Bleaching of Chemical Pulps Vis-a-Vis Pollution Abatement

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ABSTRACT

In U.S. and Canada, the bleaching of chemical pulp is rapidly changing and changing for good. The present focus on pulp bleaching is directed towards decreasing the emission of pollutants from the bleach plant. Process steps such as extended delignification at the digester, better washing of brown stock, use of "dioxin precursors free" defoamers, enzymatic pretreatment, oxygen delignification, hydrogen peroxide reinforced oxygen delignification, high or total substitution of chlorine dioxide for elemental chlorine, use of peroxygen chemicals like ozone for prebleaching, oxidative extraction with hydrogen peroxide reinforcement, and hydrogen peroxide post treament of bleached pulps are resulting in a very large reduction in the emission of dioxin, chlorinated organic compounds [AOX] including chloroform, color, BOD, COD and toxicity from the bleach plant. External treatments including secondary and tertiary treatments are helping to decrease the concentration of pollutants in the effluent to ultra- low levels. Even then, more regulations are expected and the mills are already working towards "Effluent Free" Bleach Plants. This paper gives an overview of the technologies adopted by the U. S. and Canadian Pulp and Paper Industry to produce "environmentally friendly" bleached pulps of superior quality and brightness.

Introduction

The U. S Pulp and Paper Industry is the largest Producer of pulp and paper in the world. The pulp and paper production in the U S accounts for approximately 38% of the world production capacity. According to 1989–1990 statistics[1], there are 214 pulp mills in U. S. producing about 57.5 million tonnes of pulp (utilization factor = 0.96). Among the 214 mills 118 of them are kraft (including soda) mills and 18 are sulfite mills. About 25 million tonnes of kraft pulp is bleached, out of which market bleached pulp accounted for about 8.0 million tonnes.

At present, the biggest question facing the U. S. Pulp and paper industry is how to maintain a sustained growth, but also be "Green" at the same time. This dilemma is not the prerogative of U. S. pulp and paper Industry, but also of the pulp and paper industry world - wide. The pulp and paper Industry, worldwide, is serious about its commitment to environmental protection, and the U. S. and Canadian pulp and paper Industries are no exception to that. The U. S. and Canadian pulp and paper Industries have amassed an impressive record of meeting their responsibilities to minimize the impact of the bleaching processes on the environment.

It could be said that the future of the pulp bleaching technology is being shaped by three important issues.

Environment.

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Environmental protection is the utmost priority of the pulp and paper industry. However, there are

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countervailing economic pressures to achieve this objective in a cost-effective manner. For example, last year alone the U. S. Pulp and Paper Industry has spent about a billion dollar[2] to the elimination of2,3,7,8,tetrachlorodibenzodioxin(TCDD)and2,3,7,8,-tetrachlorodibenzofuran (TCDF) in the bleaching of pulps. In 1988, the emission of TCDD and TCDF (on a toxicity equivalent) from the pulp bleaching was 320 grams and 3.5 kilograms. respectively[3]. These figures are almost an order of magnitude, less for the year 1991, due to the steps taken to reduce the formation and release of these compounds. Today, over four years from the original 1988 104 mill study, it is estimated that the discharge of dioxin from the industry which was never more than 3% of the total dioxin discharge from all other sources, has been reduced by over 90%. Based on 1988 expenditure, the paper industry spent about 3.0 million to eliminate a gram of dioxin. No other industry has spent such a huge sum of money to eliminate such a small amount of pollutant.

The 2, 3, 7, 8,-TCDD in the mill effluent is no longer a major issue now. However, the TCDD and TCDF concentrations in pulp are still an issue. At present, efforts are underway to reduce them to non-detect levels. The industry is also taking steps to decrease the emission of organochlorine compounds (referred as Adsorbable Organic Halogens-AOX) from the bleach plant. Regulations to limit the discharge of AOX have been established in Sweden, Germany, Finland and Canada. In. U.S. only the state of Oregon regulates the discharge of AOX into the receiving streams. Other states are also leaning towards some kind of regulation to limit the AOX discharge.

Adsorbable Organo Halogens (AOX)

Organochlorine discharge from the bleach plants result from the use of gaseous chlorine and chlorine chemicals for the bleaching of pulps. The formation of organochlorine compounds arise from chlorine substitution and addition reactions with residual lignin and extractives in unbleached pulp. The AOX measurement is accepted as the quantitative measure of the organochlorine compounds formed in the bleaching processes. Specific discharge limits for organochlorine compounds vary according to countries, from 2.5 kg tonne to1.0kg/tonne of ADpulp.It is anticipated that this regulation on discharge limit would be further tightened over time. For example, in Canada, British Columbia wants a complete elimination of AOX before December 31, 2002. This means that the mills in the Canadian West Coast have to-do away with not only molecular chlorine gas, but also chlorine dioxide for the bleaching of pulps[4].

