ENVIRONMENTAL ASPECTS OF THE PULP AND PAPER INDUSTRY

- an overview -

UNITED NATIONS ENVIRONMENT PROGRAMME

PULP AND PAPER INDUSTRY

Environmental Operational Guidelines

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1. Pesticide Use on Industrial Crops
2. Irrigation in Arid and Semi-Arid Areas
3. Watershed Development
4. Pulp and Paper Industry
5. Hides and Skins Industry
6. Coastal Tourism

PULP AND PAPER INDUSTRY

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FOREWORD

It has been our concern, shared by other bodies and agencies within and outside the UN family, that development projects and programmes should take due account of basic environmental parameters and constraints. It is, indeed, clear that broad-based sustained development is not feasible, especially in the long-term perspective, without sound environmental assessment and management at the inception.

These guidelines have been prepared by UNEP in close consultation with the United Nations specialized agencies concerned and were jointly financed by UNEP and UNDP. These guidelines were adopted by UNDP and are included in its Policies and Procedures Manual.

As noted in the conclusion to the guidelines for watershed management, but equally applicable to the other guidelines, there are many pitfalls to be avoided in initiating activities in different sectors of development and many opportunities that can be missed. Experience during the last ten years has also shown that remedial measures identified must be incorporated, if they are to be effective, in the very conception and design stage of projects and of planning procedures. Later attempts may prove to be only cosmetic changes as the ecosystems under consideration are particularly fragile and complex and may not recover from the stresses to which they are exposed if they exceed certain limits.

The guidelines for remedial or preventive measures which have been presented in this study are meant to be illustrative rather than exhaustive in character: there are substitutes for local experience, foresight and prudence. We have only attempted to draw attention to the kinds of considerations which must be kept centrally in mind. The objectives for which we strive in this subject area are multidenominational and interrelated, requiring a formidable array of diverse technologies and disciplines. It should be noted that although the guidelines presented here are essentially national in nature and scope, international cooperation and co-ordination to bring into play the different inputs required may often be necessary.

I sincerely hope that the present set of guidelines will be acceptable and meet practical needs, particularly in developing countries. Additional sectors will be examined and further guidelines prepared in collaboration with the United Nations specialized agencies, UNDP and other multilateral and bilateral development financing institutions, taking fully into consideration comments and advice which we expect to receive regarding the present set of guidelines.

Mostafa K. Tolba
Executive Director

PREFACE

At an informal meeting held in Rome in September 1978 the Designated Officials for Environmental Matters (DOEM) of the United Nations Administrative Committee of Co-ordination recommended on the basis of a report prepared by a consultant, Mr. O.M. Ashford, that UNEP undertake, in close collaboration with the United Nations specialized agencies, the preparation of environmental operational guidelines to assess and minimize the possible adverse environmental impact of development activities. The report of the meeting states "that priority should be given to the preparation of guidelines aimed at improving the consideration of environmental aspects at all stages in the planning and execution of projects. It was recognized that the level of sophistication in such guidelines would depend on the audience for which they were intended. Much of the available material was of a general nature which would mainly be of interest to university circles or to senior international and national officials. At the other extreme, detailed guidelines based on in-depth studies of specific projects would be very useful for specialists but difficulties were foreseen in obtaining the necessary information for such analyses, which would take a long time to complete. The meeting agreed that at this stage the primary need was for guidelines which would be useful at the operational level. For this purpose each of the major categories used in the consultant's report (e.g. agriculture) would have to be broken down into a number of subareas (e.g. crop pest control and rangeland management). A first list of subareas on which guidelines should be prepared soonest was agreed on as follows:

1. pesticide use on industrial crops
2. irrigation in arid and semi-arid areas
3. watershed development
4. pulp and paper industry
5. hides and skins industry
6. coastal tourism

At a subsequent meeting the DOEM determined that the operational guidelines should "avoid undue technicalities. They should be clear-cut statements of the environmental concerns, environmental parameters and environmental constraints arising in the area of interest. A distinction should be made between what would be useful for informed laymen, such as UNDP resident representatives or officials in the Ministry of Planning or Ministry of Economic Affairs of a developing country, to reach a decision on the need for and nature of environmental considerations in a given project at a very early stage of its formulation on the one hand, and the analytical tools required by engineers, economists and other scientific consultants in the form of coefficients, etc., to implement a project on the other. The latter should not be a part of the operational guidelines but on manuals of implementation." In the event, the six guidelines that have been prepared vary in the nature of the material assembled and the technical details analysed. This has been done deliberately.

In order to afford an opportunity to assess the practical utility of different approaches to the preparation of guidelines, it was considered necessary to establish models which could be compared and evaluated in terms of practical utility. UNEP would gratefully receive views on the analytical frameworks and approaches adopted in the different guidelines as well as suggestions for their improvement or amendment.

The environmental operational guidelines in this series are not intended to be prescriptions for corrective action or constraints on the methods, nature and scope of development activites. They are presented in the belief that dynamics and change induced by development aims are not without environmental hazards and risks; it is necessary to identify such hazards and risks where they arise and take early steps, in so far as prevailing circumstances permit, to contain or reduce them. It is necessary to take early steps, because later attempts at remedial action may be illusory, and always more costly than preventive action taken at the outset, and, as has been stated in the Conclusion to the Guidelines on Irrigation in Arid and Semi-arid Regions, "in some cases may be so costly as to bring into question the overall economic viability of the project".

We acknowledge with gratitude the contribution received from the United Nations specialized agencies, particularly the Food and Agriculture Organization, for the preparation of guidelines. Without financial assistance from UNDP, the operational guidelines could not have been completed effectively within the short time available. We are also dependent upon the assessment of the Resident Representatives and the Headquarter staff of UNDP in regard to whether guidelines meet specific needs in the field.

Within UNEP, a number of colleagues have assisted in the preparation and editing of the operational guidelines. I wish to thank in particular Mr. Nat Htun (for the guidelines on the pulp and paper industry and on the hides, skins and leather industry) and Mr. Mohamed Tangi (for the guidelines on coastal tourism). Ms. Merran Van der Tak, Ms. Shahida Chaudhary and Mr. Mark Aeron-Thomas have assisted in the research and editing of the series.

Yusuf J. Ahmad
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INTRODUCTION

This operational guideline is designed to give an overview of the major environmental concerns, parameters and constraints pertaining to the pulp industry, covering raw material preparation, pulping, manufacturing and forest management practices relating especially to the industry. The guidelines also include a review of the technological trends for manufacturing processes as well as pollution control.

By informing the decision-maker (or his advisers) of areas where such projects could have negative effects on the environment, it is hoped that action will be taken to incorporate corrective or control measures into the initial stages of project design and evaluation. It has been demonstrated in the past that prevention at the earliest stages is far less expensive in terms of economic costs, environmental degradation and social welfare than corrective measures at a later date.

The detailed technologies for alleviating, controlling and abating the environmental problems of the industry are given in the UNEP publication, *Environmental Management in the Pulp and Paper Industry.*[1] A major part of the guidelines is based on the information and data provided in the publication.

THE INDUSTRY

The pulp and paper industry can be divided into two major processes: pulping and making the final paper product. There are two main types

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[1] This is a five-volume publication being prepared for UNEP by the Swedish Air and Water Research Institute, IVL Konsult AB and funded by SIDA. The volumes are reviewed by FAO, UNIDO and members of the UNEP Environmental Consultative Committee on the Pulp and Paper Industry, and cover the following areas:
- Air and water pollutant of the pulp and paper industry;
- In-plant measures in the raw material preparation, mechanical; chemi-mechanical and sulphite pulping;
- In-plant measures in sulphate and soda pulping;
- In-plant measures in papermaking and deinking;
- External measures and alternate use of effluent.

of pulp for paper introduction, mechanical and chemical pulps. Mechanical pulp is produced by grinding or shredding the wood to free the fibres and in addition heat and pressure may be applied to assist the process. Chemical pulp is produced by cooking fibrous raw materials in chemical solutions that dissolve the lignin-binding material by loosening the fibres. Chemical pulps may be subdivided into kraft (sulphate), sulphite, semi-chemical and soda. Since over 65 per cent of the total pulp produced is composed of kraft pulp, the main impact on the environment is from chemical pulping. The industry is complex, capital-intensive and is characterized by a high degree of integration, especially with the very large bulk single-furnish products, such as newsprint or kraft liner board. This is a major reason for such products to be manufactured close to the resource base.

Forest management

Good forest management is important to ensure that the resource base for supplying wood fibres to the pulp paper industry is sustained. Some of the environmental aspects which need consideration are:

Soil erosion—caused by the possibility of long-term degradation of soils by removal of vegetation, soil disturbance during logging and loss of cycling mechanisms of soil fertility. A large fraction of the available N,P,K, calcium and other minerals is held in the trees and other vegetation. This efficient system is disrupted by removal of the tree cover. The nature and duration of the disruption in nutrient cycling will depend on the amount and kind of material removed in logging, and the speed of re-establishment of vegetative cover. Residual soil fertility will also be affected by the degree of physical soil disturbance and chemical change. Increased turbidity and sedimentation in streams, lakes and estuaries are some of the other important side effects of logging. Chemical change in the waterways can also occur if large quantities of litter are allowed to rot in them.

Effects on flora—a large number of plant species exist in forests, providing natural checks on and balances with forest insects and diseases. Extensive conversion to monoculture with the harvesting of single species on short rotation—since a young forest grows faster than an older one—may entail a significant risk of some crop pest expanding unchecked. Also, artificial selection of high fibre-producing varieties means increased dependence on higher rates of fertilization and pesticide application.

Effects on fauna—significant interactions exist between tree cover, lower vegetation and wildlife. The term wildlife is a broad one and generally includes any or all non-cultivated and non-domesticated life and the plants which interact with them. Logging operations can destroy the habitats of wildlife. Natural areas and wild species supply many benefits. These include a major resource base for recreation and tourism, genetic banks and starting material for drug synthesis.

