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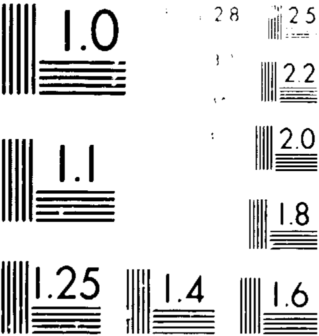

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ENVIRONMENTAL ASPECTS OF THE WOOD AND WOOD-PROCESSING INDUSTRY

K.M. Strzepek

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SECTORAL WORKING PAPERS

During the course of work on major sectoral studies by UNIDO's Division for Industrial Studies, several working papers are produced by the Secretariat and by outside experts. Selected papers that are believed to be of interest to a wider audience are presented as Sectoral Working Papers. These papers are more exploratory and tentative than the sectoral studies. They are therefore subject to revision and modifications before incorporation into the sectoral studies.

This paper was prepared by Mr. K.M. Strzepek, UNIDO consultant, as a contribution to the First World-wide Study on the Wood and Wood-processing Industries. The views expressed do not necessarily reflect the views of the UNIDO secretariat.

Preface

This is one of several research papers prepared for the First World-wide Study of the Wood and Wood Processing Industry. It deals with the technical aspects of environmental pollution for the sector as a whole; however, the mechanical and chemical processing of wood, especially the wood preserving and finishing processes, are emphasized. For most of these processes typical costs for measures to abate or mitigate adverse environmental effects have been provided. In some instances it has also been possible to point out the likely consequences of not correcting specific types of adverse environmental effects.

This paper was prepared by Kenneth M. Strzepek as UNIDO consultant to the Sectoral Studies Branch with technical supervision from the Office of the Director, Division for Industrial Studies.

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The following UNIDO documents have been prepared in the context of the world-wide study

1. First World-wide Study of Wood and Wood Processing Industries, prepared by UNIDO Secretariat

2. A Review of Technology and Technological Development in the Wood and Wood-processing Industry and its Implications for Developing Countries, prepared by Brotchie, J.F., UNIDO/IS.

3. Environmental Aspects of the Wood and Wood-processing Industry, prepared by Strzepek, K.M., UNIDO/IS.394

4. Health and Safety Problems in Wood and Wood-processing Industries, prepared by the secretariat of ILO, UNIDO/IS.

5. Potentials and Requirements of Increasing the Degree of Wood-processing in Developing Countries of Asia and the Pacific, prepared by Brion, H.P., UNIDO/IS.395

6. Tariff and Non-tariff Measures in World Trade of Wood and Wood Products, prepared by the secretariat of UNCTAD, UNIDO/IS.

7. The U.S.S.R. Forest and Woodworking Industries, prepared by Burdin et al, UNIDO/IS.

8. Wood and Wood-processing Industry as a Consumer and Supplier of Energy, prepared by Swedforest Consulting AB, UNIDO/IS.

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Executive Summary

The wood and wood processing industry covers a wide spectrum of economic activities in the transformation of raw materials to final products. Wood, the raw material for the industry, is considered an agricultural product. The management of forests and the commercial cutting of trees to provide raw material for the wood and wood processing industry is not part of the UNIDO mandate for industrial development. The UNIDO "World Wide Study of the Wood and Wood Processing Industry" therefore has placed an emphasis on the mechanical and chemical processing of wood. In this report on the "Environmental Aspects of the Wood and Wood Processing Industry" a description of the general environmental problems facing the entire industry provides a complete picture into which the specific problems to be addressed by UNIDO can be put into perspective. This report emphasizes the mechanical and chemical processing of wood, but focuses most attention on the wood preserving and wood finishing processes. The report will provide an overview of the environmental problems facing the various processes of the industry and will describe treatment alternatives.

Section I. Impact on the Forest Ecosystem from Logging Operations

A. Forest Stands.

When a wood or wood processing industry is planned for a region the local forest may be a source of the raw materials. Proper planning and management of the forest stand is necessary to assure a long term supply of the species of tree needed for the given products.

B. Land Systems. The soil and forest systems are very closely linked. Care must be taken before the choice of logging strategy,(partial or clear cuts) to avoid irreversible damage.

C. Water Systems. In general, reduction of forest cover cover increases streamflow while establishment of forest cover on sparsely vegetated land decreases it. Forest cutting may adversely affect water quality by causing erosion. Increased suspended sediments in the stream and a change of the water chemistry may result. The additional sediments can lead to premature siltation of a reservoir, for example. One economic development project may therefore be conterproductive to the objectives of another.

Case Study: The Archicaye Hydroelectric Project in Colombia was designed to provide 64,000 kilowatts of electricity to the city of Cali. The project was begun in 1944 when there was few settlers and little development in the steeped walled canyon of the Anchicaye reservoir site. The Simon Bolivar Highway, under construction at the time of design may made cuts into the steep canyon causing severe land

slides. The completion of the highway incouraged settlers to the river basin and led to deforestation of the jungle. These developments led to a major sedimentation problem in the river due to soil erosion. The reservoir was completed in 1955 and with 21 monthsd 25% of the storage capacity was lost due to siltation. By 1967 80% of the storage capacity had been lost and it was expected that within a short period of time that the power tunnel would be completely blocked making the power plant totally useless. A new reservoir planned for upstream on the Anchicaye river included in the project a plan for watershed management and control of deforestation by limiting the settlement and clearing of forest in the river basin (Carmichael, 1974).

Sukhna Lake, a multipurpose reservoir in Chandigarh, India, lost over 70% of its storage capacity in the first 20 years of it life. Subsequently, reforestation and watershed management have been introduced in the basin and the problem is decreasing.

D. Air Systems. The atmosphere and the forest also form a synergystic equilibrium. In the process of photosynthesis, the trees of the forest stand take in carbon dioxide and transform the carbon into cellulose and other carbon-based polymeric structures. Deforestation can contribute to a greater Carbon Dioxide content in the atmosphere which may result in global warming. Flohn (1980) states that a doubling of the current Carbon Dioxide content of the atmosphere would result in a 3 degree C warming at the low and mid latitudes and a 5- 10 degree warming at the polar regions. This warming would result in melting of the Artic sea ice, raising ocean levels and affecting global climate. It has been estimated that at present rates doubling of the Carbon Dioxide concentration could take place between 2040 and 2050.

E. Logging for Energy Use. Large scale use of wood as fuel, especially in industrial boilers, could effect forest soil nutrient and carbon budgets reducing forest productivity. The natural processes of shedding and decay of fallen wood allows carbonaceous material to be incorporated into the forest floor, thereby enriching the soil. Logging for fuel usage employes whole tree chipping which utilizes the entire tree including the leaves. Historically, logging has left behind wood material containing high concentrations of nutrients, so nutrient depletion was not a problem (The Conservation Foundation, 1982).

F.Transport of Wood To Processing Sites. The development of the infrastructure and the tranportation of the wood has a greater potential environmental impact than the processing of the wood (World Bank, 1980).

II. Impacts on Forest Ecosystems of Non-Wood Related Industry

Acidification of lakes and soils is viewed as one of the most serious environmental problems today facing Sweden, Northeastern US, and Southern Canada. The acidification leads to dead lakes and may also lead to a decrease in forest growth or damage to trees (Sweden,1979). Recently it has been suggested that the acidification of forest soils is releasing normally
insoluable metals, especially aluminium, allowing the metals to be taken up by the roots where they can become toxic or lethal (Ember,1982).

Vegetation injury and soil degradation due to heavy metal accumulation may cause more damage than sulphur dioxide. Fluoride has been responsible for wide spread mortality of conifierous trees near smelters, refineries, and power plants in the U.S. and Europe.

Section III. Mechanical Processing of Wood Products

A.Sawmills.

Sawmill wastes not collected end up as debris in the plant or surrounding grounds. In the past this debris was flushed to a sewer and dumped into a local water body. The load of organics in this waste water has the potential to be a major pollution source. It is possible to collect a large portion of the debris reducing the amount that must be flushed. With appropriate design and careful operation, the effluent load from sawmills can be reduced almost to zero (World Bank, 1980)

B.Wood Drying Operations. The are two basic wood drying process, natural air-seasoning and kiln-drying. Natural air-seasoning contributes very little to air or water pollution. Some volatile compounds from the wood are given off to the air and runoff from precipiation may carry some organics to the local waters.

The kiln-drying process uses fuels to provide the heat for drying and air pollution is associated with the combustion of these fuels. Water is used for cooling in the kiln-drying system and can be a source of thermal pollution.

C.Veneer Industry. The production of veneer wood products causes little air or water pollution, but can produce wood waste. The wood waste can be utilized as a fuel source or
or a raw material for chemical production to avoid becoming a pollution problem.

D.Plywood Industry. Air pollution is generated by the release of volatile chemicals from the glues and resins used, particularly formaldehyde and in preservation treated exterior plywoods, pentachlorophenol. Sawdust from the sanding process, if not contolled can contribute to air pollution and worker health hazards.

The washing of the glue-mixing and applying equipment produces a small volume of highly concentrated wastes. Plywood wastewaters contain some glue solids and wood particles, phenols, phosphates, various forms of nitrogen and high pH. The solids are treated by settling ponds or septic tanks. The dissolved organics and chemcial wastes can be treated by municipal treatment or incineration. Incineration is a very costly alternative (Nemerow, 1978).

Treatment of softwood plywood wastewaters in the USA in 1980 has been estimated to cost approximately 1 % of the export commodity price depending on the level of treatment. Likewise for hardwood plywood treatment costs have been estimated from 33 to 35 percent of the 1980 USA export commodity price.

E.Particle Board Manufacturing. Particle board adhesives use more formaldehyde than plywood adhesives thus leading to a problem of free formaldehyde emission from the product after installation in the consumers home or office. Formaldehyde is suspected to be a carcinogenic material so strict limits are now being applied to reduce the emission of free formaldehyde in the manufacturing process and in the finished product.

Section III. F : Fiberboard Manufacturing. The fiberboard industry requires the pulping of wood to produce the raw fibers. Therefore the fiber board industry is faced with environmental aspects similar to those from the pulp and paper industry which is discussed in detail in Section IV.A. Estimates of increased annual costs due to wastewater treatment range from less than 1 to 14 percent of the 1980 USA export commodity price.

Section III. G. Wood Preserving. The wood preserving industry plays an important role in the infrastructure of any economy especially economies in a developing stage. The transport, communications, and construction industries all rely heavily on products produced by the wood preserving industry. Railroads depend on wooden railroad ties that are treated with preservatives. Railroad and road networks employ preserved wood for the construction of bridges and other major structures. Telecommunication networks use wooden "utility poles " that must be treated with preservatives. The construction industry requires preserved wood products for many applications, especially in humid and tropical climates. Agriculture also uses large amounts of treated wood, eg. fence posts, storage bins, irrigation and water management structures. The importance of using preservatives to prolong the life of the wood is two fold.

First preserved wood lengthens the life of the structure and reduces needs for maintenance. Secondly the long life of preserved wood means that time is available for a replacement tree to be grown,(Reynolds, et al, 1976).

Wood preservatives fall into two broad categories:(1) oil-borne and organic solvent treatments which include pentachlorophenol in various solvents, creosote and creosote-coal tar solutions, and copper naphthenate and (2) water-borne treatments which include waterborne salts such as copper-chrome-arsenate (CCA) and ammoniacal copper arsenate (ACA) systems.

There has been a great deal of study in the past years about the dioxin content of pentachlorophenol and its environmental impact. In addition three European countries have banned wood preservatives containing arsenic. The commerically available wood preservatives discussed above, act to prevent wood degradation by making the wood substance toxic to micro-organisms and wood boring insects. An alternative to this approach is to chemically modify the wood substance making it unmetabolizable to the degrading organisms. Acetylation of wood is being examined as a commercially viable nontoxic wood preservative (Kumar, 1981).

Water Pollution. Water use for wood preservative is rather small and thus the resulting volumes of effluents small as well. The waste characteristics and volume of effluent discharges depend greatly on the type of preservative being used , the conditioning process and the treatment process.
Wastewater from oil-borne processes contain:

1. free oils and settleable solids which can readily be separated from the water,
2. emulsified oils and non-settleable solids which are more difficult to remove, and
3. dissolved organic materials extracted from the wood.

Water-borne processes produce wastewater which contain:

1. dissolved inorganics resulting from the metal salt preservatives, and
2. dissolved organic material extracted from the wood being treated, (Averill, et al, 1978).

The discharging of these wastes to water bodies can make the waters toxic to the surrounding plant and animal life.

Waste producing steps that are common to both conditioning and treatment are spillage of preservatives, dripping of treated wood on removal from the cylinder, piping leaks, surface runoff from outside storage of treated wood, and cleaning of the cylinders.

The three primary steps for treatment of oil-borne preservative wastewater are:

1. Primary Separation of free oil and settleable solids,
2. Removal of Emulsified oil and suspended solids, and
3. Removal of dissolved organics.

Separation of free oil and setteable solids is accomplished by ; gravity separation, dissolved air floation, and granular media filtration. These methods achieve removal efficiencies of 60 to 99 percent. Straw as a filter media has reported 99% removal efficiency.

Emulsified oils are broken by physical methods: heating, distillation, and centrifugation; electrical methods : attraction of charged particles; and chemical : precipiation and coagulation. These treated waters are then passes through the steps for free oil recovery mentioned above. Reduction in oil content at this step is typically 95%.

Removal of dissolved organic is usually undertaken by some form of biological treatment.

Treatment of wood preservative wastewaste by waste stabilization ponds is usually preceeded by oil-separation and collection. The pond or ponds reported for a typical size wood preserving plant have a total surface area of approximately 0.5 hectare. A five pond system with a one year retention time achieved reductions in BOD of over 99%, COD of 80% and phenol concentration over 99%. A two pond system with a retention time of eight months achieved BOD reduction of greater than 90% and phenol concentration were reduced over 99%.

Waste stabilization ponds require little capital investment and are simple and inexpensive to operate, but require a large area of land near to the plant. However, waste stabilization ponds are only suitable for climates that have warm temperatures the year round. They are not suitable for locations that experience freezing conditions.

Activated sludge system require less land than waste stabilization ponds, but require a large initial capital investment and skilled personel to operate the system. It is operational in most climates, even under strong winter conditions. Oil-separation and collection preceeds treatment by activated sludge. An activated sludge treatment plant in full operation consists of two aeration tanks and a clarifier with a detention time of 4 days. The removal efficiency of the plant was greater than 90% for BOD and COD and a more than 99% for phenol concentration.

There has been no commerical operation of trickling filters for wood preservative wastewater reported in the literature. A pilot scale plant has shown BOD reduction of 92%, COD reduction of 77% and phenol concentration reduction of over 99%. The pilot study reported good results for wastewaters from creosote preservation, but the due to the short duration time biodegradation of pentachlorophenol was low (Guo, 1978).

The increase in annual production costs for treatment of oil-borne waste waters has been estimated to range from (US$ 1980) 0.67 to 7.33 per cubic meter wastewater generated.

These estimates span a wide range of treatment alternatives and effluent qualities.

