuits can have negative effects on the process, on the quality of the final product and can even result in increased production costs due to the increased consumption of chemicals. Therefore, these potential negative effects should be controlled appropriately.

Table 7.3.1. shows the main advantages and disadvantages of the reduction of water consumption:

Table 7.3.1. Advantages and disadvantages resulting from the increase in the degree of closure of the water circuits

Possible advantages	Possible disadvantages
Improved retention of soluble material in the paper web.	High concentration of colloidal and dissolved material in the water circuits.
Reduction in energy requirements for heating and pumping.	The risk of the appearance of "slime", which causes build-ups, holes and tears in the sheet.
Improved dewatering properties on the wire in the machine, which contributes to a reduction in energy consumption in the drying section.	Risk of lower product quality such as brightness, strength, smoothness, porousness, etc.
Lower investment costs as smaller water treatment facilities are required.	Increased consumption of process additives.
Savings in raw materials due to lower loss levels generated.	Risk of corrosion (higher chloride concentrations).
Improved efficiency of wastewater treatment.	Higher risk of blockages in pipes, sprinkler injectors, wire and felts.
Reduction of wastewater.	Hygiene problems with the final products (tissue paper, paper that is in contact with food).

Source: BREF

The pulp and the water used to transport it contain dissolved and colloidal organic compounds known as anionic trash. At high concentrations, these organic substances can affect the retention and the formation of the paper web, increase the blocking of the wire and the felts, and form sticky deposits on the paper, the rollers, the wires, the felts, etc.

In the production of paper from mechanical pulp, the problems are more pronounced as most of the compounds from the wood are still present in the pulp and these partially dissolve in the process waters, resulting in pitch problems.

In the production of paper that is to be in direct contact with food, the product should be free of any harmful material that is water soluble.

The temperature reached in the paper machine should be controlled so that it does not exceed 45-55ºC in the wet end of the machine. On the other hand, in the forming section it is helpful for the pulp suspension to be hot, as the viscosity of the water decreases as the temperature increases, resulting in improved dewatering. Important aspects for the control of the effects of closure of the water circuits are:

- Preventing water from the pulp plant or other paper machines operating in parallel from reaching the water circuits. The separation of the water circuits is usually done by means of thickeners.
- Recycled sealing or cooling water, or the white feed waters of the sprinklers of the paper machine, should be treated appropriately to prevent the stopping-up and wear and tear of the paper machine.
- The sealing waters should be cooled in heat exchangers or clean waters to avoid substandard performance of the vacuum pumps.
- It is imperative to define the quality of the water required for each part of the process, so that the composition (for example, content in colloidal materials), hardness, pH and temperature of the recycled water used is compatible with the equipment or flows of the process.
- The pulp should be correctly washed before being fed into the paper machine, in order to reduce the content of dissolved and colloidal materials. Where possible, the pulp should be thickened before progressing to the next step.
- When the water circuits are closed, the chemical compounds that are added to the paper should be evaluated, as some chemical compounds are incompatible with specific pollutants or with other additives. In many cases the closure of the circuit reduces the effectiveness of the additives.
- The flows of recycled water should be analysed to avoid their exceeding the limits ensuring the quality of these waters.

Applicability

These measures can be carried out in both new and existing mills. However, existing mills require several years to put these improvements into practice. The requirements are lower for the manufacture of unbleached packaging papers, and are stricter for higher quality papers.

Environmental aspects

These measures are considered an integral part of those described in point 6.2.9, as they involve achieving or maintaining low levels of water consumption without significant adverse effects.

Operational experiences

The risk of encrustations caused by calcium compounds and slime, pitch and stickies are the most notable problems. These should be controlled by the appropriate mixture of fractions of water, pH control, increased addition of controlling additives, or purges where appropriate.

If the paper machine operates at a temperature above 50 ºC, the growth of microorganisms in the water system and their activity are less. However, anaerobic activity may take place at above 50 ºC (thermophilic bacteria), generating malodorous sulphides that should be controlled.

The optimisation techniques for the control of these measures in existing plants are normally brought into use over several years. Many mills have solved the control problems involved with these measures simply by using more chemical compounds. The appropriate selection of chemical compound additives, along with their combination, is a complicated procedure, but one that is necessary for suitable efficiency and lower environmental impact costs.

Economic aspects

The costs depend mainly on the conditions of the mill. The costs of the measures depend on the amount and nature of reordering necessary and the type of additional facilities required.

7.4. TECHNOLOGICALLY EMERGING FINAL TREATMENTS

7.4.1. Treatment of effluent with a combined ozonation and biofiltration process

Description

This tertiary treatment of effluent obtains a significant removal of COD, AOX and colour with minimal doses of ozone. A diagram of this process is shown in figure 7.4.1.

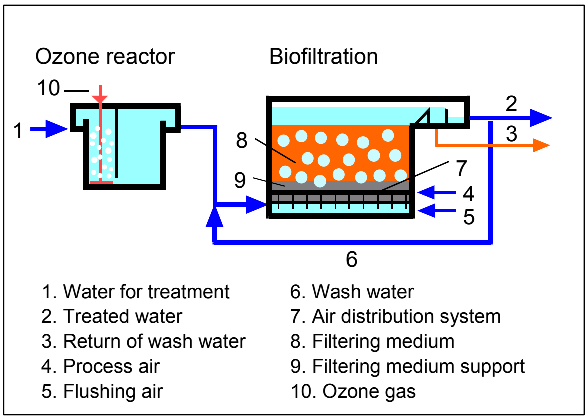


Figure 7.4.1.- Combined ozonation and biofiltration process. Source: BREF

The main objective of this process is to transform the organic components of the wastewater into partially biodegradable materials.

The results of tests with effluent from various mills after undergoing biological treatment indicate that with specific ozone consumption of 0.7-1.0 kg O_3/kg COD removed, reductions are obtained of over 50% of the original COD if this is complemented with biofiltration.

These tests have a positive economic implication as the comparison with current flocculation/precipitation techniques is highly favourable.

Stage of development

The treatment of wastewater that has been biologically purified with ozone for the additional reduction of residual COD and to improve the colour has been tested in laboratories and pilot plants. The laboratory tests [Öller, 1997] and the research in pilot plants [Möbius, 1996] have demonstrated that treatment with ozone can significantly reduce the COD and the colour depending on the quantity of ozone used. It can be considered that this technique is in development.

Main environmental effects

The effectiveness of treatment with ozone strongly depends on the individual quality of the water that is to be treated and on the specific treatment system. There is therefore no general behaviour to be considered in terms of achievable environmental effects. For effluent with certain limits in terms of

COD and the BOD_5/COD ratio, bioavailability can be enhanced to allow additional biological treatment. The ozone treated water can then be reused in the production process.

7.5. SUMMARY TABLE OF THE FINAL TREATMENTS PROPOSED

A summary table is shown below of all of the proposed technological alternatives, along with a brief description of what they involve, together with the benefits obtained from their application and the effects which each application has on the production process.

These can be classified in four categories: liquid discharge, atmospheric emissions, solid waste/sludges and energy, applicable for the manufacture of both pulps (mechanical pulp "MP", Kraft pulp "KP", sulphite pulp "SP" and pulp from recovered paper "RP") and for the manufacture of paper.

ENVIRONMENTAL PROBLEM 1: LIQUID DUMPING (PULP MANUFACTURING)

Nº	Type of pulp	Proposed measure	Description	Benefits	Effects on the production process
7.3.1.	MP, KP, SP, RP	Primary treatment of wastewater.	Primary coagulation-flocculation treatment prior to the sedimentation or flotation process.	Reduction of suspended solids and nutrients in the waters.	A certain amount of sludges is generated.
7.3.2.	RP	Anaerobic treatment as the first stage of aerobic treatment.	Biological anaerobic treatment as a stage prior to the biological treatment for wastewaters with a high biodegradable organic material content.	COD and BOD removal. This facilitates later aerobic treatment, reducing the size of the facility and the costs thereof.	None.
7.2.2.	MP, KP, SP, RP	Biological treatment of wastewater	Treatment to remove organic substances that consume oxygen, and other organic compounds	COD and BOD reduction	None.
7.3.3	MP, KP	Tertiary treatment of wastewater with chemical precipitation.	In some cases it is necessary to increase the treatment of effluent with a tertiary treatment for the removal of nutrients, mainly phosphorous. The dissolved and colloidal organic materials are destabilised by a chemical agent to cause their agglomeration and later separation by filtration of precipitation.	Reductions in nutrients such as phosphorous, nitrogen, COD and AOX.	None.
7.4.1.	MP, KP, SP	Treatment of effluent with a combined ozonation and biofiltration process.	With minimal doses of ozone, this process transforms the organic components of the wastewater into partially biodegradable materials.	Significant removal of COD, AOX and colour.	The effectiveness of treatment with ozone depends on the quality of the water to be treated and the specific treatment system.

ENVIRONMENTAL PROBLEM 2: ATMOSPHERIC EMISSIONS (PULP MANUFACTURING)

Nº	Type of pulp	Proposed measure	Description	Benefits	Effects on the production process
7.2.3.	PK, PS	Capture and processing of malodorous gases.	The gases are captured and directed to the systems of processing by incineration. In the case of low concentration gases, these can also be scrubbed.	Reduction of TRS (Total Reduced Sulphate) emissions, VOC (Volatile Organic Compounds) and HAP (Hazardous Air Pollutants).	None.
7.2.4.	PK, PS	Installation of low NO_X burners.	Installation of low NO_X emission technology in the boilers.	Notable reduction in NO_X levels.	None.

ENVIRONMENTAL PROBLEM 3: SOLID WASTE / SLUDGES (PULP MANUFACTURING)

Nº	Type of pulp	Proposed measure	Description	Benefits	Effects on the production process
7.2.6.	MP	Minimisation of waste sent to landfill sites in mechanical pulp plants.	Pressing of sludges to obtain levels of dryness that allow later incineration.	The incineration of sludges permits the generation of energy.	None.
7.2.7.	RP	In situ treatment of rejects and sludges: dewatering.	Treatment of rejects and sludges in order to increase dryness.	This enables their later valuation.	None.

ENVIRONMENTAL PROBLEM 5: LIQUID DUMPING (PAPER MANUFACTURING)

Nº	Proposed measure	Description	Benefits	Effects on the production process
7.3.4.	Control of the potential disadvantages of the closure of the water circuit.	Closure of water circuits. Obtaining information on flows and chemical analysis of the water systems to avoid the problems inherent to the closure of circuits.	This enables the behaviour of the water to be studied and controlled throughout the mill and the best operating conditions to be determined.	Higher concentration of dissolved particles in the water circuits. Risk of loss of product quality. Greater additive consumption.
7.2.2.	Biological treatment of wastewater.	Treatment to remove organic substances that consume oxygen, and other organic compounds.	COD and BOD reduction.	None.

ENVIRONMENTAL PROBLEM 6: ATMOSPHERE (PAPER MANUFACTURING)

Nº	Proposed measure	Description	Benefits	Effects on the production process
7.2.4.	Installation of low NO_X burners.	Installation of low NO_X emission technology in the boilers.	Notable reduction in NO_X levels.	None.
7.2.5.	Reduction of external noise produced.	The most widely used technique to minimise noise is the isolation of equipment in sound insulation enclosures.	Reduction in noise emitted.	None.

ENVIRONMENTAL PROBLEM 7: SOLID WASTE / SLUDGES (PAPER MANUFACTURING)

Nº	Proposed measure	Description	Benefits	Effects on the production process
7.2.7.	In situ processing of rejects and sludges: dewatering.	Treatment of rejects and sludges in order to increase their dryness	This enables their later valuation.	None.
7.2.8.	Combustion of de-inking sludges.	Combustion of de-inking sludges in a fluidised bed.	Minimisation of waste.	None.

8. CASE STUDIES

This chapter provides examples both of alternatives for pollution prevention at source and of final treatments. Each of the examples is shown in the form of a data sheet. This sheet summarises the alternative implemented by a specific company based on its objectives, both environmental and economic, describes the results obtained by the application of the measure and provides economic data for this application.

The information shown in the data sheets has been obtained both from bibliographical publications and from information supplied, on an entirely voluntary basis, by the companies themselves in which the implementation of the alternatives has taken place. It should be noted that the information shown in the sections on economic evaluation, results and savings is strictly orientational.

The implementation of alternatives for pollution prevention at source (*8.1. Case Studies of Alternatives for Pollution Prevention at Source*) and final treatments (*8.2. Case Studies of Final Treatments*) have enabled the companies involved to make both environmental and productive improvements. It is considered that the implementation of the alternatives described in chapters 6 and 7 of this Manual represent, in the majority of cases, a success in terms of pollution prevention, in economic terms, and in terms of the improved quality of the final product.

It was also considered appropriate to include section *8.3. Other examples of Good Environmental Management* in this chapter. This describes the adoption of new, more respectful, methodologies and environmental policies by various companies.

8.1. CASE STUDIES OF ALTERNATIVES FOR POLLUTION PREVENTION AT SOURCE

Case Study 1	**8.1.1. Extended modified cooking**
Company	AUSSEDAT-REY
Country	FRANCE
Production	Pulp production.
Environmental problem	High pollutant load of waste discharged.
Objective	To adopt a new technique to reduce the pollutant load of waste discharged into the Vienne river.
Background	In 1994 the company AUSSEDAT-REY decided to increase its paper pulp production capacity from 440 t/d to 1,100 t/d. A quality study carried out in the Vienne river showed that COD discharge should be reduced by half.
Measure to apply	The measure to be applied involved the following modifications to the production process: • Continuous process with extended cooking to remove the maximum possible quantity of lignin. • Washing using a wash press. • An alteration to the bleaching sequence, substituting chlorine with chlorine dioxide to reduce the discharge of organochlorine compounds. • Stripping and recycling of the condensate.
Results obtained	(see results below) • Reduction in the discharge of organochlorine compounds by a factor of 15. • 30% reduction in water consumption. • 50% reduction in COD discharged. • Contribution to the public image of the company.
Economic aspects	**Total investment:** €42,075,928 30% reduction in water consumption
Source: Environmental Management Centre. This case was presented to the UNEP (United Nations Environment Programme) in 1994 by the International Office for Water.	