The data base developed over the years on the discharge of effluent from kraft bleach plants concluded that no environmental impact exist from the discharge of well treated effluents from well operated mills. Nevertheless, the industry will be tightly regulated, and the U. S. and Canadian Pulp and Paper producers are bracing for even stringent demands from the regulatory authorities.

There are several ways by which the AOX discharge from the bleach plant can be decreased. Table 1 is the list of five commandments of pulp bleaching vis-a-vis pollution abatement The chlorinatable organic matters entering the bleach plant should be minimized to decrease the formation of AOX. Lower lignin content in the pulp, low extractives concentration, and low carry-over in pulp are some of the steps needed to decrease the chlorine demand and hence, the formation of AOX in pulp bleaching.

TABLE 1

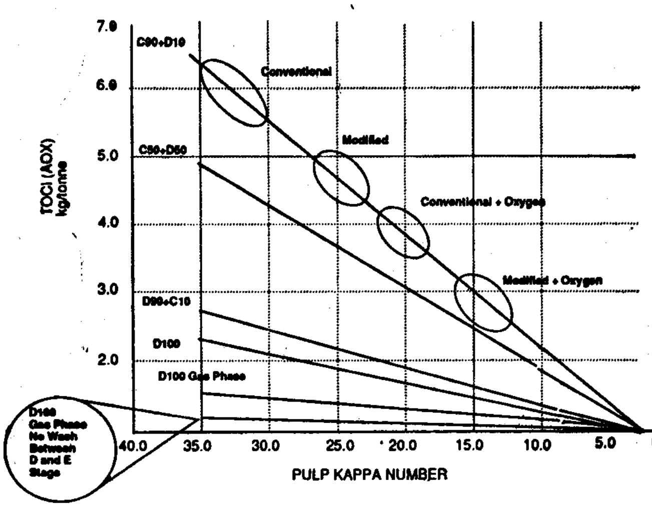
FIVE COMMANDMENTS OF PULP BLEACHING AND POLLUTION ABATEMENT

1. THOU SHALL NOT BRING HIGH KAPPA NUMBER PULP TO THE BLEACH PLANT
2. THOU SHALL NOT BRING HIGH CARRY-OVER WITH THE PULP TO THE BLEACH PLANT
3. THOU SHALL NOT USE GASEOUS CHLORINE FOR THE BLEACHING OF PULPS
4. THOU SHALL USE PEROXYGEN CHEMICAL FOR THE BLEACHING OF PULPS
5. THOU SHALL OPERATE THE TREATMENT PLANT UNDER OPTIMUM CONDITIONS TO DECREASE MAXIMUM AOX

There are a number of ways by which the first chlorination stage itself can be modified. For example, high or total substitution of chlorine with chlorine dioxide at the first stage is being adopted by many mills. Decreasing the chemical charge at the first stage is another step to reduce the emission of AOX from the bleach plant.

Extended delignification in the digester, oxygen and hydrogen peroxide reinforced oxygen delignification of pulps, combination of extended delignification and oxygen delignification and enzymatic pretreatment of pulps before the first stage are few of the many steps, the industry is taking to cut down the chemical use at the first stage (Figure 1). To complement these steps mills are also adapting to better mixing and process control to increase the efficiency of bleach chemicals at the first stage.

Effect of Kappa Number And Various Process Modification On the Formation of TOCl (AOX)



Primary Source: Peter Axegard in Bleaching: A TAPPI Press Anthology, 1987-1990

Mill Process Changes For Environmental Purposes

Several process changes have been made or being considered to meet the environmental restrictions. These changes can be categorized as.

1) Control Outside contamination
2) Remove Max'mum Lignin Before Bleaching
3) Modification of Lignin Before Bleaching
4) Modification of Bleaching Processes and change of Chemicals.

These strategies can be either used alone or in combination to improve the quality of the outfall effluent.