Water-borne preservative wastewaters must undergo a basic two step process:

1. Removal of dissolved metal salts and
2. Removal of dissolved organics.

Two of the main metal salts that must be removed are arsenic and chromium. Major treatment methods for the removal of arsenic from wastewaters include:

a) Complexation with a ferric salt and coprecipitation with the ferric hydroxide (chemical coagulation) followed by sedimentation and filtration of the precipitate.
b) Sulfide precipitation has been reported to achieve 80% arsenic removal. Cost estimates for the removal of arsenic by coagulation, sedimentaion, and rapid sand filtration range from US$(1980) $0.21 to $0.06 per cubic meter for daily flows of 750 m3/day and 40,000 m3/day , respectively (Carmichael, 1982).

The removal of hexavalent chromium from wastewater can be achieved by direct ion exchange or reduction to trivalent chromiun followed by precipitation. Chromium removal efficiency for the various methods are very high most in the order of 95% or above. Costs for ion exchange removal has been reported at US$(1980) 0.62 per kilogram chromate removed (Carmichael, 1982).

The removal of dissolved organics is normally carried out by biological treatment is similar to the discussion of the removal of dissolved organics from oil-borne waste above.

Air Pollution. There are two sources of air pollution in the wood preservative industry; pollution from the burning of fossil fuels to provide steam and other forms of energy and pollution from the release of the preservatives into the air. The most important source of air pollution in the wood preserving industry is the thermal treatment process. The volatile compounds containing many forms of hydrocarbon and toxic vapors from the preservatives are released into the atmosphere.

Case Study: The Northern Wood Preserver Limited, Thunder Bay, Ontario, Canada preserves a variety of wood products using steam vacuum conditioning and pressure treatment and both oil and water borne preservatives. Utility poles are processed with pentachlorophenol, railroad ties with creosote, and lumber for decks and wharfs with chromate copper arsenate (CCA). Three pressure cylinders are used, two for creosote and one for pentachlorophenol and CCA. The plant treats approximately 140,000 cubic meters of wood annually(Guo,1978).

Section III. H Surface Finishing. The main surface coatings are paints, varnishes and lacquers. The coating methods can be divided into two main groups: those that require atomization of the coating liquid and those that do not. Most coating compositions need a solvent to dissolve or fluidize the solid resins in the binder. The solvents are not wanted in the final coating film and are thus volatile liquids that are released by evaporation from the surface.

These volatiles enter the wastewater stream from rinse water from washing or chemical treatments from degreasing schedules and solvents from coating films. In addition to these wastes, wastewater is generated by spillage, washing of equipment, raw material production, and washing of wood products before finishing.

Air pollution occurs from the release of volatile products produced in the chemical reactions of curing or drying of films or from drying of the wood substrate. The use of water wash spray booths and water scrubbing of ventilated air produces wastewaster, thus converting an air pollution problem to a water pollution problem.

The USEPA has identified the furniture industry in the U.S. as the second largest single industrial source of hydrocarbon pollution in the industrial coating industry. A U.S. consulting firm has suggested that a 50% reduction Volatile Organic Carbons (VOC) could probably be achieved through the adaption of water based topcoats, wash coats, and sealers. It has been estimated that to retrofit existing plant for water based finishes would range from $300,000 to $500,000 per facility, (Wood and Wood Products, 1979). Installation at the design stage of water based finishes would be less costly and more efficient. The most serious drawback to water based finished is the consumer acceptence of a more cloudly or milky finish that is the result of water base finishes.

Section IV. Chemical Processing of Wood Products.

A. Pulp and Paper Industry. The basic steps of a pulp mill include wood preparation, pulping, screening, washing, thickening, and bleaching. The basic steps in a paper mill are stock preparation, paper machine operation, converting, and finishing. Large quantities of water are used in the paper and board making operations. The raw waste water streams from the pulp and paper industry are considered among the most serious water pollution problems facing all industry (Jones, 1973).

Waste water streams from the pulp and paper industry contain dissolved organic and inorganic material, organic and inorganic solids, toxic and oderous substances, bacteria and nutrients, (Sweden, 1981). These wastes vary considerably depending upon the type of procesing that is employed.

The Swedish principle for reducing effluent discharges from the pulp and paper industry has been that the greatest attention should be paid to internal measures to reduce waste generation (Odin, 1981). This principle has been found throughout most developed countries with major pulp and paper industries. A common characteristic of good wastewater treatment practice is the discharge to separate sewers of waste water of different strenghts and characteristics. There is no single treatment technology that can treat the many pollutants found in the pulp and paper waste streams and the wastewaters are segregated for efficient treatment. A sequence of separate treatment processes make up the treatment facility at a modern pulp and paper plant.

Air Pollution. Air pollution is a major problem that must be addressed in the pulp and paper industry. In 1977 the pulp and paper industry in the U.S. accounted for about 6% of total particulate emission(Stone,1977). Uncontrolled emissions of particulates and odors to the air from the pulp and paper industry are the most noticeable and objectionable of all the pollutants to the public and emissions of sulphur dioxide contribute to the acid rain problem. Older kraft mills were major sources of air pollution. However, modern plants can be designed to remove particulates and restrict odors(World Bank, 1980).

Case Study: The Menominee Paper Company, Inc. of Menominee, Michigan, USA was producing 250 short tons per day of linerboard and corrugated board from its machine No. 1. The volume of waste effluents exceeded the capacity of the plant's waste treatment facility resulting in large volumes of high BOD effluents being discharged to the Menominee River. The source of the high BOD was starches in the corrugated board waste (Courtney, QY79). The first step was to reduce water use by reusing process water. A 100-mesh screen was installed to reduce suspended solids from the machine discharge. The filtered water replaced fresh water at the venta-nip shower, vacuum thickener seals, primary headbox shower and the centrifugal cleaner. The total reduction in process makeup water was 3420 m3 per day with a simultaneous increase in production to 250 short tons per day. With additional reductions in water use and thus waste discharge the total plant waste could be treated by the existing treatment facility at the plant. This avoided a costly investment in the expansion of the treatment plant.

B. Chemical Production from Wood and Wood Waste and Environmental Consideration. In a recent book on the subject CHEMICALS FROM PULP AND WOOD WASTE, Maloney (1978) lists over 203 patents for processing wood and wood wastes into useful chemicals. He states that the use of cellulose, hemicellulose and lignin as a base for the production of chemicals and plastics on a wide basis is a matter of economics rather than technology. Presently fossil fuels are a more economically attractive alternative to wood and wood waste.

Section V. Wood Waste as an Energy Source

Wood waste can be considered as a fuel in two form, in direct combustion or converted to various types of gaseous, liquid, or solid fuel, with or without the production of chemical by-products. The utilization of low value wood waste for energy production provide a double benefit by not only solving a solid waste disposal problem, but providing a renewable source of energy.

Section VI. Recommendations.

(1) Proper planning and management of the forest stand is necessary to assure a long term supply of forest resources.

(2) Analysis of industrial pollution and its effect on the valuable resource and source of raw materials for the wood and wood processing industry, the forest, must be taken into account in any planning for industrial development, especially in developing countries.

(3) Oil-borne wood preservative effluents in developing countries are recommended to treated by waste stabilization ponds in new and existing wood preservative plants, since the activated sludge process requires capital and operating expenditures at least double those of an aerated lagoon system and requires more operator attention and skills. In cases where insufficient land exists for the lagoon system, activated sludge is advised.

(4)Wood finishing wastes are considered hazardous waste which requires special proceedure be employed in the final disposal of treatment effluents or solid wastes from settling or filtration.

(5) With the development of the wood finishing industry on a world wide basis it is recommended for the developing countries that settling ponds, tanks, and basins be used as an initial treatment for wood finishing wastewaters with final disposal of solids from these processes be in properly design harzardous waste dumps.

(6) The release of the volatile in the drying process is a environmental hazard in the form of air pollution and worker safety. Most solvents are toxic in the vapor-air mixtures that are inhaled. It is therefore important to have proper ventilation and require respiratory masks for workers.

(7) The present emission of Volatile Organic Carbons (VOC) in the US in furniture spraying operations is 250 to 300 pounds per 1000 square feet of product. It is recommended that this emission be restricted to a maximum of 120 lbs per 1000 square feet in industrial countries and that developing countries aim for the 250 to 300 target.

(8) The following methods are recommended for the reduction of VOC emission from the wood finishing industry:

1)Use of higher solid finishes applied via hot spray.

2)Airless and electorstatic spray application, which is report to emit less VOC.

3)Use of water wash spray booths and enclosed spray booths.

4)Carbon absortion and/or incineration systems to selectively decrease volatile organics.

(9) Pulp and paper effluents in developing countries are strongly recommend to be treated by aerated lagoon systems for the secondary treatment process in new and existing pulp and paper mills, since the activated sludge process requires capital and operating expenditures at least double those of an aerated lagoon system and requires more operator attention and skills. In cases where insufficient land exists for the lagoon system, activated sludge is advised (World Bank, 1980).

(10) Recommendations for the reduction of odurous emission from Kraft pulp mills are:
1)collecting and incinerating non-condensable gases;
2)proper sizing and design of the recovery furnace; and
3)installing exhuast hoods and incinerating or collecting odorous gases.

(11) Sulphur dioxide emissions and particulate emissions from kraft and mechanical pulping mills should be reduced by scrubbing exhuast gases and efficiently designing the power and recovery furnaces. Also the use of low sulphur fuels and fuel preparation for efficient burning are also recommended to reduce sulphur dioxide emissions.

Introduction

The wood and wood processing industry covers a wide spectrum of economic activities in the transformation of raw materials to final products. Wood, the raw material for the industry, is considered an agricultural product. The management of forests and the commercial cutting of trees to provide raw material for the wood and wood processing industry is not part of the UNIDO mandate for industrial development. The UNIDO "World Wide Study of the Wood and Wood Processing Industry" therefore has placed an emphasis on the mechanical and chemical processing of wood. In this report on the "Environmental Aspects of the Wood and Wood Processing Industry" a description of the general envionmental problems facing the entire industry provides a complete picture into which the specific problems to be addressed by UNIDO can be put into perspective. This report emphasizes the mechanical and chemical processing of wood. but focuses most attention on the wood preserving and wood finishing processes. The report will provide an overview of the environmental problems facing the various processes of the industry and will describe treatment alternatives.

Section I. Impact on the Forest Ecosystem from Logging Operations

A. Forest Stands. Logging and forest management effect the forest stands in two ways: 1) The cutting of trees for commercial use disturbs the forest stand by changing the forest structure 2) The introduction of new species or the selective elimination of species alters the species composition of the forest stand. The logging of a favored species can have drastic effects as demonstrated in the mixed wood forests of Maine, USA. Successive waves of logging over the past 100 years , each wave concentrating on as different species, have greatly modified the composition of the forests of central and northern Maine from what they were over 100 years ago (Spurr and Barnes,1980).

When a wood or wood processing industry is planned for a region the local forest may be a source of the raw materials. Proper planning and management of the forest stand is necessary to assure a long term supply of the species of tree needed for the given products. Tree plantations are one method to supply a selective species for processing.

B. Land Systems. The soil and forest systems are very closely linked. The soil provides a medium for the forest to grow and the forest through its root system and protective canopy protects the soil and keeps it in place. The disturbance of this balance by logging operations may permanently destroy this delicate balance. Careful planning must be taken before the choice of logging strategy, (partial or clear cuts) to avoid irreversible damage. The actual choice of cutting pattern must take into account the soil type, forest stand, the climate and expected yield to avoid such problems as erosion, soil chemistry change, and soil compaction.

C. Water Systems. In general, reduction of forest cover cover increases streamflow while establishment of forest cover on sparsely vegetated land decreases it. The form of cutting can have an effect on water yield as well. Large clear cutting of forest can lead to floods and also change the dynamics of surface runoff due to effects on groundwater flow and evapotranspiration of precipitation. Forest cutting may adversely affect water quality by causing erosion. Increased suspended sediments in the stream and a change of the water chemistry may result. The additional sediments can lead to premature siltation of a reservoir, for example one economic development project may therefore be conterproductive to the objectives of another. This problem is illustrated by the following two case studies.

The Anchicaye Hydroelectric Project in Colombia was designed to provide 64,000 kilowatts of electricity to the city of Cali. The project was begun in 1944 when there was few settlers and little development in the steeped walled canyon of the Anchicaye reservoir site. The Simon Bolivar Highway, under construction at the time of design may made cuts into the steep canyon causing severe land slides. The completion of the highway incouraged settlers to the river basin and led to deforestation of the jungle. These developments led to a major sedimentation problem in the river due to soil erosion. The reservoir was completed in 1955 and with 21 monthsd 25% of the storage capacity was lost due to siltation. By 1967 80% of the storage capacity had been lost and was expected that within a short period of time that the power tunnel would be completely blocked making the power plant totally useless. A new resevoir planned for upstream on the Anchicaye river included in the project a plan for watershed management and control of deforestation by limiting the settlement and clearing of forest in the river basin (Carmichael, 1974).

Sukhna Lake, a multipurpose reservoir in Chandigarh, India, lost over 70% of its storage capacity in the first 20 years of it life. The lake, fed by streams from the foothills of the Himalyas, was rapidly filling with silt with over 80% of the sediment coming from only 20% of the basin. The source of the unexpected sedimentation problem was erosion in the upper parts of the basin due to deforestation from over grazing and harvesting of wood for fuel. A small scale watershed management project to provide for increased productivity of the eroded forest and agricultural lands was undertaken in a sub-basin area. In conjunction with the introduction of more efficient wood stove, the project has been successful in reducing the amount of sediment leaving the sub-basin, increaseing agricultural productivity, and reforestation of the catchment. This approach is now being introduced throughout the upper parts of the basin as a forest management approach to the reservoir siltation problem (ICAR, 1980).

Forest management is becoming an important tool in water resource management through the world in all climatic regions.

D. Air Systems. The atmosphere and the forest also form a synergystic equilibrium. The air provides the carbon dioxide and the precipitation needed for forest growth. Forest cover acts as a filter for many air-borne pollutants. Excessive cutting of forest removes this filtering source and creates addition particulates from wind erosion. Forests are an important part of the Carbon Dioxide cycle. In the process of photosynthesis, the trees of the forest stand take in Carbon dioxide and transform the carbon into cellulose and other carbon-based polymeric structures. The natural processes of shedding of leaves and decay of fallen wood allow this carbonaeous material to be incorporated into the forest floor, thereby enriching the soil. Deforestation can contribute to a greater Carbon Dioxide content in the atmosphere which may result in global warming.

Flohn (1980) states that a doubling of the current Carbon Dioxide content of the atmosphere would result in a 3 degree

C warming at the low and mid latitudes and a 5- 10 degree warming at the polar regions. This warming would result in melting of the Artic sea ice, raising ocean levels and affecting global climate. It has been estimated that at present rates doubling of the Carbon Dioxide concentration could take place between 2040 and 2050.

Wind is very important to a forest due to its destructive power. An even greater problem than major wind storms is the breakage and windfall due to normally harmless winds. Local acceleration of wind due to clear cutting can turn moderate winds to destructive force. The configuration of the cut and the local topography is more important than the size of the cut in producing destructive winds. Proper planning of harvest cutting can greatly reduce the problem. Solutions to the problem include portion cuts that leave residual stands or cutting of successive strips (Spurr and Barnes, 1980).