Results obtained:

	Before application of the measure	**After application of the measure**
COD (kg/t)	95	21
SS (kg/t)	8.6	0.2
Flow (m^3/t)	204	57

<table>
<tr><th>Case Study 2</th><th>8.1.2. Extended modified cooking and oxygen bleaching</th></tr>
<tr><td>Company background</td><td>LA CELLULOSE DU RHONE ET D AQUITANE</td></tr>
<tr><td>Country</td><td>FRANCE</td></tr>
<tr><td>Production</td><td>Kraft pulp production.</td></tr>
<tr><td>Environmental problem</td><td>High pollutant load of waste discharged.</td></tr>
<tr><td>Objective</td><td>To reduce the pollutant load of the waste discharged.</td></tr>
<tr><td>Background</td><td>The company LA CELLULOSE DU RHONE decided in 1993 to increase production of bleached Kraft pulp from 130,000 t/year to 320,000 t/year. To do so, it had to modify its process to guarantee the requirements of the Garonne river (which supplies over 600,000 people with drinking water), reducing the pollutant load of waste discharged by half.</td></tr>
<tr><td>Measure to apply</td><td><p>The measure to be implemented consisted of a modification of the production process involving the introduction of an extended cooking process in counterflow. On exit from cooking, a new white liquor is obtained, with no lignin, and the pulp obtained contains 2.5% lignin, instead of the 4% it contained with the classic process. The pulp is then purified in a vacuum rotary filter, washed, and concentrated to 12%. The black liquor with the extracted lignin is incinerated in the recovery boiler.</p><p>Actions carried out:</p>
Extended cooking, with pressure wash
Removal of the lignin using oxygen
Bleaching with chlorine dioxide
Recirculation of the bleaching effluent to the black liquors</td></tr>
<tr><td>Results obtained</td><td><p>Using this measure, the content in oxidisable material of the plant's effluent is reduced to below 10 kg/t of pulp.</p>
<table>
<tr><th></th><th>Before application of the measure</th><th>After application of the measure</th></tr>
<tr><td>COD (kg/t)</td><td>55</td><td>24</td></tr>
<tr><td>BOD (kg/t)</td><td>14</td><td>1</td></tr>
<tr><td>Coloured compounds (kg/t)</td><td>67</td><td>25</td></tr>
<tr><td>Organochlorine compounds (kg/t)</td><td>0.8</td><td>0.3</td></tr>
</table></td></tr>
<tr><td>Economic aspects</td><td>Total investment: €25,154,086
Extended cooking, long wash: €8,689,593
Oxygen bleaching: €16,464,493</td></tr>
<tr><td colspan="2"><i>Source: Environmental Management Centre. This case was presented to the UNEP (United Nations Environment Programme) in 1994 by the International Office for Water.</i></td></tr>
</table>

Case Study 3	**8.1.3. Recovery and reuse of chemical compounds from the black liquors**
Company	RAKTA GENERAL CO.
Country	EGYPT
Production	Pulp manufacturing from rice straw.
Environmental problem	Pollution due to the discharge of black liquors. High consumption of chemical compounds in cooking.
Objective	Recovery and reuse of black liquors.
Background	In general, the quantity of chemical compounds necessary for the digestion of non-wood raw materials is of 20-50% in weight of the pulp produced. For economic reasons, and to prevent environmental pollution, chemical compounds should be recovered from the black liquor. In chemical pulp produced from rice straw, almost half of the silica content of the plant is dissolved in the black liquor (rice straw contains between 8-14% SiO_2). This causes problems at all stages of the process of recovery of chemical compounds. Therefore, in order for the process to be economically and environmentally viable, this silica must be removed from the black liquor.
Measure to apply	The RAKTA mill implemented this measure in a pilot plant. In the process of recovery and removal of silica carried out, the black liquor from the wash unit is filtered in a rotating filter. The filtrate from the black liquor is stored and fed into the evaporation plant in four stages. Following this, a preconcentrated part of the black liquor is fed into a moving agitator to which anti-foaming agents are added, where it is in constant contact with a flow of combustible gas from the central energy chimney. In this way, the soluble sodium silicate is converted into sodium carbonate and insoluble SiO_2. This two stage mix is transported to a decanter, via an intermediate tank, in which the precipitates are separated from the liquor. For a final clarification, the liquor is passed through a separator, where the residual insoluble particles are removed. The black liquor with a low silica content is later burned using a conventional method in order to recover its energy. The silica extracted from the black liquor, together with the organic material and the alkali, form a sludge in the decanter with a dissolved solid (DS) content of 30-40%, which is taken for incineration. The elution of the alkali from the ash in water, followed by filtration and drying, produces granulated white silica, which can be used as a mineral filler. The optimum pH is around 9-10. In the pilot plant, the capacity of treatment of the filter is 30 m^3/h, and the evaporation capacity is 18.5 t/h. The RAKTA pilot plant treats 50 t/d of preconcentrated black liquor.
Results obtained	Regardless of the quantity of silica contained in the black liquor, which is typically around 1% (in weight), after the separator a silica content of 0.05% was achieved.

	Among the additional benefits of the new recovery system are: there are only small losses of alkali or lime when the last traces of SiO_2 are purged, and there is less waste in the form of calcium silicates.
Economic aspects	The cost calculation shows that the desilication plant represents only 12% of the total investment of a conventional recovery plant. In addition, labour costs and general service costs are relatively low. A calculation made for 200 t/d of pulp shows operational costs for a caustic soda recovery plant, including desilication, of €110/t of pulp. Without recovery, the mill has to spend €180/t to buy caustic soda on the market. In this case, annual savings from the recovery of chemicals are 4.4 M euros, or 13.3% of the international market value of pulp.
Source:. The case study, a pilot project, was presented by the UNEP Working Group on Cleaner Production in the Pulp and Paper Industries.	

Case Study 4	**8.1.4. Manufacturing bleached Kraft pulp**
Company	ENCE
Country	SPAIN
Production	TCF Kraft pulp from eucalyptus wood.
Environmental problem	The global environmental impact of waste (solid, liquid and gaseous) from the plant.
Objective	Elimination, reduction or minimisation of the potential impact that liquid effluent, atmospheric emissions and/or the discharge of solids can generate in the manufacture of bleached pulp by means of the application of Cleaner Production Alternatives (CPA) in accordance with the IPPC Directive. The establishment of an Environmental Management System (EMS) in accordance with international standard ISO 14000.
Procedure	There were two investment periods for the technological and environmental renovation of the ENCE mill in Pontevedra. The 1975-1988 plan involved an investment of 43 million euros, and the 1988-1992 plan consisted of an investment of 90 million euros, as it involved the renovation of 80% of the existing facilities. The procedure of application of the CPA and the establishment of the EMS were carried out in accordance with the "Strategic Technological and Environmental Plan 1988-1992" drawn up by the Company. The implementation of this plan led to improved production capacity and quality of the pulp, increasing the competitiveness of the plant while at the same time the environmental impact of the plant was significantly reduced.
Methods	**GENERAL CPA (1988-1992)** • The implementation of an environmental management system which clearly defines the responsibilities of the significant environmental aspects. • Training, education and motivation of the operators and personnel from auxiliary companies.

Methods	• Optimisation of process control, in order to reduce the simultaneous emission of different pollutants and to maintain a low level of emissions. • Assurance of the high quality of the maintenance of the facilities, in order to maintain a high level of efficiency of the manufacturing equipment and the facilities controlling pollutant emissions. • Availability of a database of all of the chemicals and additives used, containing relevant information such as their chemical composition, their degradability, their toxicity to humans and the environment and their potential bioaccumulation. • Application of the principle of substitution, as laid out in the mill's Environmental Management System, using those products that are available that are less harmful to the environment. **CPA TO REDUCE THE IMPACT OF LIQUID EFFLUENT** • (1988) Dry debarking of the wood. • (1992) Modified cooking system, carrying out the cooking process at a low kappa index. • (1991) High efficiency washing of unbleached pulp and screening in a closed circuit. A three stage washing process is used before the oxygen stage, and there are then two additional further stages. • (1991) Oxygen delignification. • (1991) Bleaching using an ECF or TCF process and the use of a water recirculation system in the bleaching process. The bleaching system put into place in the Pontevedra mill is TCF with gas recirculation. • (1989) Purification and reuse of condensates. During stripping, all of the concentrated condensates are purified and the less concentrated are reused in the circuit. • (1989-92) Effective system of monitoring overflows, with the containment and recovery of these overflows. Construction of collection tanks in all of those zones in which there could be overflows and the installation of a network of small conducting channels to the collection pits, from which they are pumped up to be reincorporated into the circuit. • (1991) Sufficient capacity of the evaporation and combustion facilities for black liquor to process additional loads due to the recovery of overflows and leakages. • (1989) Recovery and reuse of clean cooling waters. The cooling waters are recirculated through cooling towers, with only the addition of those quantities lost through vaporisation and purges due to increased salinity. • (1988-92) Sufficient capacity of the black cooking liquor, green recovery liquor and dirty condensates overflow collection tanks to avoid overloads in the wastewater treatment plant. • (1980-93) Primary and secondary treatment of wastewaters. **CPA TO REDUCE THE IMPACT OF EFFLUENT ON THE ATMOSPHERE** • (1989) Collection and incineration of concentrated malodorous gases from cooking, the evaporation of black liquor, the stripping of condensates and the control of the resulting SO_2. • (1988-93) Collection and incineration of the diluted malodorous gases from various different points in the process.

Methods	• (1993) Reduction in TRS emissions from the recovery boiler through the computerised control of combustion and the measuring of CO and, in the case of lime kilns, by means of controlling excess oxygen, using fuel oil with a low sulphur content and controlling the residual alkali in the sludges on entry into the lime kiln. • (1988) Control of SO_2 emissions from the recovery boiler by means of the burning of black liquor with a high solids concentration. • (1989) Control of NO_x emissions from the recovery boiler and the lime kiln by means of the control of combustion conditions, ensuring a good mix and distribution of the air in the boiler. • (1992) Control of NO_x emissions from the auxiliary boiler by means of controlling the combustion conditions. • (1992) Reduction in SO_2 emissions from the auxiliary boiler by means of the use of bark, gas, fuel oil with low sulphur content and coal, or controlling sulphur emissions with a scrubber. • (1988-92) Separation of the suspended solids contained in the gases from the recovery boiler, auxiliary boiler and lime kiln by means of the use of effective electrostatic precipitators. The electrofilter of the lime kiln has been in use since the year 1988. That of the recovery boiler has been in use since 1991. That of the bark furnace has been in use since 1992. **CPA FOR THE MANAGEMENT OF SOLID WASTE** • (1992) Incineration of all non-dangerous organic waste (bark, wood fragments, waste treatment sludges etc.) in an auxiliary boiler especially designed to burn moist fuels, of low calorific power (for example: fluidised bed boilers). • (1998) External use of waste for forestry and agricultural purposes, among others. • (1993-94) Minimisation of the generation of solid waste and the collection, recycling and reuse of materials as much as possible. • (1993-94) Collection of waste with separation at source. **ECF and TCF BLEACHING** Figure 8.1 shows that in the first stage of traditional bleaching, chlorine gas was used. Figure 8.2. shows a diagram of the way this bleaching affected the effluent. The organochlorine compounds, freed following the washing of each alkali stage, were "discharged" into the bleaching effluent that would then be joined with the other waste until making up the final effluent that was taken to the wastewater plant.

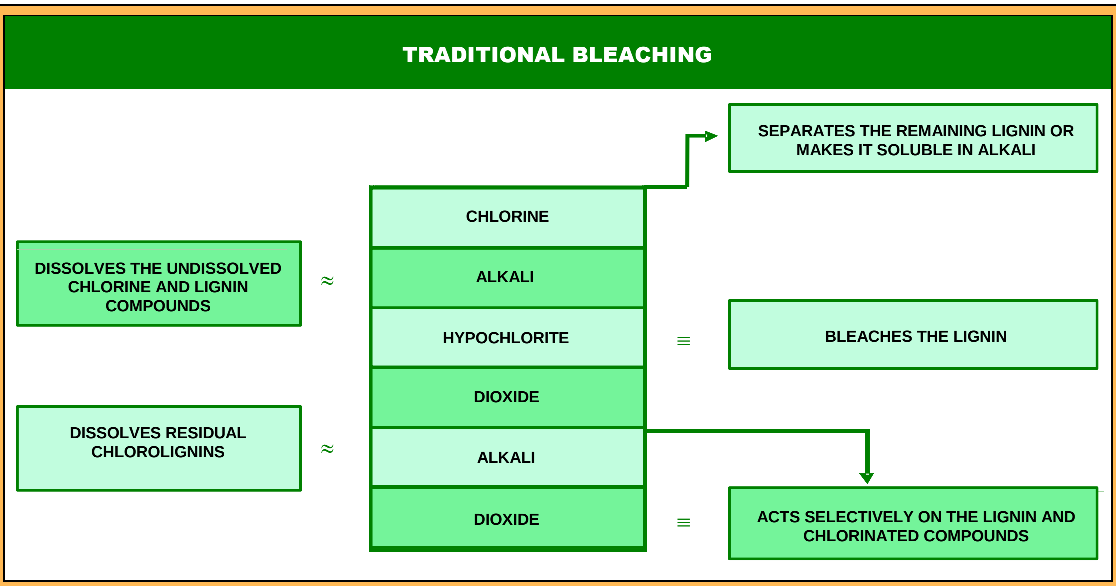


Figure 8.1.- Chart of traditional bleaching

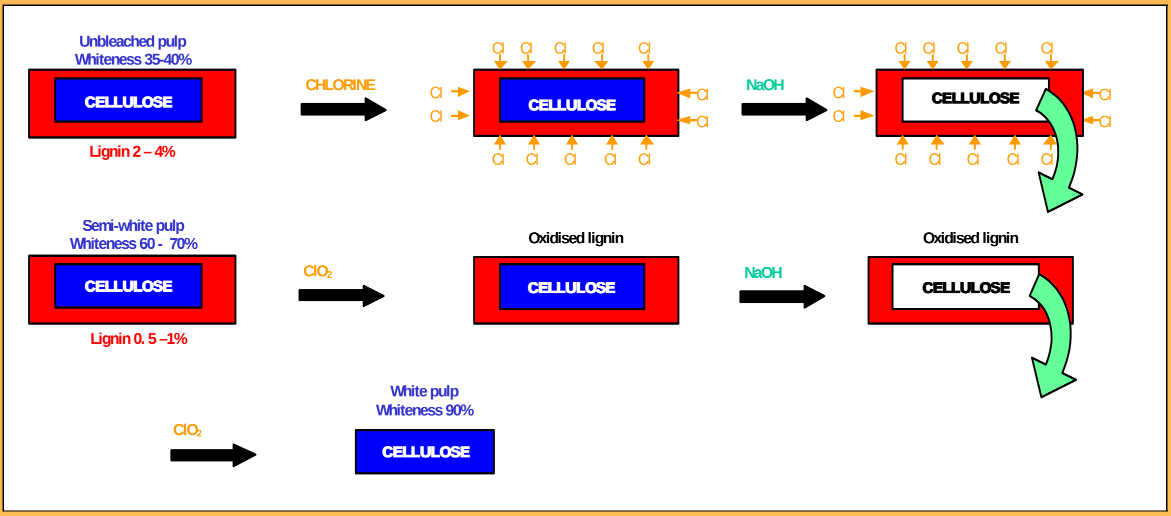


Figure 8.2.- Influence of traditional bleaching on the effluent

Methods

In figure 8.3. the difference in composition of the bleaching waste from TCF pulps can be seen. While in traditional bleaching, there is the possibility of organochlorine compounds being discharged into the effluent, in the case of TCF bleaching, this organic material will only be affected by the residual peroxide from the second or third stage of the bleaching process.

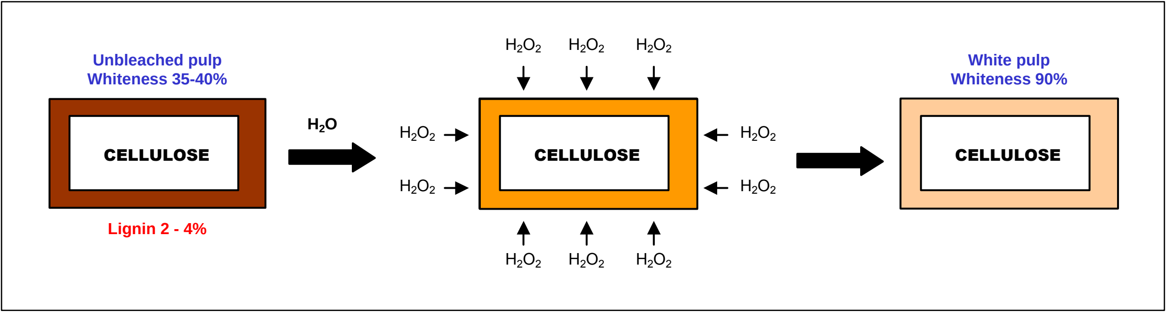


Figure 8.3.- Influence of TCF bleaching on the effluent

Methods

Figure 8.4. summarises the reduction of the environmental impact expressed in kilos of pollutant per tonne of pulp bleached, depending on the type of bleaching.