1. Control Outside Contamination.

a. Pentachlorophenol (PCP)

Pentachlorophenol is used as a wood preservative. Chlorinated dioxins are documented to be the by-product in the production of chlorophenols[5]. Pulps obtainedfrom the chips from pentachlorophenol treated woods were suspected to be the source of dioxin formation in the bleaching processes[4]. In Canada, the sales and use of wood chips from PCP treated woods are prohibited in mills using chlorine and chlorine dioxide for bleaching[4]. No such prohibition is in force in U. S. However, most of the pulp mills neither use PCP as wood preservative nor buy chips from woods treated with PCP.

b. Defoamers

Canadian Reserchers[6-8] found that certain oil based defoamers contained high levels of dibenzodioxin (DBD) and dibenzofurans (DBF). This has prompted the industry to switch to defoamers prepared from highly refined, hydrogenated oils with low napthenic content. The use of these oils in defoamer formulations resulted in a low amount of DBD and DBF content[9,10]. Mills in U. S. and canada have reported a large decrease in PCDD/PCDF levels as a result of switching to defoamers with "Low Precursors"[5]. Even with the exclusion of PCP treated chips, and the use of precursor free defoamers, studies have shown that the bleaching processes still produce a significant amount ofPCDDand PCDF[11,12] Therefore, outside contamination is not the only source for PCDD and PCDF formation in the production of bleached pulps.

2. Remove More Lignin Before Bleaching.

The formation of PCDD/PCDF and AOX is a function of chlorine use. The chlorine demand at the bleaching depends on the amount of lignin in the pulp. Any process that removes more lignin from the pulp before bleaching, therefore, reduces the demand for chlorine and chlorine-based chemicals. This has then the potential to decrease the formation of chlorinated organic compounds including PCDD/PCDF.

a. Pulping

Conventional pulping chemistry dictates that the softwood pulps from the digester should be in the Kappa number range of 30-32 (permanganate number of 20-21) to derive optimum pulp strength. By adding the alkali in stages throughout the cook, the pulping can be extended to derive low kappa number pulps without sacrificing either yield or pulp strength[13], Systems like RDH (Rapid Displacement Bleaching)[14], Superbatch[15] have been developed for extending the cook in batch digesters. Modified continuous Cook (MCC) or Extended Modified Continuous Cook (EMMC)[16] has been developed for Kamyr continuous digesters. kamyr[17] offers MCC systems that can produce softwood kraft pulps in the Kappa number range of 15-18 with minimum loss of pulp yield and strength.

The use of pulping additives mainly Polysulfide (PS) or Anthraquinone (AQ), or both result in low Kappa pulps without any yield loss[18-20]. These low Kappa pulps require significantly less chemicals in the first bleaching stage. In particular, the demand for molecular gas is substantially decreased.

At present, six mills use PS in their pulping processes; One each in Norway and Austria and four mills in Japan. Many mills in U.S are exploring this route to reduce the pulp Kappa number from the digester. The ROI for installing a catalytic oxidation process for PS production is about six to seven months. The ROI calculations were based on increased pulp yield with a small decrease in solids to the recovery boiler.

The use of AQ in the pulping process offers several opportunities. One option is to use less severe conditions in the digester. By using lower chemical charge and lower H-facror, the target Kappa number can be achieved with increased pulp yield and less solids to the recovery. The other option is to use the same pulping conditions to get a pulp of lower Kappa number. This would result in the same pulp yield, but no change in solids to the recovery boiler. The later opearation has environmental implications. The pulp can be bleached with less chemicals, thus, decreasing the AOX emission from the bleach p'ant. Anthraquinone is an expensive chemical. The economics of using AQ are mill specific. The use of AQ or PS or PS/AQ combination is attractive to mills which are recovery boiler limited, and want to achieve low Kappa pulps without big capital investment,

b. Brown Stock Washing

Improved brown stock (BS) washing results in reduced black liquor carryover with the pulp, thus decreasing the amount of chlorine and Chlorine chemicals needed for bleaching. Improved BS washing has also shown to improve the delignification efficiency at the oxygen stage. Both laboratory studies and mill trials have demonstrated that the improved BS washing lowered the formation of TCDD/TCDF and chlorinated organic compounds[11,12,21-23].

Use of evaporator condensate for BS dilution and washing was common in many mills. These mills noticed a significant increase in the first stage chemical use. Increased chemical use at the first stage led to an increase in the emmission of chlorinated organic compounds from the bleach plant. The evaporator condensate often carries significant amounts of volatile contaminants. These volatile contaminants not only increase the chemical consumption, but are also good sources for the formation of chlorinated organic compounds when chlorine is used at the first stage. The practice of using evaporator condensate for the brown stock dilution and washing has long been discontinued by many mills.

Chlorination stage is often subject to upsets in BS washing. Any upset at the BS washing increases the chlorine demand at the first stage. This then leads to increased emmission of organochlorine compounds from the bleach plant. Therefore, tight operation of the BS washers are essential to reduce both bleach chemical consumption and formation of organochlorine compounds. As discussed elsewhere, this also applies to the lignin, dissolved in oxygen delignification stage.

Process control is one other area which is becoming important in efficient washer operation. On-line Kappa number measurements are often used to relate the amount of carry-over with the pulp. Both feed-forward and feed-back process control systems are used. In any modern pulp mill the process control systems of washing and bleaching are interconnected, Many mills are now using real-time dynamic simulation models for the process control of both washing and bleach plants.

