ENVIRONMENTAL ASPECTS OF THE PULP AND PAPER INDUSTRY

- a technical review -

UNITED NATIONS ENVIRONMENT PROGRAMME

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– an overview –

UNEP, Industry Programme
Paris, May 1977

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FOREWORD

The UNEP Governing Council from its first session held in June 1973 recognized the environmental issues associated with industrial development, and in its decision noted the intention of the Executive Director to initiate preliminary work on environmental problems of specific industries.

The Pulp and Paper industry is one of the major industrial sectors agreed for examination. Consultations have been undertaken with experts nominated by Governments, Industry and international governmental and non-governmental organizations, culminating in a Seminar, held in Paris on March 1975, where the state of the art of existing remedies, problems outstanding and possible avenues of research and development to resolve these environmental issues were assessed.

This report gives a synthesis of the evaluation that has taken place, and highlights the decision and policy aspects that pertain to major environmental issues emanating from the Pulp and Paper Industry. The views expressed in this report do not necessarily represent the decisions or the stated policy of the United Nations Environment Programme.

1. INTRODUCTION

The estimated world production of paper and paperboard was approximately 148 million metric tons in 1973. About 72 percent of this quantity was based on wood fibre, nearly 24 percent was composed of waste paper and about 4 percent represented non-wood plant fibres Pulpwood consumption (1) for the manufacture of wood pulp during the same period was estimated to average 403 million m^3 (solid measure). The pulp and paper industry is not only a major consumer of the forest, but also one of the largest users of water in terms of specific water use, as well as the quantity discharged. Hence, the pulp and paper industry is normally sited where there is an abundance of good water, a forest resource, and also water courses for discharging mill effluents. This could give rise to conflicts between contrasting demands for a resource offering multiple potential uses as various interest groups expect different benefits such as recreation, wild life protection, water control and conservation, etc. Furthermore, this conflict will be accentuated when wastes and residues from the conversion of forest raw materials into pulp and paper cause an undesirable and damaging impact on the biosphere, thereby reducing the overall utility of the forest and water ways.

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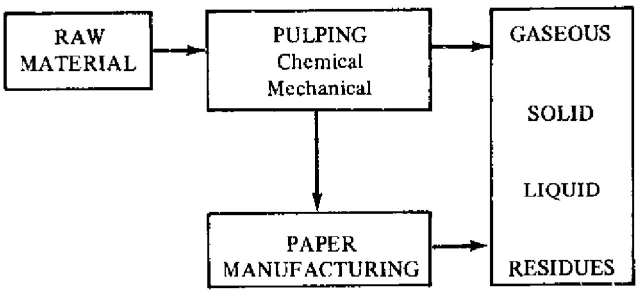
(1) Food and Agriculture Organization of the United Nations, FAO (1974)
"Wood Fibre Resources and Pulpwood Requirements"
FO : PAP/74/6 (Rev. 1)

2. THE INDUSTRY AND THE ENVIRONMENT

The manufacture of paper can be divided into two phases : pulping the wood and making the final paper product. Gaseous, liquid and solid wastes are produced during both process phases of this industry.

There are two main types of pulp for paper production, mechanical and chemical pulps. Mechanical pulp is produced by grinding or shredding the wood to free the fibers and in addition heat and pressure may be applied to assist the process. Chemical pulp is produced by cooking wood chips, materials such as straw, grass, cotton, flax fibers, bamboo as well as rags, in chemical solutions that dissolve the lignin binding material. Chemical pulps may be subdivided into kraft (sulphate), sulphite, semi-chemical and soda.



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 (derived largely from mechanical pulp) or kraft liner board. This is a major reason for such products to be manufactured close to the resource base.

Regarding impact on the environment, air pollution problems are more significant with chemical pulping processes than with mechanical processes. Since over 65 percent of the total pulp produced is composed of kraft pulp, the main impact on the environment is from chemical pulping.

2.1. **Kraft (Sulphate) Pulping** :

This process, first used in 1879, was a modification of the caustic soda system in that sodium sulfide was added to the cooking liquor. The presence of caustic soda in the cooking liquor permits the pulping of practically all wood species. The other active chemical, sodium sulfate, has a buffering action that allows digestion to take place at a lower $(OH)^-$ ion concentration, thus reducing damage to the fibers and producing pulps that are stronger than those made from sulfite processes. The kraft process produces a dark coloured pulp that normally represents from 45 to 50 percent of the initial weight of the wood used. Because of its dark colour, the unbleached pulp is used mainly in board, wrapping and bag papers. For use in the manufacture of white papers, the pulp must be treated further in a bleach plant.

Gaseous Emissions : – Sulphur compounds : – the kraft recovery furnace system is a major source of reduced sulphur and sulphur dioxide emissions. Other emission sources of reduced sulphur include multiple effect evaporators, brown stock washers, lime kilns, digesters, unit processes that handle black liquor which permit its contact with ventilation air and smelt tanks. Hydrogen sulphide can be formed in the direct contact evaporator, where carbon dioxide in the flue gas from the recovery furnace reacts with sodium sulphide in the black liquor. It can also be formed in the lime kiln.

Particulates : – occur primarily from the recovery furnace, the lime kiln and the smelt dissolving tank. Particulates are caused mainly by the carry-over of solids, plus the sublimation and condensation of inorganic chemicals. The sublimation and condensation produce a fume that initially is probably submicron in size, but has a tendency to agglomerate. From the recovery furnace, the particulates consist primarily of sodium sulfate and sodium carbonate. From the lime kiln they consist mainly of sodium salts, calcium carbonate and calcium oxide.

In addition, particulate emissions occur from boilers fired with bark and or with other fuels.