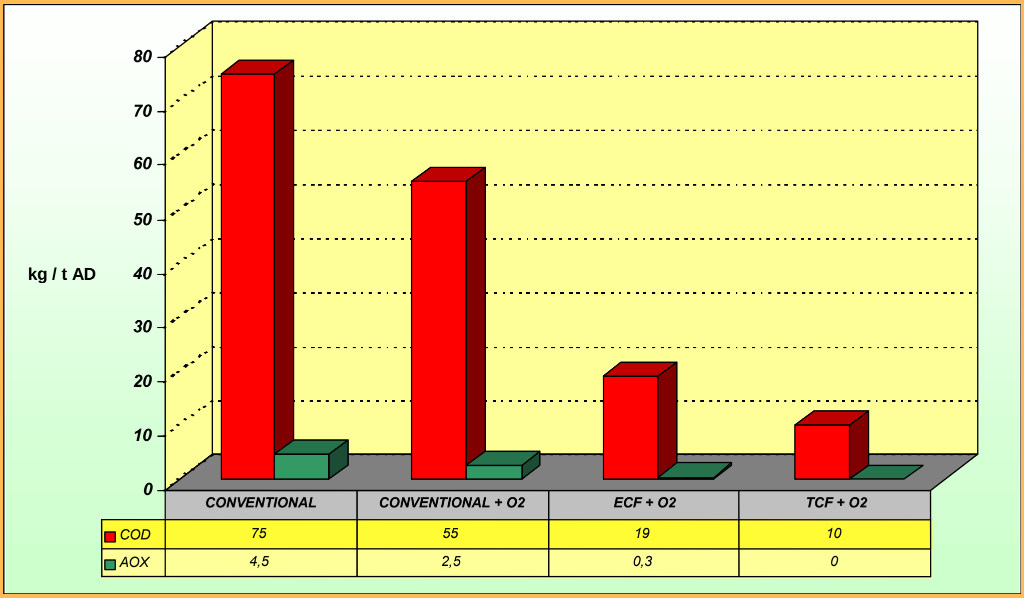


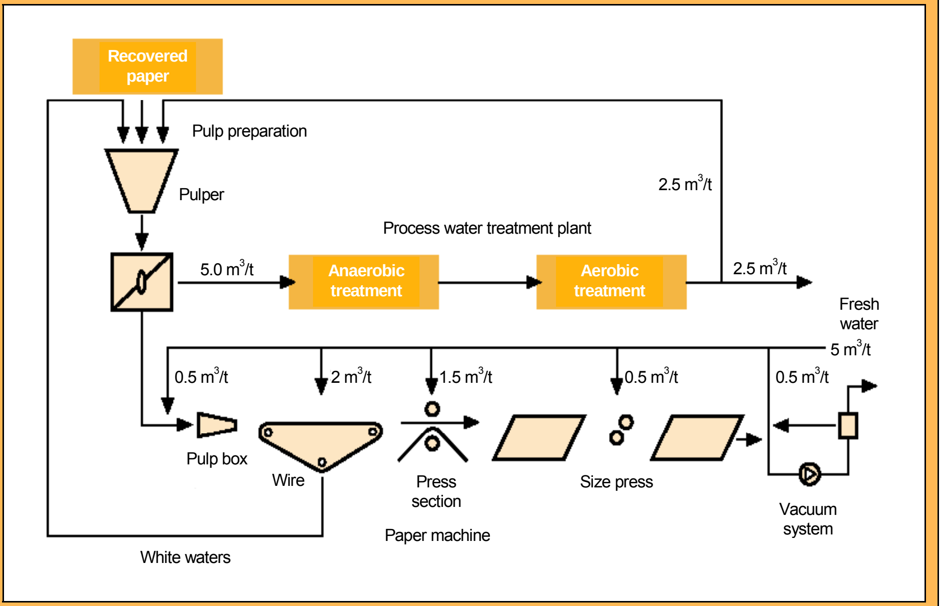
Figure 8.4.- Pollutant potential of the different bleaching techniques

Conclusions

- The technological and environmental renovation of ENCE's Pontevedra mill took place during the 1975-1988 plan, with an investment of 43 million euros and during the 1988-1992 plan, with an investment of 90 million euros. From 1993, the company continued to invest in the technological and environmental aspects of the mill, with the criteria of continuous improvement, which from 1996 onwards is proposed in the implementation of the EMS, in accordance with the standard ISO 14001, certified by external auditors. Investments in the period 1993-2004 were of 108 million euros.
- Total investment from 1975 to 2004 was 240 million euros, which, brought up to date, represents some 325 million euros, of which it can be considered that 48 million euros correspond to exclusively environmental investments.
- The environmental improvements are summarised in table 8.1. Specific water consumption has reduced from 264 m^3/t of dry pulp, to 30 m^3/t, which represents a reduction of 78%. The reduction of specific BOD$_5$ emissions and of COD in kg/t of dry pulp has been of 86% and 89% respectively. AOX discharge has been almost entirely removed.

Table 8.1. Environmental improvements

PARAMETER	Units	1974	1988	1993	2003
Flow	m^3/day	84,500	80,000	54,000	36,00
Production	t/day	320	570	716	1,46
Production	t/year	112,000	199,500	225,500	371,57
Consumption	m^3/t	264	140	75	30
pH	unit	2.5 – 4	6 – 8	7.3	7.6
Colour	unit Pt/Co	2000	1600	215	130
BOD$_5$	kg/t	50-80	15-20	4-5	2-3
COD	kg/t	180-210	80-100	15-20	9-10
AOX	kg/t	4-5	4-5	<0.05	0.06

Case Study 5	**8.1.5. Optimum water management**
Company	SAICA (Sociedad Anónima Industrias Celulosa Aragonesa)
Country	SPAIN
Production	Recovered paper production.
Environmental problem	High water consumption. Problems with waste discharge.
Objective	Reduction of water consumption per tonne of paper. Saving raw materials. Zero discharge.
Measure to apply	Installation of a process water treatment plant. For SAICA, this project had an environmental aim, but also an economic aim. The idea was to improve the production processes, achieving at the same time a reduction of the most significant ratios in terms of water consumption per tonne of paper, and savings of raw materials and natural resources.
Description of the process and backround	The SAICA company uses water in its production process fundamentally for the transportation and equalisation of the pulp suspension. The improvement applied consisted of part of the waters, once reused, being purified using an anaerobic and aerobic treatment. Part of the clarified water is reused in the production process (2.5 m^3/tonne of paper produced) and the other part is discharged into the Ebro river (2.5 m^3 /tonne of paper produced). Figure 8.5 shows a diagram of the process and a summary of the most important water flows at the different stages of the process.  Figure 8.5 - Water flows in the main stages of the process In the pulper, the white waters from the forming table and the clarified waters are reused to make the disintegration of the recovered paper used as raw material easier. Following this, the pulp is diluted with fresh water to encourage the equalisation of the suspension on entry to the headbox of the paper machine and to improve its distribution over the formation wire. The rest of the fresh water is used mainly in the sprinklers and in the vacuum system.

<table>
<tr><td></td><td>Once the sheet is formed, the water is progressively removed throughout the paper machine. Therefore on exit from the formation table, the dryness of the paper web is 20%, on exit from the presses it is 40% and on exit from the drying section, where the water is evaporated, it is 92%.</td></tr>
<tr><td>Description of the action</td><td>The actions that have been taken to control and reduce water consumption in the production processes are as follows:

Classification of the different water flows used at the different points of application depending on the quality required for the different uses.
Characterisation of the chemical composition of these flows.
Segregation and separation of the different flows.
Closure of the water circuits as a result of the use of some of the flows that were previously discharged into the sewage system, at points where they can be used, depending on the requirements of water quality.
Installation of a Process Water Treatment Plant with the reuse of the effluent from the paper manufacturing process (2.5 m^3 from a total flow of 5 m^3/t).
</td></tr>
<tr><td>Results obtained</td><td>The changes in the production process have improved the company's ratios: the consumption of water in cubic metres per tonne of paper produced has decreased by 12%; the ratio of COD in kg per tonne of paper produced has decreased by 15%; and the ratio of TSS per tonne of paper produced has also decreased by 15%.
<p>Table 8.2. shows a comparison between the situation before (2001) and after (2002) the optimisation of water use in SAICA. The figures are also compared with the values recommended by the European Union IPPC reference document: Best Available Techniques in the paper industry.</p>
<p>Table 8.2. Comparison of results after the application of the measure</p>
<table>
<tr><th></th><th>UNIT</th><th>RECOM. VALUES</th><th>SAICA 3 (2001)</th><th>SAICA 3 (2002)</th></tr>
<tr><td>Flow</td><td>m^3/t paper produced</td><td><7</td><td>3.3</td><td>2.9</td></tr>
<tr><td>COD</td><td rowspan="2">Kg/t paper produced</td><td>0.5 / 1.5</td><td>0.82</td><td>0.7</td></tr>
<tr><td>TSS</td><td>0.05 / 0.15</td><td>0.27</td><td>0.23</td></tr>
</table></td></tr>
</table>

Case Study 6	**8.1.6. Recovery of fibres in the cardboard manufacturing process**
Company	JOAN ROMANÍ ESTEVE, S.A. La Pobla de Claramunt (Anoia)
Address	SPAIN
Production	Production of cardboard from recovered paper.
Environmental problem	High pollutant load of the waste discharged.
Objective	The recovery of the fibre contained in the dewatering waters from the cardboard manufacturing process, thus increasing the efficiency of the process.
Description of the process and backround	The process of cardboard manufacturing is divided into two major subprocesses: the preparation of the paper pulp and the formation of the layers that are used to make up the cardboard. In the first, the raw material is

	introduced into the pulpers and various purification units in order to grind the recovered paper and remove the reject materials (plastics, metals, etc.) until a pulp is obtained consisting of cellulose fibres and mineral fillers of different characteristics. In the case of JOAN ROMANÍ ESTEVE, S.A., the pulp is centrifuged in order to be able to transport it to the second part of the process. In the second process, known as the "constant section", the pulp is diluted to the appropriate consistency and taken to the tank at the head of the machine, from where it feeds the different sheet formers. When each layer is formed, and due to the pressing that takes place in each forming unit, part of the water and the fibre (dewatering water) is returned to the tank. In this way, the water recirculates and the concentration of solids in the water increases. To keep the concentration constant, an essential parameter for maintaining the thickness, the grammage and the quality of each layer, fresh water is added, which results in an excess of water containing fibres. If this cannot be reused, it is sent to the wastewater treatment plant, with the consequent loss of water and useful fibres. Once the water has been treated in the treatment plant, it is difficult to reuse the fibres, as the sludges also contain flocculants and mineral fillers, and they are therefore destined for the landfill site. The reasons for the company to carry out this action are: • The possibility of recovering the fibres from the dewatering waters to return them to the pulp preparation process, and therefore increase the yield and efficiency of the process. • The possibility of recovering the water and reintroducing it into the pulp dilution process instead of having to take it to the wastewater treatment plant. • The possibility of reducing the generation of purification sludges and the costs associated with discharge these.
Description of the action	The action carried out by JOAN ROMANÍ ESTEVE, S.A. basically consists of the recovery of the excess waters (with a high fibre content) from the process of forming the layers of the cardboard. This water is taken to a fibre flotation unit where, by means of the recirculation of clarified water and the injection of air into the unit, stratification by concentration is obtained, which allows the concentrated fibres to be removed from the clarified water. The fibres are spun and returned to the pulp preparation area, where they are mixed to a certain proportion with the prepared pulp. In this way, almost all of the fibre is recovered that would previously have been sent to the treatment plant and become part of the sludges to be discharged in a landfill site. In terms of the clarified waters in the flotation unit and the centrifuge, part of these is returned to the dewatering water tank, and the rest is taken to the pulp preparation section where it is used to dilute the thick pulp. The fact that clarified water is used (which contains part of the process fillers) leads to the improved formation of the cardboard sheets, as the quality and uniformity of these increases.

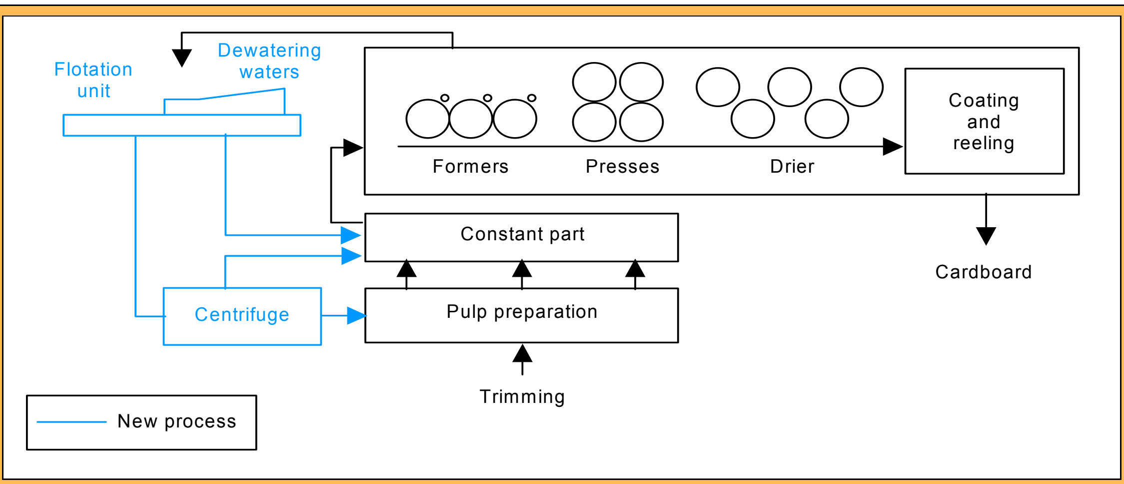


Figure 8.6. Diagram of the fibre recovery process

Material balance

	Old process	**New process**
Water consumption	210.000 m^3/year	210.000 m^3/year
Consumption of recovered paper	55,000 A	55,000 A
Production of cardboard (base 100)	100	100
Consumption of fillers/additives	4,300 A	4,200 A
Waste generation	1,190 A	830 A

Economic aspects

Costs of energy consumption and maintenance: €7,813/year

Savings:

- Consumption of fillers/additives: €60,101/year.
- Water purification and management of sludges: €17,309/year

Investment: €224,364

Payback period: 3.2 years

Results obtained

This action of recovery and recycling at source leads to a 30% reduction in sludges generated in the treatment plant from the treatment of dewatering waters with a high fibre content.

The recovery of the fibres and water has led not only to a reduction in water treatment costs, but also to an improvement in the final quality of the product, as greater uniformity is achieved in the layers formed and the quality of the fibres (understood to be a mixture of different lengths of fibre) is optimised. This action therefore increases the uniformity of characteristics of the cardboard manufactured.

As a result of the additional recovery of fibres and water, the company has been able to increase cardboard production without having to consume more raw materials or water, and has reduced its consumption of mineral fillers and additives by 2.3%, which means productivity has increased.

Source: Centre for the Enterprises and the Environment (CEMA), Ministry of the Environment of the Government of Catalonia, Spain.