Oxygen Delignification

Oxgen delignification, before multi-stage bleaching, is now an accepted technology[24-27]. By oxygen delignification, the pulp Kappa number can be decreased to about 40% with a small amount of pulp shrinkage. Oxygen is more selective towards lignin than carbohydrates, but again not as selective as conventional bleaching chemicals like chlorine or chlorine dioxide. By using magnesium compounds as inhibitors[28]. the carbohydrate degradation can be prevented to a large extent. Hydrogen peroxide reinforced single or two - stage oxygen delignification can result in about 70%Kappa number reduction with slightly higher viscosity[29-31]. Two-stage oxygen delignification is also suggested by Kamyr to further extend the delinification before the bleaching of pulps[32].

A good washing of pulps from oxygen delignification is very important. According to Allison, et. al,[33] poorly washed oxygen delignified pulps have higher bleach chemical requirement. Also, the toxicity of the bleach plant effluent is increased, with poor washing of oxygen delignified pulps.

Most of the mills which recently installed oxygen delignification have at least two washing stages after the delignification step. The capital investment on the extra washer is easily justified[34] because of increased bleach chemical costs resulting from the poor washing of pulps.

Between 1988 and 1991, 14 oxygen delignification systems were commissioned in U. S. Between 1992-1993, 9 oxygen installations will come on line in U.S. and canada. Out of these 23 installations, three of them are high consistency oxygen systems, and the rest medium consistency installations.

The disadvantages of high consistency oxygen delignification are high capital cost, complex equipment (high consistency presses,gas phase reactor and feeders). explosion risk due to oxygen rich atmosphere and loss of pulp strength when the delignification was driven above 50%. On the other hand, the medium consistency oxygen delignification consumes more alkali charge and steam. Also, the delignification has a limitation to about 40%.

The last two installation in the U. S. are high consistency oxygen systems because these mills have opted for higher delignification at a slightly higher loss in pulp strength. These mills decided to go for a high consistency stage to reduce their chemical consumption and to improve their effluent quality.

The recovery boiler in a kraft mill is the bottleneck in retrofitting the oxygen delignification step in existing mills. The addition of an oxygen stage in a fiberline has a negative impact on recovery boiler capacity. Thus, burning the organics in the recovery boiler that would otherwise be discharged to the environment has a cost, and the cost is pulp capacity. The decrease in pulp capacity has to be compensated by purchased pulp. Retrofitting an existing bleach plant with an oxygen stage requires capital, not only for the oxygen stage, but also to increase the boiler capacity to burn additional solids. Recovery boiler loading would increase as much as 6-10%A poor brown stock washing may increase this load to as much as 15%[35]. The back end of the recovery operation (for example, causticizing,etc.) should also have to be retrofitted to handle additional load.

More energy is needed to operate an oxygen delignification stage. The energy needed is more than the energy recovered from the burning of the organics generated by the stage. Therefore, an oxygen delignification stage has a net negative impact on mill's energy balance.

To use the oxygen stage effectively, the management of the transition metal ions are necessary. An acid prewash, with or without the presence of chelating agents, has shown to result not only a high Kappa number reduction, but also preservation of pulp strength[36].

3. Modification of Lignin Before Bleaching.

Modification of lignin structures before bleaching results in reduced chemical consumption in the bleach plant to achieve target pulp properties.

a. Acid Pretreatment

One example is the acid washing of the brown stock before oxygen delignification[36]. Acid washing of the brown stock not only binds the transition metal ions, but also increases the hydrophilicity of the lignin structures to respond to chemicals like oxygen and chlorine dioxide. The net result is the extension of the removal of lignin from pulp with the same or lower chemical charge. Acid prewash or buffering the brown stock at an acidic pH range is also one of the prerequisite of the enzymatic pretreatment of pulps.

b. *Enzymatic Pretreatment of the Brown Stock*

Enzymatic pretreatment of pulps[37-41] is a specific biocatalytic treatment to hydrolyse the xylosidics bond in Lignin-Carbohydrate complex (LCC) structures. Xylan hydrolysis may affect more than one physical parameter of the pulp, either releasing the lignin that is covalently attached to xylan, or solubilizing the precipitated xylan (xylan precipitation takes p'ace at the end of cooking) on the fiber surface, or a combination of these effects and/or others. The net effect is that the enzyme pretreated brown stock needs almost half the amount of active chlorine to bleach to 90% ISO brightness. Extensive mill trials are being conducted now. The future acceptability of enzymatic pretreatment as a part of the bleaching operation seems to be very high. Recent revelations[42] that enzymatic pretreatment improves the oxygen and ozone treatment of pulps have increased the chances of the enzymes to be used in the bleach plant.