Typical values illustrating the range of emissions from kraft mill operations, after control, have been reported (1) and are :

	Emission rate, Kg./KKg Air Dried Pulp (ADP)	
Process	*Particulates*	*Total Reduced Sulphur (TRS)*
Recovery furnaces	0.5 to 12.5	0.025 to 6
Smelt tanks	0.025 to 1.0	0.005 to 0.03
Lime kilns	0.025 to 3.5	0.01 to 0.5
Digesters		0 to 1.0
Multiple effect evaporators		0 to 0.75
Black liquor oxidation		0.025 to 0.10
Brown stock washers		0.005 to 0.045

(1) U.S. Environmental Protection Agency, EPA (1973)
"Atmospheric Emissions from the Pulp and Paper Manufacturing Industry".
EPA Publication N° EPA 450/1 - 73-002. September.

Odour . – from kraft mill is caused by the reaction of sodium sulfide, a component of the digesting liquor with various organic side-chain radicals from cellulose and lignin of wood chips. Some of the compounds thar are formed and their corresponding thresholds are (1), (2) :

Compound	*Odour Threshold, ppm*
H_2S, Hydrogen Sulphide,	0.0047[a]
CH_3SH, Methyl Mercaptan,	0.0021[a]
$(CH_3)_2S$, Dimethyl Sulphide,	0.0010[a]
$(CH_3)_2S_2$, Dimethyl Disulphide,	0.0056[b]
SO_2, Sulphur dioxide,	0.47[a]

(a) Concentration at which all panel members detect odour

(b) Median concentration detected by the individual panel members

The sulfide compounds are extremely odorous, being detectable at concentrations as low as 1 part per billion.

2.2. **Sulphite Pulping Process**

Sulphite pulp can be made from several types of wood, but soft woods are generally used. The specific type of wood used depends both on the final product desired and the cooking base employed. Sulphite pulping is an acid chemical method of dissolving the lignin that bonds the cellulose fibers together. Many of the older mills use a sulfurous acid-calcium bisulphite solution for the cooking acid. In Sweden, at least 80 to 85 percent of the calcium based spent liquor is recovered while with magnesium and sodium based mills recovery rates of 90 percent are achieved.

Gaseous Emissions : – sulphur dioxide is the main product emitted and the sources are the absorption towers, blow pit or dump tank, multiple effect evaporators and liquor burning or chemical recovery systems. Emissions for soluble base processes, after control, are reported to be :

(1) Leonardos G., D. Kendall and N. Barnard (1969) "Odor Threshold Determinations of 53 Odorant Chemicals". *J. Air Poll. Control Assoc.* V. 19., N° 2, p.91.

(2) Hellman, T.M. and F.H. Small (1974) "Characterization of the Odors Properties of 101 Petrochemicals Using Sensory Methods". *J. Air Poll. Control Assoc.* V. 24., N° 10, p. 979.

	SO_2, *(Kg/K.Kg. ADP)* *After control*
Absorption	0.045 to 4.53
Digester blow	0.48
Furnace	2.5 to 4.5

2.3. Semichemical Sulphite Pulping Process

Semichemical pulps can be made by any of the commercial cooking processes by reducing cooking time, temperature or the amount of chemical charged to the digester. Many types of wood can be pulped using these processes and the most extensively used is the neutral sulphite semichemical (NSSC) process. Cooking liquor is prepared either by adding fresh chemicals, sulphite and carbonate, to water and spent liquor, or by absorbing sulphur dioxide generated in a sulphur burner in a sodium carbonate solution.

Gaseous Emissions : – due to the difference in the chemical attack on the lignin when using sulphite liquors, compounds such as methyl mercaptan and dimethyl sulfide are not formed during digestion. Also, the absence of sulfide ions from the cooking liquor will virtually eliminate hydrogen sulphide as a possible emission. Exceptions to this rule might be expected in those systems where liquor is burned in such a manner that the smelt contains sodium sulfide.

Atmospheric emission sources from an NSSC mill will include SO_2 absorption towers, if they are used, blow tanks, spent liquor evaporators and the liquor burning or chemical recovery furnace.

Reported emission data for semichemical processes reported are :

	SO_2 *(Kg/KKg. ADP)* *After control*
Absorption	0.085 to 0.17
Furnace	1.08 to 3.2

2.4. Present State of the Art of Emissions Reduction and Control

Three general principles could be used :

– add-on abatement equipement,

– process improvement and control and

– process changes.

Presently, abatement equipment is the most effective method to control emissions. Although the effect of some operating variables on emission is known for some unit operations of the industry, the information is not definite enough to be used for emission control. Only in the kraft recovery furnace is sufficient data available to be able to minimize emissions by optimising operating parameters.

For gaseous emission control, combustion, absorption and liquid phase oxidation are examples of abatement techniques. Combustion involves the thermal oxidation of reduced sulphur compounds to sulphur dioxide.

Absorption usually involves scrubbing the gas stream with an alkaline process liquor, such as sodium hydroxide, lime and weak wash or white liquor.

Liquid phase oxidation is used to convert reduced sulphur compounds to less odourous or more stable substances. Oxidizing agents used are chlorine, atmospheric oxygen and molecular oxygen.

Particulates emissions : – can be controlled by electrostatic precipitators, scrubbers, cyclone collectors and wire mesh demister pads.

Electrostatic precipitators are the main type of collectors used to control recovery furnace particulate emissions.

Scrubbers may be used for lime kiln, smelt tank vents, recovery furnace and other sources. For example, a venturi recovery system using black liquor as a scrubbing medium serves as a primary particulate collection device, as well as a flue gas direct contact evaporator. Secondary scrubbers could also be installed, downstream from devices such as electrostatic precipitators. Cyclone collectors, and wire mesh demister pads are used to control particulate emissions from smelt tanks. A liquid spray, usually a lime mud weak wash is used, in most cases, with these devices.