Use of herbicides—the major adverse effects of herbicide use in forestry can be summarized as:

a) toxicological effects on non-target organisms. The effects vary greatly with exposure and the toxicity of the herbicide on the recipient organism. With proper use of herbicides, sub-lethal toxicological effects are much more likely than direct toxicity and these may influence the survival and reproduction of terrestrial organisms, with accompanying effects on populations and food chains.

b) undesirable changes in the biotic composition and functional process of forest ecosystems. Loss of soil stability and resistance to erosion and mass wasting following the death and decay of tree roots after logging can be greatly offset by the vigorous development of deeply rooting shrub species. Alterations in the microclimate following forest harvesting may be lethal or inhibitory for regeneration of the desired crop seedlings. Minor vegetation can ameliorate the microclimate until the desired seedlings become established and hardy. Also, minor vegetation developing on clearcuts after harvesting has been shown to act as a nutrient sponge, retaining nutrients that may otherwise be washed away.

c) the degree to which adverse effects are produced will be proportional to the degree to which the vegetation is killed, and selective removal of only a portion of the vegetation will generally not result in the more dramatic consequences associated with total devegetation. As with insecticides and pesticides, proper choice and application of herbicides are important to minimize adverse environmental and health effects. The safety of their use is therefore largely dependent on the concern, knowledge, training and understanding of the applicators.

Logging

Logging is one of the most hazardous of occupations. Inadequate training, poor working techniques and safety measures, coupled with the inherent dangers in felling, bucking, yarding and loading logs are the major factors contributing to accidents.

Within the total logging operation, from felling to first haul, numerous dangerous situations arise which may result in worker accidents and/or deaths. Five major classes of hazards have been categorized:

a) Falling and flying objects are major sources of danger to workers in all logging operations. Vibration from chain saws, moving equipment and falling trees can cause loose parts and even whole trees to fall. Improper cutting techniques can cause a tree to fall in an unexpected direction and/or to barberchair (split vertically), which could result in loss of control of the felling direction and propel large splinters from the stump.

b) Rolling and moving logs are hazardous to loggers during all phases of logging operations. In steep terrain, logs can roll during limbing and bucking operations or can be jarred into motion by vibration from falling trees. During yarding, logs can twist or turn unpredictably when being moved over uneven terrain, boulders or stumps. In landing and loading operations, logs which are improperly secured or handled can roll off and cause injury or deaths.

c) Chain saw operations are a significant cause of logging accidents although they cause few fatalities. When the saw is in operation, careless positioning of the chain can cause the saw to kick back towards the operator and if contact is made, lacerations and limb amputation will result. Chain saw accidents can also occur if the operator stumbles and the running saw contacts the body. Flying chips discharged by the saw can endanger the worker's eyes.

d) Slips, trips and falls are potential hazards due mostly to the unevenness of the forest floor, steepness of the terrain, and to the litter about the work areas.

e) Hazards from moving equipment, which includes skidders, tractors, shears, cranes, loaders, logging trucks and cable-rigging installations are increased when there is rain, ice or snow-packed ground, poor visibility, steep or uneven terrain and strong winds.

ILO has published a Code of Practices on Safety and Health in Forestry Work.

Fibrous raw material for pulping

Plant fibres are the main raw material for producing pulp, while minor amounts of synthetic fibres are used for making speciality papers.

Plant fibres can be classified into a number of subgroups according to origin:

Subgroup	*Species*
grain hairs	cotton linters, kapok
bast fibres	flax, jute, hemp, ramie, kenaf
fibres from grasses and other monocotyledons	straw, esparto, bagasse, bamboo, papyrus, reed
leaf fibres	abaca, sisal
wood fibres	softwoods, hardwoods

Pretreatment of raw material

The pretreatment of raw material is a very vital operation for the manufacture of quality pulp. The operations involved in pretreatment are:

- storage and handling of the raw materials;
- separation of inorganic impurities such as stones, grit, sand, etc.;
- separation of organic impurities, such as bark, pith, nodes, etc.;
- cutting and screening of the fibre raw material;

The processes differ widely from mill to mill, depending upon the type of raw material and the quality required for the pulping operation.

Preparation of wood fibres

Wood is initially moved from the stockpile through a conveyor or log flume to the debarking facilities. Bark removal is required because of the negative effects of bark on pulping processes and product quality. While kraft pulping is able to tolerate higher levels of bark residuals in its furnish, sulphite pulping demands low levels. Although there are site-specific variations, wet methods of bark removal generally have the advantage of being able to achieve more complete bark removal with less wood loss and less dirt and grit in the bark and chip system. However, wet methods have the disadvantage of producing an effluent which requires treatment, and a wet bark with a lower fuel value. The principle methods of wet debarking include hydraulic and wet drum, while the dry methods generally use the mechanical ring and dry drum.

One of the primary reasons for mills to convert from wet to dry debarking is the projected costs of effluent control. For sawmills, debarker waste waters are the major effluent source, and for pulp mills, conversion represents a significant reduction in mill effluent load. The decision to convert from wet to dry debarking is also influenced by a need for greater energy recovery from log fuel, especially at pulp mills. In many mills, bark pressing is a bottleneck and constant maintenance problem. Converting to dry debarking eliminates bark pressing and results in drier bark and, therefore, creates a potential for greater log fuel utilization.

The characteristics of hydraulic and wet drum debarker effluents are variable depending on a number of factors including wood species, climate and log handling techniques. The most important pollutants and pollution parameters in wet debarker effluent are total suspended solids, BOD_5, toxicity, pH and colour.

Effluent treatment for wet debarkers is primarily concerned with suspended solids removal. For hydraulic debarkers this treatment usually consists of screening and sedimentation, and for wet drum debarkers various combinations of screens, centrifugal separators, water extractors, and sometimes sedimentation. Existing treatment schemes vary considerably because of the differences in effluent characteristics from mill to mill. For many debarkers to meet present and probably future effluent regulations in most industrialized countries, improved treatment techniques will be required. In addition to effluents, gaseous and particulate emissions are also discharged from the incineration process.

Preparation of non-wood fibres

The preparation of *straw and bamboo* is similar to that of wood except that no debarking is necessary. Instead there may be additional screening stages after the chipper (or cutter) so as to remove dust and nodes. Water may be used to clean the bamboo prior to chipping and also the chips before storage. The effluents generally contain particulate material of inorganic and organic origin.

With *bagasse*, the most important aim is to remove as much pith as possible. The presence of pith causes high chemical demand in the pulping operation, and also the impairment of paper characteristics. Dry depithing usually takes place in the sugar mill. After slushing the bagasse in water, in the pulp mill a wet depithing is formed. The pith is then removed in a conveyor or screen and the bagasse is stored wet or moist. With Ritter storage, lactic acid is added to control biological reaction, while with conventional storage, pile water is added when building the pile to prevent temperature increase as a result of biological reactions as well as to prevent drying out.

The preparation of bagasse produces an effluent that contains dissolved organic substances and suspended solids. The sources for dissolved organic substances are the emptying of Ritter storage or the leaking out from the pile. Conveyors, pith presses and depithers are the main sources for the discharge of suspended solids.

The factors affecting the effluents discharged are residual quantity of water solubles in the bagasse, time and temperature of storage, and microbial reactions taking place during storage.

In dry pretreatment of bagasse, serious localized dust problems can occur, mainly during the storage of the bagasse.

Disposal of bark and wood wastes

The bark removed from the wood represents a major disposal problem at most mills. Acceptable disposal methods include incineration for heat generation, compositing and utilization as filler in building board. Bark residue can be burned in specially designed bark burning furnaces. It represents an inexpensive, low-quality fuel source, and depending on its moisture content can be burned alone or in combination with oil, coal or gas for the pupose of steam generation. Bark burning is most economical when used with dry debarking operations, whereas wet debarking requires mechanical pressing to remove excess water. Fluidized bed combustion systems have recently been introduced and appear to be a most efficient method of burning bark, wood wastes and sludge residues. This system permits the firing of wastes with as little as 30 per cent solids. The compositing of bark has had little success except in some of the warmer climates. Large land areas must also be available for such an operation. Some paper companies that also manufacture building board have found they can produce an acceptable building board containing up to 25 per cent bark.

Steam generation

Processes—The steam for the processes is generated from burning of spent liquor, waste products and oil, gas or coal. Waste products from the forest industry are often burned in order to reduce a disposal problem and/or to utilize the energy content of the material. Bark, sawdust, sludge and pith are examples of waste products which are burnt. Burning of waste can be carried out by pile burning, inclined grate, fluidized bed, spreader stoker or cyclone burning. The ash content of waste varies from less than 1 to about 5 per cent.

Bark and waste burning—The main emission from waste wood boilers is particulate matter. The particles consist of ash and residue of unburnt material. The amount of unburnt material varies most between 10 and 50 per cent. Spreader stoker and cyclone burning have a high carry-over of particulate matter. Normally modern waste boilers are equipped with cyclones for dust collection. A typical efficiency for cyclone equipment is 85 per cent and typical emissions are 1-5 g per kg of dry waste. New waste boilers are often equipped with electrostatic precipitators. With such equipment, a cleaning efficiency of above 95 per cent is achieved. No data on the emission of nitrogen oxides from wood waste burning have been found. Usually, the high moisture of the fuel will lower the temperature and thus the NO_x emission. Very little is known of the emissions of polyaromatic hydrocarbons.

Oil combustion—Particles emitted from oil combustion consist of partly uncombusted oil drops (cenospheres) and particles formed at the combustion. For particle control, cyclones are commonly used. However, many boilers have no control equipment. The ash can contain relatively large amounts of vanadium and nickel. The main emission from oil combustion is sulphur dioxide. The magnitude of the emission depends on the sulphur content of the fuel oil used. Nitrogen oxides are emitted as a result of oxidation of nitrogen in the fuel and reaction between nitrogen and oxygen in the combustion air. The latter reaction is favoured by high temperatures. The magnitude of the emissions depends on the nitrogen content in the fuel oil, the combustion temperature and other operating conditions. The emission normally varies betwen 4 and 15 kg NO_x (as NO_2) per tonne of oil. The formation of polyaromatic hydrocarbons is favoured by low combustion temperature and poor combustion conditions. The formation processes and their dependence on combustion conditions are, however, not very well known.