Enzymatic pretreatment of pulps is no longer a laboratory curiosity, but rather chemical ability. Enzyme suppliers include Genencor International, Iogen, Novo Nordisk, Repligen Sandoz, Voest-Alpine, and ICI.

4. Modification of Bleaching Processes and Change of Chemicals.

A number of options are available for the mills to decrease molecular chlorine use and to lower the AOX discharge. The mills can choose not to extend the delignification in the digester, but to change the bleach chemicals to reduce AOX discharge from bleach plant. The common wisdom, however, is to combine the extended delignification with other process modifications and chemical changes to achieve ultra low AOX discharge in the outfall effluent. What are the process modifications available to lower the Kappa number of the pulp entering the bleach plant ? This has been discussed earlier. By combining RDH or MCC or PS/AQ pulping with oxygen delignification as a low softwood pulp, a Kappa number as 10-12 can be sent to the bleach plant. This would result in a significant decrease in the chemical demand to bleach the pulp, and thus, a substantial decrease in the formation of AOX. The pulp can then be bleached either by a low chlorine bleaching sequence, no chlorine bleaching sequence, or chlorine chemieal free bleaching sequence depending on the governing regulation on BOD, COD and AOX.

The following options are available to the mills to reduce or eliminate chlorine chemicals from the bleaching.

1) High or total substitution of the first chlorination stage with chlorine dioxide.
2) Lowering the chlorine factor by high ClO_2 substitution, or Hydrogen peroxide reinforced oxidative extraction stage, or post peroxide bleaching of the pulps.
3) Split chlorine charge in several mixers while keeping the chlorination stage pH well above 3.0.
4) Use of peroxygen chemicals like oxygen, ozone, and hydrogen peroxide in the bleaching process.

Union Camp[43] has announced that its Franklin Mill in Virginia will switch to $OZE_{0P}D$ bleaching sequence by the middle of 1992. The ultimate objective of this mill is to use OZEP Sequence to achieve pulp of 90 brightness with little change in pulp properties. The $OZE_{P0}D$ sequence will be practiced at both their hardwood and softwood lines. The mill produces about 1500 ADtpd hardwood pulp. Many U. S. Pulp and Paper Mills are keeping a close watch on Union Camp's process. If the process becomes a success, and if Union Camp demonstrates that the OZED sequence can be operated on a sustained basis, then many mills will change their strategy of bleaching pulps. The AOX generation from OZED bleaching is less than 0.2 kg/tone of pulp. Union Camps' discharge of effluent from the bleach plant would result only from the D-stage. The effluent load from this mill will be reduced to 1/3 of the present volume, and will be subjected to both primary and secondary treatments. The discharge of AOX in the outfall is expected to be as low as 0.1 kg AOX/ton of pulp. Another important advantage of this process is that the effluent color, BOD and COD would be almost twice the order of magnitude less than conventional C_DE_0DED bleach plants. Union Camp has retrofitted its recovery boiler to handle additional solids, and will recirculate the spent liquor from the OZE stage to the soda recovery plant. The use of ozone in the bleaching of kraft pulp is still debated in the U.S. However, it is expected that many mills will switch to ozone bleaching, at least in a limited way by the year 2000.

On an interim basis, mills are changing their R3, Solvay or Matheison chlorine dioxide generation units to R8 or R9 or R10 units. The chlorine dioxide from these units, unlike the R3 or Solvay units, has less than 1% chlorine content. Also, mills which are switching their chlorine dioxide generation methods, are also switching to high or total substitution at the first stage. For many mills, handling the chlorine tank cars are becoming a safety issue. These mills have no option except to switch to total substitution.

The beneficial of using high or total substitution of chlorine dioxide to lower the formation of chlorinated organics have been reported in many studies[44-50]. Mill trials in Canada confirmed these laboratory findings[51]. Recent studies carried out at Mead Central Research[52] indicated that 100% substitution result in 75-80% decrease in AOX emission from the first stage in the bleaching of 30 Kappa number pulps. To achieve further decrease in AOX emission, the stage should be a medium consistency one and the pulp should be cleaner and should contain very low BL carry-over. Switching to 100% substitution at the first stage will increase the consumption of chlorine dioxide, since chlorine dioxide is not as effective chemical as chlorine at the first stage.