Some abatement cost data based on 1969 prices, have been reported for U.S. installations (1) and are shown in Table 1. They have been calculated on specified physical arrangements and on assumptions which appeared reasonable for the industry at that time. Absolute cost estimates for a given installation must be calculated upon costs and other considerations unique to the particular installation.

Generally, the state of the art for particulate matter collection is more advanced than for odour control. The main air pollution problems of the pulp and paper industry, according to the OECD report, are the gases containing SO_2 from calcium bisulphite recovery furnaces and odourous gases from sulphate pulp systems. Among the new methods for reducing air pollution from a kraft-mill, the scrubbing of the stack gases with aqueous solutions of Na_2CO_3 containing activated carbon in suspension appears very promising.

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(1) Organization for Economic Co-operation and Development, O.E.C.D. (1972) "Advanced Pollution Abatment Technology in the Pulp and Paper Industry" O.E.C.D. - PARIS.

TABLE 1. COST DATA FOR ABATEMENT EQUIPMENT IN THE U.S. PULP AND PAPER INDUSTRY

	Capital Cost (US $./ADT Day)	Net annual Cost (US $./ADT Day)	Annual Operations Efficiency (percent)
Precipitators (Recovery Furnace System)	1600 to 2200	400 to 550	99 +
Mesh pad (Smelt dissolving tank)	20 to 45	6 to 14	75
Packed Tower/ Cyclonic scrubbers	75 to 130	25 to 40	80 90
Scrubbers, venturi (Lime kiln)	120 to 250	40 to 90	99 +
Venturi Evaporator/ Scrubber (Kraft recovery furnace)	300 to 600	130 to 170	94 to 99

2.5. Present state of the Art of Liquid Effluent Reduction and Treatment

Effluent characteristics : – The industry produces two main effluents, pulp mill and paper-mill wastes. The waste characteristics will vary, depending upon the manufacturing processes used, degree of product recovery and end products manufactured. Pulp mill wastes are generated from grinding digester cooking, washing, bleaching, thickening, debarking and de-inking (from waste paper pulp production). These effluents can contain spent cooking liquor, fine fibers ligneous compounds, bleaching chemicals, organo-sulphur compounds, sodium sulfides, carbonates and hydroxides. Paper mill wastes originate in water which passes through the wire screens, showers and felts of the paper machines. The wastes (white waters) can contain fine fibers, sizing, dye, casein, clay ink, waxes, grease, oil and other materials depending upon the additives used in paper production. The chlorine plant can also be a significant source of wastes in the paper mill.

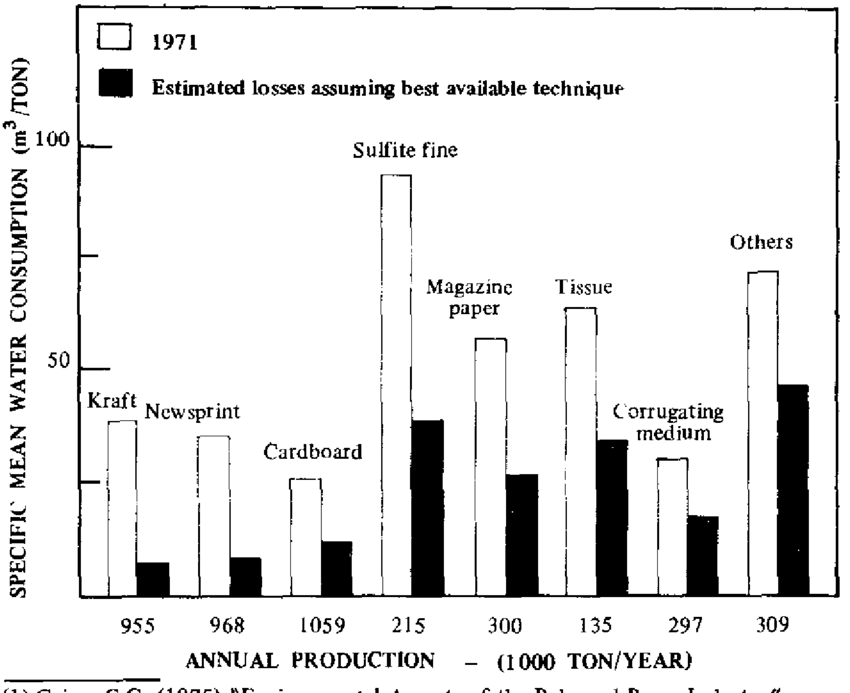
Significant effluent characteristics of the pulp and paper industry are suspended solids, BOD_5, COD, colour, toxicity, sulphite and pH. Coliform (*Klebsiella pneumoniae*) (1) could also be a characteristic that needs consideration. Heavy metals can also be present in the form of organic mercury compounds for preservation of wood, as a means to control slime growth on pulp and paper machines or found in traces in the electrolytically produced chemicals (such as sodium hydroxide) used in pulping ; and zinc compounds, as brightening agents for mechanical pulp, still used in a few countries, can also be present. However, the general trend is to replace and substitute both these metals in the manufacturing processes.

(1) Knittel, M.D. (1975) "Taxonomy of *Klebsiella Pneumoniae* isolated from Pulp/Paper Mill Wastewater". U.S. EPA - 660/2.75 024. June.

Effluent reduction : – one of the steps in minimizing the effects of the effluent on receiving streams and treatment plants is to reduce the volume of such wastes. This may be accomplished by :

- reduction of the volume of water used in production and manufacturing processes, for example by a new pulp washing system and recycling,
- classification of effluents and
- elimination of batch or slug discharges of process wastes.

