SOME EFFECTS OF BLEACHED KRAFT PULP MILL EFFLUENTS ON AQUATIC ORGANISMS - A REVIEW

Duncan Leadbitter
Executive Officer
National Ocean Watch Centre
P.O. Box 247
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INTRODUCTION

Paper is still the prime carrier of information and it is information that reduces uncertainty in decision making. Despite the promises of the paperless office ushered in by the computer age it is obvious to everyone that the reverse seems true.

We need paper and it costs money to produce and buy. There are strong economic arguments driving the current interest by the pulp and paper industry in Australia but like many development projects the financial balance sheet of profit and loss are more easily understood than some of the intangible impacts of such investment.

This paper describes, from the available literature, some of the effects of water borne wastes from pulp mills on fish and other aquatic organisms in other parts of the world.

Firstly the pulping processes that create the pollutants will be described, followed by a brief documentation of the characteristics of the wastes involved. The effects on aquatic life will be described and, finally, some comments on the Commonwealth Government's recently released Environmental Guidelines for New Bleached Eucalypt Kraft Pulp Mills will be provided.

BACKGROUND TO PULPING

Paper is made from plant fibre and the most common sources of this fibre are trees, both soft and hardwoods, either from plantations or native stands. Getting the fibre out of the trees and turning it into raw fibre (the process known as pulping) is no easy feat. There are several different types of processes available depending on the quality of the paper needed and other constraints such as cost and environmental acceptibility. Although the Kraft method is the focus of this paper it is instructive to give a brief description of the other technologies in use in the world today. Except where otherwise indicated the following information has been compiled from Anon (1984), Naturvardsverket (1987) and Bonsor *et al.* (1988).

Thermomechanical pulping is where, as the term suggests, the wood fibres of cellulose are separated from the binding agent holding them together, mostly lignin, using a combination of steam and mechanical pressure. This process is commonly used for the production of newsprint from softwoods.

Thermomechanical pulping has a high pulp yield but the short fibres of hardwoods are generally unsuitable for newsprint and thermomechanical pulps generally do not produce good writing paper from either soft or hard woods.

Variations of this method can include the use of chemicals to aid the release of the fibres. This generally results in increase in strength and decreases in energy usage over purely thermomechanical pulps. Some chemimechanical pulps, especially those prepared from young, plantation eucalypts, can be bleached to a high brightness without the use of chlorine, a distinct environmental advantage.

Chemical pulping is so named because chemicals and in particular alkalis and sulphur are used to break down the lignin. The alkali improves strength whilst the sulphur (either sulphite, sulphide or sulphate) is used to maintain the pulp brightness. Kraft pulping is but one variation of chemical pulping and is probably the most commonly used method in Canada if not elsewhere in the world. The Kraft process involves treating the wood under an alkaline mix of sodium hydroxide and sodium sulphide under high temperature and increased pressure.

In Australia, old growth eucalypts (>100 years old) are the proposed feedstock for this pulping method because their short fibre lengths produce pulps suitable for high quality writing paper production. However, because of the highly coloured nature of the wood, strong bleaching is required. Kraft pulp mills do not consume much energy, partially because most of the energy is released from the chemical breakdown of the wood, thus contributing to a poor wood pulp conversion.

All pulping activities begin with the arrival and debarking of the logs at the receiving yard. Two techniques of debarking exist, known as wet and dry debarking.

Wet debarking involves the use of barking drums that use high pressure freshwater jets and agitation to remove the bark. Large quantities of water are used and there is generally a great deal of bark (and thus organic matter) laden water to be released into the environment.

Dry debarking is accomplished using mechanical rings, although some water is needed to wash the logs prior to the next processs. The bark removed can be used as fuel elsewhere in the plant but the tradeoff is that fewer logs can be handled at any one time compared with wet debarking.

In a Kraft mill the logs are then chipped and sent to the cooker where a combination of alkali and sulphur compounds (known as white liquor) is applied under pressure and an elevated temperature to break down the lignin.

Following this digestion period the slurry is washed and the white liquor, which is now brown, is sent to a reprocessing area.

The pulp is now ready for its first bleaching stage. Modern chlorine bleach plants use an alkali assisted oxygen bleach first to reduce the organic matter in the pulp and thus the amount of organic compounds available to combine subsequently with chlorine to form organochlorines.

Final bleaching is accomplished via a series of steps using chlorine, chlorine dioxide and another alkali/oxygen step. The bleached pulp is then washed and air dried for use in the paper making process or for export.