Case Study 7	**8.1.7. Reuse of the water from the vacuum pumps in the paper machine**
Company background	Echezarreta
Country	SPAIN
Production	28,000 t/year of various types of paper from recovered paper.
Environmental problem	High water consumption.
Objective	Reduce consumption of fresh water and reduce the flow of wastewater discharged.
Measure to apply	The water brought to the process for the closure and cooling of the vacuum pumps was used in part, but the rest was being lost. The quantities are in the region of approximately 30 m^3/h. The reuse of this water means a significant saving in the consumption of fresh water and an important reduction in the flow of wastewater discharged. Once a quality study of this water and of the quality required at different points in the process where the incorporation of water was needed was carried out, the points of the process at which this water could be consumed were defined.
Results obtained	A 10% reduction in water consumption was obtained, and there was a reduction in the discharge of wastewater.
Economic aspects	For the economic study, it was assumed that 10 m^3/h of water from the vacuum pumps was reused, for which only an adaptation of the existing circuits is necessary. **Investment** (adaptation of circuits): €6,000 **Additional annual costs**: €841 (Financing costs: €600 + Maintenance costs: €240) **Reduction of annual costs:** €2,627 (10% saving in the consumption of fresh water - 63,000 m^3- which, taking into account the cost of €0.055/ m^3, results in a saving of €3,473 + 10% saving in the treatment and discharge of wastewaters which, taking into account the costs of €0.145 / m^3, results in a saving of €9,153) **Total annual savings**: €11,785 **Payback period:** 0.51 years

Case Study 8	**8.1.8. Minimisation of the quantity of cleaning water used in cleaning the pipes**
Company background	MANIPULADOS DEL TER, S.A.
Address	SPAIN
Production	Production of adhesive or pasted paper.
Environmental problem	Saving in water consumption and improvement of wastewater management.
Objective	To obtain savings in the consumption of fresh water and a reduction in the flow of wastewater discharged.

Description of the process and backround	The following processes can be distinguished in the manufacture of adhesive or pasted paper: • Adhesive: Product formed by two sheets (generally of paper) joined by means of a synthetic adhesive that can later be unstuck (one sheet is a label and the other the backing paper). • Pasted paper: A product formed by two sheets (usually both of paper or one paper, one aluminium foil or similar) joined by means of a synthetic glue in order that they cannot later be unstuck (used in paper making for gift bags, etc.). The glues used allow the adhesive to stick on the desired surfaces, and in the case of pasted paper, ensure the permanence and the stability of the unit formed by the two papers. Each type of paper and application requires a special type of glue: up to seven different qualities of glue are used, depending on the product in question. In the process used up to now, the change from one type of product to another meant that the point through which the glue entered the process had to be cleaned, to avoid the mixing of glues of different compositions, which would alter the quality of the final product. This operation generated cleaning water with glue and adhesive traces which represented 90% of the wastewaters treated externally by an authorised party. The consumption of water for the cleaning of the glue nozzles and the cost of the processing of this wastewater brought the company to consider improving the circuit by which the glue is introduced into the process. In addition, this modification has allowed changes to be made leading to faster production, as it removes the time spent on cleaning. Another of the reasons for the implementation of this measure was the company's interest in adopting measures to minimise the risk of environmental accidents. This worry has motivated, for example, the installation of collection points for waste and the emission of wastewater near to the facilities and as far away as possible from the river. The company has also established as an objective the implementation of an Environmental Management System in the mill.
Description of the action	The adhesives and glues used are of very diverse composition, which varies depending on the use intended for the final product. The waste from adhesives and glues is produced from various sources, including the waste glue from the gluing process and the water from the cleaning of the tanks and the glue circuits, as this drags out a certain amount of glue. As mentioned above, this cleaning takes place each time the product is changed, as all of the types of glue are introduced into the process through the same point. The company considered an alternative involving minimising the waste flow of the glues, consisting of the substitution of the one glue circuit with seven parallel circuits (one for each type of glue), which would remove the need for cleaning when the type of glue was changed. With the application of this alternative, the quantity of glue waste is thought to be reduced by 45%.
Results obtained	Annual production of glue waste: Old process: 860,000 kg New process: 473,000 kg

Economic aspects	Cost of waste management: With the old process: €655,570/year With the new process: €36,000/year **Savings:** • In waste management: €29,500/year • In water consumption: €7,212/year **Investment in facilitie**: €3,000 **Payback period:** Immediate
Conclusions	The modification in the process that was adopted enables the separation of waste at source. This separation is a means of optimising the productive process, as it increases flexibility for changes in production and results in a reduction in the quantity of waste to be managed; as a result, savings are made in the cost associated with the external management of wastewaters. The payback period for the investment is immediate, and therefore in addition to the environmental benefits, an important economic benefit is also obtained.
Source: Centre for the Enterprises and the Environment (CEMA), Ministry of the Environment of the Government of Catalonia, Spain.	

Case Study 9	**8.1.9. Internal treatment of the process waters by Ultrafiltration**
Mill	Holmen Paper Madrid
Address	SPAIN
Production	180,000 t/year of newsprint and coated paper.
Problem	The need to reduce the consumption of fresh water due to the installation of a new paper machine producing 250,000 t/year.
Objective	Internal treatment of the process waters by ultrafiltration to remove pollutants. Reuse of the treated water in applications where high water quality is required, to reduce the consumption of fresh water.
Description of the process	Although the specific consumption of water in Holmen Paper Madrid is in the lower interval outlined by the BREF (Reference Document on Best Available Techniques in the Pulp and Paper Industry) for the manufacture of newsprint (13 m^3/t), the extension of the plant with a new paper machine made it necessary to further close the water circuits in order to have sufficient fresh water available for the two machines. To avoid the accumulation of pollutants in the process waters and to be able to reuse the waters for uses that require high water quality, it was decided to install an ultrafiltration unit for the treatment of 800 m^3/d of water from the dissolved air flotation unit of the paper machine. The removal of pollutants allows the clarified waters to be reused in the mechanical closures, in the precision sprinklers, etc. Ultrafiltration consists of the use of a low pressure semi-permeable membrane to separate particles of high molecular weight, in the size range of

approximately 0.01 to 0.1 µm, while letting through salts and particles of low molecular weight. In this case, polyurethane filter plates with a membrane surface area of 140 m^2 were installed.

To obtain good performance in the ultrafiltration process, a prior filtration treatment of the waters is necessary. After a number of hours of operation of filtration, which varies depending on the working conditions, the membranes reach a high level of silting up and the flow of the permeate decreases to values below the acceptable minimum production levels. Backwashing is no longer sufficient to maintain average flow values in the system. When this occurs, filtration should be paused and an intense washing of the membranes should be carried out. This consists of emptying the circuit and refilling it with a reactive solution in recirculation for a certain length of time, usually approximately one hour. The cleaning reactive varies depending on the waters that are filtered and can be a strong acid, a strong base, a strong oxidant compound or a degreasant.

Results

Table 8.3 summarises the average values of the main parameters of the process waters and the efficiency which, for each of these parameters, ultrafiltration demonstrates.

Table 8.3. Reductions achieved by means of ultrafiltration of process waters

	Entrance	Accepted	Reject	Reduction
Conductivity (µS/cm)	1,200	1,170	1,234	2%
Suspended solids (ppm)	40	3	322	88%
COD (ppm)	450	339	937	25%
Turbidity (NTU)	440	1	1.146	99%

It is possible to observe that effectiveness, from the point of view of turbidity and the suspended solids, is close to 100%, while the reduction in COD, for example, is significantly less, although this can be sufficient depending on the case. It can be seen that there is no reduction in conductivity.

The waters resulting from ultrafiltration are used to clean the felt and the suction rolls in the paper machine, which require above all the total removal of solids. It is estimated that using this system, the consumption of fresh water can be reduced by almost 25%.

There are other secondary advantages of the incorporation of this process into the treatment of waste process water, which make it a CPA. These advantages are: the reduction of caustic soda consumption in de-inking (due to the higher pH level of the recirculated waters with respect to the clear filtrate from the disc filters in the machine), the reduction of sulphuric acid consumption in the waters due to the lower pH of the waters treated with respect to fresh water, and energy savings, due to the higher temperature of the waters treated with respect to fresh water, particularly in winter.

Economic data

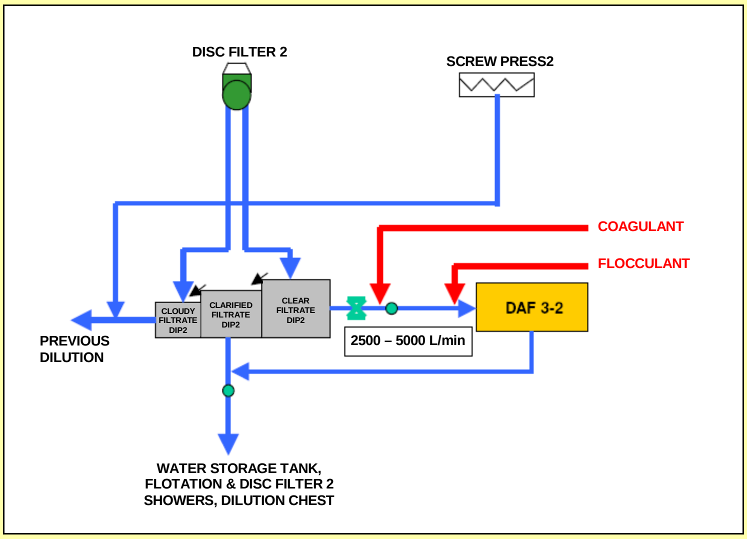
Total investment: €450,000

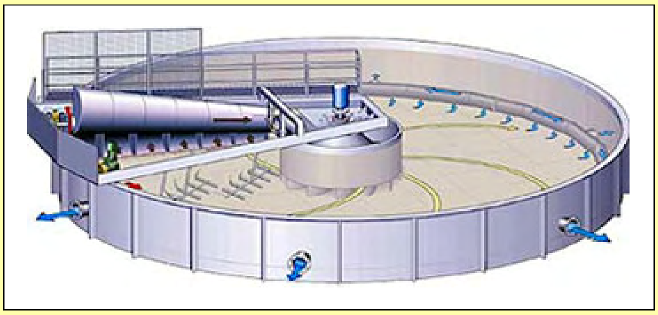
Consumption of electricity: 115 kWh

Approximate operating costs: €50,000/year

Savings: Reduction in water consumption by 800 m^3/d, which is equivalent to a saving of €245,000/year.

Payback period: approximately 2.5 years

Case Study 10	**8.1.10. Dissolved air flotation**
Mill	Holmen Paper Madrid
Address	SPAIN
Production	180,000 t/year of newsprint and coated paper.
Problem	Accumulation of pollutants in the process waters, especially dissolved and colloidal materials and stickies, which affect the final productivity of the machine and the quality of the final product.
Objective	To improve the quality of the process waters by means of their treatment by Dissolved Air Flotation (DAF) to remove suspended solids and stickies, and then the recirculation of the treated water in the manufacturing process itself.
Description of the process	The waters coming from the disc filters in the second circuit and the paper machine are treated with dissolved air flotation in order to be reused as clean dilution water and as water for sprinklers (Figure 8.7).  Figure 8.7. Integration of the DAF unit into the process The largest quantity of fresh water used in a paper mill is used in the paper machine, specifically in the table sprinklers, which means it is important to substitute the fresh water of these points with process waters. To attain this objective, it is necessary to carry out the internal treatment of the process waters before they can be reused. In this case the treatment selected was dissolved air flotation with an effective surface area of 69 m^2 and a height of 1m. In the flotation unit (figure 8.8), the suspension is saturated with pressurised air, in such a way that its expansion generates small bubbles that allow the removal of pollutants of between 0.1 and 10 µm by dragging out, forming scum that can be easily removed. To make the removal of material more successful, coagulation and/or flocculation additives are used.

	 Figure 8.8. Dissolved air flotation unit
Results	The physico-chemical optimisation of the dissolved air flotation units allows a good level of removal of suspended solids, stickies and to a lesser extent dissolved and colloidal materials. In the case of manufacturing newsprint, only flocculant need be added to reach high levels of efficiency, while in the case of coated paper, a combination of coagulant and flocculant is necessary. In general, treatment with DAF allows: • Removal of 99% of suspended solids. • Removal of 80-95% of ash. • Removal of 10-16% of COD.
Economic data	**Diameter of the DAF:** 9.5 m **Flow of the design:** 350 m^3/h **Solid load entry:** 70 kg/h **Investment for DAF**: €253,000 **Total cost including pumps, pipes, installation, etc.**: €380,000 **Operating costs**: €100,000/year approximately. **Savings:** The reason for the application of this measure is to improve the quality of the process waters in fairly closed circuits, to avoid the accumulation of pollutants that affect the manufacturing process and/or the quality of the final product. As a consequence of this measure, the number of breakages and stops to clean the machine can be reduced.

Case Study 11	**8.1.11. Recovery and recycling of coating products**
Company	Torraspapel, mill in Sant Joan les Fonts.
Country	SPAIN
Production	Coated paper from virgin fibre.
Environmental problem	• High solid content of the wastewater treated in wastewater treatment plants. • High levels of sludges produced. • Loss of raw materials.
Objective	Recovery of the waste discharged from the 6th stage of cyclonic purification in the paper machine.

Measure to apply	Installation of a grinder for the recovery of the solid material present in the coated brokes separated in the rejects from the cyclones of the machine.
Description of the process and backround	The aqueous suspension of the mixture of components for paper manufacture, before entering the paper machine itself, is submitted to a purification process to separate any impurities that it might contain. This purification takes place in a system of cyclones in which the heavy particles are separated from the fluid by centrifugal force. The system is arranged in a multi-stage cascade. This means that the rejects from the first stage are purified in a second stage, the accepted material from the second stage enters into the first again, its rejects are treated in the third, and so on. There are a total of six stages in the Sant Joan machine. The rejects from the 6th stage of purification contain essentially coated brokes, with a high proportion of mineral fillers, in suspension with water, and which, due to their weight and size, are rejected in this stage and cannot be recycled as they are. This is therefore wastewater that is generated and is sent to the wastewater treatment plant. The objective is to entirely reuse this wastewater and to reintroduce it as mineral filler in the circuit of the paper machine.
Description of the action	A grinder manufactured by the Austrian company GAW was tested in the pilot plant, in order to test its efficiency in the treatment of the fillers from the paper. Following tests carried out in this pilot plant, the efficiency of this system was verified. The system allows savings in raw materials and reduces waste from the mill, with the additional advantage of a reduction in costs of the treatment of the liquid waste and lower production of solid wastes, which extends the useful life of the landfill site. The equipment is a grinding facility equipped with a feed store, a grinder, an exit store and and corresponding pumps, agitators and automated elements for the automatic operation from the distributed control system of the paper machine.
Description of the facility	The facility consists of: • A 400 l deposit, with stirring and dilution control, to receive the waters from the 6th stage of the purification process in the machine. • A pump sending to the grinder. • A grinding system that deals with all of the wastewater, reducing and unifying particle sizes. • An exit deposit, for the continuous dosing of the machine. • Dosing pump to the paper machine. • The corresponding pipes for the transporting of fluids, and automatic and manual valves. • Instruments to measure flow and level. The facility is entirely automatic and its operation and control are integrated into the DCS of the paper machine (see Figure 8.9).