Hence, in order to reduce the quantity of waste water, a major endeavour is to "close" the white water system, so that excess water from the paper making process is minimized or completely eliminated. According to the investigations (1) made by the Swedish Environmental Care Project (SSVL), specific fresh water consumption for different kinds of paper produced by Swedish mills, could be significantly reduced by closing the system. The lowest value, shown on the chart below, represents estimated losses assuming best available techniques operating under optimum conditions that are achievable in practice. Temporary or accidental discharges are not included in the values.



(1) Geiger C.G. (1975) "Environmental Aspects of the Pulp and Paper Industry" paper prepared under the joint UNIDO/UNEP Environment Programme and presented at the Sixth SIDA/UNIDO/SSIF In-plant Group Training Programme for Engineers in the field of Pulp and Paper Industries.

New processes : – A number of new processes are under research and development to reduce the strength as well as modify the characteristics of pulp and paper mill effluents. The majority of these processes are based on replacing sulphur or chlorine containing chemicals, so that not only will emission of odorous gases from sulphur compounds be greatly reduced, but it will also permit the recycling of bleaching effluent to the chemical recovery system. Some of these processes are based on nitric acid, amine, hydrotropic, hydrogenation, peracetic acid and biological pulping. Although from environmental considerations, these new processes would have much less pollution impact, there are still technical problems, especially with the quality of the pulp, to be overcome. Also, the economics of the new processes, considering investment and production costs, are not yet established.

Amongst the new processes that are receiving special attention and show potential for commercial implementation are the Alkaline-Oxygen, and Rapson pulping processes (1).

With the Alkaline-Oxygen process, one of the manufacturing sequences receiving greatest interest involves an alkaline treatment to soften the wood chips, mechanical disintegration and treatment with oxygen under alkaline conditions, at about 250 °F and ten atmosphere pressure, to remove most of the remaining lignin. Continuous process towers are used so that the net consumption of oxygen is about 2.5 percent ADT, based on ingoing pulp.

With the Rapson process, a closed cycle concept, the bleach plant effluent and evaporator condensates are used for pulp washing and in preparation of the cooking liquor so that no fresh water is added in pulping or chemical recovery. The spent bleaching chemicals and the organic matter dissolved during bleaching thus get into the pulping chemical recovery cycle. All the organic matter is burned and the spent bleaching chemical, sodium chloride, leaves the furnace with the pulping chemical smelt. The inorganic smelt is dissolved and then causticized to form "white" liquor for use in pulping. By evaporating the recovered white liquor and filtering, the crystalized sodium chloride formed, is removed. This can then be used as make-up for chlorine dioxide generation and as make-up for chlorate production.

Although preliminary economic considerations indicate that the processes still under development, would be similar to or more expensive than conventional processes, these processes could be eventually more economical, with increased pollution abatement requirements.

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(1) – Rapson W.H. and Reeve D.W. (1976) "Non Waste Production of Bleached Kraft Pulp". Paper prepared for the U.N. Economic Commission for Europe Seminar on the Principles and Creation of Non-Waste Technology and Production, Paris. U.N.E.C.E. Env/Sem 6./R4/Com.3, December.

– U.S. Environmental Protection Agency, EPA (1976) "Environmental Consideration of Selected Energy Conserving Manufacturing Options : Pulp and Paper Industry Report".
EPA 600/7-76-034e December.

Another method which is expected to assume considerable importance is oxygen bleaching. This process consists of replacing, partly or entirely the first two stages of the conventional bleaching sequence with oxygen under pressure in an alkaline medium.

Treatment methods : – Pulp and paper mill wastes could be treated in the following manner :

(i) recovery of chemicals, fibers and fillers ;

(ii) sedimentation or flotation to remove suspended matter ;

(iii) chemical precipitation, (or other more advanced but at present not commonly applied methods such as the use of activated carbon, reverse osmosis and ion exchange) to reduce colour ;

(iv) activated sludge treatment to remove oxygen-demanding matter ;

(v) lagooning, for purposes of storage, settling, equilization, and also for biological degradation of organic matter.

Recovery : – main processes are based on filtration, sedimentation or flotation for fibers and evaporation for chemicals. Filtration devices are usually some variation of a revolving, cylindrical, perforated screen or filter that removes the suspended solids in the form of a mat, which is subsequently scraped off the drum and returned to the paper-making stock system. Conical or other sedimentation tanks are also used to separate the suspended matter by difference in specific gravity.

Sedimentation and Flotation : – will not only enable product recovery, but also decrease the solids content of the waste and, therefore, lower the pollutional strength of the effluent. Modern paper mills usually have circular concrete or steel sedimentation tanks. Their diameters generally vary from about 5 m to 40 m, (some approaching 100 m) with solids discharged at a maximum concentration of 6 to 8 per cent. The fillers present in the effluent make final clarification difficult and effluents usually contain 30 ppm or more of suspended solids, unless up-flow-type clarifiers are used.

Chemical Precipitation : – use of chemicals will increase the quantity of sludge which must be disposed of. In a process described (1), precipitation with lime as a coagulant, in three stages to a final pH of 11 has been used. In the first stage, calcium sulphide settles out and is returned as a slurry to the cooking-liquor make-up. In the second stage, lignin is precipitated and converted to a cake on a rotary filter. In the third stage, settling removes any remaining colloidal material that is left when the pH is raised to 11. About 40 per cent BOD removal is reported to be obtained.

In an OECD report (2), massive lime treatment at a bleached kraft mill in America was reported. By treating the most highly coloured effluents only, the report states that approximately 70 percent of the mill's total colour load and 20 to 40 percent of BOD could be removed from the effluent.