The production process is not standard from mill to mill and this, combined with other factors outlined below, causes the effluent from a given mill to be unique, thus making environmental impact prediction extremely difficult.

SOURCES OF POLLUTANTS

Pulp mills generate a wide variety of liquid effluents ranging from the benign to those with chronically and/or acutely toxic effects on living organisms. Due to the size of modern plants the quantity of pollutants produced is extremely large. Although the organochlorines and especially the dioxins are the most well known and certainly the pollutants of prime concern, there are other substances which can have substantial environmental effects if not treated properly or are disposed of in poor locations.

Despite the continuing concern over pollutant production there have been remarkable changes in pollution abatament over the last twenty years. Many older pulp plants would never get a licence to operate today. Nevertheless the larger size of modern plants and the fact that few advances (other than volume reduction) in the control of toxic substances have been forthcoming highlights the need for rigorous analysis of pulp mill proposals.

Effluent discharges vary widely from mill to mill. The differences are due to different technological developments, varying environmental pressures at the time of initial mill design, deliberate decisions on in-plant versus external measures for effluent quality control, type of feedstock and the skill levels of the operators, i.e. the human factor. In many cases technology has only changed the form of the pollutants. For example old mills would discharge all excess lime mud, screen and cleaner rejects to the sewer whereas newer plants dewater these substances and send them to landfill.

On the whole, modern plants have quite sophisticated methods for preventing and recovering accidental spillages, reprocessing some process chemicals, reducing the production of some pollutants and, as just described, changing pollutants from an unacceptable form to a more acceptable one.

The major categories of pollutants can be described as follows:

1. Colouring substances

Dissolved high molecular weight substances such as fulvic and humic acids from pulp mills affect the absorption of light in the water (Hine & Bursill 1985). These substances do not easily decompose and so their effect on the photosynthetic ability of plant life is dependent on their distribution and concentration gradients.

2. Turbidity and sediments

Suspended solids consist of bits of fibre and other organic and inorganic particles. Flocculation in seawater can make these substances settle out relatively quickly only to be resuspended during high energy periods. The sources of sediments include the debarking area and the washing plants.

3. Oxygen consuming substances (BOD and COD)

Sugars, alcohols, organic acids and other easily degradable organic substances are part of the waste stream from the bleaching, washing and debarking areas. Chemical oxygen demand is also generated from the oxidation of some of the sulphur compounds used in the pulp cooking reactions.

4. Nutrients

There are both direct and indirect sources of nutrients and, thus, the potential for eutrophication, from pulp mills. The dissolved and particulate organic compounds contribute to heterotrophic production, while the nutrients that are either discharged directly, or are released by mineralizing processes in the bed of the recipient water body can create the conditions for high primary production.

Again the debarking area, washery and bleaching units are the sources of nutrient inputs.

5. Malodorous substances and those affecting taste

Some substances in the waste stream such as terpenes and other reduced sulphur compounds cause fish to avoid an area and may also impart an unpleasant taste and smell in the recipient water. Chlorinated phenols are also known for causing taste and smell at low concentrations.

Clackwell *et al.* (1979) estimate that the taste threshold for these substances to be 50-200 mg/l and for smell 0.5-60 mg/l. Tainting in fish has been detected in fish up to 8 km from a Kraft mill (Lengi 1986).

6. Acidity/alkalinity

Depending on the character of the effluent and the receiving water, changes in pH may be induced near a pulp mill outfall. Obviously this problem is greater in poorly buffered fresh water rather than estuarine or marine waters.

7. Chlorate

The present move to substituting chlorine dioxide for chlorine in the bleaching process so as to reduce the production of organochlorines results in the creation of chlorates. Kringstad & Lindstrad (1984) note that little is known about these compounds, especially their environmental effects.

8. Toxic substances

Effluents from both bleached and unbleached pulp mills contain substances that are toxic to aquatic organisms. In the case of unbleached effluents this situation may result from the tendency of trees to use chemicals as defence mechanisms against disease and insect attack. However the chlorination of the wide variety of organic compounds in the waste stream appears to substantially increase toxicity as well as increasing their resistance to biodegradation and increasing their ability to bioaccumulate.