Gas burning—Gas is a clean fuel. The only emission of importance is that of nitrogen oxides. The emissions depend very much on the combustion conditions, furnace design, etc., but may be considerably higher than that from oil combustion. Emissions of up to 70 kg NO_x (as NO_2) per tonne fuel have been reported.

Coal combustion—The ash content of coal is relatively high, usually between 5 and 20 per cent. Of the ash produced in stokers and cyclone-fed boilers about 50 per cent or less will be found as fly ash, while the rest is retained in the boiler as bottom ash. In pulverized coal-fired boilers about 90 per cent will be found as fly ash. Electrostatic precipitators or bag filters are used to control the emissions. A high collection efficiency is necessary. With a collection efficiency of 99.5 per cent, the particle emission is in the order of 400-500 g per tonne of coal used. The particles contain relatively large amounts of trace elements. Some of these elements, such as cadmium, zinc and lead, are enriched on the finer particle fraction due to volatilization and resorption processes. Trace elements such as mercury halogens, sulphur and selenium are emitted mainly or partly in gas phase. About 90 per cent of the mercury in coal will be emitted to the atmosphere. The emission of SO_2 depends on the sulphur content of the coal, usually between 0.5 and 2 per cent, and is of the same order of magnitude or larger than the sulphur dioxide emission from oil combustion. The emission of nitrogen oxides from coal combustion is (as from oil combustion) as a result of oxidation of nitrogen in the fuel and the reaction between nitrogen and oxygen in the combustion air. The emission depends on the nitrogen content in the fuel and combustion technique and conditions. Normally it is in the same range as for oil combustion and varies between 5 and 20 kg NO_x (as NO_2) per tonne of coal used. The emissions of polyaromatic hydrocarbons (PAH) has not been thoroughly studied. Difficulties with sampling and analytical procedures make many reported values unreliable.

KRAFT AND SODA PULPING

The kraft process is now the dominant pulping process. Its versatility and flexibility make it suitable for use with any wood species. The rapidity of the process and the high strength property of its pulp are further advantages.

Manufacturing processes

In the sulphate process an alkaline cooking liquor containing sodium hydroxide and sodium is used. In the soda pulping process, only sodium hydroxide is employed. In large mills the chemicals in the cooking liquor are normally recovered and reused.

Cooking of raw materials can be carried out in batch or continuous digesters. With batch cooking, the digester is filled with chips or other raw materials. During and after chip filling, steam is added until no air remains in the digester. After this operation, the cooking (white) liquor is introduced and cooking is started by raising the temperature. The cooking temperature is retained for a certain time, then the pressure is decreased by releasing steam and gases and the digester is emptied into a blow tank. In a continuous digester the chips and cooking liquor are continuously fed to the digester and the pulp is also discharged continuously. A continuous digester is usually equipped with a washing zone so that part of the pulp washing takes place in the digester.

The pulp blown from the digester is washed in a system often consisting of several stages through which the pulp and washing liquid flow in counter-current directions. After washing, the pulp is screened to remove solid impurities such as knots and fibre bundles.

The unbleached pulp is treated with chlorine compounds (chlorine, chlorine-dioxide and hypochlorite) in several stages. Between the bleaching stages the pulp is again screeened to remove any remaining impurities and then dried or brought to an integrated paper mill.

The black liquor from pulp washing has a relatively low concentration of dry solids and has to be concentrated by evaporation before burning. Two different methods are used. One method is based on indirect evaporation of the liquor with steam in a multiple effect evaporator. In the second method, the final part of the evaporation is carried out by direct evaporation with flue gases from the recovery furnaces. The most common is a conventional recovery boiler operating at reduced conditions where sodium sulphate (Na_2SO_4) is reduced to sodium sulphide in the presence of carbon. In the bottom part of the furnace, a bed is formed and from this bed a smelt consisting of sodium bicarbonate (Na_2CO_3) and sodium disulphide (Na_2S) is continuously removed.

The smelt from the furnace is dissolved in a dissolving tank and the green liquor formed is treated with lime to convert carbonate to hydroxide in the causticizing process. The resulting "white liquor" is reused in the digester.

Most sulphate mills recover the sludge resulting from causticizing (lime mud) and reburn it to lime in a rotary lime kiln. Fluidized bed calciners are used at some mills instead of conventional rotary kilns.

Environmental considerations

Liquid effluents and solids—In continuous pulping the digester relief gases contain most of the volatile components of kraft cooking. If the spent liquor tends to foam, the condensate can be heavily contaminated. As these vapours carry a major fraction of draft mill odour, their condensate is too foul for reuse. While the composition is complex, turpenes, resin acids and total reduced sulphur (TRS) compounds are identified as major components causing toxicity, and methanol is usually responsible for a significant fraction of the biochemical oxygen demand (BOD).

After the separation of turpentine, a valuable byproduct, the foul condensate should be treated to remove toxic components before discharge to sewer. Two methods are generally used: air stripping and steam stripping of the condensates. Air stripping offers a considerable saving over steam stripping. However, for many operations the small gas volume to be handled favours steam stripping. Steam stripping is also a preferred method if methanol is an economic route to BOD reduction.

Batch digesters produce two contaminated streams: relief gas and flash steam. About 70 to 80 per cent of volatile contaminants are contained in the relatively small relief gas stream. Both streams can contain significant quantities of black liquor carried over in flash steam in the form of spray or foam. Both require condensing systems of a size to be able to handle very high peak flows, and control systems which are able to react to very rapid changes in the flow rate. This condensing requirement becomes particularly critical when the non-condensibles are to be positively collected for odour control.

Virtually all spent liquor solids not removed in brown stock washing ultimately pass into the sewer. A high proportion of any contaminant in the wash water stream will pass into the sewer. Long periods of retention in unbleached storage plus high dilutions during screening enables most residual liquor to diffuse out of the fibre and into the whitewater transport streams. Any recycle system downstream of the brown stock washers may reduce the volume of the sewered stream, and fibre loss, but it will not restrict the dissolved solids discharge.

In unbleached pulp and paper production, very little of the whitewater passes into the dryers. The majority of dissolved material is, therefore, either discharged from the machine or returned to the screenroom for similar discharge. Unbleached kraft effluents are principally dependent on the efficiency of pulp washing and the number of spills. The BOD and colour of a sample of effluents are usually a good indicator of the washing efficiency.

With bleached kraft, toxicity is the major addition to the effluent when chlorine bleaching is used. Oxidative bleaching processes have been fairly well shown to reduce toxicity to a significant degree, as well as to reduce colour from the extraction effluents. There is normally very little increase of suspended solids in effluents as a result of bleaching.

The colour of the black liquor is mainly due to the high molecular lignin fraction. The most volatile components in the black liquor are methanol, ethanol, organic sulphides and terpenes.

Gaseous emissions and odour—Gaseous emissions from kraft process include both gaseous and particulate materials.

The major gaseous emissions are the malodorous reduced sulphur compounds, organic non-sulphur compounds, oxides of sulphur and oxides of nitrogen. The malodorous sulphur gases all have extremely low odours threshold levels of between 1 and 10 parts per billion (ppb) by volume.

The main potential sources for the emissions of reduced sulphur gas to the atmosphere include: digester blow and relief gases, vacuum washer hood and seal tank vents, multiple-effect evaporation hotwell vents, recovery furnace flue gases following direct contact vents, smelt dissolving tanks, slaker vents, black liquor oxidation tank vents, lime kiln exit vents and wastewater treatment operations.

Additional emissions from the kraft pulp mill include oxides of nitrogen and hydrocarbons. Oxides of nitrogen can be emitted from combustion sources, such as recovery furnaces, the lime kiln of the chemical recovery system, and the power boilers. Hydrocarbons and other organic non-sulphur compounds can be emitted in varying quantities from the digester, washers, evaporators and direct contact evaporators. Both these two types of pollutants may be potential contributors of photochemical air pollution. Water vapour is also emitted in varying quantities from all kraft pulp mill sources. Condensation of water vapour into a visible plume may be hazardous if the plume restricts visibility adversely, such as across a highway, air field or harbour.

The major potential sources of particulate emissions from the kraft chemical recovery system are the recovery furnaces, the smelt dissolving tank and the lime kiln. The recovery furnace is the largest potential particulate emission source. The major chemical constituent in the recovery boiler particulate emission is Na_2SO_4, with small quantities of Na_2CO_3 and sodium chloride, NaCl, also present. The smelt dissolving tank vents and lime kiln exhaust gases are also sources of varying quantities of particulate matters consisting primarily of carbonate, hydroxide, sulphate and chloride salts of calcium and sodium.

SULPHITE PULPING

Manufacturing processes

The sulphite pulping process for producing chemical pulp is carried out in basically the same type of equipment as the kraft or soda process. In the sulphite process, however, the fibre raw material is treated with a solution containing dissolved SO_2, hydrogen sulphite or sulphite ions with pH value between 1.5 and 12, producing acid sulphite or bisulphite chemical pulps. Neutral sulphite pulping is usually limited to the production of chemi-mechanical or semi-chemical pulps.

The base in the cooking liquor is calcium, magnesium, sodium or ammonium. Calcium can, however, only be used for acid sulphite pulping and magnesium only for acid sulphite and bisulphite pulping.

After cooking the pulp is washed and the reclaimed cooking liquor treated to recover the pulping chemicals. The washed pulp can be bleached and dried in the same way as kraft and soda pulps. Usually batch digesters are used for sulphite pulping, but continuous digesters are frequent for semi-chemical processes. In the digester, the lignin is sulphonated and becomes water soluble and can be separated from the cellulose fibres. The spent liquor can, after evaporation, be burned in a furnace.