E. Logging for Energy Use. The cutting of forest stands for energy is an ancient endeavor. The use of the forest as a renewable source of energy is in conflict with the growing demand for wood and wood products. Additionaly, large scale use of wood as fuel, especially in industrial boilers, could effect forest soil nutrient and carbon budgets reducing forest productivity. Logging for fuel usage employes whole tree chipping which utilizes the entire tree including the leaves. Historically, logging has left behind wood material containing high concentrations of nutrients, so nutrient depletion was not a problem (The Conservation Foundation, 1982).

Priority and management strategies need to be establish to allow for the most efficient utilization of forest resources.

F.Transport of Wood To Processing Sites

Forests are the source of raw material for the wood and wood processing industry. This requires that infrastructure be developed to transport the wood to the processing sites. The development of the infrastructure and the tranportation of the wood has a greater potential environmental impact than the processing of the wood (World Bank, 1980).

Improper logging and road building can lead to soil erosion, soil compaction and loss of soil nutrients. Wood is transported by rail. truck, flume, and river. River transport can be by tug and barge or by "river drives". River drives can cause major environmental damage. They litter the stream with branches and bark, contributes to bank erosion and stripps soil cover along river banks causing decreases in dissolved oxygen content and increase turbidity in the stream (Stone, 1978 and World Bank, 1980).

The non-river modes of transport can be contributors to air pollution. Rail and trucks contribute hydrocarbons from combustion engines to the atmosphere with trucks also a source of dust.

II. Impacts on Forest Ecosystems of Non-Wood Related Industry

"Acidification of lakes and soils is judged by the Swedish pulp and paper industry to be one of the most serious environmental problems today. The acidification leads to dead lakes and may also lead to a decrease in forest growth or damage to trees(Braennland,1982)."

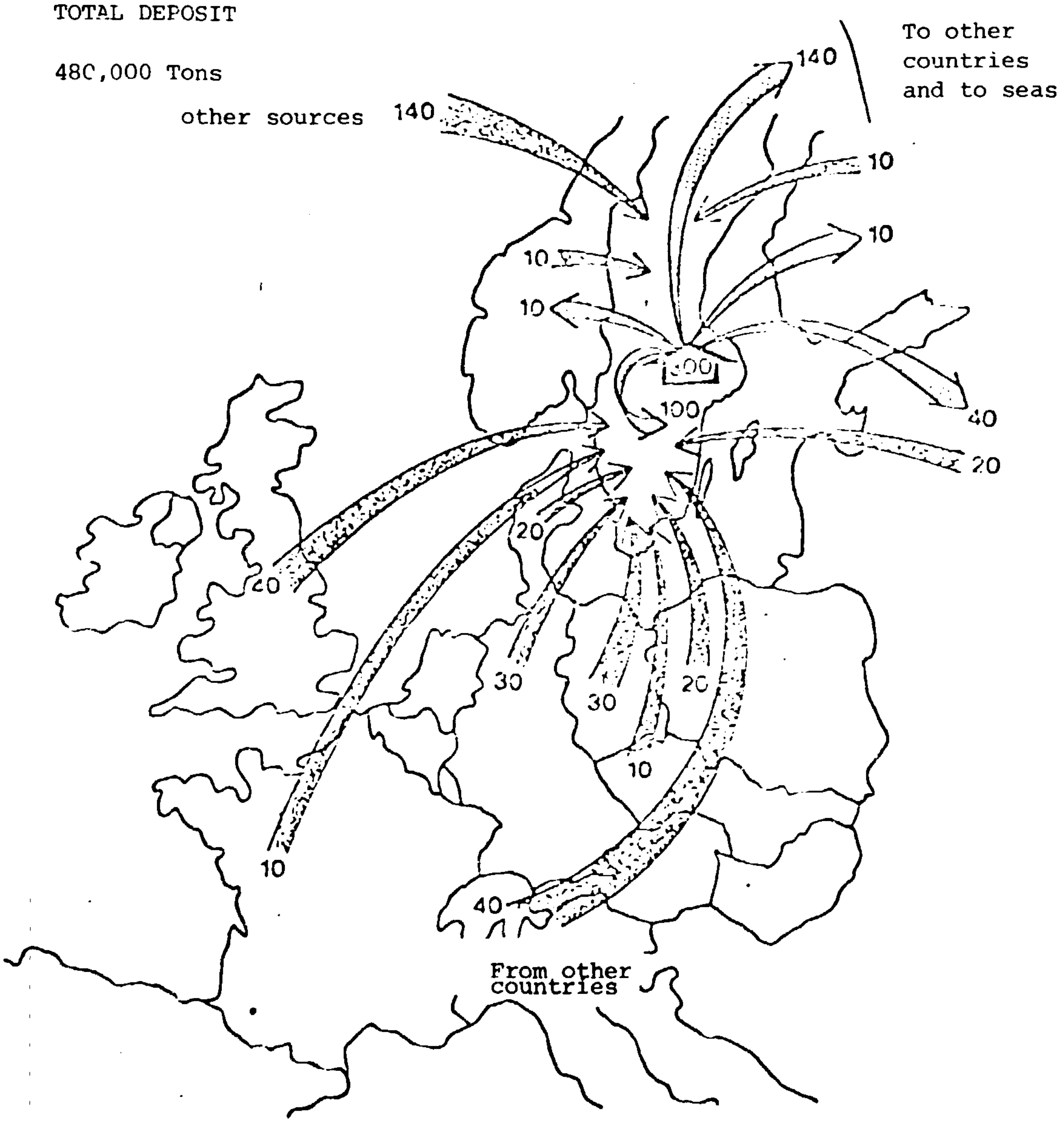
The major part of the sulphur dioxide (70 to 80%) comes from outside Sweden. Figure II-1 illustrates the long range transport of industrial sulphur dioxide emissions over Europe which are deposited on the forests of Sweden in the form of acid rain. In Sweden itself urban heating and energy production (using oil) are the most important sources of sulpur dioxide with the pulp and paper industry's share quite small.

Recently it has been suggested that the acidification of

Figure II-1. The Sulphur Exchange Between Sweden and Surrounding Countries

TOTAL DEPOSIT

480,000 Tons



Source: Sweden, 1981

forest soils is releasing normally insoluable metals, especially aluminium, allowing the metals to be taken up by the roots where they can become toxic or lethal(merow,1982).

Vegetation injury and soil degradation due to heavy metal accumulation may cause more damage than sulphur dioxide. Fluoride has been responisble for wide spread mortality of conifierous trees near smelters, refineries, and power plants in the U.S. and Europe. Smog from Los Angeles, California, USA, blown 130 Kilometers east to the pine forest of San Bernardino, California, has caused neddle drop, decreased growth and death. Those trees not killed are more suseptible to the pine bark beetle (Barnes and Spurr, 1980).

Care must be taken when planning industry that their pollutant will not have an effect on the valuable resource and source of raw materials for the wood and wood processing industry, the forest.

Section III. Mechanical Processing of Wood Products

A.Sawmills. Sawmill operation preceed most other steps in the wood processing Industry. Sawmill processes include debarking, cutting and shaping raw timber. These processes produce various types of waste that contribute to air and water pollution.

Hydraulic and wet drum debarking produce little to no air pollution, but the water uses in the bebarking process becomes contaminated with dirt, wood chips, and organics. The water can be treated by settling and then recycled with some blow-down to avoid fouling. The blow-down contains high levels of organics and may be a potential water pollution problem depending on the characteristics of the receiving water.

A plywood plant in the U.S. that produces 9,300,000 sq. meters of plywood per year employs a wet barking process. The average effluent from the barking process is 13,100 Kg/day of suspended solids and 600 kg/day of BOD. A treatment plant was built to treat the barking and other wastes. The treatment plant was composed of a clarifier, primarily for the barking wastes and an activated sludge process, that received the effluent of the clarifier and other wastes from the plant. The treatment plant achieved a 95% reduction in BOD and at 1980 prices amounted to an annual cost of $423,222 for investment and operational expenses (See Appendix A.).

Mechanical and dry drum debarking produce particulate matter which if uncontrolled could pose a local air pollution and worker health harzard. Dry debarking usually is preceeded and followed by log washing to remove dirt, sand and stones. This wash water is low in volume and after removal of sand is usually recycled.

The cutting and shaping operations create sawdust, wood chips, and particulate matter. If uncontrolled these wastes can pose a local air pollution and worker health hazard. Air handling equipment for the collection of air-borne particulates from saw-mill processes is available to greatly reduce the problem.

Sawmill wastes not collected end up as debris in the plant or surrounding grounds. In the past this debris was flushed to a sewer and dumped into a local water body. The load of organics in this waste water has the potential to be a major pollution source. It is possible to collect a large portion of the debris reducing the amount that must be flushed. With appropriate design and careful operation, the effluent load from sawmills can be reduced almost to zero (World Bank, 1980) If the amount of waste remaining in the waste water is still a pollution threat then a treatment plant can be added . The collected sawdust and wood chips that are not utilized for other purposes (see Sections IV.B and V) are sometimes burned posing a potential air pollution problem.

B.Wood Drying Operations. There are two basic wood drying process, natural air-seasoning and kiln-drying. Natural air-seasoning contributes very little to air or water pollution. Some volatile compounds from the water are given off to the air and runoff from precipiation may carry some organics to the local waters.

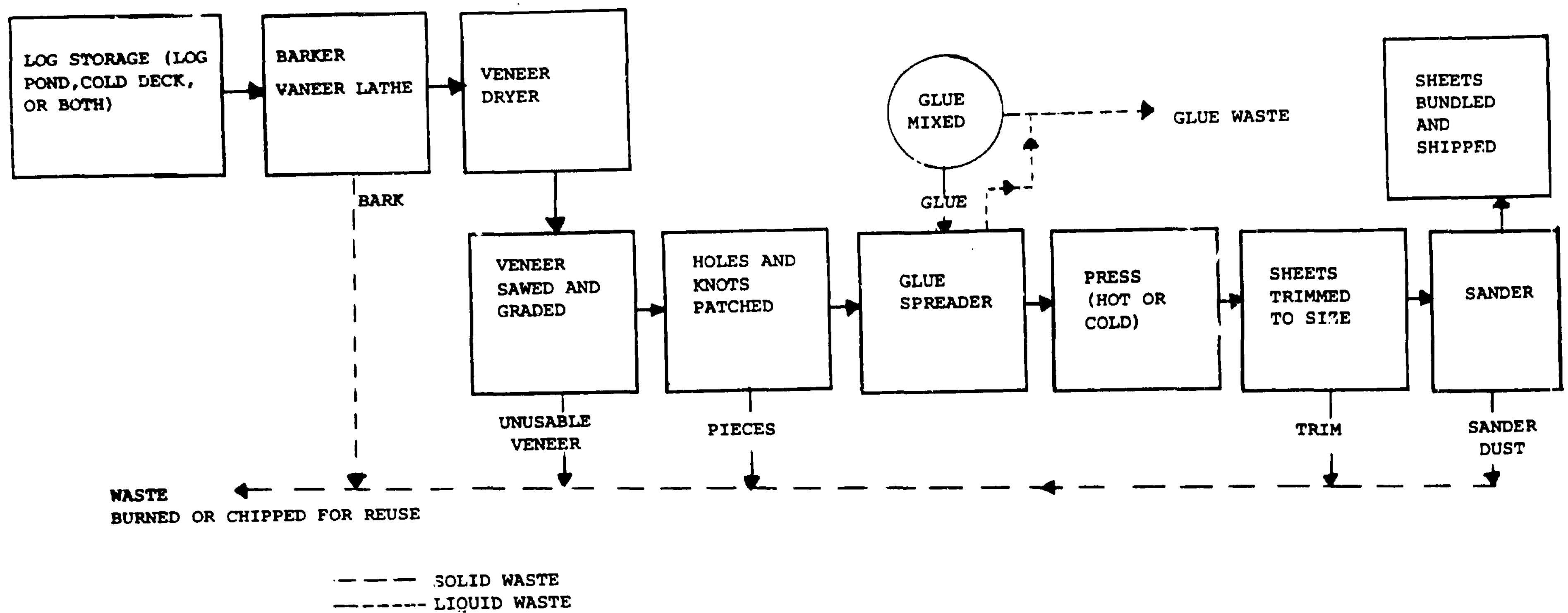
The kiln-drying process uses fuels to provide the heat for drying and air pollution is associated with the combustion of these fuels. Water is used for cooling in the kiln-drying system and can be a source of thermal pollution.

C.Veneer Industry. The direct production of veneer wood products causes little air or water pollution. However, the barking process which preceeds the veneering process is a source of water pollution and must be addresses,(See Section A. Above).

D.Plywood Industry. The plywood industry is divided into two parts: 1) The green end encompasses drying, barking and veneering. These have been discussed above. 2) The glue end produces final products from veneers. This process is illustrated in figure III-1. The plywood industry is also divided by type of wood used, softwoods or hardwood. The softwood plants larger than hardwood plants and thus produce

FIGURE III-1

PLYWOOD PLANT FLOW DIAGRAM



Source: Nemerow, 1978

more wastes.

Air pollution is generated by the release of volatile chemicals from the glues and resins used, particularly formaldehyde and pentachlorophenol. Sawdust from the sanding process, if not contolled can contribute to air pollution and worker health hazards.

The washing of the glue-mixing and applying equipment produces a small volume of highly concentrated wastes. Plywood wastewaters contain some glue solids and wood particles, phenols, phosphates, nitrogen and high pH. The solids are treated by settling ponds or septic tanks. The dissolved organics and chemcial wastes can be treated by municipal treatment or incineration. Incineration is a very costly alternative (Nemerow, 1978).

For a softwood plywood plant producing 9,300,000 sq. meters of board per year the USEPA studied alternative treatment methods to treat the liquid effluents from the gluing process.

Alternative A. Complete recycling of glue waste and reuse in glue preparation.

Alternative B. In addition to alternative A, the complete retention of waste water from log conditioning.

Alternative C. Alternative B plus the complete retention of the dryer wash water.

The performance of these alternatives for glue wastes and the 1980 total annual investment and operational costs which includes the annual costs from treating the green end wastes as well are presented below (See Appendix A.)

Alter.	% BOD Removal	% SS Removal	% Phenol Removal	Total Annual Costs (1980 US$)	TAC as % of Product Value
A	15.8	6	64	433086	1.1
B	99.3	96.8	72	439691	1.1
C	100	100	100	442691	1.1

For a hardwood plywood plant producing 464,500 sq. meters of board per year the USEPA studied alternative treatment methods to treat the liquid effluents from the gluing process.

Alternative A. Complete recycling of glue waste and reuse in glue preparation.

Alternative B. Treatment of the log conditioning waste by a waste lagoon.

Alternative C. Treatment of the log conditioning waste by activated sludge.

Alternative D. Complete retention of the dyer wash waste.

These alternatives are separate processes treating only the processes described. They can be added together to form a complete system.

The performance of these alternatives and the 1980 total annual investment and operational costs which include the costs of treating green end wastes are presented below (See Appendix A.).

Alter.	% BOD Removal of process BOD	Total Annual Costs (1980 US$)	TAC as % of Product Value
A	100	424256	33
B	30	425097	33
C	90	446912	35
D	32	423330	33

E.Particle Board Manufacturing. The particle board industry uses chips and wood waste from the other branches of the wood processing industry. These chips are then glued and pressed to form various board types. The water pollution problem is similar to that of the plywood industry with the washing of glue mixing and applying equipment. The waste waters are treated similarly.