However, the following problems were encountered : foaming and carry over of solids from the clarifier are intensified ; the cooking liquor is more dilute ; lime kiln fuel requirements are increased ; and more foaming problems in the cooking liquour system occur.

Because of the high lime requirements of this process, a second system using moderate quantities of lime has been developed in an unbleached kraft mill. In this stoichiometric lime system, pulp fibre serves as a precipitation and dewatering aid. Calcium hydroxide as a slurry is mixed with total mill effluent in direct proportion to flow. The mixture is retained in a flocculator and clarified in a centre-feed clarifier. The coloured substances are precipitated as calcium salts, together with the fibre and other settleable solids. The treated effluent is saturated with calcium hydroxide. In one application, the effluent is aerated and discharged to the receiving stream. The O.E.C.D. report states that operating results have shown this system to be capable of operating successfully under widely varying conditions to give a relatively constant effluent colour in the range of 125 ppm APHA colour units. Performance was reported to be directly related to control of lime feed.

Other methods, such as the use of activated carbon, reverse osmosis, ion exchange, iron hydroxide precipitation, amines for colour removal were also reviewed in the report.

Activated Sludge Treatment : – aerobic biological processes have been most successful on kraft-mill wastes. However, when the process is applied continuously the capital and operating costs have been reported to be high. It has been reported (1) that this process has been used in a kraft-mill with normal 16 mgd (7101/sec) flow and an average BOD of 140 ppm. Three hours of aeration were provided with a 25 percent of sludge return. Based on average concentration, the BOD loading of the aerator was 56 pounds per 1,000 ft^3 (897 Kg/m^3) and mixed liquour concentrations varied between 0.2 to 0.3 percent. Air requirements approximated 1 ft^3 per gallon (0.008 $m^3/1$) of waste. Nitrogen and phosphorous nutrients were added, as needed, to maintain one pound of available nitrogen and phosphorus for each 20 and 75 pounds of BOD respectively. An 85 percent reduction of BOD, while treating 60 percent of the wastes, was reported. Aeration with oxygen is a process that is also being used. With this technique, higher BOD loadings compared with conventional activated sludge process is possible, thereby resulting in smaller aeration tanks and less space requirement.

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(1) Nemerow, N.L. (1971). "Liquid Waste of Industry Theories, Practices and Treatment". Addison - Wesley Publishing Company.

(2) Organization for Economic Cooperation and Development, OECD (1972) "Advanced Pollution Abatement Technology in the Pulp and Paper Industry", OECD Paris.

Lagooning : -- stabilization basins or naturally aerated lagoons have been widely used for BOD reduction and also as a major method for final waste treatment (1). In countries with moderate to warm climatic conditions favouring biological oxidation, and if land is readily and inexpensively available, this process can give dependable waste treatment and stabilization. Odour, however, could be a problem. Storage usually ranges from 10 days to 10 months and for stabilization, retention periods last 10 to 30 days. The basins are normally designed for a loading of 10 to 300 lb BOD/acre day (1.02 to 30.6 g/m^2 day). With loadings of less than 50 lbs BOD/acre day (5.10g/m^2 day), removal efficiencies of 90 percent have been achieved. With higher loadings the efficiencies level off to range of 60 to 70 percent.

If land is limited, then mechanically aerated basins could be an alternative. Typically, land usage may be two acres per mgd (180 m^2 per l/sec) as compared to 40 acres per mgd (3660 m^2 per l/sec) for naturally aerated basins. Optimal ratios of BOD : N is approximately 50 : 1 for 4 days aeration and could be increased to 100 : 1 far 15 days aeration. If aeration is extended beyond 15 days, nutrient addition is not normally required. About 0.1 to 0.2 lbs (0.045 to 0.09 kg) of sludge is produced for each pound (kg) of BOD removed.

3. POSSIBLE IMPLICATIONS OF ENVIRONMENTAL AND RESOURCE CONSERVATION MEASURES

There are three major policy and regulation issues that will have special implications for the pulp and paper industry. The first is national regulations specifying, on grounds of health and hygiene, certain wrapping standards, prescribing materials which may be used for this purpose, or the establishment of a list of substances that are prohibited.

The second is pollution abatement requirements and the associated costs.

The third is the non-exclusivity of the forest as the primary source of raw materials for the pulp and paper industry. In an era of increasing leisure and environmental concern and awareness, forest use raises issues beyond those associated with their role as an industrial raw material.

In most of the pulp and paper producing countries, specific regulatory enactments regarding water pollution have been or are about to be adopted. On the other hand, air pollution legislations are less advanced and also

(1) Webster, G.R. (1975), "How to Assess Environmental Impacts, Pollution Abatement Control Technology. Technology Transfer Mechanisms".
Paper prepared for UNEP Industry Sector Seminars, Pulp and Paper Meeting, Paris, March 1975.

generally less well defined. With solid waste, legislations, when they exist, are normally confined to local measures of limited scope.

Many of the pulp and paper mills were designed and built when there was very little requirement for pollution abatement. For these mills to comply with increasingly stringent environmental legislations, retrofitting or installation of add-on abatement equipment will be costly.

Furthermore, availability of the necessary space for these abatement systems could also be a constraint. In the construction of new mills, especially in developing countries, there is an important need to ensure that environmental protection is incorporated in the plant design at the planning stage. Economically, this method has been found to be less expensive and more effective than subsequent retrofitting.