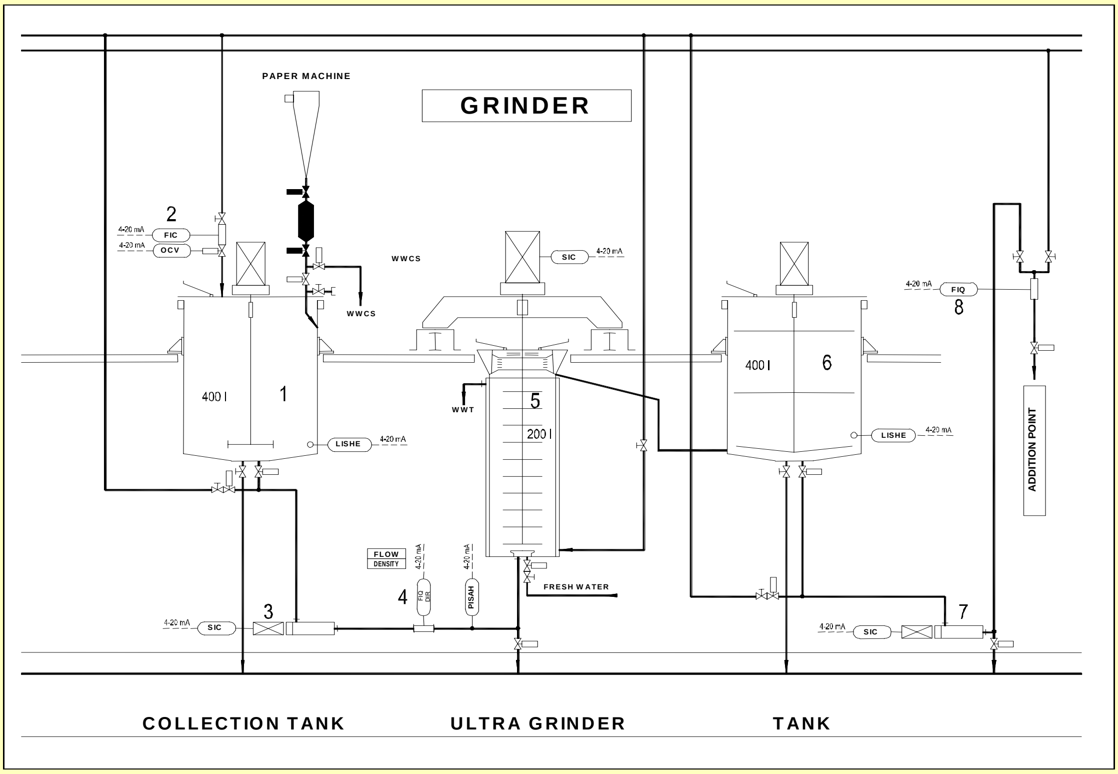


Figure 8.9. Diagram of the grinding facility at Torraspapel

Results obtained

As described above, this facility allows the recovery and return of solid material to the paper machine.

It is therefore the direct recycling of raw materials, essentially fibres, calcium carbonate and other mineral fillers. This recycling has an ecological effect on:

- Less use of raw materials to manufacture one tonne of paper.
- Reduction of the solid material in the wastewater sent to the wastewater treatment plant, with the resulting increase in yield of the wastewater treatment equipment and improved quality of the treated water.
- Significant reduction in sludges extracted by the wastewater treatment plant, achieving alongside this the prolongation of the useful life of the landfill site, to which these are finally sent.

Economic aspects

The valuation of the investment cost is 435,000 euros:

This calculation is based on the recovery and recycling of raw materials. The material recovered has the following composition:

- 11.5% organic material
- 88.5% mineral material

The saving in purchasing costs should be added to the cost of treatment in the wastewater treatment plant and the landfill site, as shown in the box below:

RAW MATERIALS SAVED	(Kg/day)
Organic materials	644
Mineral material	4,956
TOTAL	**5,600 Kg/day**

	This saving represents, in the cost of materials: 511,00 euros per day **SAVINGS IN TREATMENT COSTS** (euros/t dry waste discharged) Wastewater treatment plant chemical costs 45.1 Transport costs for sludges 5.5 Landfill site costs 5.0 TOTAL **55.6 €/t dry waste dumped** **ANNUAL AMOUNT**: Considering that 5.6 t/day of dry material is recovered, (5.6t/d x €55.6/t + €511/d) x 355 d/year = **€291,937/year** Therefore the **payback period** for this facility is: 435/292 = **1.48 years**.

Case Study 12	**8.1.12. Installation of frequency variators in the motor of the pump of the paper machine pit**
Company background	Echezarreta
Country	SPAIN
Production	28,000 t/year of various types of paper from recovered paper.
Environmental problem	High consumption of electrical energy.
Objective	To obtain energy savings.
Measure to apply	The measure consists of: 1. The use of frequency variators. These are advisable for those motors that have to work at varying load levels. In the same way as starters, these enable the starting current to be toned down, but they have the original advantage of allowing the motor pump groups to work at the point of maximum performance. 2. In the long term the company could consider substituting the older motors with lower performance with motors designed to obtain greater levels of energy savings. These motors require less energy for the same power when compared with conventional motors. The high efficiency of these motors implies low energy requirements and major reductions in operating costs. Therefore these motors have a short payback time.
Results obtained	A 0.4% reduction of energy consumption is obtained.
Economic aspects	Economic balance applied in the case of the installation of a frequency variator for the motor of the pump of the paper machine pit: **Investment** (variator for a 30 kW motor): €.4,700 **Additional annual costs**: €330 (Financing costs: €240 + maintenance costs: €95). **Reduction in annual costs** (savings in electricity consumption): €5,713 **Total annual savings**: €5,385 **Payback period:** 0.87 years

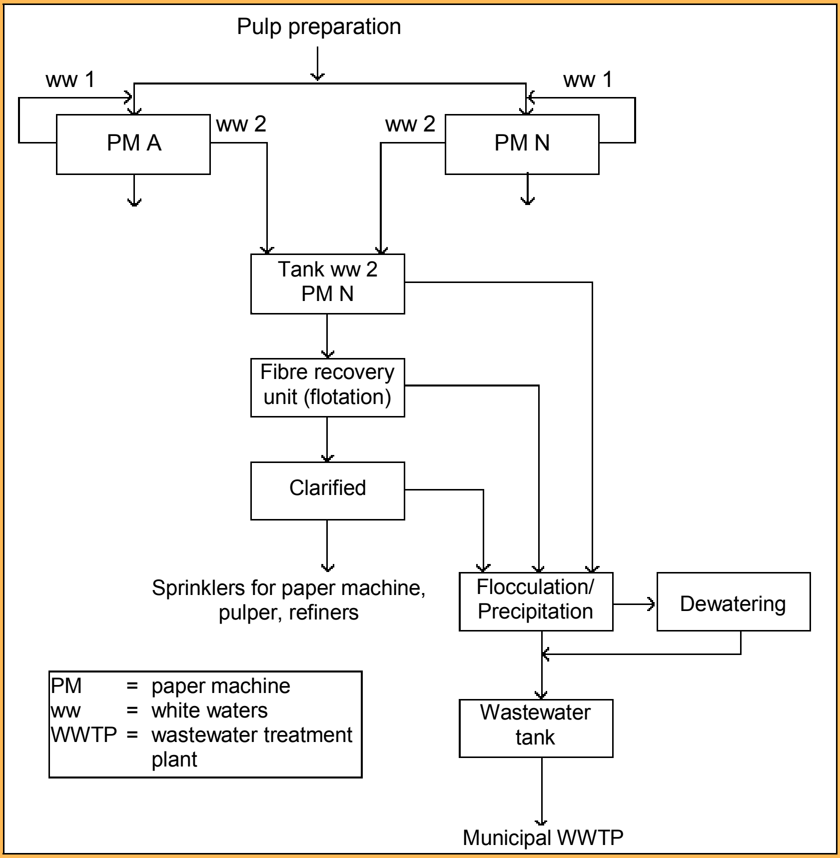
8.2. CASE STUDIES OF FINAL TREATMENTS

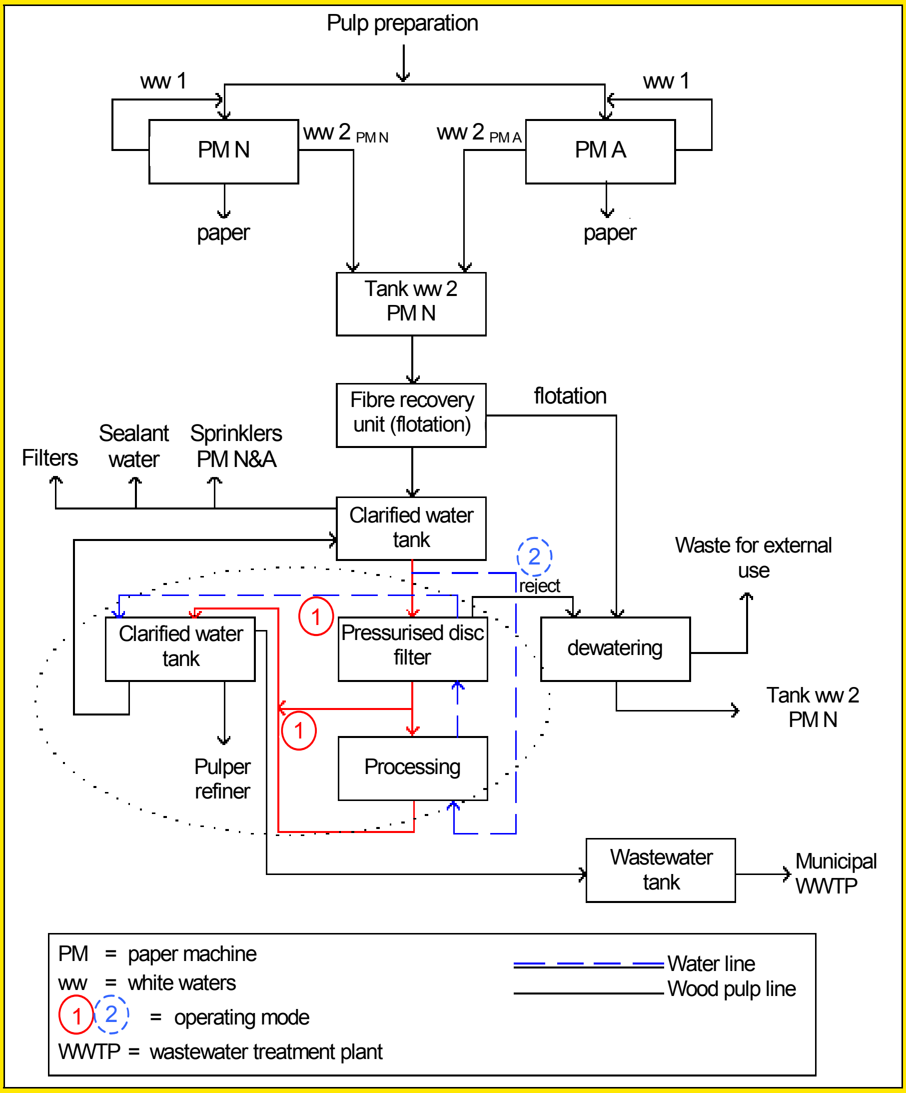
Case Study 13	**8.2.1. Installation of a primary wastewater treatment plant**
Company	Physico-chemical treatment plant in the paper industry (Source: IHOBE)
Country	SPAIN
Production	31,000 t/year of carbon paper from bleached chemical pulp.
Environmental problem	High pollutant load in waste discharged.
Objective	To reduce the pollutant load of waste discharged.
Measure to apply	Within the study of the possibility of treating the waters within the company and not sending them to the wastewater treatment plant, an intermediate possibility was considered. This consisted of carrying out the primary treatment of the waters in the mill, then sending the treated waters to the wastewater treatment plant. This possibility is interesting because a primary treatment plant is relatively simple and involves a much lower investment than if secondary treatment were also to be carried out. Primary treatment allows a considerable reduction in the suspended solids and the COD of the treated water that can then be treated without difficulty in the wastewater treatment plant. The primary treatment facility implies the generation of a new type of waste: the sludges removed from the wastewater. This waste is in theory inert, but has to be managed appropriately, carefully depositing it in the landfill site, or reusing it for other purposes such as in cement or brick manufacturing. In any case the quantity of sludges generated will be small.
Results obtained	Separation of the suspended solids from the wastewater, consisting mainly of fibres and fines.
Economic aspects	Economic balance: **Investment** (primary treatment): €360,600 **Additional annual costs**: €24,000 (correspond to the operating costs). **Reduction in annual costs:** €114,192 (corresponding to the lower level of discharge of wastewaters and the reduction of the pollutant load of wastewater discharged by 60%). **Total annual savings**: €90,192 **Payback period**: 4 years

Case Study 14	**8.2.2. Wastewater treatment plant**
Company	PALOMA Sladkogorska tovarna papirja http://www.paloma.si/palomaeng
Country	SLOVENIA
Production	Tissue paper of different qualities (toilet paper, hand towels, serviettes...) from recovered paper (53,000 t in 2003) and virgin fibre (23,500 t in 2003). • CB paper (100% virgin fibre). • TT paper (virgin fibre/recovered paper). • AP paper (100% recovered paper). • PP paper (100% recovered paper).
Environmental problem	Pollution of the river Mura due to the discharge of wastewaters from the paper mill. High specific water consumption.
Objective	Installation of a wastewater treatment plant for process waters to minimise the impact of these being discharged.
Measure to apply	To minimise the environmental impact produced by the discharge of the plant's waste, the following actions were considered necessary: • Physico-chemical treatment of the wastewaters followed by aerobic biological treatment. • Dewatering of the physico-chemical sludges by means of a physico-chemical treatment. • Thickening of the biological sludges. • Improved quality of the process waters by means of the installation of micro filters, to reuse part of these waters and reduce water consumption.
Results obtained	The improvements obtained with the treatments implemented were as follows:

Parameter	BAT ref.	Before AR treatment (2002)	After the biological treatment (2003)
COD (kg O_2/t)	2 - 4	34.2	2.96
BOD$_5$ (kg O_2/t)	0.05 – 0.5	8.8	0.37
TSS (kg/t)	0.1 – 0.4	32.4	0.3
AOX (kg Cl/t)	< 0.005	0.02	0.0029
Total N (kg N/t)	0.05 – 0.25	0.29	0.06 – 0.09
Total P (kg P/t)	0.005 – 0.015	0.016	0.004 – 0.009
Cd (g/t)		2	0.08
Cr(g/t)		7	0.289
Ni(g/t)		2	0.07
Pb(g/t)		2	0.13
Z(g/tn)		111	7.70
Effluent (m^3/t)	8 - 25	29.7	25.1

	To summarise, it can be seen that there were reductions of: • 15% of specific water consumption, • over 90% of COD from the final effluent from the plant, • 96% of BOD, • 99% of total solids and • 67% of N in the waste.
Economic aspects	**Total investment:** €4,200,000 **Operating costs:** €835,000/year **Savings**: €1,195,000/year **Investment payback period:** 10 years

Case Study 15	**8.2.3. Treatment of effluent using ozone**
Company	Buettenpapierfabrik Gmund; SME, 5,000 t/year
Environmental problem	Dumping of wastewaters with high COD content and which could be recycled.
Objective	Reduction of the volume of effluents from the manufacture of paper and reuse of water from the manufacture of paper.
Description of the process and backround	This is a small mill, producing 5,000 t/year, in which coloured paper is manufactured using two paper machines (Figure 8.10).  Figure 8.10. Initial situation

	Due to the colouring process, the contaminated waters have a high pollutant content. The water resulting from the thickening of the sludges from the wastewater treatment plant were discharged directly, without being reused, which meant that the wastewater discharged had a high COD content. The flow of wastewater discharged reached almost 29 m^3/per tonne of paper manufactured.
Measure to apply	Treatment of the clarified water in the flotation process of the white waters from the paper machines by filtration, in a pressurised disc filter, and then ozonation for it to be reused in the process, thus avoiding it being discharged (Figure 8.11).  Figure 8.11. Process after adopting the measure
Results obtained	With the treatment implemented in the Gmund mill, good levels of water decolouration were achieved (L*>97) with doses of O$_3$ of between 20 and 55 g/m^3 for slightly coloured waters and of 65 to 80 g/m^3 for intensely coloured waters. The pH decreases slightly but is maintained within the band 8.0-7.0, which is acceptable in many cases. A slight reduction in conductivity occurs (50 µS/cm).