The air pollution problem in the particle board industry is more acute than the plywood industry. Particle board adhesives use more formaldehyde than plywood adhesives thus leading to a problem of free formaldehyde emission from the product after installation in the consumers home or office. Formaldehyde is suspected to be a carcinogenic material so strict limits are now being applied to reduce the emission of free formaldehyde in the manufacturing process and in the finished product.

Table III-1 Formaldehyde exposure limits in Europe

COUNTRY	EXISTING LIMIT (parts/million)	PLANNED LIMIT (parts/million)
Denmark	0.96	0.32
Finland	2.0	1.0
Norway	1.0	no change
Sweden	1.0	0.5
Netherlands	2.0	no change
United Kingdom	2.0	no change
Belgium	2.0	no change
F.R. Germany	1.0	no change
Switzerland	1.0	no change
Italy	1.0	no change

Source: Ogle, 1982

The free formaldehyde emission can be controlled by reducing the amount in the glue , but then moisture content, pressing time and temperature must be altered resulting at present in a more costly production process. Iso-cynate based resin has received much research by the particle board industry as a replacement to formaldehyde based resins (Ogle,1982).

F : Fiberboard Manufacturing

The fiberboard industry requires the pulping of wood to produce the raw fibers. There are two processes used in the fibreboard industry , the wet process and the dry process. The wet process is faced with environmental aspects similar to those from the pulp and paper industry which is discussed in detail in Section IV.A.

Fiberboard manufacturing produces additional organic waste to the wastewater stream due to the adhesives used. The waste water contains 40% of the organic material in solution with the remaining 60% as suspended organics or wood fibers. Biological treatment of the wastewater is possible, but nutrient balance must be adjusted or fiberboard wastes mixed with municipal wastes before treatment. It is suggested to reduce BOD from the wastestream by using phenolic resins to aid in coagulation (Joergenson, 1979).

A dry process fibreboard plant in the U.S. producing 227,000 kg/day with a liquid waste of 0.945 cubic meters per day addressed its wastewater problem by providing for the complete retention of the cauldron washwater. This treatment resulted in 100% reduction of wastes and required a total annual investment and operational cost of 1980 US$ 11,319 less than 1% of annual production value.

The USEPA studied alternative treatment process for a wet process fibreboard plant producing 127,000 kg/day of fibreboard and generating 1432 cubic meters per day of liquid waste.

Alternative A. Screening and Primary Clarification.

Alternative B. Screening and Primary Clarification with activated sludge.

Alternative C. Screening and Primary Clarification with a waste lagoon.

Alternative D. Screening and Primary Clarification with Activated Sludge followed by final treatment by waste lagoon.

The performance of these alternatives and the 1980 total annual investment and operational cost are presented below (See Appendix A.).

Alter.	% BOD Removal	% SS Removal	Total Annual Costs (1980 US$)	TAC as % of Production Value
A	10	75	90,520	1
B	90	69	791,120	12
C	80	69	434,000	6
D	95	69	954,800	14

Section III. G. Wood Preserving

The wood preserving industry plays an important role in the infrastructure of any economy, especially economies in a developing stage. The transport, communications, and construction industries all rely heavily on products produced by the wood preserving industry. Railroads depend on wooden railroad ties that are treated with preservatives. Railroad and road networks employ preserved wood for the construction of bridges and other major structures. Telecommunication networks use wooden "utility poles " that must be treated with preservatives. The construction industry requires preserved wood products for many applications, especially in humid and tropical climates. Agriculture also uses large amounts of treated wood, eg. Fence posts, storage bins, irrigation and water management structures. The importance of using preservatives to prolong the life of the wood is two fold. First preserved wood lengthens the life of the structure and reduces needs for maintenance. Secondly the long life of preserved wood means that time is available for a replacement tree to be grown,(Reynolds, et al, 1976).

Wood preservatives fall into two broad categories:(1) oil-borne and organic solvent treatments and (2) water-borne treatments. The preservatives that are presently in frequent use in group 1 include pentachlorophenol in various solvents, creosote and creosote-coal tar solutions, and copper naphthenate. Group 2 preservatives include waterborne salts such as copper-chrome-arsenate (CCA) and ammonical copper arsenate (ACA) systems.

The oil borne and organic solvent preservatives are the most widely used. In the U.S. in 1978 creosote was used for approximately 53% of all wood products treated. Creosote leaves a very dark color and a strong odor. It is primarily for external uses such as railroad ties, utility poles, timbers, piling, industrial lumber and fence posts,(Smith, 1978). Pentachlorophenol produces a much lighter finish than creosote but leaves an oily surface. It is used for utility poles, farm lumber and fence posts. However, if used with a liqiud petroleum-gas solvent pentachlorophenol will not leave an oily surface. "Clean" pentachlorophenol is used for treatment of windows, doors, plywood, and utility poles, (Arsenault,1978). Copper naphthenate is used as a retail wood preservative sold to the public primarily for greenhouses and pleasure boats, (Smith, 1978).

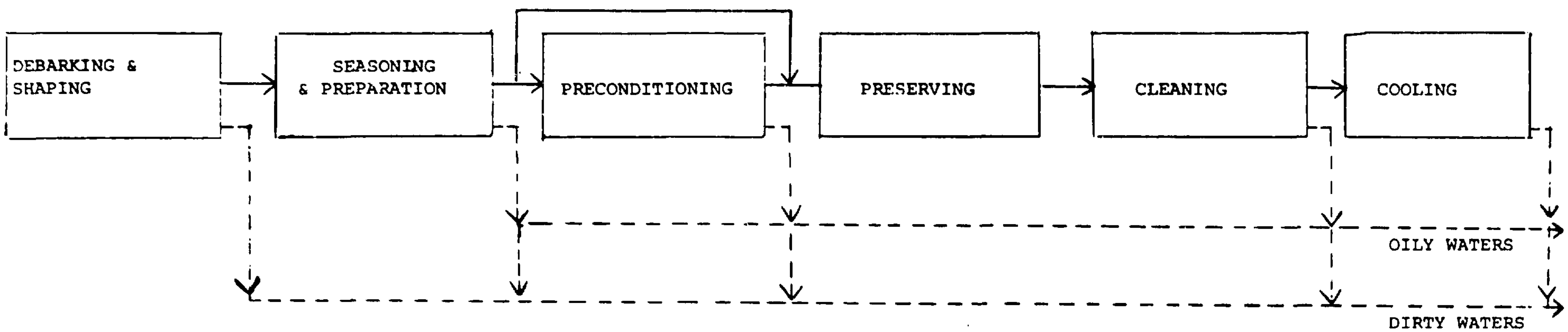
Water borne treatments are popular for applications where it is necessary to paint wood after treatment or where odors from oil-borne treatment are unacceptable such as public buildings or private homes. Water borne salts become fixed in the wood allowing for wide marine application because pilings treated with water borne salts are totally resistant to marine borer attack. The most prominent water borne salt preservatives, CCA and ACA, accounted for 16% of the total treated wood in the U.S. in 1974. In CCA the reduction of hexavalent chromium to the trivalent state by the wood substance is accompanied by a fixation of arsenate in the wood. The copper is fixed by an ion exchange mechanism. In ACA the evaporation of the ammonia solubilizing agent is accompanied by copper fixation to the wood via ion exchange and copper arsenate precipitation in the wood cells (Arsenault,1978). The use of the water borne salts is increasing (Smith, 1978).

Industrial wood preservation accounts for the majority of wood treatment. Preservation is carried out by impregnating wood with preservatives by either a thermal process, a pressure process, or both. The choice of treatment depends upon the relative preservation effectiveness and effect upon the physical properties of the wood.

The environmental impacts of the wood preserving industry depend not only on preservative chosen, but also on the choice of the wood conditioning process and the process chosen by which the wood will be treated. Figure III-2 is a flow chart of the basic steps in the wood preserving process. In addition the alternative sub-processes are listed. Proper choice of the conditioning and treatment

FIGURE III-2

TYPICAL PRESSURE WOOD PRESERVING PROCESS FLOW CHART



WASTEWATERS:	RINSE WATER COOLING WATER WOOD CHIP SLURRY	SAPWATER CONDENSATE CONDENSED VAPORS	CONDENSATE SAPWATER CONDENSED VAPORS		CONDENSATE CONDENSED VAPORS	RUN-OFF
SUBPROCESSES:	DRUM BARKERS RING BARKERS BAG BARKERS CUTTERHEAD BARKERS HYDRAULIC BARKERS	AIR SEASONING KILN DRYING STEAM-VACUUM CYCLING BOULTONIZING VAPOR DRYING TUNNEL CRYING MECHANICAL PREPARATION	CLOSED STEAMING OPEN STEAMING LOADING AND SEALING CYLINDERS	FULL CELL EMPTY CELL LP CAS	FLASH STEAMING FINAL VACUUM	ATMOSPHERIC IN-SITU UNLOADING

Source: Reynolds, et al, 1976

sub-processes can greatly reduce environmental harm. A brief description follows of the major conditioning alternatives and the two major treatment processes.

Conditioning

Fresh cut wood after debarking has a high moisture content. This water must be removed for effective treatment with preservatives. Two conditioning methods, "air seasoning" and "kiln-drying", are used mostly in conjunction with treatment by water-borne preservatives. Air seasoning involves the natural drying of wood out of doors. When the wood is kiln-dryed it is placed in an oven at 150-220 degrees F and dried to proper moisture content, (Reynolds, et al, 1976). "Steam vacuum drying" takes place in a pressure vessel and is primarily used (followed by treatment) with oil-borne preservatives, although it can be used with water-borne preservatives. There are two types of steam vacuum drying; open steaming and closed steaming. In open steaming, steam is introduced to a pressurized kiln. Condensate which contains contaminants is continuously withdrawn. After sufficient heating a vacuum is applied to bring about a net reduction in the moisture content of the wood. In closed steaming water is put in the bottom of the vessel and steam is generated by the heating of the water. The condensate continuously returns to the bottom of the vessel. A vacuum is applied to remove excess moisture from the wood, and then the contaminated water is emptied. Separable oils are removed, and then recycled for use with the next batch.

The last major conditioning alternative is "boiling under vacuum" (BUV) or "Boultonizing". BUV is only applicable for use with an oil-borne preservative process and acts as a pre-treatment process as well. The wood is placed into a pressure vessel and completely cover by the preservative solution. The solution is heated and a vacuum applied. The low pressure and high temperature allow the water in the wood to evaporate and be removed by the vacuum. The vapor that is withdrawn contains not only the excess water vapor, but also volatile compounds from the preservative solution and other contaminants from the wood itself (Richardson, 1978).

Treatment Processes

There are two alternative treatment process for the impregnation of preservatives into wood, the thermal and the pressure processes.

The thermal process entails loading open horizontal tanks with air-seasoned or kiln-dried products. The wood is secured to prevent floating and then the tank is filled with heated oil-borne preservatives at temperatures of 200 to 235 degrees F. The wood remains completely submerged for 6 or more hours while the air in the wood becomes heated causing it to expand. The tank is then emptied of the heated solution and is immediately filled with a cold solution at about 100 degrees F. The cooler solution causes the air to contract in the wood's cells producing a partial vacuum that draws the preservative into the wood (Arsenault,1978).

The pressure process involves charging a pressure vessel with pre-conditioned wood. The pressure vessel is usually a cylinder 1-3 meters in diameter and up to 35 meter long. The wood is placed on trams and rolled into the cylinder. The cylinder is then filled with preservative, oil or water borne, and pressure is applied to force the preservative into the wood. The pressure, steam or mechanical, is applied from 1 to 12 hours at pressures of 90 to 200 psi and temperatures of 175 to 225 degrees F. The pressure process has two variations, the empty cell and the full cell processes (Reynolds et al, 1976).

In the empty cell treatment only the internal walls of the wood's cell are covered. This is accomplished by pressuring the cylinder with air before the preservative is added. Thus when the pressure forces the preservative into the wood, the air is forced into the center of the wood. When the pressure is released the trapped air forces the preservative out of the wood cells leaving only the interior walls coated. This utilizes less preservative and is sufficient for such products as utility poles, fence posts, railroad ties and lumber.

By not pressurizing the cylinder before adding the preservative, less air will be trapped in the wood and more preservative will remain. In the full cell treatment , a vacuum is applied to the cylinder , so very little air is trapped in the wood and the preservative fills most of the wood cells. This treatment processes is necessary for marine pilings, dock timbers and wood that is exposed to severe conditions.

Environmental Consideratios

There has been a great deal of study in the past years about the dioxin content of pentachlorophenol and its environmental impact. The Swedish government has banned the use of pentachlorophenol as a wood preservative. In addition three European countries have banned wood preservatives containing arsenic. It is felt that chromium-containing preservative will be the next to come under close environmental scrutiny.

The commerically available wood preservatives discussed above, act to prevent wood degradation by making the wood substance toxic to micro-organisms and wood boring insects. An alternative to this approach is to chemically modify the wood substance making it unrecognizable to the degrading organisms. Acetylation of wood is being examined as a commercially viable nontoxic wood preservative (Kumar, 1981).

Water Pollution

Water use for wood preservative is rather small and thus the resulting volumes of effluents small as well. The waste characteristics and volume of effluent discharges depend greatly on the type of preservative being used , the conditioning process and the treatment process. Together these waste can cause toxicity, deplete dissolved oxygen, turbidity and effect taste, color, and odor of the receiving water.

Figure III-2 lists the waste water associated with the wood preserving process. The problems associated with debarking and shaping have been discussed above in Section III.A. This section will focus on the problems unique to wood preservation. As can be seen in Figure III-2, the primary water pollutants comes from condensate and condensed vapors in the conditioning and treatment steps. The choice of conditioning process and treatment process can effect the volume and characteristics of the wastewater. Following is a qualitative description of the pollutants in the condition and treatment processes.

Boiling Under Vacuum:The condensate contains moisture from the wood,which is contaminated with volatile oils, phenols, and entrained preservative solutions.

Open Steaming:The condensate that is continually withdrawn is contaminated with preservatives from previous treatment processes in the same pressure vessel, usually oil-borne, and wood extractives primarily carbohydrates. During the continuous withdrawal of the condensate emulsions are formed.

Closed Steaming:The condensate is removed at the end of the steaming process containing the same contaminants as opening steaming, but due to the emptying via a large pipe the emulsification process is limited (Richardson, 1978).

Thermal Treatment: Tank washing and spillage.

Pressure Treatment:Condensate from final vacuum to remove excess preservative (Richardson,1978).

Waste producing steps that are common to both conditioning and treatment are spillage of preservatives, dripping of treated wood on removal from the cylinder, piping leaks, surface runoff from outside storage of treated wood, and cleaning of the cylinders.

Table III-2 lists quantitative data on the range of pollutant concentrations found in oil- and water-borne wastewaters from treatment plants in Canada.