3.1. Pollution Abatement Requirements and Costs

Atmospheric pollution by the pulp and paper industry emanates primarily from chemicals used in processing, and comprise mainly particulates, odorous gases and sulphur dioxide. Most air pollution problems are related to pollutants containing sulphur – an element which is present in practically all chemical pulp manufacture –. It has been estimated that about one-third of the sulphur lost in the process is emitted in gases. Generally, air pollution problems are limited to the neighbourhood of the mills and contribute to local pollution problems. Emissions of sulphur compounds also add to the general problem of atmospheric pollution by sulphur, which may have serious ecological effects in certain countries. On an international basis, an OECD report (1) concluded that, with regard to the pulp and paper industry, air quality is receiving less attention than water quality protection.

Water quality is characterised by three major parameters : suspended solids, Biochemical Oxygen Demand (BOD_5) and toxicity. The Chemical Oxygen Demand (COD) test is also now used in place of, or simultaneously with BOD_5. The OECD report states that in 1970, the pulp and paper industry discharged a total of 3.8 million tonnes of suspended solids. In some countries this may represent as much as 75 percent of the total solids discharged by industry. Hence, the amount of suspended solids discharged to the receiving waters is a significant percent of the total combined production of pulp and paper. With regards to BOD_5, a total of about 6 million tonnes was estimated to have been discharged by this industry. This may represent in some countries as much as 90 percent of the total discharge of industry. Approximately one half of the BOD_5 load in 1970, was estimated to have originated from the sulphite and semi-chemical mills.

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(1) Organization for Economic Cooperation and Development, OECD (1973) "Pollution by the Pulp and Paper Industry, Present situation and Trends". OECD Paris.

TABLE 2. BEST PRACTICAL CONTROL TECHNOLOGY CURRENTLY AVAILABLE EFFLUENT LIMITATIONS IN Kg/KKg.

Subcategory	*Maximum 30-day Average*		*Maximum Day*	
	BOD_5	*TSS*	*BOD_5*	*TSS*
Dissolving Kraft	12.25	20.05	23.6	37.3
Market Kraft	8.05	16.4	15.45	30.4
BCT Kraft	7.1	12.9	13.65	24.0
Fine Kraft	5.5	11.9	10.6	22.15
Papergrade Sulfite (Blow Pit Wash)				
Bisulfite-Surface	16.55	23.65	31.8	43.95
Bisulfite-Barometric	18.05	28.1	34.7	52.2
Acid Sulfite-Surface	16.8	23.65	32.3	43.95
Acid Sulfite-Barometric	18.5	28.1	35.55	52.2
Papergrade Sulfite (Drum Wash)				
Bisulfite-Surface	13.9	23.65	26.7	43.95
Bisulfite-Barometric	15.3	28.1	29.4	52.2
Acid Sulfite-Surface	15.5	23.65	29.75	43.95
Acid Sulfite-Barometric	16.9	28.1	32.5	52.2
Continuous Digesters	19.85	28.95	38.15	53.75
Dissolving Sulfite				
Nitration	21.55	38.05	41.4	70.65
Viscose	23.05	38.05	44.3	70.65
Cellophane	25.0	38.05	48.05	70.65
Acetate	26.45	38.05	50.8	70.65
GW-Chemi-Mechanical	7.05	10.65	13.5	19.75
GW-Thermo-Mechanical	5.55	8.35	10.6	15.55
GW-CMN Papers	3.9	6.85	7.45	12.75
GW-Fine Papers	3.6	6.3	6.85	11.75
Soda	7.1	13.2	13.7	24.5
De-ink	9.4	12.95	18.1	24.05
NI Fine Papers	4.25	5.9	8.2	11.0
NI Tissue Papers	6.25	5.0	11.4	10.25

pH for all subcategories shall be within the range of 5.0 to 9.0

Zinc*

Subcategory	*Maximum 30-day Average*	*Maximum Day*
GW-Chemi-Mechanical	0.17	0.34
GW-Thermo-Mechanical	0.13	0.26
GW-CMN Papers	0.15	0.30
GW-Fine Papers	0.135	0.275

* Applicable only to mills using zinc hydrosulfite

Source : EPA (1976)

In America, it is generally recognized that the 1972 Federal Water Pollution Control Act Amendments mark a major change in the direction of the national water quality management programme. This Act requires the "application of the best practicable control technology currently available" (BPCTCA) by not later than July 1, 1977. The Environmental Protection Agency has defined the effluent discharge level associated with this technology and these are shown in Table 2 (1).

As a national goal to be met by 1985, the U.S. is also aiming for an end to the discharge of pollutants into navigable waters. This has been interpreted to mean "zero pollutant discharge".

A study (2) has been undertaken by the pulp and paper industry to determine the cost of meeting these effluent requirements. The key findings are that achievement of the 1977 objectives may call for capital expenditures beyond the end of 1971 of at least US $ 1.2 Billion, accompanied by operating costs of at least US $ 4 per ton of paper board production, all expressed in 1972 U.S. Dollars.

The estimated costs for achieving "zero pollutant discharge" could add another US $ 4.3 billion as well as U.S. $ 32 per ton of product, again expressed in 1972 U.S. $, and more important, reflecting 1972 energy costs.

The disposal of solid wastes in the pulp and paper industry has so far received less attention than air emissions and liquid effluents. Major solid waste components are : bark, sludges and screenings.

Bark when burned will be an energy asset but this may necessitate the installation of equipment to render it more amenable to burning. Furthermore, if this creates air pollution problems, then abatement devices will have to be installed. The disposal of sludge, resultong from biological treatment processes can also be a problem, however, this problem is not unique to the pulp and paper industry.

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(1) U.S. Environmental Protection Agency, EPA (1976).
"Development Document for Effluent Limitations Guidelines (BPCTCA) for the Bleached Kraft, Ground wood, Sulfite, De-ink and Non-integrated Paper Mills". EPA. 440/1-76/047-b, December.