Recovery of pulping chemicals is in practice limited to sodium- and magnesium-based liquors since calcium cannot be recovered economically unless there is extensive in-plant process modification and there is only limited experience with the recovery ammonium.

When sodium is used as a base, the inorganic compounds form a sulphide and carbonate smelt on the bottom of the furnace as in a kraft pulp recovery furnace. The SO_2 formed is absorbed in the chemical recovery system.

When magnesium is recovered the evaporated liquor is burnt in a furnace and the magnesium compounds into magnesium oxide. The magnesium oxide is collected in a dust separator and then dissolved in water. The magnesium-containing solution is then used to absorb sulphur dioxide from the flue gases and used again.

When ammonium-based liquors are burned, the ammonia is oxidized mainly into nitrogen and cannot be recovered. Sulphur is oxidized into sulphur dioxide which can be recovered in an ammonia scrubber.

Environmental considerations

Liquid effluents and solids—The BOD, COD and colour value of the spent liquor from all types of sulphite pulping increases as the pulp yield decreases. Recent information suggests that there is also a reduction in toxicity with increased yields. Ammonia-base pulping must be considered separately from sodium, calcium or magnesium base, since both its toxicity and BOD are likely to be greater in the same yield range. For normal market pulps, sulphite bleaching contributes slightly more BOD than kraft bleaching, but the toxicity may be somewhat lower. Also, ammonia-base pulps, especially those which are poorly washed, may be significantly more toxic because of reactions between chlorine and ammonia ions. Characteristically, sulphite effluents are much less coloured and cause less foam problems than kraft. Some taste and odour problems in fish have been attributed to sulphite effluents.

Gaseous emissions and odour—Even though many technological similarities exist between the sulphite and the sulphate or kraft process, the air pollutants generated in each of these processes are quite different. The sulphite process usually operates with acidic SO_2 solutions and, therefore, SO_2 is the main gaseous air pollutant. The SO_2 emission can amount to between 1 and 50 kg per tonne of pulp. The SO_2 losses depend mainly on the design of the acid preparation system and the operation of the gas relief from the digesters. In bisulphite and neutral cooking, the SO_2 emission is normally less than 2 kg per tonne of pulp. Typical SO_2 emission from the washing system is in the range of 1 to 10 kg per tonne of pulp. In certain special cases of alkaline sulphite liquor burning in recovery boilers where chemical reduction may take place, H_2S may also be emitted. Organic reduced sulphur compounds are not produced. Since the odour threshold level for SO_2 is about one thousand times higher than reduced sulphur compounds, odours generated in the sulphite pulp mill will generally be much less than in the kraft process. The potential for release of SO_2 into the atmosphere increases with decreasing pH.

Very little data exist for oxides of nitrogen emission from sulphite pulp mills. The emission from spent liquor combustion will probably be of the same order as kraft pulp mill recovery furnaces. One exception is probably ammonium-base recovery furnaces where the nitrogen content in the liquor increases the NO_x formation. At present, there are no reported data on hydrocarbon emissions.

The sulphite process will also emit particulate matters. In calcium-based mills, particulates from the burning of spent liquor are normally removed from the flue gases by a cyclone. Particulates emitted are in the range of 10 to 25 kg per tonne of pulp. For magnesium and sodium based liquor burning, the particulates are removed by electrostatic precipitators or cyclones. Minor particulate emissions also occur with the burning of ammonium sulphite spent liquor.

MECHANICAL AND THERMOMECHANICAL PULPING

Manufacturing processes

The raw fibre material for mechanical and thermomechanical pulps is usually softwood. Some low density hardwoods may also be used. At present there is no information on the application of these processes on non-wood raw fibre materials.

Mechanical pulping is the simplest method of producing wood pulp. It consists of two principal physical methods of producing groundwood pulps. Older technology consists of grinding logs and stone grindings on large grind stones. Modern technology, which is rapidly gaining use, consists of chip refining or refiner groundwood. The process converts pulpwood chips to groundwood pulp, using attrition mills with counter-rotation metal shearing discs. Refiner groundwood is generally preferred to stone groundwood because it yields longer fibres and thus stronger paper. Compared with chemical pulping, groundwood pulping requires a higher net power consumption, and it provides a shorter pulp fibre due to the considerable fibre damage caused by grinding, so that the pulp produces a relatively weak paper that easily discolours upon exposure to light. On the other hand, groundwood provides a much higher yield, converting some 95 per cent of the wood into pulp, compared to about a 50 per cent yield from the kraft process. Another important advantage of the groundwood process is that it produces very minimal on-site air pollution and generates much lower water pollution loads compared to the chemical pulping processes.

Groundwood's strength is compensated for by blending long fibre chemical pulp prior to the papermaking stage. Its short fibre length helps to provide a smooth printing surface for its two principal products: newsprint and uncoated groundwood printing papers.

The objective of mechanical pulping processes is to achieve physical separation of fibres with as little loss of usable papermaking substance as possible. The losses which are experienced include water soluble components, dirt, fibre debris resulting from excessive mechanical fragmentation, and material made soluble by chemical additives for reduction of energy or fibre damage and fibre brightening.

Most mechanical pulping plants are integrated with the papermaking facilities (e.g. newsprint). This eliminates the energy use and potential fibre loss of an additional water removal step, as well as avoiding undesirable changes in the papermaking properties of the fibre due to drying. Paper machine whitewaters are, therefore, returned to the groundwood process to save fibre and heat energy.

A recent development in refiner groundwood involves presoftening the chips using heat and refining it under pressure. This process is called thermomechanical pulping. Longer fibres are formed with this pulping process which makes the pulp suitable for replacing some of the more expensive chemical pulp added to newsprint.

Environmental considerations

The discharge of dissolved solids from mechanical pulping depends upon the raw material (wood species, felling time, storage time, amount of bark, etc.) and on process variables, particularly the temperature in the preheating and refining operation. Depending upon the wood species, the chemical composition of dissolved substances in groundwood and thermochemical pulping can consist of carbohydrates, lignin, extractives, acetic acid, formic acid, methanol and ash. Usually carbohydrates are the main component, followed by lignin.

Suspended solids in the groundwood whitewater are primarily fibre fines. Bark and wood weakened by rot contribute greatly to this debris, giving it a darker colour than whole groundwood. In addition, the high surface-to-weight ratio of the fine absorbs relatively more heavy metal ions and is more susceptible to darkening by oxidation.

Toxicity and BOD of groundwood effluents are caused by water soluble solids such as low molecular weight carbohydrates, extractives and inorganic solutions within living wood cells. Conventional screening and paper forming equipment have very low tolerance for such dissolved solids, as they affect formation, strength and brightness of the product as well as operating functions such as drainage, slime growth, pitching, scaling and corrosion. It is not possible to force water soluble solids out with the product, so they must be expelled from the process by methods which are environmentally acceptable.

Sufficient whitewater must be discharged to remove the dissolved solids at the maximum concentration at which they can be tolerated in the process. This is at odds with suspended solids reduction, which is optimized at minimum whitewater effluent volume. Optimum in-plant control of groundwood effluents requires determination of the minimal acceptable volume of water necessary to purge the dissolved solids. This required fresh water should then be applied where it will do the most good. High pressure, low volume showers for wire and felt cleaning are still a first selection. Showers for groundwood washing should account for the balance of this minimum volume, thereby displacing as much as possible of the contaminated groundwood stream before it reaches the more critical papermaking operations. The resultant effluents will have to be treated externally.

PAPERMAKING

In the paper mill the pulp is converted to paper. An integrated paper mill is situated near a pulp mill and receives the pulp as a slurry directly from the pulp mill. The non-integrated paper mill normally obtains the pulp in dried and baled form and then the first operation is to disintegrate the pulp in water.

The first stage of the papermaking operations is the stock preparation. The fibre types to be included in the stock are heated and mixed. Chemicals and fillers are also added.

Many pulps need refining in conical or disc refiners in order to develop suitable strength characteristics. The consistency of the pulps is carefully regulated during the stock preparation operation. Whitewater from the paper machine is preferred for the adjustment of the pulp consistency in order to save the fibre and heat content of the whitewater. The resulting closing of the whitewater system also reduces the raw water consumption and the size of possible external effluent treatment installations.

The stock is pumped to the paper machine system where it is screened and then brought to the paper machine itself. The sheet is dewatered on a fine mesh wire, pressed in several roll presses and air dried in a steam-heated dryer section. After drying the sheet may be surface treated in a calender or coated before it is wound up on shafts to large reels. The paper is then finished according to the customer's requirements, including rewinding, cutting to sheets and off-machine coating.

A great variety of paper qualities can be fabricated, each requiring its own special manufacturing procedures. Papermaking requires a large quantity of water. However, the discharged effluent characteristics vary from mill to mill depending on the degree of whitewater closure, paper grade produced, size of the mill and raw material used. The pollutants consist of suspended solids (fibres, fibre fragments, inorganic filters) as well as dissolved substances (dissolved wood components, papermaking additives). Generally, the main quantity of the dissolved substances are generated in the pulp mill.

Water effluent from papermaking operations could be eliminated completely if air instead of water were used to convey the fibres prior to formation of the web. There are several examples of dry forming of paper—largely in high value speciality paper.

Major water pollution reduction occur would if dry forming were applicable to commodity grades of papers such as toilet tissues, linerboard, printing papers newsprint. At present it is not possible to reproduce economically, in a dry forming process, the paper qualities found with the commercial wet forming operation.

WASTE PAPER

General

Waste paper is an increasingly important raw material for production of newsprint, tissues, printing and writing papers, magazines and boxboard. The greatest portion of waste paper is not chemically treated but is pulped mechanically. Processing with chemicals (deinking) is, however, necessary for newsprint and writing paper. There are two main methods of deinking: flotation and washing. Flotation deinking in 1978 accounted for about two thirds of all deinked fibres produced worldwide. The washing deinking method is used mainly in the United States, while flotation deinking remains the dominant process in all other areas.