To date about 300 low molecular weight substances have been identified in pulp mill waste but these represent only 10% of the total weight of organochlorines (Leach & Thakor 1989, McKague 1981). Bonsor *et al.* (1988) suggest that the major cause for concern in regard to organochlorines is that environmentally undesirable substances as, or even more, dangerous than the famous dioxins will be discovered. Some of these substances may be breakdown products of chemicals discharged into the environment. For example Neilson *et al.* (1984) found that the bacteria mediated breakdown of some chlorophenols produced daughter molecules with a greater biological activity.

The composition of any particular mill organochlorine load is difficult to ascertain not only because of identification problems but because of varying precursors in the feedstock and different processing techniques. However, both acute and chronic toxic effects are well documented and are described later.

Although genotoxic chemicals have also been identified in the waste stream (Carlberg *et al.* 1986) there is still considerable debate over whether the effects of such compounds are expressed in organisms. Certainly, in Sweden deformed fish larvae have been found on regular occasions in laboratory studies and various head and spinal deformities have been detected in fish in the field. There is also continuing speculation over the ability of secondary treatment to eliminate the genotoxic activity of effluent and whether the Ames test is the most appropriate test for mutagenicity.

Bioaccumulation of phenolic substances has also been shown to occur but the fish excrete the compounds over a period of weeks if transferred into clean water (Landner *et al.* 1977, Carlberg *et al.* 1988, Hakansen *et al.* 1988). Although this may have no effect on the fish the vagaries of consumer demand may add special importance to this problem.

The interaction between various pollutants also needs consideration. For example in some areas the stimulatory effect of high nutrient levels on plant growth is countered by the photosynthetic inhibition caused by the colour in the water. It has also been found that deoxygenated water contributes substantially to the toxicity of bleach effluent (Graves *et al.* 1981).

EFFECTS OF POLLUTANTS ON FISH AND OTHER AQUATIC LIFE

Macleay and Associates (1987) provide an excellent review of the literature dealing with the effects of mill effluents on aquatic life. More recent information has come from the completion of a major integrated Swedish study (Environment/Cellulose project - Sodergren 1989).

The complexity of the mix of substances emanating from a Kraft bleached pulp mill makes assessing the effects on the biota in receiving waters extremely difficult. As with many other areas of research, after-the-fact investigations only give clues about what may or may not be happening, and laboratory studies fail to take into account all environmental variables which may inhibit or enhance the impact of pollutants.

However, a broad appraisal of the literature reveals that:

1. a considerable volume of literature does not provide any clear picture of the environmental effects of bleached Kraft pulp mill effluents. A combination of poor experimental designs, a general paucity of research information on effluent characteristics and effects on marine and estuarine organisms makes unambiguous decisions on the environmental safety of such plants open to question;
2. the effects of pollutants manifest themselves in terms of the physiological, growth, reproductive and possibly evolutionary aspects of the biota studied. It may be that the components of the effluent having effects on individual aspects of species' biology may differ. For example, organochlorines may affect reproductive capabilities but high nutrient levels may not. Alternatively both organochlorines and high nutrient levels may affect community structure but in different ways;
3. the type of effects that can be expected include acute and chronic toxicity, altered taste and smell, oxygen deficiencies, eutrophication, bioaccumulation, disease and changes in community structure;
4. in the case of pollutants that decompose slowly or accumulate in the environment the character of the receiving water is of little importance. That is, whether the area is well flushed and dilution occurs within arbitrarily set criteria or not is irrelevant;
5. some countries (e.g. Austria) have already phased out chlorine bleached. Others such as Canada and Sweden are gradually reducing organochlorine emissions. The speed with which these reductions take place and the target levels are entirely dictated by industry economics.

An analysis of some of the available literature reveals the following effects on fish and other aquatic organisms:

1. Physiological disturbances in invertebrates and fish.

Most wetland food webs are detritus based. Few organisms graze on the flora directly but many utilise the bacteria which breakdown plants as a source of energy. MacCubbin *et al.* (1981) found that in comparison to some studies which show that input of dissolved organic substances to the water stimulated these bacteria the input of Kraft mill effluent inhibits the bacteria at relatively low concentrations (<1ppm).

Kinae *et al.* (1981) documented the ability of Kraft pulp mill effluent and effluent contaminated sediments to retard the development of, and even lyse (or break down), sea urchin eggs. The most toxic substances in the effluent used were slime control agents. The authors suggested that sea urchin eggs could be used to monitor the toxicity of effluent in a cost effective way.