(2) National Council of the Paper Industry for Air and Stream Improvment Inc, NCASI, (1974) "An Engineering Estimate of the cost to the Paper Industry of Achieving selected EPA National Effluent Limitation Levels".
NCASI Technical Bulletin N° 270.

The 1970 costs of pollution control in OECD member countries have been estimated (1) by product categories. These are shown in Table 3, which also include the then projected 1975 and 1980 costs.

These costs data are the most detailed and comprehensive information that have been published. Although they need updating to reflect overall price increases, the data nevertheless provide an indication of the level of investment that would be needed for pollution control in the pulp and paper industry.

The important cost concepts used in the OECD study are :

(i) Pollution control measures are defined as measures beyond those normally required for economical operation of the mill and motivated by the objective of reducing polluting effluents and emissions.

(ii) The cost estimates cover water and air pollution control. These costs have been expressed in 1970 U.S. Dollars, and reflect the exchange rates prevailing in December 1970. Estimates are based on 1970 equipment prices and operating costs.

(iii) The water pollution control costs include both external and internal measures : the term external measures refer to treatment facilities for the waste water effluents ; the term internal measures refer to specific techniques introduced within the production process, minimizing the quantity of pollutants to which it gives rise.

(iv) The pollution control costs have been defined as the sum of net operating costs and capital charges :

Net operating costs include labour costs, energy cost and maintenance, giving credit for recovery of heat, chemicals, fibres, etc...

Capital charges include (a) depreciation on capital expenditure, assuming a 10 year write-off period ; (b) interest on capital, based on interest rates prevailing in the country concerned in November 1971.

The annuity method has been used ; i.e. the sum of depreciation and interest has been equaly distributed over the whole ten year period.

(v) Pollution control costs for 1975 and 1980 are estimated for only those mills which were operating in 1970.

(vi) The term "investment" used in the tables and text refers to the total amount of money expended to install pollution control facilities in pulp and paper mills during a fixed time period. This concept should be distinguished from annual capital costs (depreciation and interest).

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(1) Organization for Economic Cooperation and Development, OECD (1973) "Pollution by the Pulp and Paper Industry", OECD Paris.

TABLE 3. ESTIMATED POLLUTION CONTROL COSTS IN THE PULP INDUSTRY

Countries	1970 Share of **		Estimated Pollution control costs					
	Production %	Exports %	In US $ per tonne (1)			In % of product price (2)		
			1970	1975	1980	1970	1975	1980
I. Semichemical pulp								
Canada	5	–	0.25	6.03	8.78	0.2	4.8	7.0
Finland	5	–	3.55	1.28*		2.8	1.0*	
France	3	–	1.80*	11.30*	16.70*	1.4*	9.0*	13.4*
Italy	2	–	0	25.00		0	20.0	
Japan	30	–	3.33	13.98		2.7	11.2	
Netherlands	0	–	3.60	3.60	3.60	2.9	2.9	2.9
U.S.A.	47	–	2.31	12.11		1.8	9.7	
Total or Average	92	–	2.53	12.05	–	2.0	9.6	–
II. Sulphite pulp								
Canada	10	20	0.62	11.22	17.22	0.4	6.5	10.0
Finland	13	18	2.65	5.44*		1.5	3.4	
France	4	2	1.48*	14.12	23.40	0.9	8.2	13.5
Japan	8	0	8.33	22.24		4.8	12.9	
Sweden	16	23	2.87	9.76	15.91	1.7	5.6	9.2
U.S.A.	26	25	3.47	18.01		2.0	10.4	
Total or Average	77	88	3.24	13.53	–	1.9	7.8	–
III a. Non-integrated sulphate pulp								
Belgium	1	1	8.71	11.51		4.9	6.5	
Canada	45	41	1.15	5.22	7.53	0.6	2.9	4.3
Finland	18	12	0.72	1.90*		0.4	1.1	
France	2	1	0.32*	5.22	11.03	0.2	2.4	6.2
Italy	0	–	0	24.00		0.0	11.9	
Japan	6	–	1.38	6.68		0.8	2.8	
Sweden	25	24	1.45	4.42	8.20	0.8	2.2	4.6
U.S.A.	n.a.	17	–	–	–			
Total or Average	97	96	1.22	4.55	–	0.7	2.6	–

Continued

Countries	1970 Share of***		Estimated Pollution control costs					
	Produc-tion %	Exports %	In US $ per tonne (1)			In % of product price (2)		
			1970	1975	1980	1970	1975	1980
III b. Integrated sulphate pulp and paper								
Canada	6	41	0.03	5.02	6.57	0.0	2.9	3.2
Finland	3	12	0.67	2.14*		0.4	1.2	
France	2	1	0.50*	5.51	7.04	0.3	3.2	4.1
Italy	0	–	0	16.00		0.0	9.2	
Japan	12	0	1.55	7.62		0.9	4.4	
Sweden	6	24	1.64	5.25	7.38	0.9	3.0	4.3
U.S.A.	69	17	2.21	11.80		1.3	6.8	
Total or Average	98	95	1.88	10.05	–	1.1	5.8	–
IV. Newsprint (3)								
Canada	47	73	0.51	3.55	6.55	0.3	2.2	4.0
Finland	7	12	0.15	0.52*		0.1	0.3	
France	3	0	0.12	2.68	2.68	0.1	1.6	1.6
Germany	3	0	0.66	0.72	1.44	0.4	0.4	0.9
Italy	1	0	0	2.00		0.0	1.2	
Japan	10	0	0.37	3.02		0.2	1.8	
Netherlands	1	0	0	5.70	5.70	0.0	3.5	3.5
Sweden	6	7	3.62	4.86	4.01	2.2	2.9	2.4
Switzerland	1	0	1.19	1.64	1.98	0.7	1.0	1.2
U.S.A.	16	1	0.91	3.75		0.6	2.3	
Total or Average	95	93	0.72	3.26	–	0.4	2.0	–