The important distinction between these systems is that in flotation deinking essentially all of the fillers and dissolved contaminants remain with the fibres while ink particles, hot melts, and other substances lighter than water are removed. In washing deinking fillers, dissolved solids and suspended solids are to a large extent removed with consequent lower yields.

The major sources of discharge from waste paper processing are the deinking stage and the screening stage. Others are accidental spills and whitewater, floor drainage, wash-up, cooling and sealing water.

Organics present include additives, products of hydrolysis and fibres lost in the process. Inorganics derive from mineral fillers, ink pigments and other materials separated from the fibre in waste paper, as well as chemicals if used in the process.

Waste paper effluent discharge

The effluent can be kept at a low level in a modern integrated waste paper process. Depending upon the quality of the product and the equipment used the effluent flow will vary from a few m^3 per tonne of waste paper processed to more than 100 m^3 per tonne for an old deinking process employing the washing system.

Normally the whitewater from the waste process is recirculated from the dewatering stage to dilution before the screening and cleaning operations or to the flotation cells. Remaining process water follows the pulp to the paper mill. This quantity must be replaced in the waste process. Clarified whitewater from papermaking operations may supply the greater part.

A considerable yield loss of the raw stock occurs in waste paper processes, especially if deinking is involved. This loss appears in the waste water primarily as BOD and TSS. If a bleaching operation is involved in the waste paper process, the yield loss will further increase in the range of about 2 to 3 per cent.

The major pollutants of waste paper effluent, as discussed above, are dissolved and suspended solids. Colour can be a factor in deinking and bleaching operations, although it is a minor one in comparison with the colour values which result from manufacture and bleaching of chemical pulps.

Part of the surprisingly high COD values in waste paper deinking originate from non-settleable fines, fibre fragments and ink particles cleaned out in the deinking operation.

The amount of ink sludge produced in the deinking operation is about 50 to 100 kg per tonne of pulp produced from waste paper. This sludge should be separated from the main effluent and dewatered. It can then be disposed of together with the other solid wastes in a land fill or be burned in bark boilers. In the latter case, it might cause an emission of dust to air.

Apart from the treatment of the ink sludge, the treatment of the effluent from a waste paper mill is much like the treatment of paper mill effluent. About 60 to 70 per cent of BOD can be removed in a biological treatment plant. This indicates that the effluent from a waste paper mill is degradable to about the same extent as the effluent from a newsprint mill.

In many countries a significant quantity of waste paper is recovered and recycled for pulp and paper manufacture. Larger quantities of waste paper could be recovered and recycled if collection systems were established with more emphasis on source separation or isolation of the discarded paper and paperboard. However, a large portion of the discarded paper and paperboard is not recoverable because it is mixed up with garbage: tin cans, bottles, plastics, as well as other non-fibrous materials.

POLLUTION ABATEMENT AND CONTROL

The first step in abatement and control is to develop a clear understanding of the problem. Basically, pollution is caused by the discharge of materials which are not utilized in the product, and which have an effect on the environment. The reduction of pollution can be carried out by two approaches.

One method is to control and treat the pollutants formed before they are discharged into the biosphere and this strategy can be termed "corrective". Another method is the improvement of processes and systems, by increasing conversion efficiencies and/or the substitution of alternate materials, so that not only less residues are formed, but they are also more biodegradable, and less toxic and hazardous. Furthermore, any by-products that are formed are recycled and reutilized, through the application of low- and non-waste technologies. This latter strategy can be termed "preventive", which is intrinsically more resource conserving and less polluting. This strategy should, therefore be pursued and implemented whenever feasible.

In order to be able to decide what strategies to take, it is necessary to determine:

- What are the recoverable materials (such as the fibre in suspended solids);
- whether there is a material which can be produced to make another saleable material;
- what components are causing environmental problems;
- the best way to treat the discharges.

It is, therefore, necessary to identify and quantify the problem correctly by proper sampling and analysis of effluents. If these measurements were not properly carried out, then the information and data base for decision making, designing and operating of preventive and corrective processes will be erroneous.

Effluent parameters

The major parameters characterizing effluents are:

- dissolved organic substances,
- dissolved inorganic substances,
- suspended organic solids,
- suspended inorganic solids,
- biochemical oxygen demand, BOD,
- chemical oxygen demand, COD,
- colour,
- pH,
- temperature,
- toxicity,
- metallic ions,
- non-metallic ions,
- foaming characterictics.

In-plant control

The first step in effluent reduction is through in-plant control. Generally, this can be achieved by applying a few basic principles:

- reduce to a minimum the quantity of fresh water entering the process: the quantity of effluent eventually discharged is dependent upon the amount of water entering the system;
- design the process system so that the effluent is taken from the

process stream with the lowest suspended solids concentration;
- protect the system from inadvertent process upsets by providing adequate storage capacity for process fluids and operate that storage as close to half-full as possible;
- provide sumps, catch basins, tanks, pumps and filters to capture and dispose of emergency spills and wash-ups. If the recovered material is usable, it is reprocessed, otherwise it must be disposed of in an environmentally accceptable way.

Although each mill has its own approach to water re-use, the process waters most frequently collected and re-used are:
- water used in wood handling and barking drums,
- condensates from evaporators and heat exchangers,
- wash water from screening and cleaning system,
- bleach plant washer filtrates,
- paper machine whitewater.

Pretreament

The most common pretreatment methods are grit and debris removal and waste water screening. Inorganic ash, grit from the wood preparation process, sand and gravel must be removed from the waste effluents to prevent abrasion and damage to pumps, piping and solids dewatering equipment. The grit chamber is a gravity settling tank that can be either manually cleaned periodically or cleaned by methanical removed equipment. Bar screens are commonly used to remove large debris that might cause clogging of overflow weirs and sludge withdraw lines. In addition to bar screens some mills also employ fine screens to remove knots, waste broke, bark and other fibrous material that could cause problems in the solids handling and dewatering facilities.

Another pretreatment process is the neutralization of waste waters. Not only will the pH of the waste water affect conditions in the receiving streams but extreme pH can cause severe corrosion as well as adversely affecting secondary treatment. Waste water pH should normally be between 6.5 and 8.5 to prevent disturbance to secondary biological treatment systems. The design of the neutralization method depends on the pH, acidity and alkalinity of individual streams as well as their volume. The acid streams are usually from the effluent of acidic bleaching stages and related chemical production waste waters containing hydrochloric, sulphuric and other acids with pH values in the 1 to 3 range. Ash waste waters from power plants and lime kiln recovery operations contain large amount of inorganic alkaline solids. Waste waters from kraft pulping operations are alkaline while from sulphite pulping they are acidic. Caustic extraction wastes from the bleach plant are also strongly alkaline.

In kraft mills acidic and alkaline waste water streams can be combined and effectively neutralized by appropriate mixing, blending and pH control. In some mills, the various effluents may have been combined long before reaching the effluent treatment plant. Such combined effluents can have widely varying pH fluctuations. In such instances specially designed automatic pH control systems are needed for rapid addition of caustic or acid for effective neutralization and to protect secondary biological systems.

Another pretreatment facility commonly used is an emergency spill tank, basin or lagoon to retain toxic, extremely acidic or alkaline effluents which occur from unexpected process upsets. Such a facility permits special treatment of this effluent, and regulates its flow into the main waste water stream in order to minimize the effects on waste treatment operations.

Primary treatment

The suspended material in waste mill streams consists mainly of fibre, fibre debris, bark, filler and coating materials which escape internal recovery systems. The most common method used to reduce suspended materials is sedimentation, although in some cases flotation and filtration are used. Sedimentation methods usually employ a gravity clarifier or a lagoon (basin) with adequate retention time to settle out 80 to 95 per cent of the suspended solids. Colloidal materials and chemical type dispersants in mill waste waters can inhibit settling as well as temperature differentials between ambient air and the waste water. When such conditions occur, flocculation chemicals such as alum, ferric chloride or polyelectrolytes can be added to improve settling efficiency. BOD removed in primary treatment is related to organic and fibrous material that has settled out of the waste water. Dissolved solids and colour remain in the clarified effluent.

Secondary treatment

The main purpose of secondary treatment is to remove BOD caused by the dissolved organic constituents in the clarified effluent. Such

BOD can overload the assimilative capacity of the receiving waters causing oxygen depletion and death of aquatic organisms.

BOD reduction is accomplished by using a variety of biological treatment processes. The two most common methods are the activated sludge and the aerated lagoon methods. Other methods include trickling filters and oxidation ponds.

Prior to biological treatment, essential nutrients of nitrogen and phosphorus may have to be added, usually in the form of ammonia and phosphoric acid. Under normal conditions one part of phosphorus and five parts of nitrogen are needed for every 100 parts of BOD removed.

Aerated lagoon systems involve aerating the effluent in the presence of low concentrations of biological organisms. In the presence of dissolved oxygen the biological population feeds on the waste organic matter. Such a system is capable of BOD reduction in the order of 40-75 per cent. Typical design conditions are from 0.5 to 1.0 ha of lagoon per 5,000 m^3 per day of waste water flow. Mechanical surface aeration has proven to be the best method. With adequate aeration, a 75 per cent BOD reduction can be expected at a four-day retention period and over 90 per cent at a seven-day retention period. While aeration lagoons require considerably more land than some other more sophisticated processes of BOD reduction, they have the advantage of:

- large volume and rapid mixing which can absorb slugs of strong wastes without appreciable change in the character of the effluent;
- requirement of less nutrients ;
- generation of less active solids and thus there is no single disposal problem.