Extensive studies have been conducted in Sweden on the effects of chlorinated pulp mill wastes on fish. In a relatively recent study (Hansson 1977, Andersson *et al.* 1988a, 1988b, Sodergren *et al.* 1988) involving perch sampled at differing distances from a modern bleaching mill it was found that liver related problems could be detected in fish living up to 4.5 km from the plant. Changes to the white blood cell pattern indicated a suppressed immune system response with implications for disease. Gonad growth reduction was found in fish up to 10 km from the mill.

Growth rates in perch exposed to pulp mill wastes were higher than those not exposed to mill wastes and it appears that the energy unexposed fish devote to reproduction goes into tissue development in exposed fish (Sandstrom *et al.* 1988). This pattern was not totally consistent amongst fish species and, although reduced gonad growth was observed in roach, the effect was nowhere near as marked as for perch.

Swedish studies have also documented spinal anomalies in fish exposed to pulp mill effluent in the laboratory (Mayer *et al.* 1988) and in the field (Neuman & Kara (1988). Thulin *et al.* (1988) reported over 50% of pike showing deformed jaws at distances of up to 6 km from the Norrsundet bleached Kraft mill. Fish in the waters affected by this mill also showed a variety of other injuries including skin sores, fungal infections, deformed gill filaments and gill rakers, shortening of the gill covers, skeletal deformation and fin erosion.

2. Disease

Suppressed immune systems and stress contribute to susceptibility to disease. It has been postulated that neoplasms seen in some fish in Japanese waters may be due to pulp mill wastes, but given the cocktail of pollutants in many industrial areas in Japan it would be difficult to isolate causative factors (Kinae *et al.* 1981).

In Sweden the incidence of fin rot in perch is significantly higher in fish from the vicinity of bleaching pulp mills than from near non-bleach mills. Lindesjoo and Thulin (1987) found that regrowth of the fins, which possibly occurs when fish move out of the affected area, is characterised by curvature of the fin rays.

Of interest to northern New South Wales, where red spot is an economically significant disease of fish, are some findings by Hazen and Esch (1983) from the United States that pulp mill effluent sustained the populations of a similar fish ulcer agent, *Aeromonas hydrophila*, at a level 100 to 1000 times greater than sites upstream of the discharge. The authors described the mill effluent as an organic soup consisting of nitrogen, phosphorus and organic carbon and it is interesting to note that either the mill did not bleach or that bleaching did not play a role in the result.

Other types of disease-causing organisms such as species of *Vibrio* are also associated with carbohydrate pollution such as that from sugar and cellulose (or wood) treatment plants.The concentration of some coliform bacteria such as *Klebsiella* (Shertzer 1985) was found to be higher in pulp mill effluents than in surrounding waters whilst Hendry *et al.* (1982) found the potentially harmful *Pseudomonas* in bathing areas downstream of a pulp mill waste outfall.

3. Behavioural changes in fish

The effects of bleached Kraft mill effluent on the movement of fish has been only partially studied but it has been found that marked avoidance of low concentrations (threshold level of 0.06% effluent) was found for the four species observed (Wildish *et al.* 1977, Lewis & Livingston 1977, Greer & Kosakoski 1978). Wildish *et al.* (1977) found that the herring avoided the long chain complex molecules such as lignosulphates and perhaps lignin more so than the resin acids and other breakdown products of low molecular weight that are known to be toxic.

The implications for fish migration are not known but studies of thermomechanical mill at Boyer, Tasmania, by Davies *et al.* (1988) suggested that fish migrating upstream avoid that part of the river where relatively high concentrations of pollutants are found. Fortunately, in this case, the waste stream tends to hug one bank.

Studies of salmon in Canada show that the swimming performance of juvenile salmon forced to swim through pulp mill effluent is increasingly impaired as effluent concentration increases (Howard 1975).

4. Community effects

4.1 Benthos

Studies on the meiofauna of lakes used as the receiving waters for pulp mill wastes in Finland document a typical response to pollution, namely, a marked drop in diversity of benthic species with the individuals of the species remaining occurring in large numbers (Sarkka 1977). Nematodes are commonly one of the few groups of animals surviving heavy pollution.

4.2 Effects on plants

Bothwell and Stockner (1980) found that exposure of some freshwater Canadian algae to low concentrations of secondary treated Kraft mill effluent generally resulted in increased biomass. At high concentrations a change in species composition occured. The algae appeared to be relatively tolerant to low concentrations of toxic substances and thus able to respond to the relatively high nitrogen and phosphorus levels.