Continued

Countries	*1970 Share of****		*Estimated Pollution control costs*					
			In US $ per tonne (1)			*In % of product price (2)*		
	Production %	*Exports %*	*1970*	*1975*	*1980*	*1970*	*1975*	*1980*
V. Other Paper and Board								
Belgium	1	3	1.63	3.06	3.19	0.7	1.3	1.3
Canada	2	6	0.13	3.23	3.69	0.1	1.4	1.6
Finland	3	20	0.46	0.74*		0.2	0.3	
France	5	3	0.40	0.72	1.29	0.2	0.3	0.6
Germany	7	5	3.14	3.52	5.41	1.4	1.5	2.4
Italy	6	2	0	3.50		0.0	1.5	
Japan	11	4	0.37	5.71		0.2	2.5	
Netherlands	3	5	0.70	2.60	5.30	0.3	1.1	2.3
Sweden	6	19	1.35	4.14	4.18	0.6	1.8	1.8
Switzerland	1	0	1.98	2.09	2.16	0.9	0.9	0.9
U.K.	9	2	0.98	1.37	1.05	0.4	0.6	0.5
U.S.A.	39	20	1.30	4.69		0.6	2.0	
Total or Average	93	89	1.11	3.80	–	0.5	1.7	–

* Water pollution control only.

** Sources : Production and cost figures : national replies to questionnaire.

Exports : the Pulp and Paper Industry, OECD, 1971.

Notes : (1) Based on the December 1970 value and exchange rates of the U.S. Dollar.

(2) Product selling prices have been estimated as follows : Newsprint, US $ 165 / tonne - Paper and Board, US $ 230 / tonne.

(3) Except for Canada, pollution control costs for newsprint do not include pollution control costs incurred in manufacture of chemical pulp used in newsprint. Approximately 20 percent of total fibre in newsprint is chemical pulp.

3.2. Recycling of Waste Paper

With the increasing concern for environmental protection as well as the need to secure forestry resources, not only as the major supplier of raw material for the pulp and paper industry, but also as a host for multiple and potentially conflicting uses, ranging from recreation to energy, increasing attention is being directed towards recycling and reusing of waste paper. The resource and environmental benefits that can be accrued are significant, as shown in Table 4.

TABLE 4. ENVIRONMENTAL IMPACT COMPARISON OF MANUFACTURING 1 000 TONNES LOW GRADE PAPER FROM VIRGIN MATERIALS AND FROM WASTE PAPER (1)

Environmental Effect	*Unbleached kraft pulp (virgin)*	*Repulped waste paper (100 % waste)*	*Change from increased recycling (%)*
Virgin materials use (oven dry fibre)	1000 tonnes	0	-100
Process water used	91 million litres	38 million litres	- 61
Energy Consumption	18 million MJ+	5.3 million MJ	- 70
Air pollutants, effluents, (transportation, manufacturing, harvesting)	42 tonnes	11 tonnes	- 73
Waterborne wastes discharged (BOD)	15 tonnes	9 tonnes	- 44
Waterborne wastes discharged (suspended solids)	8 tonnes	6 tonnes	- 25
Process solid wastes generated	68 tonnes	42 tonnes	- 39
Net post-consumer wastes generated	850 tonnes	– 250 tonnes	- 129

+ includes black liquor and bark fuel value

(1) U.S. Environmental Protection Agency, EPA (1973) Report to Congress on Resource Recovery.

4. CONCLUSIONS

Pollution abatement technologies encompassing both internal and external measures are available to significantly reduce particulates and sulphur oxides emission from pulp and paper mills. However, odourous gases, because of their very low threshold levels, remain a problem to be solved.

Similarly, conventional effluent treatment systems are available to reduce BOD_5 and suspended solids to acceptable discharge levels. Although a number of chemical precipitation methods, as well as more sophisticated techniques such as the use of activated carbon, reverse osmosis, ion exchange etc., are being developed to reduce effluent colour, none of these methods have been entirely satisfactory from an economic point of view.

Internal measures to reduce both the strength and quantity of the discharges from pulp and paper mills are being increasingly implemented. Water use reduction by a variety of methods, ranging from improved good house-keeping to closed cycle systems, in conjunction with new production processes should lead to an evolution towards low and non-waste technologies.

Recycling and reuse of residues also play an important role and increased use of waste paper for repulping is a definite and positive contribution towards resource conservation and environmental enhancement.

Internal and external measures, especially retrofitting of pollution abatement equipment, are costly and sometimes not feasible with old mills. Therefore every attempt should be made to incorporate appropriate environmental protection and resource conservation measures in the planning and design stage of new installations.

There is an associated cost to be incurred in abating pollution and protecting the environment. The studies that have been reported, although generalized and with broad assumptions, indicate that this internalized cost would be a significant part of the production cost. However, the externalized cost in terms of damage to the biosphere, needs to be considered. Because of increasingly competitive demands made on the forest for a multiplicity of uses, not the least of which is the use of its capacity to act as a source and sink for sustaining and propogating the ecosystem, careful plans and rational decisions must be made for the equitable use of this renewable resource, without destroying it. In this overall context of environmental protection and management, the pulp and paper industry has a most important role to play.

Design : EUROPUBLICA, 7, place Vendôme, 75001 Paris — France
Printed in France AUGUSTIN S.A., 75009 Paris — TÉL. 073.02.66
This publication is printed on recycled paper