No longer mills in U.S practice simple extraction; almost all the mills have switched to oxidative extraction. The addition of small amounts of oxygen to the extraction stage results in 1 to 2 points drop in Kappa number of the pulp out of the extraction stage. Oxidative extraction provides two options. By maintaining the same CE Kappa number as a conventional extraction stage, a lower chlorine multiple can be used at the first chlorination stage. On the other hand, by taking advantage of the lower Kappa number out of the oxidative extraction stage, the amount of chlorine dioxide needed to achieve the target brightness can be lowered at the D-stage. Most Mills prefer to lower their chlorine multiple at the first stage to improve their effluent quality, Reinforcing the oxidative extraction stage with a small amount of hydrogen peroxide results in an additive effect on the chlorine multiple, as well as on the chlorine dioxide use at the back end[53].

Post hydrogen peroxide treatment of pulps in HD storage is becoming common in U. S. The post hydrogen peroxide bleaching allows the mills to lower their chlorine dioxide charge at the final D-stage. The post hydrogen peroxide bleaching provides 3 to 4 brightness point increase in the final pulp. The pulp has a much better brightness stability than a pulp of the same brightness from the final D-stage. The post hydrogen peroxide bleaching, by lowering the brightness demand at the final D-stage, allows the mill to reduce its chlorine multiple at the first stage and chlorine dioxide charge at the final D-stage. This enables the mill to decrease its AOX emission from the bleach plant.

Hypochlorite is being phased out as a bleaching chemical in many mills. This is due to the formation and emission of chloroform resulting fron its use. The use of hypochlorite will be eliminated altogether from the bleaching sequence by the end of 1995, as mandated by the 1991 Clean Air Act.

The U. S. Pulp and Paper Industry is looking beyond the reduction of AOX emission from the bleach plant. At present, the mills are evaluating the toxicity of the effluents even at very low AOX levels. Research is underway to identify the toxic substances generated in the bleaching processes. Once this task is complete, bleaching processes will be modified or new bleaching chemicals will be introduced to produce 90% ISO pulps without any toxic substances in the effluent.

Unlike Scandinavian or European Mills, the secondary effluent treatment is very common in U. S. This allows the U. S. Mills to retain some amount of chlorine dioxide in the bleaching process. Already, steps are being taken by the mills to reduce their water consumption, so as to decrease their effluent load to the treatment plant. With process modifications and the use of chemicals like ozone, oxygen and peroxide, it is expected that the closed-cycle bleach plant would become a reality, and the effluent volume and AOX discharge from the bleach plant will be negligible.

The Figures 2-6 in the following pages depict the evolution of bleaching operation in U.S., and describe the future hypothetical bleach plants with very little discharge of effluents. Operating such a bleach plant will not come cheap. The capital and operating costs for these mills will be enormous (Figures 7 and 8). However, the discharge of BOD, COD, Color and AOX from these mills will also be very low (Figure 9).

Reduction of chlorine use in the bleaching has resulted in an imbalance in the supply of caustic, since both the chemicals are derived from the electrolysis of brine. Efforts are underway to use sodium carbonate or other cheaper alkali in the bleaching

FIGURE 2

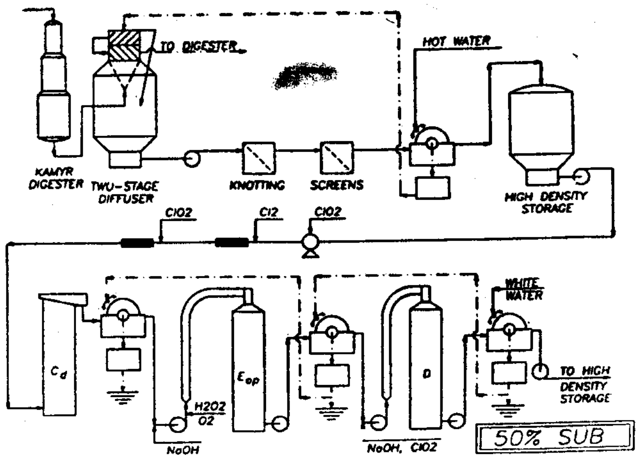
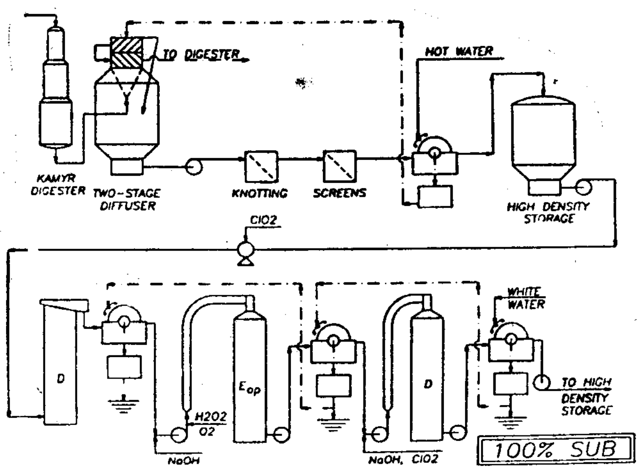