The activated sludge process for BOD reduction is generally applied where land area is limited. It differs from the aerated lagoon method in that very high concentrations of biologically active material or so-called activated sludge are brought into contact with the organic wastes in the mill effluents. The rate of BOD reduction is thus quite fast with overall retention times in the 2-6 hour range. The preclarified effluent enters the aeration basin where it contacts the activated sludge. Oxygen is introduced by sparging with compressed air, by mechanical aeration or by a combination of the two. The biological population feeds on the organic matter, removing it from the waste waters. Effective removal and stabilization of BOD mean that the biological community is healthy and will result in the production of additional biological organisms. To sustain the process, the biological mass from the aeration basin is separated from the final effluent by a gravity clarifier and returned to the beginning of the process. Since additional biological organisms are formed, a portion of these are wasted to maintain optimum conditions. BOD reduction of 85 per cent can be achieved on both sulphite and kraft mill effluent.

Tertiary treatment

The residual components remaining in the effluent after secondary treatment are the dissolved colour constituents and bacteria of pathogenic and non-pathogenic origin. Where mills have separate sanitary sewage treatment facilities, pathogenic bacterial pollution can be so contained. The treatment of other forms of bacteria by chlorination and ozonization has not been possible because of the high chemical demands and relatively high waste water flows. Colour removal has been achieved in the laboratory by (i) activated carbon absorption, (ii) foam separation, and (iii) massive lime treatment processes. Depending on stream standards and the use of the receiving water, tertiary treatment of paper mill effluents may or may not be required.

Gaseous emissions control

Gaseous products emitted into the atmosphere from pulp and paper mills can be grouped under five main categories:

- particulate matter, such as sodium sulphate and calcium carbonate;
- malodorous gases, such as hydrogen sulphide and organic sulphides;
- sulphur dioxide;
- other compounds such as nitrogen, carbon monoxide, chlorine and chlorine dioxide;
- water vapour and carbon dioxide.

Particulate emissions can be controlled by electrostatic precipitators, scrubbers, cyclone collectors, wire mesh demister pads, and filters. The two major types of particulate matter control devices used for kraft recovery furnaces are electrostatic precipitators following cyclone or cascade-type direct contact evaporators, and venturi-type evaporator-scrubbers. Packed tower or showered mesh demister scrubbers are used for particulate control on smelt dissolving tank exhaust gases, while venturi or cyclonic scrubbers are normally used for particulate control on lime kiln.

Gaseous emissions can be controlled by incineration, condensation, scrubbing, air or stream stripping, liquid phase oxidation and absorption processes.

For a kraft pulp mill, external control of gaseous and particulate matter emissions can be summarized and tabulated as follows:

Emission source	*Gaseous control*	*Particulate control*
Digester gases	Incineration Condensation	NA (not applicable)
Washer vents	Incineration	NA
Evaporator gases	Incineration Scrubbing condensation	NA
Condensate water	Steam stripping Air stripping	NA
Condensate stripper vent	Incineration	NA
Black liquor oxidation tower vent	Incineration	NA
Tall oil vent	Scrubbing	NA
Recovery furnace	Scrubbing	Precipitators Scrubbing Filtration
Smelt tank	Scrubbing	Scrubbing
Lime kiln	Scrubbing	Scrubbing Precipitators
Slaker vent	NA	Scrubbing
Bleach plant	Scrubbing	NA
Paper machines	Adsorption Condensation	NA
Power boilers	NA	Cyclones Precipitators Scrubbing

A significant amount of information and data are available on the performance of the different gaseous treatment methods, to enable an optimum choice of the air pollution control system to be made.

INDUSTRY AND POLLUTION CONTROL TECHNOLOGIES TREND

With increasing requirements for environmental protection and resource conservation, the pulp and paper industry has been improving and developing manufacturing processes that produce lower levels of wastes and which possess greater conversion efficiencies. Some of the processes receiving great interest are:

Oxygen pulping

The major incentive for the use of oxygen pulping is a reduction in both air and water pollution levels. Since sulphur compounds are not used in the process, as in kraft pulping, there are no malodorous organic sulphur compounds discharged—either in air emissions or water effluents, from the mill.

A second important incentive comes from the potential elimination of the chlorination stage in the pulp bleaching system. This is important, because the conventional chlorination and subsequent alkaline extraction stages contain large quantities of chlorine compounds and are difficult to recover and so pose a pollution problem. The first two stages would be replaced by oxygen pulping. The effluent from the oxygen treatment contains no chlorine and so can be recovered and recycled to the recovery furnace where the organic material is burned for energy and the inorganic material is recovered in the form of fresh pulping chemical.

With present technology, oxygen pulping strength is lower than that of kraft. Thus, the major incentives for the use of oxygen pulping technology are its pollution abatement aspects.

The first commercial oxygen pulping mill in the world is being constructed in the United States. If pulp deficiencies are corrected, the oxygen pulping process could gain a degree of acceptance as a substitute for the kraft process. Conversion of kraft to oxygen pulping would require a major capital investment.

Rapson process

A number of changes in the conventional kraft pulping process are made to eliminate pollutants in the effluent and thus make it a closed-cycle system. The process, however, does not affect solid waste or air emissions.

A mill based on this process was constructed in Canada and initially proved very satisfactory with discharges comparable to very well operated conventional mills with secondary treatment. Recently, the mill ran into corrosion problems in the recovery, which required closing down the recycle system until the cause of the problem has been identified. The potential for corrosion increases with the degree of recycling and system closing.

Oxygen bleaching

Oxygen is being used commercially in pulp bleaching as a substitute for the chlorination and extraction stages of a conventional kraft bleaching sequence. The advantages and results from the standpoint of pollution are similar to those experienced with oxygen.

Displacement bleaching and washing

One of the reasons bleach plant effluent is difficult to handle from the pollution point of view is because of its high dilution of the dissolved organics and inorganics. High dilution occurs because of the need to add large quantities of water to the pulp after each bleaching state. In a recent Swedish development, the pulp is washed by displacement rather than by dilution as in the conventional processing step. This enables the bleach plant operator to use less water and discharge a considerable amount of more concentrated effluent.

Small-scale mills

The domestic consumption of paper in many developing countries is too low to absorb the output from one mill of the capacity that is generally regarded as necessary for a viable operation. The quest for economically viable, small-scale pulp and paper mills within the class of 50 to 100 tonnes per day capacity has become a matter of some urgency in recent years, particularly for developing countries. The basic causes of the problem of mill size are the economies of scale associated with increasing capacity. In general, the more complex the pulping process, the higher the capital cost of a plant of a given capacity. Therefore, it could be expected that mills based on fibrous raw materials that are easy to pulp would be the most readily adaptable to small-scale operations.

Chemical losses in pulp and paper mills, particularly small-scale mills, besides contributing to pollution problems, can be a considerable cost factor. The recovery boiler is one of the most expensive single pieces of equipment in the pulp mill and at present there is no satisfactory solution to reduce capital cost in this chemical recovery stage, especially for small mills. Although reverting the low-heat economy chemical recovery systems would enable most of the chemicals to be recovered, no heat would be available outside the recovery cycle. This would mean very high energy costs for the mill.

Causticizing costs could be reduced by eliminating the green liquor clarifier, if the small mill produces unbleached pulp. Savings can also be made by combining some clarification and washing functions in the same tank, as practised in the larger mills.

The technologies for waste water treatment and air pollution control in small-scale mills are similar to those used in the larger mills. However, small-scale mills have a disadvantage in that the economies of scale exert a very strong influence on the cost of the pollution abatement systems.

Pollution control trend

In the more industrialized countries, pollution control strategies are increasingly focusing on specific pollutant parameters in addition to biological oxygen demand and suspended solids removal. There are some new developments and trends in control technologies in these countries:

a) A gradual shift to the use of activated sludge treatment is evident as a result of growing space limitations on aerated basin usage. Simultaneously, there has been a substantial increase in the use of oxygen-assisted activated sludge treatment, the choice in some cases accompanied by decisions to use oxygen for black liquor oxidation, oxygen bleaching and oxygen-assisted lime kiln firing at kraft mills. Although certain process advantages are claimed for oxygen-assisted activated sludge treatment, these have not been fully confirmed in practice, though such efforts are in progress.

b) A pronounced trend away from vacuum drum filtration toward pressure plate, and more recently, pressurized moving belt filters is now evident.

c) With greater regulating stress on protecting local ground-water start with potable water supply potential, as well as a desire to achieve optimal use of available land disposal sites, there is a trend for a higher degree of engineering attention, such as leachate collection for recycling, with regard to land disposal of sludges.

d) For odour control, because of continued success, technological attention has shifted from the kraft recovery furnace to the lime kiln. A recent development involves air sparger oxidation of lime and slurry from recausticizing system clarifiers before final dewatering to reduce residual sulphide content of the material fed to the kiln.

e) Application of fabric bag filtration of wood-fired power boiler stack gases represents a significant advance in emission control technology over inertial conventional separators. This has been made possible by developing systems control to minimize accidental fires and media plugging.

Some of the mill investigative and control programme development techniques have focused on in-plant and in-process measures to reduce the waste load. Some of the measures are:

a) Engineering systems to achieve further reduction in the carry-out of pulp liquor solids in wasted pulp.
b) Development of a management strategy for designing systems capable of detecting process material (pulping liquor-related) losses, segregating them for later chemical recovery system recycle and employing computerized control features to minimize operator judgement for achieving optimal operation of storage facilities.
c) Availability of improved information for targeted design of water use economy measures by better identification of reuse limitations, functional water properties, and capability of on-line treatment devices to remove undesirable materials. This has opened the way to major water use economy while closed-cycle processes continue to be developed, when combined with more extensive operating experience with bleach plant wash water cycle.
d) Increasing knowledge of environmental capability for assimilating discharges. Experiments, using fish productivity as measurement criteria, are being carried out in carefully controlled studies to determine discharge levels of bleached and unbleached pulping effluents. The programme also includes supplemental studies of bio-accumulation, re-productivity capability and significance of food system alterations and is being expanded to consider a broader range of climatic (geographic) environments, aquatic populations and industry categories.