TABLE III-2

Reported Characteristics of Wood Preserving Wastewaters from Oil-borne and Water-borne Preservative Treatments

Parameter (1)	Oil-Borne (2)	Water-Borne (3)
Flow,gpm	1-45	20-50
COD, mg/l	900-110,000	1,700-4,100
BOD_5, mg/l	350-26,800	-
Phenols, mg/l	13-2,350	1.0-30
Oils, mg/l	6-3,060	-
Dissolved Solids, mg/l	243-18,350	-
Suspended Solids, mg/l	8-1,844	-
pH	2.1-7.4	5.0-5.3
Copper (Cu), mg/l	-	0-170
Chromium (Cr), mg/l	-	375-475
Arsenic (As), mg/l	-	180-300
Fluorine (F), mg/l	-	590-740
Phosphates (PO_4), mg/l	-	640-820
Ammonia (NH_3), mg/l	-	1,260-1,340

Source: Reynolds, et al, 1976

Treatment of Wood Preservative Wastewaters

Figure III-3 lists the treatment processes employed for the two types of wood preservatives. The three primary steps for treatment of oil-borne preservative wastewater are:

1.Primary Separation of free oil and settleable solids,

2.Removal of Emulsified oil and suspended solids, and

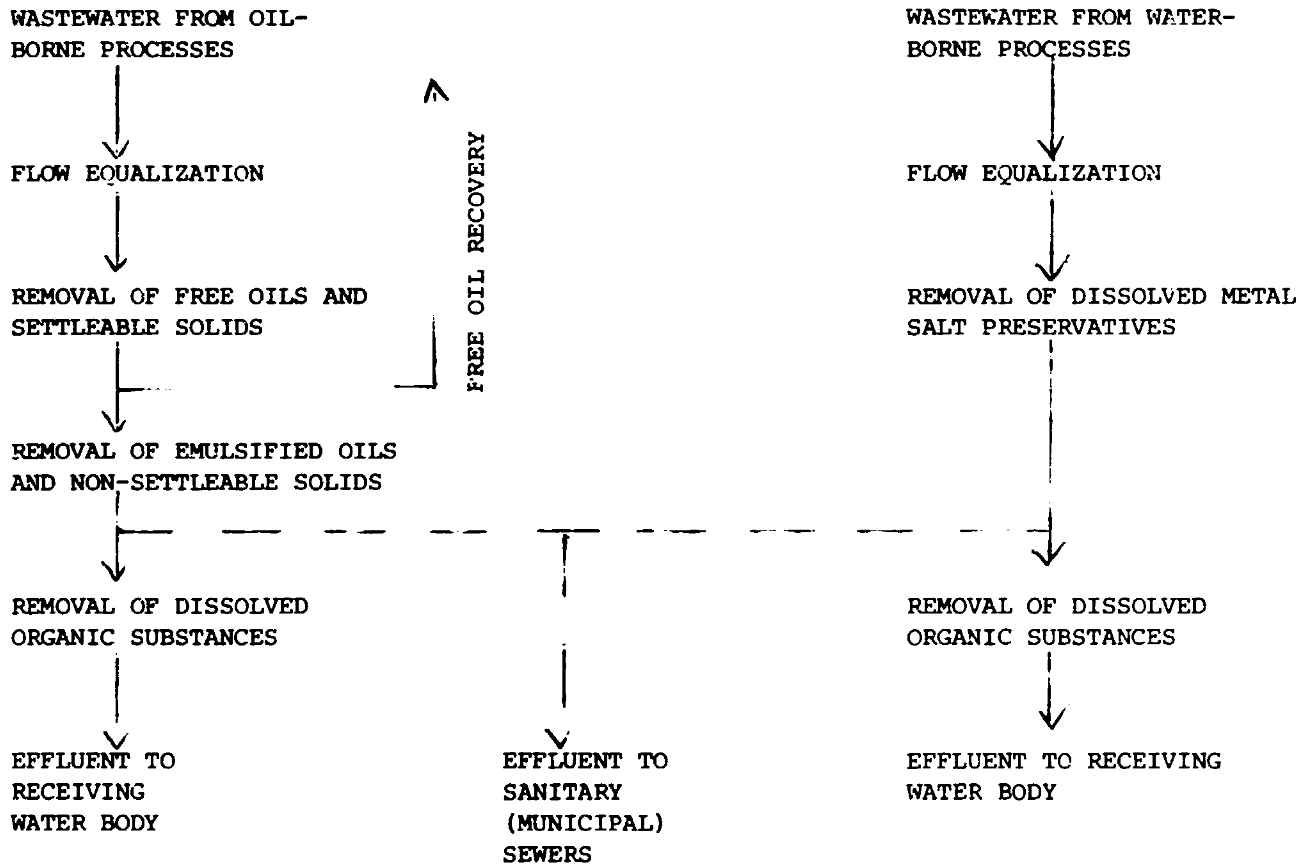
3.Removal of dissolved organics.

Figure III-4 illustrates the possible options available at each step. The removal of dissolved organics is usually accomplished by biological treatment. The biological treatment processes that have been successfully employed to treat oil-borne wastewater are waste stabilization ponds, activated sludge systems, and trickling filters(Averill, 1978).

Treatment of wood preservative wastewaste by waste stabilization ponds is usually preceeded by oil-separation and collection. The pond or ponds reported for a typical size wood preserving plant have a total surface area of approximately 0.5 hectare. A five pond system with a one year retention time achieved reductions in BOD of over 99%, COD of 80% and phenol concentrations over 99%. A two pond system with a retention time of eight months achieved BOD

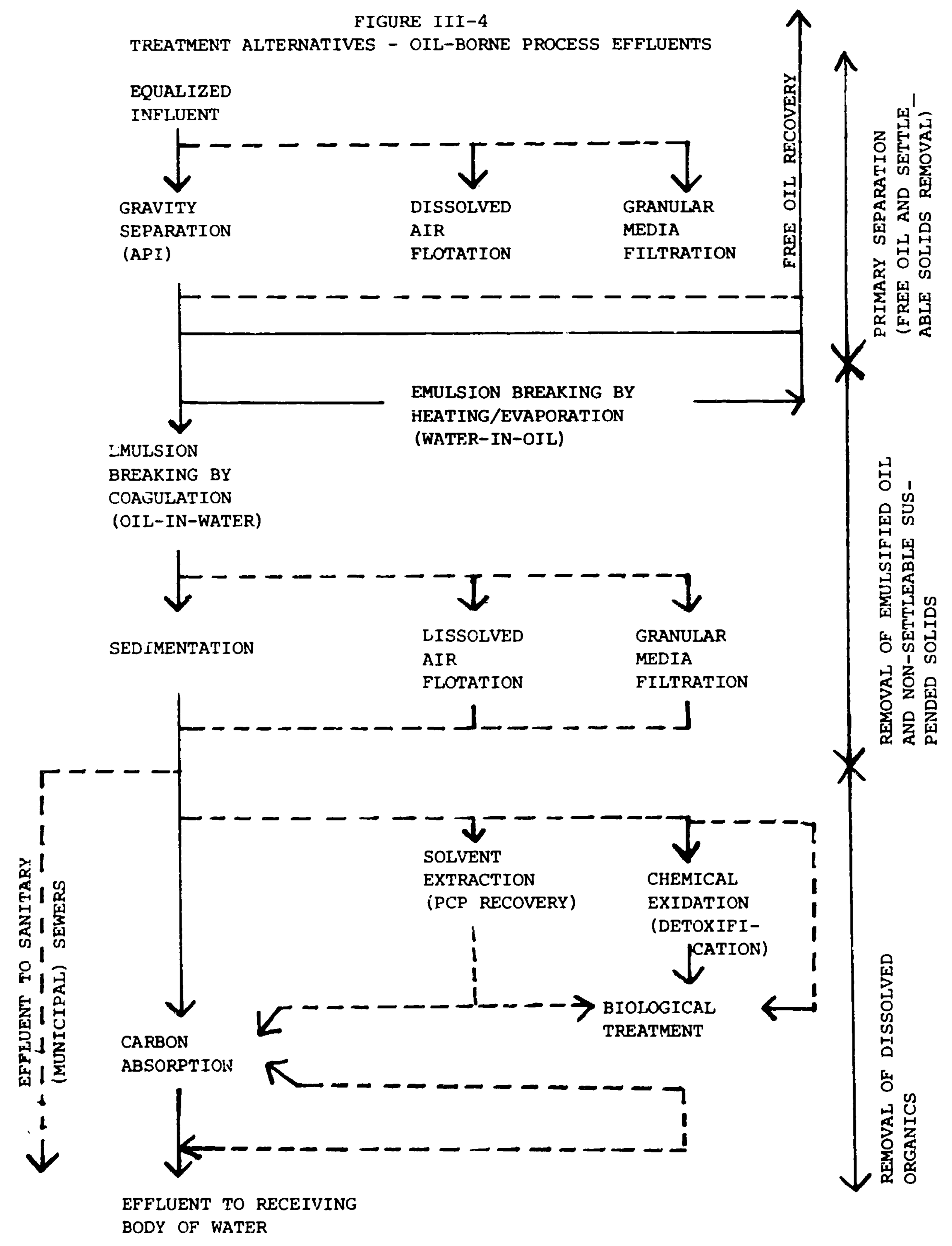
FIGURE III-3

GENERALIZED WASTEWATER TREATMENT FLOW CHART



Source: Averill,1978

FIGURE III-4
TREATMENT ALTERNATIVES - OIL-BORNE PROCESS EFFLUENTS



Source: Averill,1978

reduction of greater than 90% and phenol concentration were reduced over 99%(Averill, 1978).
Waste stabilization ponds require little capital investment and are simple and inexpensive to operate, but require a large area of land near to the plant. Moreover, waste stabilization ponds are only suitable for climates that have warm temperatures the year round. They are not suitable for locations that experience freezing conditions.

Activated sludge system require less land than waste stabilization ponds, but require a large initial capital investment and skilled personel to operate the system. It is operational in most climates, even under strong winter conditions. Oil-separation and collection preceeds treatment by activated sludge. A Canadian activated sludge treatment plant in full operation consists of two aeration tanks and a clarifier with a detention time of 4 days. The removal efficiency of the plant was greater than 90% for BOD and COD and a more than 99% for phenol concentration.

There has been no commerical operation of trickling filters for wood preservative wastewater reported in the literature. A pilot scale plant has shown BOD reduction of 92%, COD reduction of 77% and phenol concentration reduction of over 99%. The pilot study reported good results for wastewaters from creosote preservation, but the due to the short duration time biodegradation of pentachlorophenol was low (Guo, 1978).

The USEPA has studied alternative treatment processes for an oil-borne steam wood preserving plant. The plant produces a liquid waste of 53 cubic meters per day. The alternatives are:

A. Oil separation

B. Coagulation, filtration, and an aerated lagoon plus A.

C. Activated sludge plus B.

D. Chlorination polishing plus D.

Performance and cost estimates for the alternatives are listed below (Strzepek, 1982).

Alternative	%COD Removal	%Phenol Removal	%OIL & Grease Removal	Total Annual Cost (1980 US$) $/1000 liters
A	82	0	85	0.67
B	91	0	95	3.15
C	99	98	97	5.95
D	99	99+	98	7.33

Little cost data was found in addition to that above for the various treatment alternatives for wood preservative plants. Given the capital and skilled labor constraints of activated sludge system it is recommended that for developing country application waste stabilization ponds be used for the treatment of the oil-borne wood preservative effluents except in areas where land or climate are constraints.

Water-borne preservative wastewaters undergo a basic two step process:

1. Removal of dissolved metal salts and
2. Removal of dissolved organics.

Figure III-5 lists the alternative treatment processes for the different metal salts found in water-borne wastewaters. Chemical reduction and oxidation reactions followed by precipitation or filtration are used to remove the different metals and lime is added to neutralize acidic wastewaters. Two of the main metal salts that must be removed are arsenic and chromium. Major treatment methods for the removal of arsenic from wastewaters include:

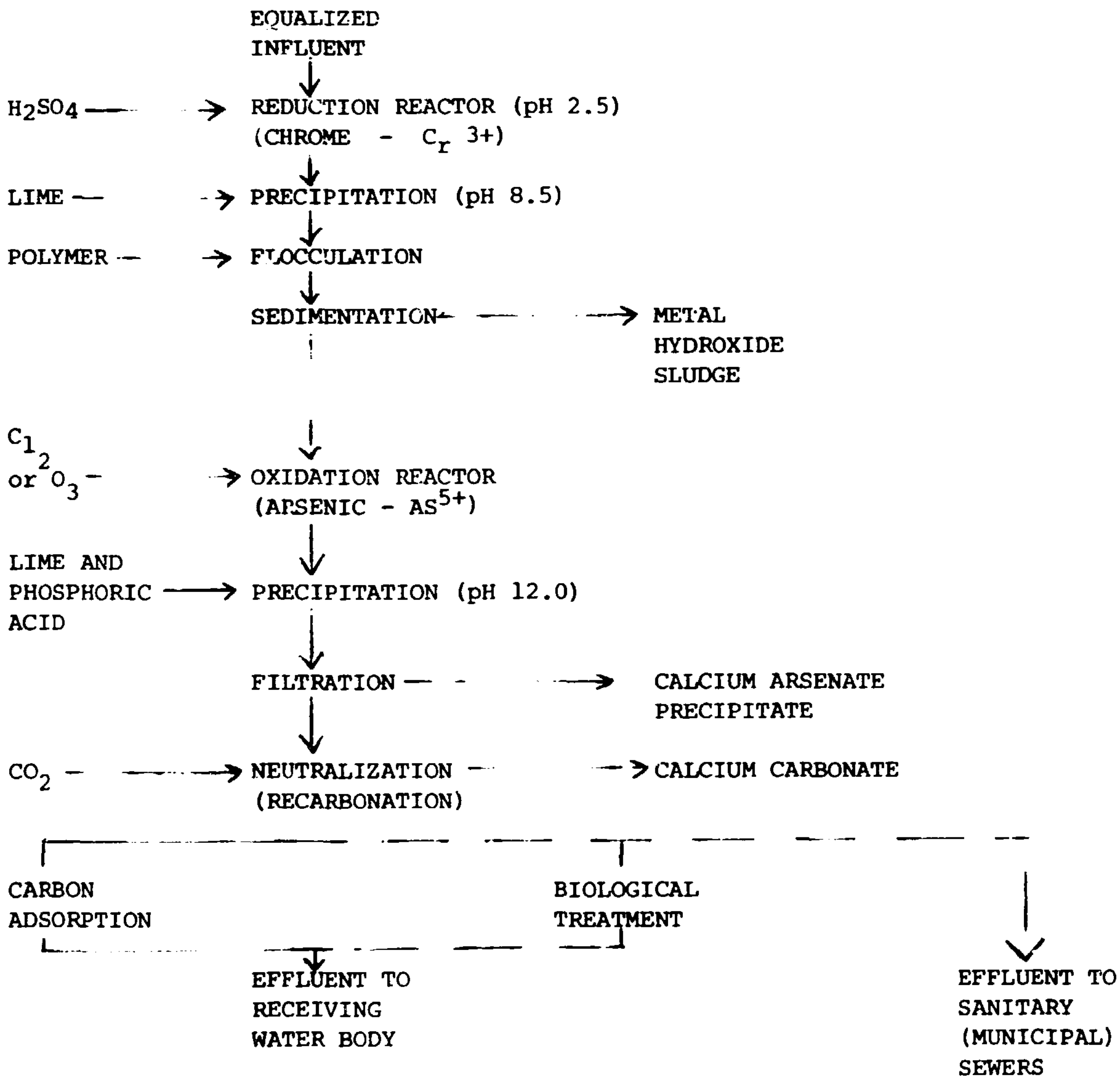
A) Complexation with a ferric salt and coprecipitation with the ferric hydroxide (chemical coagulation) followed by sedimentation and filtration of the precipitate. These methods provide for removal of 80 to over 99 % of arsenic.