	Thanks to the treatment proposed, the flow of effluent was reduced to 14 m^3/t, which is 52%. In addition, COD was reduced by 58% and total solids in the wastewater discharged by 86%. In addition to these effects, a reduction in the consumption of dewatering additives was obtained for sludges of some 20 t/year, with the added advantage of reducing the environmental effect produced by the discharge of this type of product.
Economic aspects	**Investment**: €1,200,000 **Treatment costs**: These vary between 0.07 and 0.17 euros/m^3 of water treated, of which 31% is due to the ozonation stage and 69% to pressure filtering. **Saving made**: €92,000 /year of savings in discharge costs.

Case Study 16	**8.2.4. Energy recovery from sludges**
Company	CARTIERE BURGO
Country	ITALY
Production	Production of 150,000 t/year of newsprint with a grammage of between 42 and 48.8 g/m^2. Useful width of the machine: 7 m. Machine speed: 1,170 m/min.
Environmental problem	High generation of sludges, 340 tonnes per day.
Background	This de-inked pulp and paper production plant was producing a high quantity of sludges and rejects, which could have been reused in the generation of steam and/or electricity, as a source of renewable energy, which would also have reduced the need to dump them in landfill sites. The waste generated is of three types: • Rejects: Consisting of paper, plastic, metal, fibres and fabrics; these are the impurities in the paper separated during classification or in the first steps of purification. • De-inking sludges: The average proportion of the de-inking sludges is 20% in dry material of the paper recovered or 25% of the product, also in dry material. • Primary sludges: These are the sludges separated in the primary treatment stage of wastewaters. • Biological sludges: Consisting of the purge of sludges in the biological treatment of the wastewaters. In general, it is estimated that production of these, based on dry material, is 65 to 70% of the mass of material removed through biological means. The Cartiere Burgo mill, which manufactures newsprint from recovered paper, with production of 150,000 t/year, generates on average 25,000 t/year of de-inking sludges. These sludges have a minimum calorific value of 10,000 kJ/kg, which is equivalent to $2.5x10^8$ MJ of thermal energy.

<table>
<tr>
<td>Measure to apply</td>
<td>
The company opted for BFB combustion technology (Bubbling Fluidised Bed). The combustion of de-inking sludges requires a special technology that allows flexible operation and the recovery of the low calorific values of the sludges. The combination of drying, with residual heat, and combustion in a "bubbling fluidised bed" or BFB, constitute the most widely used solution in plants today, as they make it possible to work with fuels of low calorific value and high moisture content (Figure 8.12).

The boiler generates steam from reheated water, which expands in a turbine to generate electrical energy.

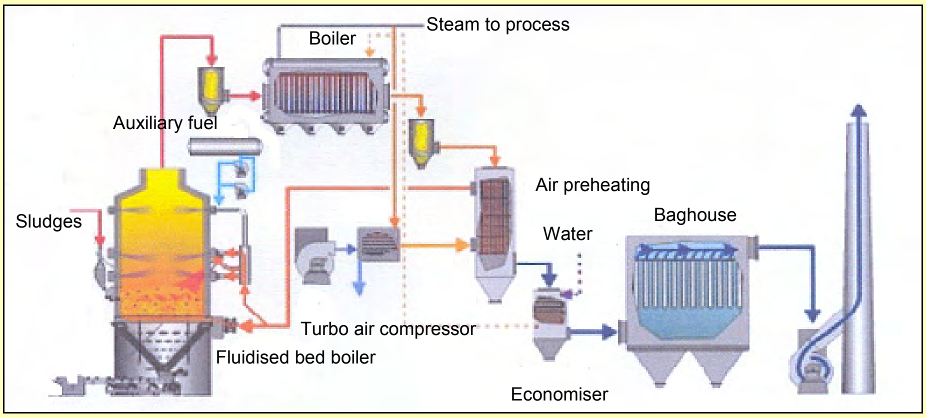


Figure 8.12. Combustion and steam generation in a BFB boiler
</td>
</tr>
<tr>
<td>Results obtained</td>
<td>
The proposed solution is considered to be environmentally favourable, as it allows the use of a raw material of vegetable origin (degraded or non-recoverable cellulose fibres) as an alternative fuel. This technique has enabled an average of over 50 million kWh/year to be obtained. The production of energy is 3.2 MWe, 14 t/hour of steam at 52 bar and 430ºC.

Reduction by 80% of the waste produced, which is inert, with the possibility of use in other applications.

The gas emissions have pollutant concentrations below the emission limits. Table 8.4. shows the figures published by the Cartiere Burgo plant in Mantova (Italy).

Table 8.4. Gas emissions
<table>
<tr><th>Pollutant</th><th>Units</th><th>Emission</th></tr>
<tr><td>Particles</td><td>mg/m^3N</td><td>19.7</td></tr>
<tr><td>SO_2</td><td>kg/h</td><td>1.46</td></tr>
<tr><td>NO_X</td><td>ppm</td><td>74</td></tr>
<tr><td>HCl</td><td>kg/h</td><td>3.86</td></tr>
<tr><td>NH_3</td><td>ppm</td><td>11.9</td></tr>
<tr><td>CO</td><td>ppm</td><td><1.2</td></tr>
<tr><td>VOCs as methane</td><td>ppm</td><td><1.5</td></tr>
<tr><td>VOCs as carbon</td><td>ppm</td><td><1.6</td></tr>
<tr><td>PCBs</td><td>ng/m^3</td><td><2.8</td></tr>
<tr><td>PCDD/PDCF</td><td>ng/m^3</td><td>0.54</td></tr>
<tr><td>Opacity</td><td>%</td><td>0</td></tr>
</table>
</td>
</tr>
</table>

Economic aspects	The **investment** made was of 9 million euros. The value of the **benefits** obtained from the generation of electricity, at conventional prices of energy in the industry, is 1.9 million euros/year, which gives a payback period on the investment of 4.7 years.
Conclusions	The energy recovery from sludges is an economic and environmentally interesting alternative, applicable to mills of de-inked pulp with production of 100,000 t/year or greater. The implementation of a treatment plant for the energy recovery from sludges and other paper waste involves the characterisation of the de-inking sludges and the inventory of other waste, in order to make up a pool of waste which allows the determination of the thermal resources available. At greater production levels, the capacity of the plant that can be installed increases, which represents greater benefits in both economic and environmental terms. With capacities of below 100,000 t/year, there is the possibility that the alternative of energy recovery from the de-inking sludges, together with other physico-chemical or biological sludges and other paper waste, may still be economically viable. However, this requires a more detailed preliminary study. It will probably be more profitable in DIP for tissue paper.
Other examples of application	The company Cartiere Burgo has two plants for the generation of electricity, one in Mantova (Italy) with a capacity of 3.2 MW and the second in Verzuolo (Italy) with a capacity of 7 MW. Both use bubbling fluidised bed (BFB) technology. The DIP plant of Honsha Mill Fuji, which belongs to the group Daishowa Paper Manufacturing Co Ltd, put into operation in April 2000 an energy recovery plant using BFB technology with a capacity to generate 65 t/hour of steam, and providing power of 14.5 MWe. The Golbey paper manufacturing company (France) has a cogeneration plant using sludges and other waste, which can treat 400 t/day of dry material with a capacity of 90 MWt. This also uses bubbling fluidised bed (BFB) technology. The Sachsen paper mill uses a bubbling fluidised bed (BFB) boiler to burn de-inking sludges and paper rejects, with an ash content of 51% and 55% moisture content. The plant has the capacity to generate 196 t/day of solids and 39.6 t/hour of steam, working in conditions of 84 bars and at a temperature of 490ºC. Other companies, such as Cross Pointe Paper Corporation (Wisconsin) have also opted for energy recovery from paper waste using BFB technology, which shows the versatility of BFB for energy recovery from sludges, which has benefits over other processes such as Circulating Fluidised Bed (CFB) technology.

8.3. OTHER EXAMPLES OF GOOD ENVIRONMENTAL MANAGEMENT

Case Study 17	**8.3.1. Systematic solution for optimum water management**
Companies	Group of 30 paper mills in the Tuscany region of Italy.
Address	Results of the European project PAPERBREF EVK1-2000-200690, carried out by Lucense, PTS, CTP, ARPAT and Serv.Eco Srl. http://www.paperbref.info
Production	14 mills producing tissue paper from virgin fibre. 3 mills producing tissue paper from recovered paper. 12 mills producing packaging paper from recovered paper. 1 paper mill.
Environmental problem	High levels of water consumption in the paper and cardboard factories.
Procedure	**Beginning data** • Knowledge of the current situation in the plant: use of water, water flows and circuits. • Flow chart of the process with the existing consumption and recirculation of water. • Analysis of the water to determine the accumulation of organic and inorganic material on closing the water circuits. • Estimate of the impact of the physico-chemical quality of the waters on the process. **Analysis of the data** • Estimate of the potential reduction of fresh water used. Determination of the losses of reusable water. • Alternatives for the modification of the circuits to improve the management of water without affecting the process or the quality of the final product, considering improvements in the use, consumption and quality of the water.
Methods	**Methods that do not affect the pollutant load of the process:** • System of cooling waters (up to 6 m^3/t): reuse of these non-contaminated waters at other points of the production process. • Preparation of additives with fresh water and dilution of these when necessary with process waters. • Reduction of the flow of sealing waters: there are alternative pump manufacturers for lower consumption of sealing waters such as, for example, mechanical seals. • Closed circuit for vacuum pump sealing waters with cooling treatment and solids removal. • Identification of losses of fresh water throughout the process.

To close the water circuits and minimise the potential negative effects, the stability of the process must be maintained and the contamination of the product should be avoided. To do this, the following should be taken into account:

- Sufficient storage capacity of pulp, waters and brokes. Control of accidental overflows.
- Appropriate management of brokes, separating the white water circuits from the broke circuits in order to avoid instability at the wet end of the machine.
- Clarification of process waters prior to their reuse to produce clarified waters with a low solids content that can be reused: effective fibre recovery processes to remove suspended solids, such as disc filters, and DAF flotation units to remove suspended solids and colloidal materials with the help of a process of coagulation/flotation.
- Separation of circuits. This is of particular importance in integrated plants where there should be 1-3 circuits in the pulp preparation area and 1 circuit for the paper machine.
- Reuse of water in counterflow to the fibre flow. This aspect is fundamental in integrated plants to avoid a high pollutant content in the water circuits of the paper machine.

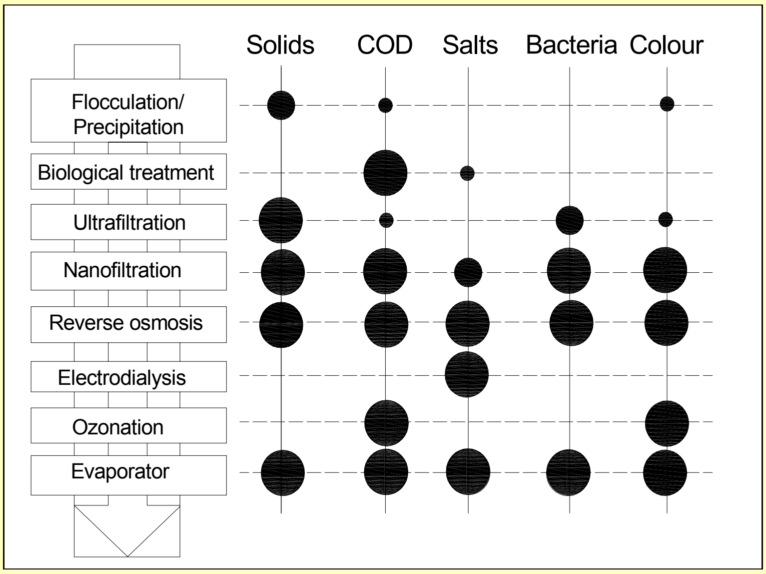
The closure of water circuits reduces the flow of wastewaters but increases their pollutant content, which means that the appropriate treatment of these waters is needed to achieve the characteristics required for discharge.

Therefore the following alternatives should be considered:

- Equalisation tank for wastewater.
- Primary treatment: physico-chemical treatment by flotation or separation to remove suspended solids up to values of 30-200 mg/l. Following dewatering, the sludges can be incinerated or used in agriculture.
- Secondary treatment if necessary to remove organic material. Normally an aerobic treatment is sufficient but if the organic load is very high and two stages are needed, a preliminary anaerobic treatment can be carried out.
- Tertiary treatment, for example chemical precipitation, if it is necessary to remove a specific pollutant such as phosphorous, suspended solids or dissolved and colloidal organic materials.

To almost entirely close the water circuits, emerging technologies should be considered as internal treatment systems for the process waters prior to their reuse. The integration of these technologies requires a significant amount of investment, increases operating costs and increases the generation of rejects and sludges. In some cases the economic viability of these technologies has still to be demonstrated.

There are different technologies for the removal of solids, salts and organic material, as shown in figure 8.14.

	 Figure 8.14. Technologies for the removal of solids, salts and organic material (*The size of bubble is related to the effectiveness of the treatment.*)
Conclusions	Figure 8.15. shows the proportion of the different methods with the potential to reduce water consumption described in the BREF.

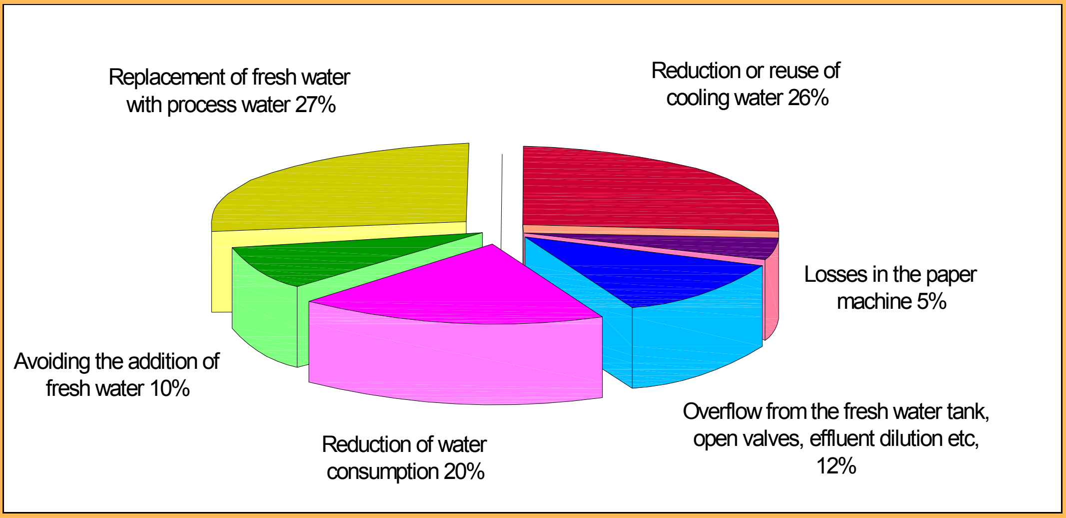


Figure 8.15. Methods with the potential to reduce water consumption. Source: BREF

Case Study 18	**8.3.2. Methods of prevention and reduction of emissions in a newsprint mill from recovered paper**
Company	Holmen Paper Madrid (HPM)
Address	Spain
Production	MP61: 200,000 t/year newsprint or LWC coated paper. MP62: 300,000 t/year of newsprint.
Environmental problem	Integrated pollution control in the plant in order to adapt to the current legislation (IPPC - Integrated Pollution Prevention and Control legislation).