FIGURE 3



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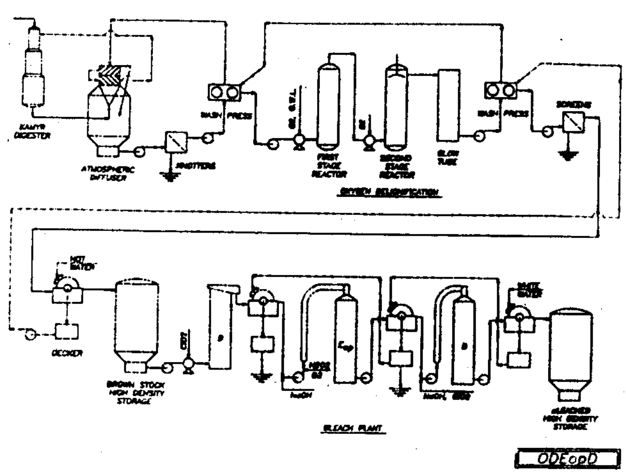

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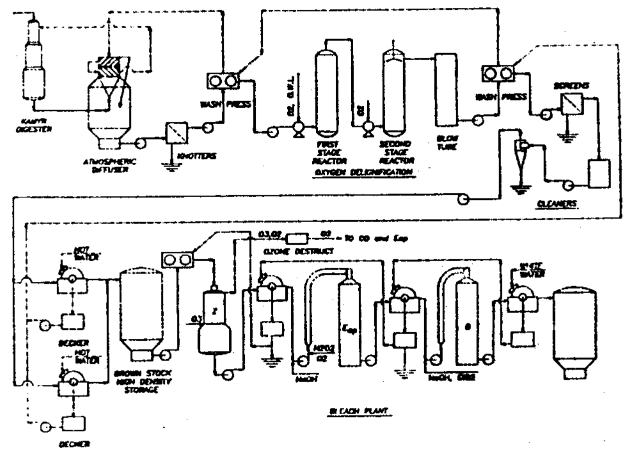

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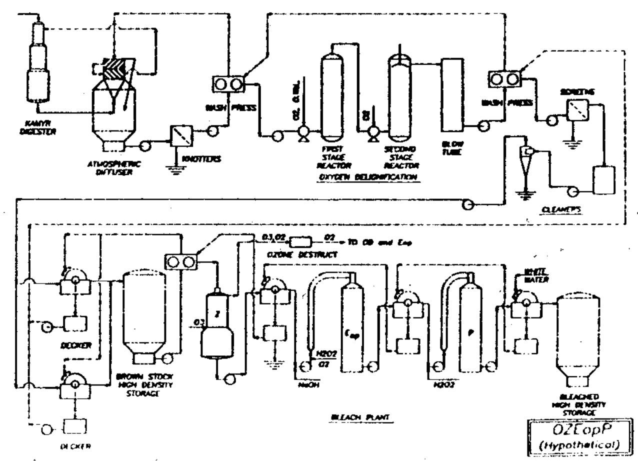
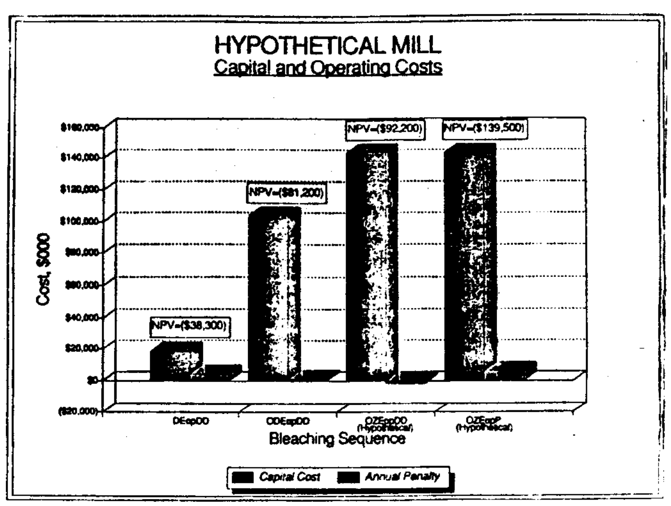