B) Sulfide precipitation has been reported to achieve 80% arsenic removal (Carmichael, 1982).

Table III-3 lists the estimated costs for the removal of arsenic by coagualtion, sedimentation, and rapid sand filtration.

FIGURE III-5

Treatment Alternatives - Water-borne Process Effluents



Source: Averill,1978

Table III-3. Cost of Arsenic Removal

Flow M3/day	Total Cost US$/m3(1980)
757	0.21
1892.5	0.15
3785	0.13
18925	0.07
37850	0.06

Source: Carmichael,1982

The removal of hexavalent chromium from wastewater can be achieved by direct ion exchange or reduction to trivalent chromium followed by precipitation. Chromium removal efficiency for the various methods are very high with most in the order of 95% or above. Costs for ion exchange removal has been reported at US$(1980) 0.62 per kilogram chromate removed (Carmichael, 1978).

Biological treatment is also used to removed dissolved organics. The biological treatment methods that have been employed for water-borne wastewater are the same mentioned for oil-borne wastewaters.

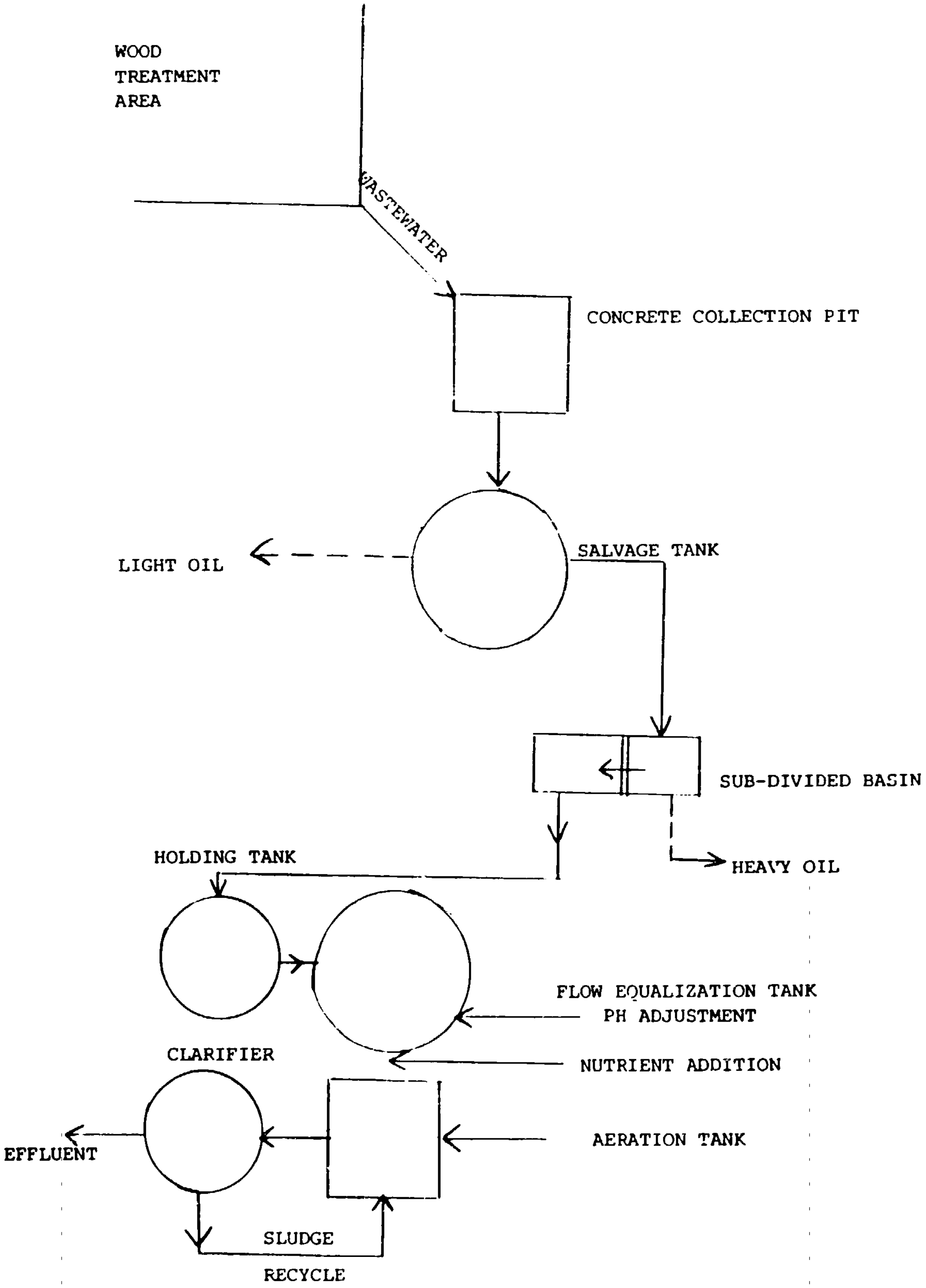
Case Study

The Northern Wood Preserver Limited, Thunder Bay, Ontario, Canada preserves a variety of wood products using steam vacuum conditioning and pressure treatment and both oil and water borne preservatives. Utility poles are processed with pentachlorophenol, railroad ties with creosote, and lumber for decks and wharfs with chromate copper arsenate (CCA). Three pressure cylinders are used, two for creosote and one for pentachlorophenol and CCA. The plant treats approximately 140,000 cubic meters of wood annually(Guo,1978).

The major source of wastewater comes from the condensate of the steam conditioning with a secondary source from runoff from the wood treatment area. The same cylinders are used for the conditioning and treatment so the condensate is very highly contaminated. There is no waste generated by the CCA preserving process since all wastewater is recovered and recycled in the CCA process or reuse in other parts of the plant.

Figure III-6 is a schematic of the treatment facility at the Northern Wood Preservers plant. Table III-4 lists the characteristics of the plants wastewater before and after treatment, (Guo,1978).

FIGURE III-6
WASTEWATER COLLECTION SYSTEM AND TREATMENT PLANT AT THE
NORTHERN WOOD PRESERVES LIMITED, THUNDER BAY, ONTARIO



Source: Guo, 1978

TABLE III- 4

Operating Results of the Activated Sludge System at
Northern Wood Preservers Limited

Parameters	Influent Ave.	Influent S.D.	Influent Min.	Influent Max.	Effluent Ave.	Effluent S.D.	Effluent Min.	Effluent Max.	% Reduction
pH	8.2*	-	6.4	9.6	6.8*	-	6.1	7.3	-
BOD_5 (mg/l)	2400	1420	570	6400	180	200	8	750	93
COD (mg/l)	3400	1520	1220	7400	710	550	55	2000	79
Phenols (mg/l)	750	440	120	1600	0.32	0.24	0.01	0.80	99
Suspended solids (mg/l)	60	43	16	211	170	221	20	940	Negative

S.D. - Standard Deviation
* - Median Value

Source: Cuo, 1978

Air Pollution

There are two sources of air pollution in the wood preservative industry; pollution from the burning of fossil fuels to provide steam and other forms of energy and pollution from the release of the preservatives into the air. This study will focus on the pollution from the preservatives themselves since these are often toxic substances.

The most important source of air pollution in the wood preserving industry is the thermal treatment process. The volatile compounds containing many forms of hydrocarbon and toxic vapors from the preservatives are released into the atmosphere. At least one of the prominent compounds, phenols, produce odors that are unpleasant for the public in the surrounding areas. Capturing these escaping vapors and condensing them and returning them to the tanks is the only control alternative. The thermal process is not widely used so the problem has not been heavily addressed.

In conditioning and treatment processes using steam and pressure , part of the process is the collection and condensation of the vapors. A potential air pollution problem thus becomes a water pollution problem. Therefore the main focus has been on treatment of the contaminated wastewater. Even with good pressure vessels and condensers some volatile vapors escape into the atmosphere.

Section III. H Surface Finishing

Surface finishing pertains to the protective and decorative coating of wood surfaces. The main surface coatings are paints, varnishes and lacquers. There are many different methods for the application of these coatings. The important factors in the choice of finishing technology are 1) the nature of the wood surface, 2)the geometric design of the work to be coated, 3) the specifications for quality and allowable costs of the coating film, 4)production quantity and rate, 5)the requirements for surface preparation before coating application, and 6) the end use of the product(Bobolek, 1967).

The coating methods can be divided into two main groups. Those that require atomization of the coating liquid and those that do not. The methods that fall into the atomization group are:

A. Spray Painting

1)Conventional, in which the paint is atomized with compresed air.

2)Steam spraying, in which the compressed carrier is steam.

3)Electostatic spraying, which uses a

potential difference between the work piece and the spray gun to attract most of the spray to the object to be coated.

4)Hot spray, employing hot paint under pressure in which the solvent explodes the paint into a spray when it is expelled into the atmosphere at normal pressure.

5)Airless spray, where paint is broken into a spray by mechanical means rather than a compressed carrier.

6)Flame spray, in which the coating as a powder is sprayed through the action of a flame, thereby melting the suspended particles which resolidify on striking the surface being coated.

Non atomization methods include:

A.Hand brushing.

B.Hand roller coating.

C.Roller Coating.

1)Direct roller coating, in which the paint as a thin layer on the roller is transfered to the work by rolling over it.

2)Reverse roller coating, in which the roller rotates in the direction opposite to the travel of the work, thereby allowing more intimate contact and generally a smoother surface.

3)Coil coating, a high-speed roller coating process for long strips of substrate supplied in coils rather than in individual flat sheets.

D. Knife coating, using a blade as a spreader for the paint instead of a roller.

E. Curtain coating, in which a thin film of paint in the form of dropping curtain , such as would escape from a Slot in the bottom of paint reservoir, is laid down on the work passing a conveyor through the curtain.

F. Dipping, which entails the immersion of the work in a tank of paint, followed by controlled withdrawal to give a uniform film.

G. Tumbling, in which a metered amount of paint is distributed over a considerable number of pieces by tumbling in a closed container.

H. Flow coating, wherein paint is squirted through judiciuosly placed orifices at the work piece and then drains away to leave a uniform coating even on a comparatively irregular object.(Martens,1968)

It is not within the scope of this report to discuss the technical merits of each of the finishing technologies, but to make one aware of the environmental aspects.

Most coating compositions need a solvent to fluidize the solid resins in the binder. The solvents are not wanted in the final coating film and are thus volatile liquid that are released by evaporation from the surface and solvent diffusion.

These volatiles are found in the rinse water from washing or chemical treatments or of solvents from degreasing schedules, solvents from coating films, and water or other volatile products produced in the chemical reactions of curing or drying of films or from drying of the wood substrate. Most of these volaties are removed by evaportation and proper ventilation. Some coatings require elevated temperature in ovens while other dry best at room-temperature (Bobalek, 1967).

Air Pollution.

The release of the volatile in the drying process is an environmental hazard in the form of air pollution and worker safety. Most solvents are toxic in the vapor-air mixtures that are inhaled. It is therefore important to have proper ventilation and require respiratory masks for workers.

The USEPA has identified the furniture industry in the U.S. as the second largest single industrial source of hydrocarbon pollution in the industrial coating industry. The furniture industry, just one element of the wood finishing industry, accounts for under 1% of the total "volatile organic compounds"
(VOC) produced in the U.S. The present emission of VOC in

furniture spraying operation is 250 to 300 pounds per 1000 square feet of product. It has been proposed that this emission be restricted to a maximum of 120 lbs per 1000 sqare feet (Wood &Wood Products, 1979).

A U.S. consulting firm has suggested that " a 50% reduction (in VOC) could probably be achieved through the adaption of water based topcoats, wash coats, and sealers". It has been estimated that to retrofit an existing plant for water based finishes would range from $300,000 to $500,000 per facility, (Wood and Wood Products, 1979). The most serious drawback to water based finished is the consumer acceptence of a more cloudly or milky finish that is the result of water base finishes.

Other methods suggested to reduce emission of VOC are:

1)Use of higher solid finishes applied via hot spray.

2)Airless and electorstatic spray application, which is report to emit less VOC.

3)Use of water wash spray booths and enclosed spray booths.

4)Carbon absortion and/or incineration systems to selectively decrease volatile organics.

And 5) filters ,which contain 100% solids, in the flatwood finishing areas.(Wood and Wood Products, 1979).

Water pollution.

Wood finishing has primarily and air pollution problem, but as seen above one of the solution of the air pollution problem is to convert it to a water pollution problem. The use of water wash spray booth and water scrubbing of ventilated air produce wastewaters that contain the same volatile and toxic chemicals.

In addition to these wastes, wastewater is generated by spillage, washing of equipment, raw material production, washes of wood products before finishing and during the curing stage. These combined liquid waste contain oils, resins, solvents, plasticizers, pigments, extenders, and dyes Settling tanks, ponds and basins are the most common type of liquid treatment for paint wastes, with distillation and incineration also widely used. Other advanced treatment methods have been emplyed in some plants, but require much capital expense and skilled labor to operate. Oxidation, reduction, neutralization, and filtration are used on water-based wastes containing heavy metals (Nemerow, 1978).

Wood finishing wastes are many times considered hazardous waste which requires extreme caution be taken in the final disposal of treatment effluents or solid wastes from settling or filtration.

With the development of the wood finishing industry on a world wide basis it is recommended for the developing countries that settling ponds, tanks, and basins with careful final disposal of solids be used as an initial treatment process for wood finishing wastewaters.

Section IV. Chemical Processing of Wood Products

A. The Pulp and Paper Industry

Cellulose fibres are the primary raw material for the paper and board industry. Over 99.5% of this cellulose fibre comes from the pulp of natural fiborous stems with about 25% of raw material provided from recycles material (World Bank, 1980). Wood, both softwoods and hardwoods, account for about 94% of virgin pulp with the remainder coming from non-wood sources, especially in the developing countries. The main non-wood sources are bagasse, straw, and bamboo. Reed, hemp, jute, flax, cotton and rags are also used.

The pulp and paper industry is on a world-wide scale with approximately 70 nations producing pulp products. Presently 20% of virgin pulp is produced in Africa, Asia, and South America with this proportion continuing to increase (World Bank, 1980).

The major constituents of wood are cellulose fibre, used in paper making, and lignin and carbohydrates that bind the fibres. The objective of the pulping process is to release the cellulose fibres from the binders so that they may be processed into paper and board products. There are two main pulping technologies, mechanically breaking the lignin bond or chemically breaking down the lignin and carbohydrate bonds, which then release the cellulose fibres. The mechanical process produces high yields of fibre, but damages the fibres resulting in lower strength and quality products. The chemical process produces low yields of fibres, but the fibres are relatively undamaged and of a greater length than the mechanically produced fibres. This means higher strenth and quality final products. Another issus, in the "kraft" chemical process, residuals and by-product recovery can allow the plant to be almost energy self-sufficient.