There is an underlying trend in the pulp and paper industry for increased in-plant control measures, recycling and closing of systems. Environmental problems may vary widely from mill to mill and solutions must be appropriate in order to ensure optimal results. The accurate characterization of waste streams is necessary for the determination of appropriate solutions.

There are two important emerging trends of the industry toward a broader definition of environmental concerns. The first both stems from corporate integration and involves a growing perception of the industry as a forest products totality, integrating forestry operations, pulp, paper and wood products manufacture, secondary converting of paper and wood products, and recycling of consumer-used material in manufacturing operations.

The second development is based on a realization that public environmental quality concerns are becoming increasingly focused on the potential for generating environmental health effects. To a growing degree, the term "environment" encompasses not only the general environment, but also the working environment of employees and the possibility of industrial products serving as a vector of environmental health effects. This trend is reflected in both legislative enactments and regulatory programmes of a number of countries.

EXAMPLES OF DISCHARGE STANDARDS AND CRITERIA

Table 1. Examples of discharge standards and criteria

CANADA

Federal standards for emission from the pulp and paper industry were stated during 1977.

Emission from wood (and woodwaste)—fired boilers (proposed standards)

Regional standards exist. Standards given are from Quebec.

Particles

New plants: 225 mg/m^3 (corrected to 12 per cent CO_2 concentration)
Existing plants: 450 mg/m^3 (corrected to 12 per cent CO_2 concentration)

Emission from sulphate pulp mills (proposed standards)

Standards in practice 1980 (Quebec).

Particles	*New plants*	*Existing plants*
Recovery boiler kg/tonne pulp $_{90}$	2	3.5
mg/m^3	225	450
Lime kiln g/tonne pulp $_{90}$	500	500
mg/m^3	380	380
Smelt dissolver g/tonne pulp $_{90}$	150	250
Total reduced sulphur		
Recovery boiler kg/tonne pulp $_{90}$	85	340
(ppm)	5	20
Lime kiln (ppm)	20	20
Stripper evaporation digester (ppm)	5	5
Pulp washing	5	
Black liquor oxidation	5	

Emission from sulphite mills

	kg/tonne
SO_2	
New plant with recovery of chemicals	10
New plant without recovery of chemicals	2.5
Existing plant	10
Particles	
New plant without recovery of chemicals	2.5

Ambient air concentration

Standards applying to ambient air concentrations. The standards are divided into desirable acceptable and tolerable levels (mg/m^3)

	mean	*max desir.*	*max accept.*	*proposed max.tolerable*
SO_2	1 h	0.450	0.900	
	24 h	0.150	0.300	
	1 year	0.030	0.060	
Particles	24 h	—	0.120	
(geometric mean)	1 year	0.06	0.070	
NO_2	1 h	0.060	0.400	1.000
	24 h	—	0.200	0.300
	1 year	—	0.100	—

Maximum acceptable level is meant to protect humans, nature and climate from negative effects.
Maximum desirable level is the long-term goal for air quality. At this level no detectable negative biological effects are found.
Maximum tolerable level indicates danger and requires immediate action.
Standards for H_2S, total reduced sulphur compounds, polyaromatic hydrocarbons, etc., are being considered.

JAPAN

Standards given are national standards; regionally, more stringent ones exist.

Emission from boilers or waste burning

SO_2

q = $K \times 10^{-3}\,(He)^2$ must not be exceeded
q = emission of SO_2 (m^3/h)
He = effective stack height (m)
K = constant varying between 3.5 and 17.5; for new plants (in central regions) K is 1.17–2.34

Emission from oil-fired boilers

Particles

max. stack gas flow m^3/h	standard (mg/m^3) normally	extreme
40,000	300	200
200,000	200	50
>200,000	100	50

Emission from continuously operating refuse fired boilers

Particles

40,000	700	200
>40,000	200	100

Emission from plants producing chemical products

Hazardous substances a.o. Cl_2 – 30 mg/m^3

Emission from boilers fired with liquid fuels

NO_x

Conc. of NO_x in the stack gas (ppm)

New plants: 180 Existing plants: 230

Minimum excess of oxygen in stack gas 4 per cent NO_x concentration is corrected for real excess of O_2

Emission of odorous compounds

q = $0.108\,(He)^2 C_m$
q = emission of odorous compound (m^3/h)
He = effective stack height (m)
C_m = ambient air standard (ppm) (see below)

Standards applying to ambient air concentration.

Ambient air concentration

	mean	ppm
SO_2	1 h	0.1
	24 h	0.04

Odorous compounds

C_m max conc. at plant area boundary line (ppm)

MM	0.002–0.01
H_2S	0.02 –0.2
DMS	0.01 –0.2
DMDS	0.009–0.1

When ambient air concentration reaches high levels (limits are given) extreme action must be undertaken.

SOVIET UNION

The emissions to the atmosphere are regulated through hygienic standards not to be exceeded in residential areas.

Ambient air concentration (mg/m^3)

	max. conc.	*24-hour mean*		*max. conc.*	*24-hour mean*
SO_2	0.5	0.05	H_2S	0.008	0.008
NO_2	0.085	0.085	MM	0.10^{-6}	–
dust (untoxic)	0.5	0.15			
soot	0.15	0.05	DMS	0.08	–
Cl_2	0.1	0.03	DMDS	0.7	–

Around emitting plants there is a restricted area (with a diameter of 1 km) where no residential houses are allowed.

SWEDEN

If nothing else is stated the emission standards apply to the total emission during one month divided by the amount of product manufactured or by the volume of gas emitted. They also apply to all operating conditions throughout the plant.

Emission from kraft pulp mills

Emission monitoring is regulated.

SO_2

Recovery boiler: 5 kg/tonne

Particles

Recovery boiler
New plants: 250 mg/m^3 N
Plants existing before 1969-07-01: 500 mg/m^3 N
Lime kiln
New and existing plants: 250 mg/m^3 N

Odorous compounds

Cooking, spent liquor evaporation, stripping of condensate.

Tall oil boiling plant

At new plants measures are to be taken such that odour outside the plant area is eliminated.

H_2S

Recovery boiler

10 mg/m^3 N must not be exceeded more than 5 per cent of the operation time at new plants and 10 per cent at existing plants.

Lime kiln: 50 mg/m^3 N

Emission from sulphite mills

SO_2
New plants: 10 kg SO_2 /tonne pulp produced*)
Existing plants: 20 kg SO_2 /tonne pulp produced*

*SO_2 from oil firing is excluded.

Particles

Burning of liquor:
New plants: 250 mg/m ^{3} N
Existing plants: 500 mg/m ^{3} N

Emission from wood and bark burning

Particles

New and existing plants 500 mg/m ^{3} (corrected to an excess of air equivalent to 10 per cent CO_2 concentration), but less than 30 kg/h.

Ambient air concentration

Regulations applying to ambient air concentration are based on air quality criteria and are meant to protect human health. Regulations are divided into standards valid under present conditions (max. conc.) and standards acting as a goal for long-time planning.

SO_2	*max. conc.*	*planning goal*
Winter mean (Oct.-March)	0.100	0.060
24 h mean*	0.300	0.200
1 h mean°	0.750	–
Soot	*max. conc.*	
Winter mean (Oct.-March)	0.040	
24 h mean*	0.120	

* must not be exceeded more than 2 per cent of time October to March.
° must not be exceeded more than 1 per cent of the time during a 30-day period.

Total suspended particles

No standards exist. The American standards (see below) are recommended.

UNITED STATES OF AMERICA

Regulations of emissions are valid from September 1976. They are based on best economically available technique. In specially polluted areas, stricter regulations are valid.

Emission from sulphate pulp mills

Particles

	mg/m^3	*kg/tonne*
Recovery boiler	100	1.0
Oil-fired lime kiln	300	0.535
Gas-fired lime kiln	150	0.028
Smelt dissolver	120	0.15

Total reduced sulphur

	ppm	g/tonne
Recovery boiler	5	75
Oil-fired lime kiln	5	12.5
Gas-fired lime kiln	5	12.5
Smelt dissolver	5	12.5
Pulp washing	5	5
Black liquor oxid.	5	5
Stripper	5	5
Digester	5	5
Evaporation	5	5

Emission from sulphite mills

Federal authorities have recommended that the emission of SO_2 should not exceed 10 kg/ton pulp.

Regulations of emissions of SO_2, NO_x and particles and stack-gas opacity exist for fossil-fuelled plants for steam generation with the effect < 73MW.

Ambient air concentration (mg/m^3)

Primary standards are based on air quality criteria and are meant to protect human health.

		prim.	*sec.*
SO_2	3 h	—	1.300
	24 h	0.365	—
	1 year	0.080	—
Particles	24 h	0.260	0.150
	1 year	0.075	0.060
NO_2	1 year	0.100	

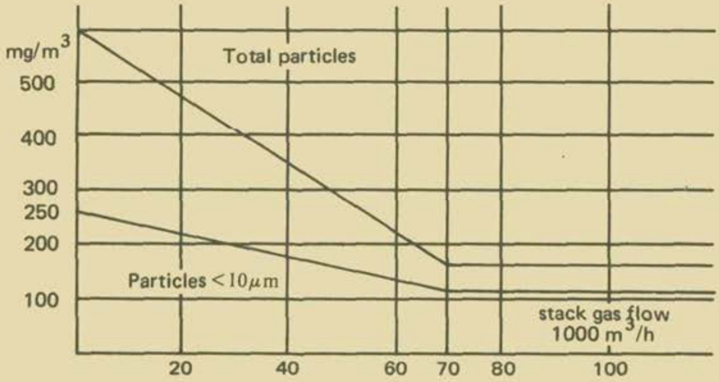
FEDERAL REPUBLIC OF GERMANY

The regulations apply to emissions from new plants or plants which considerably change their site, nature or operation of plant.

Particles

The standards are valid for normal operation of control equipment.

The particle concentration must not exceed the values given in the figure below.



Inorganic gaseous chlorine compounds

Regulations for emission monitoring exist.