FIGURE 7



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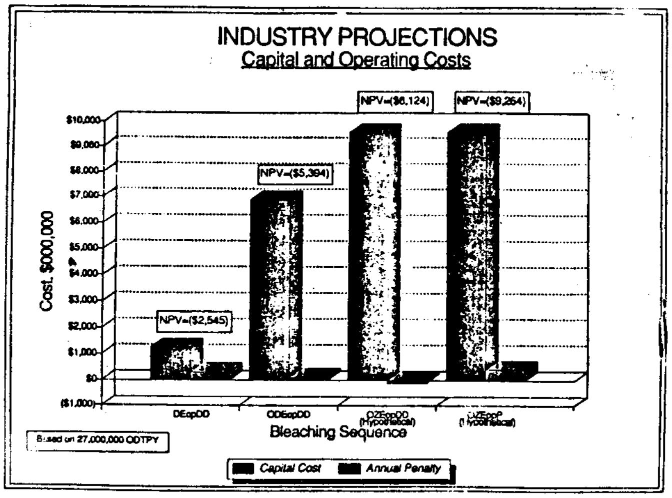
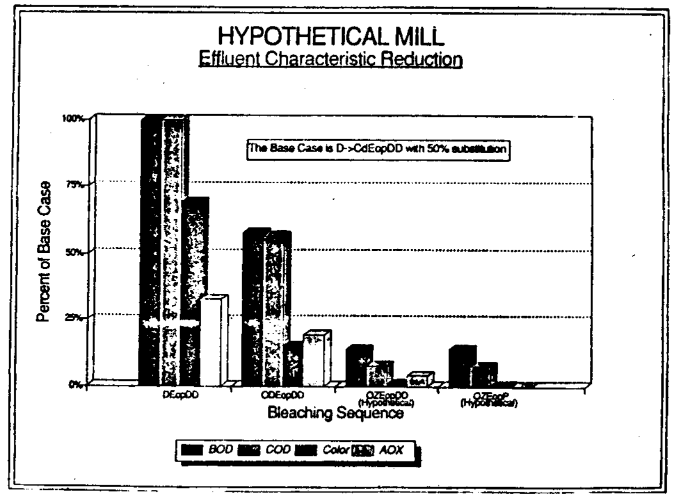


FIGURE 9



process[54 55]. One step in this direction is the rapid caustic extraction as practiced in the PAPRICYCLE Process[56]. Causticizing of sodium carbonate to derive sodium hydroxide is looking very promising[57]. The U.S. has the world's largest soda ash deposit in Wyoming, and this should provide adequate amounts of sodium hydroxide for use in the bleaching of pulps and make-up of chemicals[57].

The production of hardwood pulp has increased dramatically over the last ten years. The simple reason is, hardwood with its less lignin content needs less chemicals to cook and bleach, and therefor, generates less amount of pollutants. The rotation of the hardwood forest is also shorter, unlike the softwood forest; some take as much as 50 years. This would become very critical in both the Northeastern and Northwestern U.S. and Canada, as the concern and resistance to the deforestation of the old growth softwood forest will grow and continue. Hybrid hardwood species will not only shorten the rotation, but will also provide higher wood yield per acre resulting in less deforestation. Hardwood pulping will therefore become a significant step towards environmental improvement.

Waste paper recycling has increased over the last five years, easing the use of virgin fiber in products like magazine paper, newsprint, etc. The socalled "Urban Forest", the cities and towns that provide the waste paper for recycling, will ease the pressure on the forest resources of U.S. and Canada. It is estimated that by 1998, at least 40% of the fiber for the manufacture of paper in U.S. will come from waste paper sources[58]. It is anticipated that waste paper utilization would slow down the deforestation of old growth forests.

CONCLUSION :

This paper outlined the steps that are being taken by the U.S. and Canadian Pulp and Paper Industries to produce quality paper with little impact on environment. Unlike many other countries, the effort on the part of the U.S. Pulp and Paper Industry to decrease the emission of pollutants from the manufacture of paper is voluntary. The industry has always lived up to its corporate responsibility and took efforts to produce paper with as little impact on environment as possible. In U.S., the pulp and paper industry is the only smoke-stack industry still surviving and yet has shown a sustained growth over the years. The industry has voluntarily spent a large sum of money to change the process to minimize. environmental impact. The industry is intending to spend more money in the future for further change and is targeting for pollution-free production of paper. These are very exciting years for the Industry which is witnessing a quantum leap in the pulping of wood, bleaching of pulps, and waste paper recycling in high quality products. These changes will countinue and the Industry will strive to produce environmentally friendly" bleached pulps of higher qualityand brightness.

To my daughter, the kraft mill smell is "Mead Smell". The effluent from the mill is like "Daddy's Coffee". But, days are not far off when "Mead Smell" and "Daddy's Coffee" color effluent are the thing of the past, More and more process changes are being adapted by the industry, to provide ' environmentally friendly" product.

Finally, our raw material is wood, and therefore, the survival of the industry depends on the survival of the forests. So we have a vested interest to keep the forest green.

We will always keep the earth as green as possible because our livelihood depends on forests and once the forests are gone, the industry will be gone too.

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