Experiments by Stockner and Costella (1976) on phytoplankton revealed a variable response to pulp mill effluent. Some species needed a period of adaptation before growing normally and the period of adaptation was longest in Kraft effluents of the six tested. Other species showed an ability to grow in concentrations of 90% effluent.

Field studies show marked decline in productivity near pulp mills and it has been suggested that colour in the water over-rides the nutrient effect of the effluent (Stockner & Cliff 1976). Moore and Love (1977) found a decrease in photosynthesis in phytoplankton associated with high concentrations of pulp mill effluent and suggested that pH may be the main controlling factor once the plankton were adapted to the waste. Similar variability was also displayed by macroalgae which showed inhibition in the laboratory but not in the field.

For macroalgae Hellenbrand (1977) found that any observed inhibitory responses were reversible but the marked reduction in brown algae growth documented by Kringstad and Lindstrom (1984) was attributed to the presence of chlorates in the water which have a herbicidal effect.

In a complex study of algae and seagrasses in Florida, Zimmerman and Livingston (1976) found that although species diversity did not change markedly except close to the mill outfall, there was a dramatic decrease in biomass. It was suggested that the mill effluent destroyed the stability of existing communities and allowed opportunistic species to settle and grow. A totally new community was created which was supported by the mill effluent. In the transition zone between this community and unaffected communities there was an area of high diversity which seemed to be stimulated by the additional nutrients, but not affected by the toxicity.

4.3 Rocky shore communities

Canadian studies of the response of rocky shore communities to field concentrations of pulpmill effluent have documented community simplification for both sub- and intertidal animals and plants (Harger *et al.* 1973, Harger & Nassichuk 1974).

In a study of mussels and barnacles transplanted near a pulp mill in Howe Sound, British Columbia, Wu and Levings (1980) found that while both species were tolerant of bleached Kraft mill effluent their growth rates and reproductive abilities were impaired. Due to the dispersive ability of many invertebrate larvae the effects of suppressed reproductive ability might not be as severe as expected providing that the larvae in the water column can survive.

In a study on the effects of chloroform, on the survival of larvae on the eastern oyster (*Crassostrea virginica*) Stewart *et al.* (1979) found that larval mortality occurred at concentrations of less than 0.05 parts per million. Sodergren (1989) noted that although chloroform emissions from bleached kraft mills declined rapidly over distance (to levels below 1 part per billion) the presence of chloroform can be used as a method of quickly tracking the distribution of other organochlorides.

4.4 Effects on fish

In Apalachee Bay, Florida Livingston (1976) investigated the fish populations of the same area studied by Zimmerman and Livingston (1976). Biomass decreased but species diversity was not appreciably affected. In the area of chronic impact it was found that game and commercial species were severely depleted. Since species diversity was maintained the proportion of less desirable species must have assumed a greater importance. It may be seen as "positive" that vacant niches created by such pollutants are not filled by desirable species, given the bioaccumulative nature of some of the compounds.

Species shifts have also been noted in Canada and Sweden. In the Swedish study it was found that close to the mill the density of fish was very low and recruitment drastically reduced (Hansson 1987, Neuman & Karas (1988). Further away carp-like fish dominated and further away still a normal Baltic Sea fish community reappeared.

Kelso (1977) found a shift from yellow perch to suckers close to the discharge zone of a mill and also noted avoidance behaviour in fish artificially placed in contaminated water.

Despite what seems to be substantial documentation of the effects of Kraft mill effluent there is still much to be learned. In reality the studies, particularly the community studies, have been nothing more than sophisticated observations and the reasons for the observed patterns remain little more than conjecture. For example, to explain the changes in fish communities would involve a myriad of studies which could investigate the eutrophic effects of the nutrients that favour some fish feeding strategies or larvae over others. Alternatively the large amounts of coloured water may affect the distribution and abundance of aquatic plants which provide food and shelter for fish. It is also possible that pure avoidance behaviour may be the case and it is equally possible that there are more sinister reactions involving toxic substances on reproductive viability or the survivability of fry.

THE GUIDELINE/DISCHARGE LIMIT DEBATE

There is no doubt that chlorine bleached Kraft pulp mills are significant polluters of aquatic environments. In the current climate of heightened public environmental awareness there is an increasing number of questions being asked about the need for such environmentally damaging processes.