Procedure	Study of the technologies outlined in the BREF (Reference Document on Best Available Techniques in the Pulp and Paper Industry). Selection of the appropriate technologies for the process in HPM. Adaptation and integration of the Cleaner Production Alternatives (CPA) described in the BREF to the process. Study of new alternatives.

GENERAL CLEANER PRODUCTION ALTERNATIVES (CPA)

Training, education, motivation and raising awareness of personnel and operators.

HPM produces a training plan on a yearly basis which covers the training needs detected in each of the departments within the company. This plan additionally includes raising awareness of all the personnel of the company's environmental management and the way each job influences the overall impact.

Whenever new processes, new technologies or new systems are introduced, the personnel directly involved with these are specially trained.

Raising awareness is done by means of courses, talks, information posters, internal memos and through the monthly publication of the company newsletter.

Optimisation of process controls

To obtain high levels of efficiency in paper manufacturing, it is extremely important that each process is stable and the quality is uniform. These characteristics are also important from an environmental point of view. Instability may cause breaks in the sheet and, as a result, disturbances to the water circuits. Continued measurements and precise control of the processes are essential.

The main areas in which this control is important are:

- Control of the disc filter (*save all*), in order to control the loss of fibres and to reduce the pollutant load of the effluent for its reuse in the machine's sprinklers. For this, HPM has an additional system of purification and recovery of the fibres by means of dissolved air flotation (DAF), which treats the very clear filtrate from the disc filters. The exit effluent from the DAF is used in specific sprinklers. The turbidity of this effluent is controlled in the laboratory. Moreover, to guarantee the correct operation of the disc filter, the consistency of the pulp is controlled on entry to the polydisc.
- Control of the consistency of the mixing tank, in order to reduce the variations in quality entering the machine.

  HPM controls both the consistency and the flow of all the substances arriving at the mixing tank, which are: pulp from the brokes system, pulp from the disc filters and pulp from each of the de-inking lines.

In addition to these controls, for each of the stages of the process control parameters have been set which ensure that the stage develops in the manner desired.

For this, there are procedures and instructions in which the parameters within which the process has to be carried out are defined. In order to guarantee this, there are devices down the line to measure the different parameters (pH, suspended solids, conductivity, consistency...) of which the signal is transmitted to the monitors in the control room. In addition, there are daily laboratory controls both for the measurement of parameters with no on line detectors and to compare with other values obtained.

There are also procedures for the calibration of all of the apparatus measuring both process parameters and paper properties, and environmental parameters.

Correct maintenance of the facilities

Three types of maintenance are carried out in the facilities of Holmen Paper Madrid: predictive, preventive and corrective.

Predictive maintenance encompasses the methods of obtaining samples and analyses of the lubricant oils of the different equipment in the mill, in order to ensure they are in the best condition possible for optimising performance and the performance of the mechanical equipment, in addition to optimising the generation of used oils.

Preventive maintenance encompasses everything from simple operations such as noting data, cleaning, greasing, etc., to complex operations of assembling and dismantling equipment and elements, systematic replacing of worn out parts, etc. These operations are divided into types, each of which takes place with a specific frequency.

These two types of maintenance are fundamental for the correct operation of all the systems and equipment. Nevertheless, there is a third type of maintenance: corrective maintenance, which obviously involves repairing faults detected in preventive maintenance or unexpected breakdowns of equipment, instruments, mechanisms, etc.

In order to carry out the indicated maintenance tasks, there is a maintenance department which is divided into separate speciality areas (mechanical, electrical, preventive, instrumentation and control) of which the personnel have the training and equipment necessary to carry out the tasks allocated to them. Those maintenance tasks which cannot be carried out by the company are subcontracted to companies that are specialists in, and where appropriate authorised to carry out, the required work.

Environmental Management System

Holmen Paper Madrid has an Environmental Management System based on the UNE-EN ISO 14001 standard certified as of 16th September 2002 by the accrediting body AENOR.

The Environmental Policy of the company is based on this system. With this policy, the company's management states the commitment of the company to pollution prevention, compliance with the applicable requirements, the priority of respect for the environment in crisis situations and the tendency towards continuous improvement in the environmental management of the company.

The environmental management system encompasses, in addition to the elements outlined in the points above, all the aspects necessary to ensure compliance with the company's Environmental Policy.

Among the advantages and guarantees implied by this environmental management system, the following can be highlighted:

- All of the environmental aspects associated with the activities of HPM carried out in their facilities are identified. Their environmental impact is assessed annually in accordance with defined criteria and from specific data. In this way certain aspects are prioritised, which means that those that are most relevant are considered priorites when annual objectives are defined.
- There are means of accessing the applicable environmental legislation applicable both to the aspects identified and to the aspects carried out and foreseen. The requirements resulting from this are identified and collected in databases.
- Annual objectives are defined with concrete programmes which enable the constant improvement of management.
- Documentation in the form of procedures or instructions is held for all those environmental management processes that must be carried out in a determined fashion to ensure that this management is correct (for example: waste management, effluent control, emissions control, specific cleaning operations...).

- The person responsible for carrying out the various tasks and functions within the system is named.
- Training on environmental subjects for those personnel whose tasks can directly affect the environment and the raising of awareness of all the personnel with respect to the environment is guaranteed, so that everyone is aware of specific actions or situations with implicit risks.
- Internal and external audits of the system are carried out. These enable faults to be detected and potential problems to be corrected.

CPA TO REDUCE WASTEWATER EMISSIONS

The generation of effluent is closely linked to the consumption of fresh water. This means that measures for the reduction of emissions into water are often carried out by reductions in fresh water consumption.

The reduction in consumption of fresh water can be attained with a series of measures that normally translate into the optimum management of water that enables the consumption of fresh water to be minimised and also allows for the necessary water quality to be maintained at each point of the process, in order the the process can be carried out without problems and the quality requirements for the product are achieved.

The greatest quantity of fresh water is consumed in the paper machine, specifically in the table sprinklers, which means that a large proportion of the techniques used and under development look for the reduction in the consumption of fresh water at these points.

CPA TO REDUCE THE CONSUMPTION OF FRESH WATER

Separation of the most contaminated water from the less contaminated water and reuse of process waters

One of the means of saving fresh water is by the separation of less contaminated waters from those which are most contaminated, in order for these less contaminated waters to be used to substitute fresh water in the points where this is possible.

On the one hand, the cooling waters have a circuit that is independent from the process waters circuit. For their reuse, there are cooling towers that enable the temperature to be lowered in order for them to be reused, without them being mixed with process waters and therefore contaminated. The purge that enables the balance to be maintained is taken to the fresh water tank.

In addition, the sealing waters from the vacuum pumps have an independent circuit that enables them to be recovered and reused following their refrigeration in cooling towers. However, these waters drag out fibres from the vacuum, which means they are partially contaminated, and therefore the purge is taken to tanks of clarified process water.
On the other hand, all of the process waters are clarified at different points, as shown below, by means of disc filters and microfiltration equipment, which allow the separation of more or less contaminated water and its later recycling depending on the quality required at the point of use.

Optimum water management (suitability of the circuits), clarification of water by flotation and recycling of water for different purposes

Both the current pulp manufacturing lines (DIP2 and DIP3) and the future lines (DIP4 and DIP5) have been designed with two loops, in order that at the end of them, by using disc filters and screw presses, the pulp is thickened and large quantities of water are recovered.

The disc filters in de-inking extract water of two qualities, known as cloudy filtrate and clear filtrate, with both being reused in the process, for example in the dilution of recovered paper used as a raw material for the production of pulp, and at many other points of the process.

In the paper machine, both the PM61 and the anticipated PM62, the white waters obtained in the wet end of the paper machine are purified in disc filters and flotation systems (DAF), with three resulting types of water: cloudy, clear and superclear. The clear and superclear waters are used at different points in the paper machine, including various sprinklers in the wet end, and for the dilution of chemicals.

This enables fresh water to be substituted with recycled water at these points, which throughout the process represents a reduction in water consumption. Moreover, this also signifies energy savings as it is not necessary to use the same amount of energy to heat water from the process as when fresh water is used, as its temperature is considerably higher from the start.

In any case. this type of clarified water cannot be used in some types of sprinkler that are considered critical points, particularly in the press section.

To try to maximise the use of this type of water, HPM has carried out a development project for the use of ultrafiltration techniques to clarify process waters, and therefore allow them to be used in some sprinklers where it is currently not possible to use them. This technology is not currently considered a CPA, but as an emerging technology.

Reduction in the consumption of fresh water by means of strict separation of loops together with a counterflow of water

As mentioned above, each pulp line has two loops. The water used in each of these loops, together with the water used in the paper machine, flow as counterflow, that is, that the flow of the white waters from the paper machine to the pulp mill flows in the opposite direction to the flow of the pulp.

The white waters are used for the dilution of pulp in the mixing tank and in the machine tank and the excess of clear water in the machine is sent to the pulp mill to be reused.

The processes are designed to avoid as much as possible the water passing from the pulp mill to the paper machine through disc filters and presses at the end of the second loop. In this way, the flow of anionic trash and colloidal or dissolved material to the paper machine is minimised, thus preventing these substances from affecting the process at a later stage.

Generation of clear waters from process waters from the pulp mill (flotation)

All the lines of the pulp mill, along with the water from the wet end of the machine, have DAF (dissolved air flotation) systems.

With the help of flocculants, the anionic trash and the fines are agglomerated, forming flocs. These flocs stick to the air bubbles formed in the DAF unit and are floated to the surface, from which they are then scraped off. The clarified water is removed from the lower part of the DAF unit.

The cleanliness level in the water achieved by this treatment means that it can again be reused in the process.

Control of the potential disadvantages of closing the water systems

To control the disadvantages of the closure of circuits, the following measures should be highlighted:

- The adequate separation of the loops in order that the minimum possible quantity of water reaches the machine from the pulp plant.
- The suitable treatment of the white waters which will feed the sprinklers in the machine so that the dirt does not silt up or wear out the machine equipment (DAF treatment).
- Sufficient cooling of the vacuum seal waters in cooling towers.

- The suitable washing of the pulp before entry into the machine so that the use of chemicals in the machine such as flocculants, coagulants or bactericides can be reduced. This is obtained by the use of screw presses after the disc filters in de-inking.
- The correct monitoring of the water circuits, which can be achieved using on line measures consisting of instruments placed at different points of the circuits, and periodic measures carried out in laboratories.

By using these systems, the mill personnel can follow the stages of the process and avoid potentially problematic situations which might prevent the correct recycling of the process waters.

Construction of balanced systems for the white waters, clear waters and brokes. Use of constructions, design and equipment with low water consumption

In the case that a prolonged broke occurs, there is a brokes system which, by means of the clear filtrate, enables the pulp which falls into the pulper from the brokes system (these are located below the machine and are linked to each other) to de diluted with clarified water. The diluted pulp is sent to the mixing tank and reincorporated into the process at the table.

The PM61 has:

- Clear filtrate tank (save all) of 1,500 m^3
- Wet brokes tank of 1,000 m^3
- Thickened pulp tank of 250 m^3

The new Paper Machine 62 will have the following tanks:

- Clear filtrate tank (save all) of 4,000 m^3
- Wet brokes tank of 5,000 m^3
- Thickened pulp tank of 100 m^3

Separate pretreatment of the effluent from coating preparation

The PM61 is suitable for the manufacture of coated papers. The preparation of the coating slip in the kitchen generates effluent with pigments and binders from unused coating liquid, production waste and wash waters. These effluents are sent for pretreatment which means that firstly, they cause no harm to later biological treatment and secondly, the materials from purification can be reused.

The treatment used consists of an ultrafiltration system in which the water and the coating products are separated by the use of semipermeable membranes. The pores in the membrane only allow through molecules of water, metal ions, salts and starch monomers, while the other components of the coating slip, pigments and binders, are retained as they are too large.

Once treated, the waters are sent for primary treatment and following their biological treatment, are sent for purification.

The pigments and binders recovered can be reused in the process for the reduction in waste generation (see CPA for the reduction of solid coating waste).

Selection of less damaging substances and chemicals

The Company has an approval procedure for products through which before a new product can be ordered, it must be approved by the Management Systems department, which is responsible for environmental management. For these products to be approved, their biodegradability, toxicity and bioaccumulation are considered, with this information requested from each supplier.

When two comparable products have similar economic and technical results, the product with the better environmental results will be selected.

Measures to reduce the frequency and effects of accidental spillages

All tanks used for the storage of chemicals have equipment to measure the level and have a basin to collect any possible overflow. In addition, any new tanks constructed for the extension of the mill will be provided with spill containment systems.

The loading zones for chemicals in new facilities will be designed in such a way as to avoid any potential spill from reaching any water network that could allow its escape: Rainwater network, black waters or process waters.

Specific instructions in the case of spillages have been included in the emergency plan of current and future facilities. In addition, specific training has been provided, and will continue to be provided regularly, to plant operators so that they can react correctly in such cases.

With respect to possible spillages into process waters that could reach the wastewater treatment plant, this plant has a regulating tank with a capacity of 1,500 m^3 which means this spillage can be stored and then added to the treatment process in a controlled manner, so that it does not affect operation. In the PM62, there will be a tank for the same purposes of 3,000m^3.

CPA FOR WASTEWATER TREATMENT

Primary wastewater treatment facility

Before the effluent proceeds to the biological treatment plant, the waters undergo a dissolved air flotation treatment, which reduces the amount of solids in suspension and the content of organic material in the water.

Current facilities already have a clarifying unit for the effluent by flotation (known internally as DAF2) in which this pretreatment is carried out. In addition, future facilities will also have another unit for the treatment of the new effluent generated.

The clarified effluent is sent to an intermediary tank of 20 m^3 from which it can be pumped either to any point in the process where it is required, or to the wastewater treatment plant.

The solids or sludges removed by DAF are sent to the sludge thickening units, using the best available techniques to extract as much water as possible and therefore reduce the generation of solid waste, which also makes dealing with the sludges later easier.

Biological wastewater treatment facility

In the PM61, following the pretreatment of effluent in the DAF2, the waters are sent to the biological treatment plant. The mill has an activated sludge aerobic biological treatment plant. Once treated, the waters reach values of suspended solids, COD and BOD_5 that guarantee a coefficient K=1, in accordance with Spanish legislation (K: factor that is a function of the pollutant load, the value K is multiplied in proportion to waste discharged (€/m^3)).

The new facilities will generate a higher quantity of effluent but of the same characteristics, and therefore a new biological treatment plant will be built that is similar to the current one, with primary treatment similar to that which is currently used. Together with this, the two plants will be able to treat all the effluent generated in the mill, while continuing to ensure that the discharge parameters meet values that guarantee a coefficient of K=1.

The new plant will additionally have heat exchangers that allow the residual heat of the effluent on entry to the wastewater treatment plant to the used to heat part of the fresh water entering the mill, thus also achieving a saving in energy.

The plants are monitored by the use of continuous measuring equipment and by periodic tests in laboratories that guarantee the necessary information for correct operation.

CPA FOR THE REDUCTION OF ATMOSPHERIC EMISSIONS

The use of combined steam and electrical energy production

The mill obtains 100% of thermal and electrical energy needed from the supply provided by Peninsular Cogeneración (a company of which 50% is owned by Holmen Paper and 50% by Iberdrola). Peninsular Cogeneración currently has a cogeneration plant with a gas turbine and a steam turbine of 41.5 MW situated in the same location.