The concentration of inorganic gaseous chlorine compounds must be < 30 mg Cl_2/m^3 (0 °C, 1 atm, dry gas) when the emitted amount of Cl_2 is > 3 kg/h.

Reduced sulphur compounds

Regulations regarding emissions of SO_2 and particles from fossil-fuelled stationary sources exist.

The concentration of dimethyl sulphide and the concentration of mercaptans must not exceed 20 mg/m^3 (0 °C, 1 atm, dry gas) when the emitted amount is > 0.1 kg/h.

Ambient air concentration (mg/m^3)

Regulations for ambient air concentration are divided into long-time (IW1) and short-time (IW2) mean values (mg/m^3).

Particles (harmless dust)

Particles	$<10\mu m$
IW1	0.10
IW2	0.20

Particles	$>10\mu m$
IW1	0.20
IW2	0.40

Cl_2	
IW1	0.10
IW2	0.30

SO_2	
IW1	0.140
IW2	0.40

H_2S	
IW1	0.0050
IW2	0.010

NO_2	
IW1	0.10
IW2	0.30

NO	
IW1	0.20
IW2	0.60

Deposition of particles (harmless dust)

IW1	0.35 g/m^2, 24 h
IW2	0.60 g/m^2, 24 h

Table 2. Interim guidelines for effluents. Best practical control technology currently available (BPCTCA)

UNITED STATES

Type of production	BOD $_5$, kg/t			SS, kg/t		
	24h	month	year	24h	month	year
Sulphate, unbleached	5.6	2.8	...	12.0	6.0	...
Sulphate, dissolving	23.6	12.3	6.9	37.3	20.1	11.1
Sulphate, bleached, unintegrated	15.5	8.1	4.5	30.4	16.4	9.0
Sulphate, bleached integrated (board tissue)	13.7	7.1	4.0	24.0	12.9	7.1
Sulphate, bleached, integrated (fine paper)	10.6	5.5	3.1	22.2	11.9	6.6
Sulphate, paper grade (diffuser washed)	31.8	16.6	9.3	44.0	23.7	13.0
Sulphite, dissolving	41.4	21.5	12.1	70.7	38.1	20.9
NSSC, Na-base	8.7	4.4	...	11.0	5.5	...
NSSC, NH_3-base	8.0	4.0	...	10.0	5.0	...
Unbleached sulphate —NSSC, cross recovery	8.0	4.0	...	12.5	6.3	... ...
Chemimechanical	13.5	7.1	4.0	19.8	10.7	5.9
Thermomechanical	10.6	5.6	3.1	15.6	8.4	4.6
Mechanical, integrated	7.5	3.9	2.2	12.8	6.9	3.8
(newsprint)	7.5	3.9	2.2	12.8	6.9	3.8
Mechanical, integrated (fine paper)	6.9	3.6	2.0	11.8	6.3	3.5
Soda	13.7	7.1	4.0	24.5	13.2	7.3
Deinking	18.1	9.4	5.3	36.2	18.8	10.6
Waste paper based board	3.0	1.5	...	5.0	2.5	...
Fine paper, unintegrated	8.2	4.3	2.4	11.0	5.9	3.3
Tissue unintegrated	11.4	6.3	3.5	10.3	5.0	2.9
Tissue, waste paper based (not deink)	13.7	7.1	4.0	17.1	9.2	5.1
Sulphite paper grade (filter washed)	26.7	13.9	7.8	44.0	23.7	13.0
Wet debarking	0.7-3.2	0.4-1.7	0.2-1.0	0.2-7.5	0.1-4.0	0.1-2.2
Log and chip washing	0.1-0.4	0.1-0.2	0.1	0.2-2.6	0.1-1.4	0.1-0.8

24 hour and monthly values must be fulfilled by all units. The average yearly value is applied only to mills with biological cleaning followed by wastewater basins with regulated discharges.

t — av. yearly production per 24 h
24 h — denotes maximum per 24 h
month — max. monthly av. 24 h values
year — max. yearly av. 24 h values

Table 3. Summary of legislation relevant to water pollution by the pulp and paper industry. SS = suspended solids; BOD = biological oxygen demand

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CANADA

Main aspects of legislation

Regulations are based on best practicable technology.

Federal regulations are minimum standards for national application. Provincial requirements are equivalent or more restrictive.

Regulations apply to new mills at startup. Compliance dates for existing mills negotiated individually.

Discharge limits are set for SS, BOD_5 and toxic discharges.

Proposed standards

BOD requirements (kg BOD_5 /ADMT):	*Existing mills*	*New mills*
Sulphite 55 per cent or less yield	116	77
55-65 per cent yield	77	52
more than 65 per cent yield	68	34
Sulphite bleaching	16	16
Kraft pulping	29	16
Kraft bleaching	12	12
NSSC	36	27

SS allowances calculated using component process categories method.

BOD values for kraft mills are those permitted prior to toxicity reduction systems. Such systems usually result in BOD reduction of 75-90 per cent.

FINLAND

Main aspects of legislation

Discharge of waste submitted to permit only, up to now. The administration has set up some general goals for discharges.

Proposed standards

Based on water quality, health, etc. Goals for SS and BOD (in kg/tonne):

	BOD_7	SS
Sulphite	57	10
unbleached	40	10
bleached	60	10
dissolving	100	10
Sulphate	19	5
unintegrated unbleached	10	5
unintegrated bleached	20	5
integrated unbleached	15	5
integrated bleached	25	5
Semichemical	20	5
Newsprint, paper and board	9	5
Fibre board	20	5

FRANCE

Main aspects of legislation

By the act of 16 December 1964 polluters may be required to meet a charge for pollution discharged and receive help for financing antipollution investments.

Minimum discharge standards are fixed in uniform manner. Can be locally stricter.

An agreement signed with the Minister of the Environment covers a programme of pollution reduction for chemical and semi-chemical pulp mills.

Maximum discharge allowed (kg/tonne)	*Primary treatment*	*Secondary treatment*	
	SS	*BOD_5*	*SS*
Kraft unbleached	2.5	5	10
Kraft bleached	10	9	20
Sulphite:			
with liquor recovery	12.5	45	50
without liquor recovery	15	80	85
Semi-chemical:			
more than 150 tons/day	5	8	5
less than 150 tons/day	13	60	60

Biological treatment by aerated lagoon.

FEDERAL REPUBLIC OF GERMANY

Main aspects of legislation

A new law has been accepted which means that the discharges will be regulated by charges.

Each mill and community is given a calculated value (so-called reference value) for its discharges. The value shall be expressed in "damage units" for different discharges, which are shown in the table.

The cost charged to the polluter is founded on the reference value. Each mill and community is also given a maximum value based on experience for its discharges. This may not be higher than twice the reference value.

The charge was 12 DM per damage unit in 1981. It increases each year reaching 40 DM per damage unit in 1986.

Proposed standards

Substance	*Number of damage units/unit of measure* *Damage unit*	*Unit of measure*
Sedimentable material with an organic content > 10 per cent	1	m ^{3} /year or ton/year
Sedimentable material with an organic content < 10 per cent	0.1	m ^{3} /year or ton/year
Oxygen demanding material, COD	2.2	100 kg/year
Mercury and its compounds	5	100 g Hg/year
Cadmium and its compounds	1	100 g Cd/year
Toxicity towards fish*	0.3-G_F°	1000 m ^{3} wastewater/year

*Type of toxicity and test procedure is not specified.

°G_F is the dilution factor at which waste water is no longer lethal to fish. If $G_F \leq 2$, 0 damage units are given.

JAPAN

Main aspects of legislation

Under the 1971 act all mills have to observe minimum standards all around the country (applied in successive steps between 1972 and 1976). Can be locally stricter.

Proposed standards

Standards for 1976 deadline (expressed in ppm)

	BOD	*COD*	*SS*
Semi-chemical	300	600	150
Sulphite (paper grades)	300	600	150
Sulphite (dissolving grades)	600	800	150
Sulphate (dissolving grades)	130	300	150
Sulphate (paper grades)	120	200	150
Paper and board	120	120	150
Bleached straw	300	600	250

SWEDEN

Main aspects of legislation

Protection of the environment by using the best practicable means.

The regulations are based on the Environment Protection Act of 1969. "Specific values" for pollution load are not discharge standards as they can be lowered when necessary.

SS =suspended solids
BOD =biological oxygen demand

The specified values for BOD$_7$ are generally achievable by internal mill measures while those of SS usually require a sedimentation basin.

Proposed standards

No precise standards; each case examined separately on the basis of *specified values* (in kg/-tonne) as follows:

BOD$_7$ from	A	B	C	D	E
Barking	1-3	1-3	1-3	1	1
Washing		5	3-7*	10-15	-
Grinding	15				-
Condensate		2-3	4-10	5	-
Bleaching	2-15	8-9	10-13	2-15	-
Accidental discharges		1-3			
SS	2-5	2-5	2-5	2-5	2-5

A =mechanical pulp
B =sulphate
C =sulphite
D =semi-chemical
E =fibre building board

*Corresponds to 97-98 per cent recover.

UNITED KINGDOM

Main aspects of legislation

Legislation is based on maintenance of water quality as required by each use.

Amendments to legislation are under consideration.

Proposed standards

Standards related to SS—BOD—toxicity—colour—pH—ammonia, etc.

No national standards. Values generally used are:

BOD_5 = 20 mg/l max
SS = 30 mg/l max

Can be more stringent.

UNITED STATES

Main aspects of legislation

The Federal Water Pollution Control Act Amendments of 1972 declares that it is the national goal that the discharge of pollutants into the receiving water bodies be eliminated by 1985.

In addition to this goal, specific interim requirements are stipulated. They relate to the application of the "Best Practical Control Technology Currently Available" (BPCTCA) (the goal for 1 July 1977), the "Best Available Technology Economically Achievable" (BATEA) (the goal for 1983) and "New Source Performance Standards" (NSPS) (present goal for new mills).

Guidelines for BPCTCA were issued in February 1976 and January 1977.