Although Australia hosts a variety of pulp mills, including some employing limited chlorine bleaching, the recent attempt by the pulp industry to locate a world scale bleached Kraft pulp mill at Wesley Vale in Tasmania created an atmosphere in which many of these questions have been asked but satisfactory answers are still to be forthcoming. Until recently consumers demanded high brightness pulp, without questions as to the consequence of this demand. Is the existence of this demand sufficient to justify the perpetuation of the *status quo* ? Whether consumers have been informed of the consequences of such a choice is open to question. Certainly the environmental impact statement for the Wesley Vale project glossed over many of the potentially serious impacts of such a mill.

The Federal government's response to the problem, after refusing to issue an export licence for the project, was to announce the preparation of guidelines for pulp mills. Despite expectations in the community of a far-sighted document that addressed all types of mills, including existing plants, the government only provided guidelines for new bleached eucalypt Kraft paper mills using chlorine (or derivatives) as the bleaching agent.

The gudelines are based upon two principles, namely:

1. That there is a safe level of organochlorine discharge.
2. That the cost of pollution controls should not make the pulp production process uneconomic. This is to be achieved by requiring that the Best Available Technology Economically Achievable (BATEA) be used.

Of greatest concern to the fishing industry are the environmentally persistent organochlorines arising from the chlorine bleaching process. Bonsor *et al.* (1988) note that not only does the bulk of the organochlorine waste load remain unidentified but that the likelihood of discovering substances as dangerous as dioxins is high. Macleay and Associates (1987) state that "At the present time we don't know at what level the concentration of any effluent constituent accumulated in fish or other aquatic life poses a threat to that organism (or to a commercial fishery resource), nor do we have any proven techniques for making such assessments." This is despite the considerable research effort mounted over several decades in the major pulp producing nations. Given that Fandry *et al.* (1989) could not find any information on the effluents from bleached eucalypts, the claims made in the guidelines that no known environmental effects will occur at the discharge levels specified seem tenuous at best.

There is considerable disagreement between the Canadians and the Swedes over the concentration levels at which effects on fish can be observed. Recent Swedish studies suggest that the 'no effect' concentrations could be at least ten times lower than that accepted in Canada and, now, in Australia. The guidelines claim that because these levels were determined from field experiments in the seriously polluted Gulf of Bothnia they are unreliable. However, not only have they been confirmed by laboratory experiments but Bonsor *et al.* (1988), who have compiled the most up-to-date analysis of the situation in Canada, admit that most of the North American studies have not looked for the subtle effects detected by the Swedish research.

Given the gaps in the available knowledge and the sensitivity of the pulp mill issue one has to question why the Swedish information was not given greater weight and a more conservative approach to effluent standards adopted particularly when levels specified according to dilutions in water fail to address problems associated with accumulation in sediments and organisms. The BATEA principle may provide a clue. In specifying a discharge limit of 1 kg of AOX (Adsorbable Organic Halide) per air dried tonne (ADT) of pulp the guidelines authors have only specified what is economically achievable, not what may be ecologically necessary.

That the Federal government lacks confidence in the Guidelines is evidenced by the fact that, with the exception of dioxins, there are no performance standards set for the accumulation of organochlorines in the environment nor for the known impacts on the biota such as physiological and/or ecological impacts.

In short the Guidelines are too open ended because of the uncertainties involved. Although the Guidelines specify that environmental damage will be identified before it becomes irreversible there is no definition of what constitutes damage. If we are to rely on overseas experience the imposition of fishing closure due to public health scares will be the first indication that irreversible damage is occurring.

Unfortunately the current headlong plunge into economic and technological rationalism has taken us even further from grappling with intangible values such as those inherent in an unpolluted environment. Users who depend on pollution free aquatic environments are justified in feeling threatened by the producers of chlorine bleached pulp. Yet there are too many precedents to imagine that Australia will deal with future problems any differently from other countries. The combination of large multinational corporations and compliant governments desperate for foreign exchange makes the closure of a contaminated fishery a more attractive alternative to the shut down of a multi-million dollar pulping mill.

It is interesting to note that, in comparison to Sweden for example, Australia proposes to utilise native hardwood stands for its proposed ventures in pulp production. Swedish millers now only use plantation timber as feedstock but plant more trees than they use.

Current indications are that bleach free technologies will become attainable in one or two decades. This would enable ample time for plantations to be established and thus ensure a more mature approach to reaping the economic benefits of pulp production.

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