For the new machine PM62 it is anticipated that the electrical energy will be obtained from the network, while thermal energy will be obtained from the existing auxiliary boilers and from the cogeneration plants.

Reduction in emissions of SO_2 through the use of natural gas in the boilers

All of the current and future boilers, along with the cogeneration plant of 5.5 MW, use natural gas as their only fuel source.

Sulphur emissions are very low in comparison with other fossil fuels.

Careful selection of the products used for coating the paper

As mentioned above, the company has an approval procedure for those products that are used as raw materials.

The company will take into consideration for the approval of products that the materials used for the preparation of coating slip minimise possible generation of volatile organic compounds, and that they do not contain carcinogenic compounds.

CPA FOR THE REDUCTION OF SOLID WASTE

Minimisation of the generation of solid waste and the recovery, reuse and recycling of materials wherever possible

As indicated in the techniques for reducing emissions into water from the plant, there are various techniques for the recovery of fibres and fillers from the water circuits so that these can be reused in the process. If this were not the case, the final quantity of solid waste would increase.

To minimise the final quantity of process waste, the sludges and rejects undergo water removal treatments by dewatering and pressing.

However, during the manufacturing process, unusable paper remains are produced. These remains come from defective products that have not passed quality controls, or remains of reels and process losses. All of the paper remains are recycled in the same process. For this, two ways are used: dilution in the pulpers installed below the paper machine, which form part of the broke system, or sending the paper remains to the raw material store (recovered paper).

Another of the measures that contributes to the minimisation of waste is outlined in point 5 of this section, referring to the recovery of the content of effluent from the coating process.

Separation of the different waste fractions at source, to allow the recovery or recycling rather than the final disposal in a landfill site

All of the waste generated during the process is classified in order for it to be dealt with in the appropriate manner. The lines of the pulp manufacturing plant classify the rejects separately (plastics, cords, metals, etc. from the recovered paper that is used as a raw material) from the process sludges. In this way, the sludges can be separated in order to be treated as described in points 6 and 7 of this section, while the rejects are sent to the landfill site.

In the new facility, it is anticipated that the rejects will be separated into two major groups: rejects from the drum pulper and rejects from high consistency purification.

The former are larger in size and may contain metals that will be removed by means of a magnetic separator for their later recovery. Once free of metal, they can be ground if it is desirable to reduce their size to enable them then to be incinerated more easily. Once ground, they will be mixed with the second type of rejects. All the rejects will then be subject to the removal of excess water to reach a level of dryness that enables them to be managed more easily (whether this is in the landfill site or in an incineration plant).

In addition to the majority waste mentioned (sludges and rejects), there is other, minority waste: Woods, along with wires and other metals are separated and sent on to bodies dealing with this type of waste to be recycled; 1000 l containers of chemicals can be directly returned to suppliers for their reuse or sent to a third party for their recovery or reuse.

Optimisation of the number of stages used pulp purification

The pulp manufacturing lines are designed with a series of purification stages in cascade in order to keep the generation of waste to a minimum.

Purification in cascade consists of the rejects from one purifier passing on to another new stage of purification which carried out a finer separation of the materials to be removed from the fibres, and so on in succession until all the stages are completed. The rejects from the last stage make up the final rejects.
This is applied to the cleaners (cyclones) and to the screens (rotating purifiers with holes or slots). Coarse purification (cyclones and holes) has 3 stages, slot purification 3 stages, cyclonic purification 4 stages and fine slot purification 4 stages.

The new pulp manufacturing lines will also be designed on the same principle, in order that rejects are minimised and the quantity of cellulose fibres accompanying the rejects is minimised.

Flotation systems to reduce losses of fibres and fillers

Both the existing pulp lines (DIP 2 and DIP 3) and the future ones (DIP 4 and DIP 5) have disc filters and screw presses that enable the separation of the fibres and fillers from the waters to allow them to be recovered. The water recovered is taken to air flotation units inserted into each of the lines (DAFs).

The fibres and fillers are recovered and returned to the production process, being used again for the production of paper and minimising waste generation. The clarified water, as outlined above, is used in earlier stages of the process.

Meanwhile, the white waters from the paper machine are taken to disc filters and specific DAF flotation units which allow the efficient separation of the fibres and fillers and the recovery of the waters for their use in previous stages.

Recovery and recycling of the fillers contained in the effluent from the coating kitchen

The PM61 is equipped for the manufacture of coated papers. This type of paper is manufactured by means of the surface application of a coating layer onto a paper base. This application takes place in the size press and the coating slip which is applied is prepared in the so-called "coating kitchen".

For the preparation of the slip in the coating kitchen, calcium carbonate, kaolin, latex and starch are the main ingredients used. The preparation of this slip in the kitchen generates wastewater rich in the aforementioned elements, basically from batches of coating liquid that cannot be used, production waste and wash waters.

This wastewater will be treated by pretreatment which means on the one hand that the substances used in the coating do not damage later biological treatment and on the other hand that the consumption of auxiliary products can be minimised by directly recovering part of these, preventing their final appearance in the form of waste.

The treatment used for this is ultrafiltration units. This treatment is the preferred method and is defined as a CPA in the BREF.

Thickening and drying of sludges before final disposal

The sludges generated in the de-inking stages and by the dissolved air flotation (DAF) units are treated in thickening stations in order to remove as much water from them as possible.

This is done by means of the use of gravity tables and screw presses that obtain dryness levels of the sludges of 55%. In this way, the quantity in weight of the sludges generated is minimised and their dryness is increased, which means that the number of transports required for their removal from the mill is reduced, and their calorific value is increased.

The water extracted is taken for primary treatment (DAF2) for purification.

Reduction in the quantity of waste sent to landfill. Identification of the possibility of recovery operations and use of waste for recycling or incineration with energy recovery

As indicated above, the current facilities of Holmen Paper Papelera Peninsular generate approximately 65,000 tonnes of sludges annually, which will become 83,000 tonnes when the plant is fully optimised. The projected extension will increase this quantity to around 270,000 tonnes of sludges in total.

HPM began a development programme to look for alternative uses for the sludges sent to landfill. As a result of this programme, in the year 2003 not a single tonne of sludges generated was sent to landfill, with the main alternatives found being as follows:

- Use of the sludges in the ceramics industry

By means of the addition of the paper sludges to clays for the production of thermo-clay, some of the properties of this product were improved.

Sludges are rich in calcium carbonate and cellulose fibres. When the sludges are mixed with the clay, they provide the material with greater strength. In addition, they can improve its insulating properties and the carbonate improves its dimensional stability.

At present, Holmen Paper Madrid supplies its sludges to 8 ceramics companies located in the autonomous communities of Castilla La Mancha and Extremadura.

For the new facilities the company has undertaken an expansion plan into new ceramic areas, for some of which tests are already in progress, in order for them to be able to absorb some of the new quantities generated in the the future.

- Use of sludges in agriculture

In January 2002, Holmen Paper Madrid, together with companies dealing with the composting of sludges, began investigating the viability of the use of sludges for agricultural purposes.

The results of these investigations have shown that sludges from the paper industry alone are not suitable for composting, as their content in fertilising elements is low. However, the mixture of the paper sludges with sludges from biological treatment stations enables the dryness of the former to be increased and compensates for the deficiency in fertilising materials by adding body. This makes the subsequent composting of the resulting product easier.

HPPP is registered in the Water Treatment Plant Section in the Register of the Application of Sludges in Agriculture in the Community of Madrid. This registration authorises HPPP to use its sludges for agricultural purposes, provided this is in accordance with the norms of application. At present, all of the sludges for these uses are managed by a company that is registered in the Register of Companies Trading in the Application of Sludges in Agriculture in the Community of Madrid.

In order to manage the sludges generated in the new facilities, the company is in a stage of studying the supply of sludges to new companies in the ceramic and agricultural sectors. In addition, the company is studying new sectors such as cement, where research is currently being carried out with positive results.

At the same time, Peninsular Cogeneración is studying the viability of a new plant for the incineration of sludges with energy recovery. For this, the installation of a fluidised bed boiler is projected, using natural gas as fuel.

CPA FOR ENERGY SAVING

The implementation of a system to monitor the use of energy and its utilization

In the current facilities, the energy supply comes from the facilities of Peninsular Cogeneración, as mentioned above. From the control room of the plant, some of the most important parameters enabling the evaluation of energy consumption such as gas consumption, steam production, electricity production etc can be seen continually.

A daily register is kept of the energy balance, determining the consumption of gas in each operative facility, hours of operation, energy bought from the network (if necessary), enthalpy of steam and hot water supplied to the plant, energy sold on the network...

All of these parameters are analysed and revised daily and monthly with the objective of evaluating trends and establishing appropriate measures to maintain acceptable ratios.

The use of energy-efficient technologies

Energy savings include the use of efficient technologies in terms of energy use.

Among the technologies listed as efficient, those which stand out and which already form part of the PM61 are: disintegration at high consistency which takes place in the pulpers (with a pulp consistency of between 17 and 18%); double wire forming table; appropriate vacuum systems; recovery of a large percentage (60-80%) of the condensates from steam, and heat exchangers at the steam exits from the driers with external air to make the most of residual heat; the use of frequency variators in equipment, mainly in pumps and fans, for the constant adjustment of energy demand.

In the extension of the facilities, all of the aspects above are being taken into consideration, as are others that have been detected during operation of the PM61. For example, the cooling towers for wastewater necessary to reduce the temperature of the effluent before its entry into the biological reactors will be substituted with heat exchangers in which the cooling liquid will be fresh water. In this way it is possible to raise the entry temperature of the water in such a way that less energy is required later to heat it to use temperature.

These improvements will also be taken into account for the existing facilities in the PM61 when renovations or substitution of equipment is required.

Optimisation of dewatering in the press section using a shoe press

The new PM62 paper machine will have more advanced technology in the press section (foreseeably a shoe press). In this way the extraction of water from the paper web is improved, obtaining greater dryness by increasing the pressure area, and also the contact time, with respect to traditional presses.

This technology will allow a level of dryness on exit from the press section of between 45 and 50%, thus improving the dryness in comparison to that obtained in the press section of the PM61 (approximately 43%).

This increased dryness in the sheet of paper means that a lesser quantity of energy is required (less steam) to dry the sheet to its final moisture content, of around 8.5%.

In addition, this press technology results in an increase of the useful life of the cloths in the press section, which means a reduction in this type of waste.

CPA IN THE USE OF CHEMICALS

Databases with all of the chemicals and additives used

It is important to be aware of the composition of all the substances and chemical preparations used in the process, along with their degradability, toxicity to humans and the environment, and their capacity for bioaccumulation.

At present this information is collected and communicated to those involved in their use by means of the safety data sheet on each one of the products. Occasionally, these safety data sheets do not contain all of the information mentioned above, and this is therefore requested directly from the supplier.

It is anticipated that a database will be available next year containing all of the information mentioned above. This database is produced by the HOLMEN group especially for the products used in our mills. This system improves the information collection and maintenance system, along with the accessibility of this information as it can be consulted on the mill's intranet.

Application of the substitution principle: less dangerous products are used if they are available

When tests are carried out with new products, whether it is to incorporate them into the process or to use them as substitutes for preparations that are already in use, the characteristics mentioned above are taken into account, so that whenever it is technically viable, the substitution of dangerous products for others that are not dangerous is encouraged.

Measures for the elimination of accidental spills into the soil or into the water in the unloading and storage of chemical products

The loading, unloading and storage facilities for bulk chemical products have collection basins that enable the collection of at least the quantity of the largest container used, in the case that this container should break. Those chemical products supplied in containers (normally of 1,000 or 200 litres) are stored in a specific zone that has the appropriate shelving for this type of storage. This zone has a compartmentalised drainage system for the collection of possible spills which prevents these, should they occur, from reaching the sewage networks.

9. CONCLUSIONS

The main challenge facing the paper manufacturing sector today is to achieve sustainable development that is respectful of the environment, while maintaining competitiveness.

To attain this objective, it is necessary to minimise the consumption of natural resources and the environmental impact of pulp and paper producing facilities, while also increasing the productivity and/or quality of the final products. To do so, it is necessary to optimise each and every one of the stages in the production process, considering in conjunction with this the resources necessary, the mechanical factors of the machines, the chemical phenomena involved and the emissions produced. Once the necessary measures have been adopted for the prevention of pollution at source, it is also necessary to carry out final treatment of the emissions from the plants, in order to minimise their final environmental impact.

Within its specific characteristics, the paper industry has for decades been in compliance with some of the concepts of sustainable development, such as for example the recycling of its products, the reuse of sludges, the closure of water circuits, the regeneration of black liquors, etc., motivated at all times by the economic benefits resulting from these measures This makes it clear that the implementation of environmental improvements for pollution prevention can also result in important economic benefits. Moreover, the alternatives proposed in this manual for the prevention of pollution are based on the best available techniques which comply with the prerequisites of being technically and economically viable.

In the Mediterranean Area countries, 7 million tonnes of pulp are produced each year (40% of this in France and 30% in Spain), corresponding to 3.78% of global pulp production. A total of 28 million tonnes of paper are produced every year, of which 58% is from recovered paper (87% in the North, 10% in the East and 3% in the South); this production corresponds to 9% of global production of paper and cardboard products. Total paper consumption is 36.5 million tonnes (84% in the North, 11% in the East and 5% in the South) with consumption per inhabitant per year that varies from 3 to 204 kg.

The most innovative paper industries have adopted numerous measures in the last two decades that have enabled them to reduce their atmospheric emissions by means of the optimisation of energy consumption, the use of fuel with a low sulphur content, the use of improved process control systems, etc. Atmospheric pollution is fundamentally linked to the manufacture of cellulose pulps or the obtaining of energy and the application of the best available techniques allows the main emissions of CO_2 to be greatly reduced, to a ratio of 0.36 kg/t; SO_2 to a ratio of 0.45 kg/t and NO_x emissions to a ratio of 1.12 kg/t. Lastly, foul odours are also a major problem in pulp mills, and to a lesser extent in paper mills.

Changes in bleaching systems have enabled AOX to be removed by over 90% in the last decade, and dioxins to be entirely removed.

The closure of water circuits provides numerous economic and environmental benefits, but also involves numerous problems, due to the quantity of pollutants accumulated during the process. With the objective of further closing the water circuits, internal treatments of some of the flows must be carried out, in order for the treated water to be usable in the plant. The recirculation of water and the use of internal treatments have enabled water circuits to be closed by over 90%. The main pollutants present in the process waters are suspended solids and dissolved and colloidal material that is both organic and inorganic in nature, which means that the final wastewater is easily treated by primary and secondary treatments, and if necessary with a tertiary treatment, in order to remove the nutrients.

The generation of solid waste is fundamentally linked to the processes of energy production, recovery of black liquors, the treatment of water and the production of recovered paper, in particular de-inked recovered paper. Due to the high costs of landfill sites and the current trends in legislation, the majority of this waste is recycled, used for its energy potential or used in other processes.

The paper sector requires a high level of energy consumption, which means that energy costs can reach over 25% of total production costs. A reduction in energy consumption is therefore important. This can be achieved by means of the use of equipment with lower energy consumption and the use of combined cycle systems.

To summarise, there are today numerous alternatives that are technically and economically viable for the prevention and reduction of pollution at source. There is a wide range of Cleaner Production alternatives available, enabling the adaptation of one or other of these alternatives possible for the majority of types of company that make up the sector.

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