The basic steps of a pulp mill include wood preparation, pulping, screening, washing, thickening, and bleaching. The basic steps in a paper mill are stock preparation, paper machine operation, converting, and finishing. Large quantities of water are used in the paper and board making operations. The raw waste water streams from the pulp and paper industry are considered among the most serious water pollution problems facing all industry (Jones, 1973).

W TER USE

The pulp and paper dustry has traditionally been one of the highest water using industry. In the USA in 1971, it accounted for 18.5% of total industrial water use (Bond and Straub, 1973), in Japan, 1977, 12.1% (UN-ESCAP, 1981), in

Belgium, 1966, 4% (UN, 1976), and in Sweden it is the largest industrial water user, (Sweden, 1977). Table IV-1 lists some of the specific water uses in the pulp and paper industry for various countries.

Table IV-1. Water Use in the Pulp and Paper Industry

Nation	Water Use (M3 per ton)
Finland	250 to 500
USA (average)	236
UK (average)	90
USSR	70 to 435
France (average)	150
Sweden	75 to 500
Canada (newsprint)	375

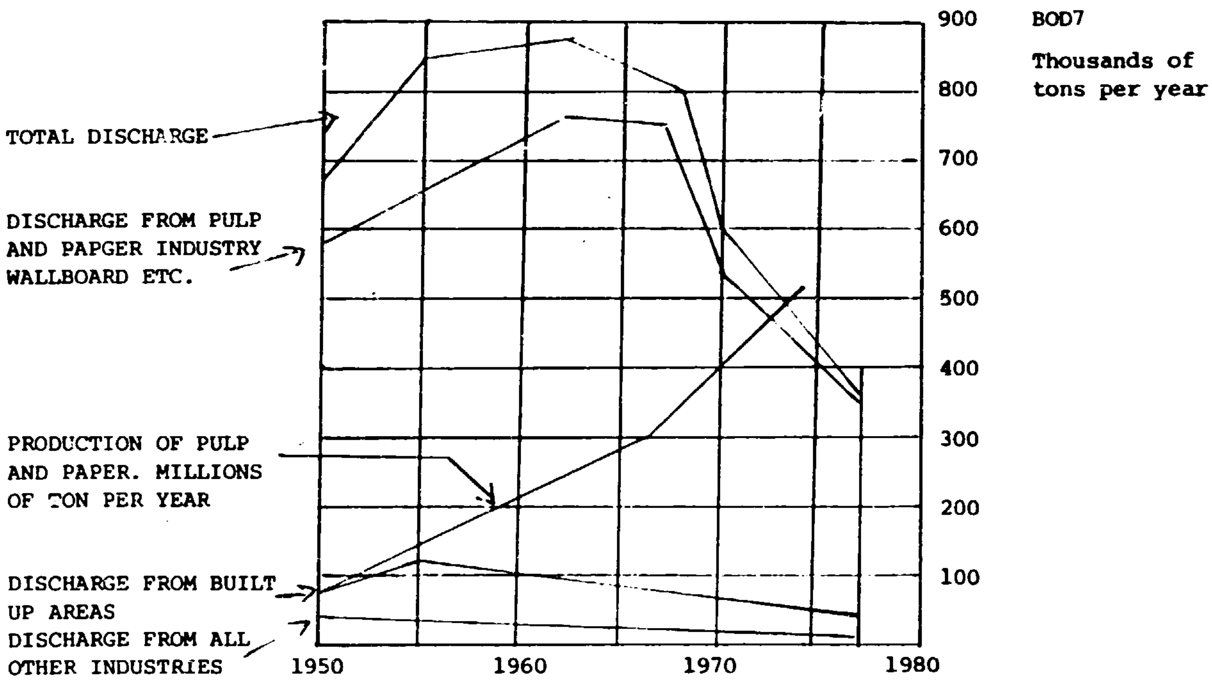
Source: (UN, 1976)

The data listed in table IV-1 does not represent water use requirements, but a static picture of water use in the pulp and paper industry. The pulp and paper industry has responded to the recent environmental regulations by reducing water use as one means of reducing waste water discharges. Therefore, the specific water use continues to drop in the industry as reflected in Figure IV-1 for the Swedish Pulp and Paper Industry.

Figure IV-2 provides a schematic of the pulp and paper industrial processes and the water use and effluent

FIGURE IV-1

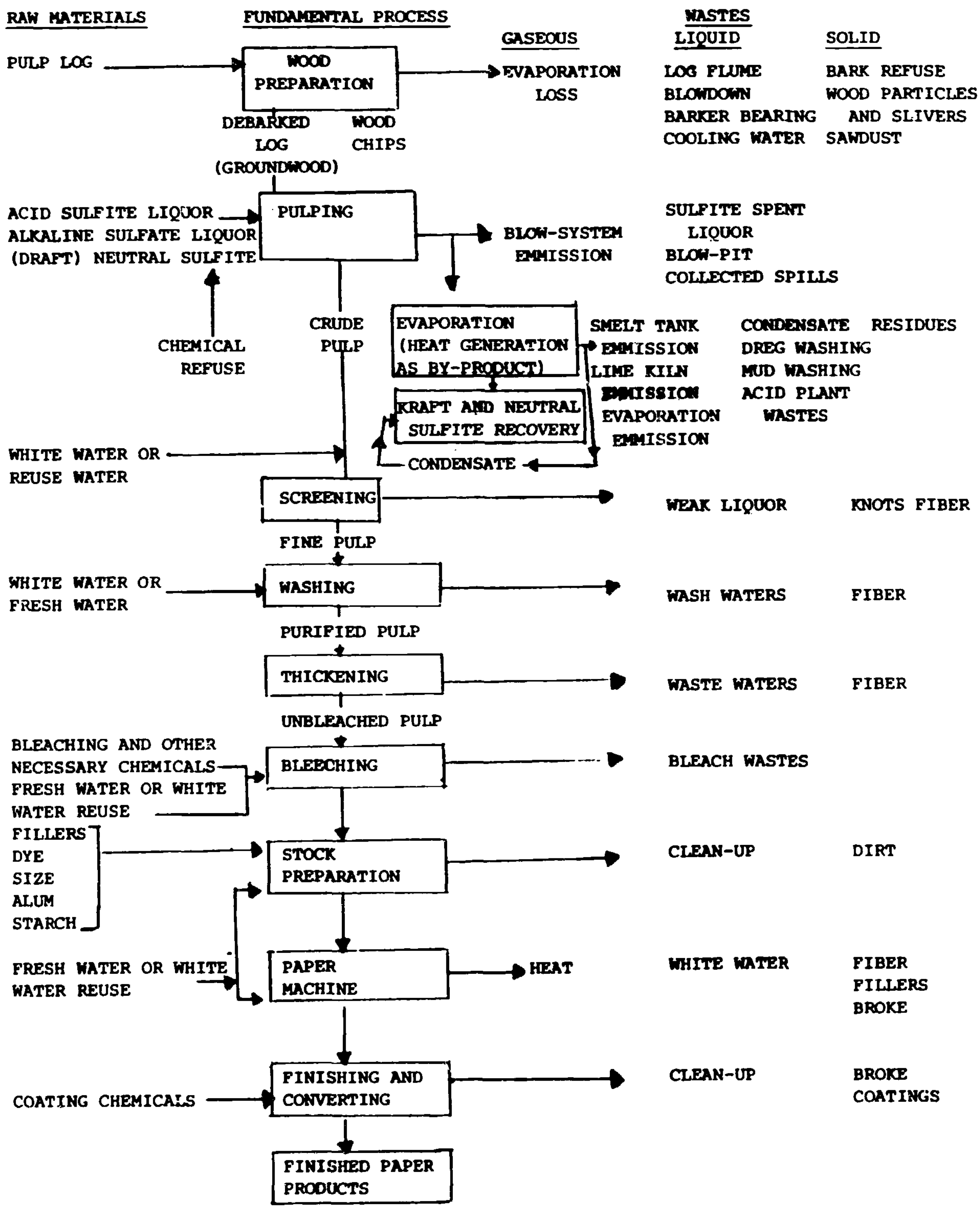
DISCHARGE OF BOD7 (BIOCHEMICAL OXYGEN DEMAND)
IN THOUSANDS OF TONS PER YEAR



Source: Sweden, 1981

FIGURE IV-2

SIMPLIFIED DIAGRAM OF FUNDAMENTAL PULP AND PAPER PROCESSES



Source: Nemerow, 1978

discharges therefrom. Water is used for pulp processing, washing, dissolving or mixing the various loading, sizing and coloring ingredients, carrying the fibres through the screens and refiners to the papermaking machine, and operation of the paper making machine (Jones, 1973). A majority of the water in the pulp and paper industry is used for process water. Table IV-2 lists the distribution of water use within the industry for a number of countries.

Table IV-2. Water Use Distribution in the Pulp and Paper Industry

Nation	% Water Use		
	Cooling	Process	Other
Belgium	21	75.8	3.2
Japan	12.7	80.7	66

Sources: (UN-ESCAP, 1981);(UN, 1976)

The average consumptive use in the USA in 1959 was 4.3% (Bond and Straub, 1973), but has been increasing as specific water use decreases.

RECYCLING AND REUSE

The major use of water in the pulp and paper industry is for process water. A large part of the process water becomes contaminated as a result of contact with raw materials, by-products, or residues. To reuse this water, treatment must take place or process changes made to reduce contamination or accept lower quality water. There is an upper limit to the amount that water can be reused or recycled in the pulp and paper industry because raw water must be added to prevent buildup of dissolved solids, slime and fungi growth. However, there is a great potential for water reuse and recycli... in figure IV-2. The major process water that are reused or recycled are:

1) water from the log flumes and barkers
2) evaporator condensate from the liqour recovery area
3) bleach plant washer filtrate
4) white water from the paper machine
5) washer water from the coarse screens (Jones, 1973).

Table IV-3 lists some of the process waters that can be reused and in what process. In addition, by-product recovery potential is listed.

Cooling water is only a small part of the total water use, but water can be conserved by recycling of cooling water through cooling towers or ponds.

TABLE IV-3

Water Reuse in Pulp and Paper Industry

Fundamental Process	Wastewater Source	Reuse Areas	By-Product Recovery
Wood Preparation	Evaporator Condensate, Bleach plant pulp washer filtrate.	Log flume, hot pond, debarker, Showers	
Kraft Pulping	Condensate from recovery evaporators and heat exchangers, smelt dissolving Underflow from Turpentine separator.	Dilution water; causticizing, screening, deinking, and wood preparation. Lime and shower system.	Turpentine from Digester Relief
Soluble-base Bisulfite			Chemical Recovery from spent liquor.
Paper Machine Operations	White water from Paper Machine	Paper machine, stock preparation, bleaching, pulp washing and wood preparation.	

Source: Jones, 1973

CHARACTERISTICS AND TREATMENT OF WASTE WATER STREAMS

Waste water streams from the pulp and paper industry contain dissolved organic and inorganic material, organic and inorganic solids, toxic and oderous substances, bacteria and nutrients, (Sweden, 1981). These wastes vary considerably depending upon the type of procesing that is employed. A qualitative description of the wastes from the various steps in pulp and paper manufacturing is listed below:

1. Wood preparation - Solid and biologically degradable liquid wastes from transport and debarking.

2. Pulping Process - a) Mechanical - cooling water discharges, solid and biologically degradable liquid wastes. b) Sulfate (Kraft) - Cooling water and biolocially and chemically degradable liquid wastes, solids. c) Sulfite - High BOD and suspended solids. d) Semi-Chemical - High BOD, COD and solids.

3. Pulp Screening - Much solid waste and suspended solids.

4. Washing and Thickening - High solids and suspended solids.

5. Bleaching - High BOD, dissolve solids, color and unreacted chlorine.

6. Paper Machine - High solids and medium BOD with varying COD depending upon paper being produced.

Table IV-4 provides a quantitative description of the

TABLE IV-4

Typical Mill Waste Water

Product	BOD, ppm	Suspended solids, ppm
Pulp		
Groundwood	645	
Soda	110	1720
Sulfate (kraft)	123	
Sulfite	553	
Miscellaneous paper		
No bleach	19	452
With bleach	24	156
Paperboard	121	660
Strawboard	965	1790
Deinking used paper	300	

Characteristics of kraft-mill wastes

Characteristics	Maximum	Minimum	Average
pH	9.5	7.6	8.2
Total alkalinity, ppm	300	100	175
Phenolphtalein alkalinity, ppm	50	0	0
Total solids, ppm	2000	800	1200
Volatile solids, %	75	60	65
Total suspended solids, ppm	300	75	150
Volatile solids, %	90	80	85
BOD, 5-day, ppm	350	100	175
Color, ppm	500	100	250

Source: Nemerow, 1978

typical waste from a combined pulp and paper mill.

TREATMENT

The Swedish principle for reducing effluent discharges from the pulp and paper industry has been that the greatest attention should be paid to internal measures to reduce waste generation (Odin, 1981). This principle has been found throughout most
developed countries with major pulp and paper industries. For example, the emission of lignin residue from a bleeching chemical pulp plant can be reduced 50% by using oxygen bleeching instead of conventional bleeching. This process change has been employed in six plants to date in Sweden (Odin, 1981).

The possible process changes to reduce effluent discharges are listed in Table IV-5.

A common characteristic of good wastewater treatment practice is the discharge to separate sewers of waste water of different strenghts and characteristics. There is no single treatment technology that can treat the many pollutants found in the pulp and paper waste streams and the wastewaters are segregated for efficient treatment. A sequence of separate treatment processes make up the treatment facility at a modern pulp and paper plant. The

Table IV-5. Alternaive Process Changes

		Wasteloads Reductions,%	Wastewater Quantities Reductions%
Wood Preparation:	Water Reuse	80-90	70
	Long Log	95	85
Pulping Process:	Water Reuse	30	30
	Liquor recovery	60-90	60-90
Pulp Screening:	Water Reuse	20-60	20-60
Washing and Thickening:	Use of Vacuum Filters	20-60	20-60
	Multistage countercurrent V.F.	60-90	60-90
Bleaching:	Water Reuse and Recirculation in Multistage Operation	30-80	-
Paper Machine:	Fiber Recovery and White Water Reuse	20-70	60-80

Source: Jones, 1973

sequential processes can be grouped into four categories (Jones, 1973):

1) Pretreatment - Remove coarse material, naturalize acid or alkaline wastes, mix wastes to eliminate oders or reduce temperature.

2) Primary treatment - Removed suspended solids and coarse organics.

3) Secondary treatment - Remove BOD and some COD.

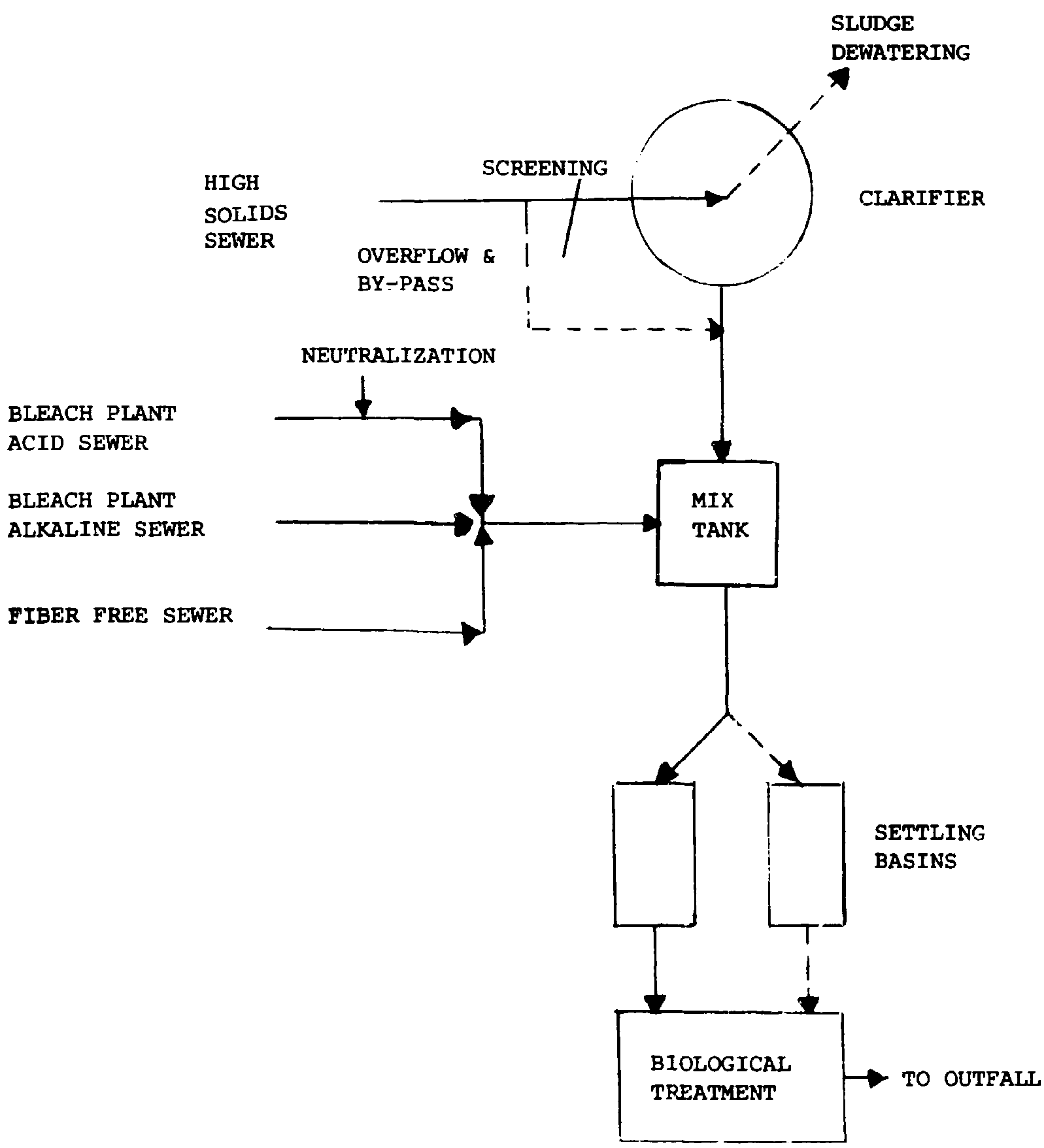
4) Tertiary treatment - Removal of color, dissolved solids and coliform.

Figure IV-3 shows a typical waste treatment facility for a pulp and paper mill illustrating the sequential treatment approach.

Pretreatment normally involves some type of screening and a neutralization process with attempts made to blend waste streams to accomplish the neutralization. The primary treatment processes that are employed may use flocculation by clarification. The clarification process can be by gravity or by flotation. Some mills use settling basin in addition to or replacing the clarifier. For the pulp and paper industry, traditional activated sludge processes and the contact stabilization modification process have been successful. Both of the above processes are aerobic processes. The convential activiated sludge process works well for waste waters from sulfite mills, while the contact

FIGURE IV-3

TYPICAL BASIC FLOW DIAGRAM FOR A MODERN BLEACHED KRAFT PULP MILL



Source: World Bank, 1980

stabilization modification of the activiated sludge process is well suited for waste water from an integrated Kraft mill (Jones, 1973).

The World Bank (1980) in a monograph Environmental Considerations for the Pulp and Paper Industry, aimed at the developing countries, strongly recommend an aerated lagoon system for the secondary treatment process in new and existing pulp and paper mills, since the activated sludge process requires capital and operating expenditures at least double those of an aerated lagoon system and requires more operator attention and skills. In cases where insufficient land exists for the lagoon system, activated sludge is advised.

Tertiary treatment processes for the pulp and paper industry include the use of holding ponds to attain additional BOD and COD removal and extent detention and bacterial flocculation. Other methods are biological filtration and irrigation with secondary treatment effluent.

CASE STUDY

The Menominee Paper Company, Inc. of Menominee, Michigan, USA was producing 250 short tons per day of linerboard and corrugated board from its machine No. 1. The volume of waste effluents exceeded the capacity of the plant's waste treatment facility resulting in large volumes of high BOD effluents being discharged to the Menominee River. The source of the high BOD was starches in the corrugated board waste (Courtney, 1979). The first step was to reduce water use by reusing process water. A 100-mesh screen was installed to reduce suspended solids from the machine discharge. The filtered water replaced fresh water at the venta-nip shower, vacuum thickener seals, primary headbox shower and the centrifugal cleaner. The total reduction in process makeup water was 3420 m3 per day with a simultaneous increase in production to 250 short tons per day. With additional reductions in water use and thus waste discharge the total plant waste could be treated by the existing treatment facility at the plant. This avoided a costly investment in the expansion of the treatment plant.

Air Pollution

Air pollution is a major problem that must be addressed in the pulp and paper industry. In 1977 the pulp and paper industry in the U.S. accounted for about 6% of total particulate emission(Stone,1977). Uncontrolled emissions of particulates and odors to the air from the pulp and paper industry are the most noticeable and objectionable of all the pollutants to the public and emissions of sulphur dioxide contribute to the acid rain problem. Older kraft mills were major sources of air pollution. However, modern plants can be designed to remove particulates and restrict odors(World Bank, 1980).

Odor is a problem associated with the kraft process as a result of gaseous emissions of hydrogen sulphide,methyl mercaptan, dimethyl sulphide, dimethyl disulphide; oxides of sulphur; and oxides of nitrogen. In addition organic compounds can be emitted such as terpenes, hydrocarbons, alcohols, and phenols.
The sources of sulphur dioxide emissions are the kraft recovery furnace, the lime kiln, smelt dissolving tank, waste-wood fueled power boiler, and high sulphur fuels used in the power boiler. New design of kraft mills has greatly reduced the odor causing emissions. The kraft recovery furnace and the power furnace both contribute to the particulate emission problem.

Mechanical pulping plants are not faced with the same problems as the Kraft plants, although terpenes and phenols are released in small amounts in most pulping operations. The major air pollution problem is the emission of particulates and sulphur dioxide from the power furnace (World Bank, 1980).

Treatment Practices

Odorous emission have been reduced in new kraft mill design by:

1)collecting and incinerating non-condensable gases;

2)proper sizing and design of the recovery furnace; and

3)installing exhuast hoods and incinerating or collecting odorous gases.

Sulphur dioxide emissions and particulate emissions from kraft and mechanical pulping mills are reduced by scrubbing of exhuast gases and more careful design of the power and recovery furnaces. Use of low sulphur fuels and careful fuel preparation for efficient burning are also employed to reduce sulphur dioxide emissions(World Bank,1980)

B. Chemical Production from Wood and Wood Waste and Environmental Consideration

In a recent book on the subject CHEMICALS FROM PULP AND WOOD WASTE, Maloney (1978) lists over 203 patents for processing wood and wood wastes into useful chemicals. He states that the use of cellulose, hemicellulose and lignin as a base for the production of chemicals and plastics on a wide basis is a matter of economics rather than technology. Presently, fossil fuels are a more economically attractive alternative to wood and wood waste.

The use of wood and wood waste to produce useful chemicals is one solution to the waste disposal problem faced by the pulp and paper industry, the wood processing industry, and logging industry. Some of the products available from wood products are; activated carbon, sugars, charcoal from wood chips, and resins and waxs from bark. By-products from spent pulping liquors are sulphur,lignin, sugars, tall oil and rosins. Solid wood wastes can be converted to useful fuels through digestion, pyrolysis or use directly as a fuel. Some basic chemicals that can be formed from wood waste are methanol, formaldehyde, ethanol, furfural, and phenol.

Some of the products that can directly use wood and wood wastes or chemical produced from these wastes are drilling muds, rubber additives, polyurethanes, inks, dyes, adhesives and others.

Although the transformation of a environmental problem into a useful resource is possible the production of these chemicals and associated products will have certain environmental impacts for which the reader is referred to environmental literature on the petro-chemical and associated industries.

Section V. Wood Waste as an Energy Source

Not all wood residues produced can be considered waste. Chips, shavings, and other by-products of the sawmills and planing mills have available markets in the pulp and paper industry and the particle board industry. Therefore the classification of these materials as waste is economically inaccurate, (Shafizadeh,1977). Approximately 25% percent of all wood residue produced is bark and presents a difficult problem for utilization. It consumes more chemicals than wood in pulp production and has been limited to soil conditioning in local markets. Sawdust is an additional problem wood waste. It does not have the long fibers of chips and is not as useful in particle or flake board.

Wood waste can be considered as a fuel in two form, in direct combustion or converted to various types of gaseous, liquid, or solid fuel, with or without the production of chemical by-products. Appel(1977) presents result of a study that shows that wood waste can be converted to a heavy oil by processing with water, sodium carbonate, and a gas rich in carbon monoxide. Appel also reports the construction of a 1 ton per day pilot plant in the U.S. to test the commercial potential of the process.

Powell(1978) reports the development in Ghana of a domestic stove, a super-heated steam bread-baking oven, and a fish smoking oven all of which burn sawdust. In addition improvements in efficiency have been made on sawdust utilization in charcoal manufacturing.

The utilization of low value wood waste for energy production provide a double benefit by not only solving a solid waste disposal problem, but providing a renewable source of energy.

Haggin (1982) reports of a proposal to produce 330,000 gallons per day of methonal from 3500 tons per day of green wood chips with complete environmental capatibility. Capital costs are estimated at 250 million (1981 US $). The plant proposed for the northeastern US would provide 3% of New England's motor fuel at a price of $0.80 per gal.

Section VI. Conclusions

The Wood and Wood Processing Industry historically has been one of the major industrial sources of environmental pollution. Although in recent years major steps have been made to reduce the amount of pollution being discharged to the air and water environment. For example the Swedish pulp and paper industry has reduced total discharge of BOD from 870,000 ton per year in 1960 to 370,000 tons per year in 1977 while at the same time increasing production over 100 %.

The environmental impact by the wood and wood processing industry is not limited to the processing stage rather the World Bank (1980) reports that the development of the infrastructure and the transportation of the wood has a greater potential environmental impact than the processing of the wood.
This report has outlined the potential environmental impacts of the various sectors in the wood and wood processing industry, possible treatment technologies for each sector, and potential ways of harnessing the by-products of the industries as useful resources.

The main conclusion of the report though is that the nations of the world that have a well developed wood and wood processing industry have demonstrated the tremendous harmful environmental impact that ignoring treatment of industry waste can cause and the tremendous costs of trying to remedy the situation on existing plants. It is clear that any country planning to develop its forest resources for raw materials or for processing should undertake careful planning and implement environmental controls at the inital development stage to avoid harmful environmental impact and avoid the tremendous cost of retro-fitting treatment technology at a latter date.

Section VI. Recommendations.

(1) Proper planning and management of the forest stand is necessary to assure a long term supply of forest resources.

(2) Analysis of industrial pollution and its effect on the valuable resource and source of raw materials for the wood and wood processing industry, the forest, must be taken into account in any planning for industrial development, especially in developing countries.

(3) Oil-borne wood preservative effluents in developing countries are recommended to treated by waste stabilization ponds in new and existing wood preservative plants, since the activated sludge process requires capital and operating expenditures at least double those of an aerated lagoon system and requires more operator attention and skills. In cases where insufficient land exists for the lagoon system, activated sludge is advised.

(4)Wood finishing wastes are considered hazardous waste which requires special proceedure be employed in the final disposal of treatment effluents or solid wastes from settling or filtration.

(5) With the development of the wood finishing industry on a world wide basis it is recommended for the developing

countries that settling ponds, tanks, and basins be used as an initial treatment for wood finishing wastewaters with final disposal of solids from these processes be in properly design harzardous waste dumps.

(6) The release of the volatile in the drying process is a environmental hazard in the form of air pollution and worker safety. Most solvents are toxic in the vapor-air mixtures that are inhaled. It is therefore important to have proper ventilation and require respiratory masks for workers.

(7) The present emission of Volatile Organic Carbons (VOC) in the US in furniture spraying operations is 250 to 300 pounds per 1000 square feet of product. It is recommended that this emission be restricted to a maximum of 120 lbs per 1000 square feet in industrial countries and that developing countries aim for the 250 to 300 target.

(8) The following methods are recommended for the reduction of VOC emission from the wood finishing industry:

1)Use of higher solid finishes applied via hot spray.

2)Airless and electorstatic spray application, which is report to emit less VOC.

3)Use of water wash spray booths and enclosed spray booths.

4)Carbon absortion and/or incineration systems to selectively decrease volatile organics.

(9) Pulp and paper effluents in developing countries are strongly recommend to be treated by aerated lagoon systems for the secondary treatment process in new and existing pulp and paper mills, since the activated sludge process requires capital and operating expenditures at least double those of an aerated lagoon system and requires more operator attention and skills. In cases where insufficient land exists for the lagoon system, activated sludge is advised (World Bank, 1980).

(10) Recommendations for the reduction of odurous emission from Kraft pulp mills are:

1)collecting and incinerating non-condensable gases:

2)proper sizing and design of the recovery furnace; and

3)installing exhuast hoods and incinerating or collecting odorous gases.

(11) Sulphur dioxide emissions and particulate emissions from kraft and mechanical pulping mills should be reduced by scrubbing exhuast gases and efficiently designing the power and recovery furnaces. Also the use of low sulphur fuels and fuel preparation for efficient burning are also recommended to reduce sulphur dioxide emissions.

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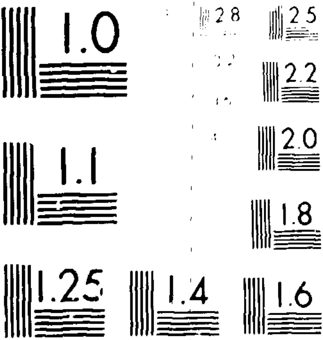

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APPENDIX A.

The data for cost on the treatment of Mechanical Wood Processing waste water was taken from Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Plywood and Wood Industry., R. E. Williams, United States Enviromnetal Protection Agency, Washington, D.C., April 1974. The costs presented were in 1973 US$. These costs were updated to 1980 costs by multiplying them by Non-residential construction price index for the US provide in the OECD 1980 Yearbook of Economic Statistics, 1981 Paris.

The value of Production figures for finding the percentage of treatment cost of total annual production values were found by multiplying the yearly production amount by the 1980 unit product value for export of USA commidities. These figures are published by the FAO in the 1980 Yearbook of Forest Products, FAO, 1982, Rome.

Softwood plywood was assumed 9.53 mm (3/8 in.) in thickness and hardwood plywood was assumed 6.35 mm (1/4 in.)

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