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Concern About AOX

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CONCERN ABOUT AOX

A Working Paper from SFM Network Project:
Factors Influencing Kraft Pulp Mills when Reducing Impacts of Effluent Discharge

by

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ABSTRACT

The purpose of the Sustainable Forest Management Network is to reduce impacts from the forest industry through Policy and Institutional Analysis in an interdisciplinary research program. Understanding legislative mechanisms for pollution control and setting effluent parameters as relationships among government, industry and public evolve is an objective of the SFMN project entitled Factors Influencing Kraft Pulp Mills When Reducing Impacts Of Effluent Discharge.

This working paper reviews the pulp mill effluent parameter AOX. Public fears about chlorinated organics developed since the 1960s in association with dioxin released from industrial accidents and government cover-ups. Labelled "the most toxic substance known to man" in the media, a series of activist reports fostered doubt concerning the legitimacy of the scientific knowledge about dioxins. In the 1980s, dioxins were found in pulp mill effluents. Industry moved quickly to eliminate sources in plants and effluent treatment systems. Governments implemented the precautionary principle by requiring strict AOX standards and best available technology standards through legislative changes. Managing the scientific uncertainty of environmental impacts is the challenge facing resource professionals and policy makers in the future.

INTRODUCTION

One of the goals of the Sustainable Forest Management Network (SFMN) is to identify and reduce impacts from forest resource utilization by investigating policy and institutional arrangements through an interdisciplinary research program. This SFMN project, entitled "Factors Influencing Kraft Pulp Mills When Reducing Impacts Of Effluent Discharge", examines the influence of the evolution of the kraft pulp mill effluent parameters on the forest industry. The development of one parameter, AOX, offers a unique opportunity to understand the effect of standards on the industry. Since its inception in the early 1980s, legislation for minimizing AOX has been cumbersome and susceptible to political pressure and public controversy. Understanding the factors controlling AOX and finding alternative institutional arrangements is critical today, as we face the future with concerns about chlorinated pulp mill effluent constituents, related endocrine disruption, and global market trends toward total chlorine free (TCP) pulp or zero effluent kraft mills. As partial fulfillment of the SFMN project objectives, this working paper will review the development of AOX control from available literature.

KEY FINDINGS

AOX Defined

Public fears about AOX in kraft pulp mill effluent started in the early 1980s in association with previous fears about dioxins and culminated with several provincial governments setting stringent parameter limits in the late 1980s (Lindsay and Smith 1995). AOX measures adsorbable chlorinated organics in effluent from kraft pulp mills using chlorine in its bleaching processes. AOX is primarily non-toxic material (99%) with a small amount of fat-soluble toxic chlorinated organics (1%). While AOX is not a measure of toxicity, the associated fat-soluble chlorinated group (dioxins, furans, & polychlorinated phenolic compounds) is considered to be toxic with bio-accumulative tendencies. Since 2,3,7,8-TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) has been found to cause cancer in rats, it is considered the most toxic of the dioxin group and governments have focused primarily on controlling TCDD (Harrison and Hoberg 1994). The term "dioxin" has come to mean more than a common name for TCDD. The association among AOX, dioxins, and "toxins" in Canada became a major factor influencing the pulp and paper industry and developed over the past 25 to 30 years from situations occurring in the USA and Europe. It is this association that has caused considerable scientific debate about the role of the public and implementation of the precautionary principle to mitigate uncertainty.

Dioxin Fear

Concerns about dioxin increased within a larger context as the public slowly learned about disastrous impacts of chemicals released from agricultural and industrial development. Widespread chemophobia, fear from unknown impacts of chemicals on health and the environment, resulted. Winner (1986) indicated that after World War II, a series of events was influential. In the 1950s, toxic hexachlorophene was used in soap as an antibacterial agent and touted as an effective treatment for acne. In the 1970s, after high concentrations of hexachlorophene were linked to human infant mortality and brain abnormalities in monkeys, the U.S. Food and Drug Administration made the chemical available only by prescription. Preservatives, colouring agents, and other food additives were linked to human health problems. Atmospheric nuclear bomb testing increased human radiation exposure. Pesticides, herbicides, chemical fertilizers and industrial pollutants were later found in food and water supplies. These factors greatly increased levels of public chemophobia.

Boddington (1984) indicated that the dioxin sensation came from the turbulent times in the 1960s, a decade when universal protest was at its height, including environmental issues, i.e., DDT, phosphates, mercury. Governments throughout the world responded to the depth of environmental concern by establishing environmental departments and industrial regulations. The formation of the U.S. EPA in 1970 coincided with the recognition of Agent Orange (2,4,5-T and 2,4-D) as a major instrument in the cause against the Vietnam War (Barnes 1985). Scientific investigations into the chloracegenic effects of Agent Orange, found dioxin to be a 2,4,5-T impurity and this knowledge provided a foundation for dioxin research.

Growing concern arose about dioxin toxicity and its widespread distribution in the environment, as noted by numerous studies[1] conducted in the early 1970's and 1980's. Over these years, the public was bombarded with information of the potential health threats (Kleopfer 1984). Chemophobia influenced the dioxin problem (Kay 1989). Subsequent industrial accidents and improper handling of the 2,4,5-T and the dioxin impurities, contributed further to public concern. Dioxin contamination in Missouri (Kleopfer 1984) occurred when a plant producing Agent Orange and hexachlorophene between 1968 and 1972, disposed waste sludge in surrounding communities. Even though some of the sludge was incinerated, approximately

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[1] Moore 1973, Blair 1973, IARC 1977, Cattabeni et al. 1978, Esposito et al. 1980, NRCC 1981, Hutzinger et al. 1983, Stalling et al. 1983, Kinbrough 1984, FRG 1985, US EPA 1988, McNelis et al. 1989, Hutzinger et al. 1986.

81,000 litres were sprayed on Missouri roads and stock yards, causing cases of human chloracne and animal deaths. Site remedial actions carried on into the 1980s.

In the late 1970s, large amounts of chemical wastes (including 2,3,7,8-TCDD), in Hyde Park and the Love Canal near the Niagara River, New York State, were found leaking into the environment. In Europe and the U.S., dioxins were emitted from municipal waste incinerators. Dioxins were released from fires involving certain types of electrical equipment containing polychlorinated biphenyls and chlorinated benzenes. In 1974, the pulp industry was suspected of releasing dioxin/furans (Swanson et al. 1988). In 1976, an Italian industrial accident released a cloud of toxic gases containing 2,3,7,8-TCDD (Fortunati 1984). This accident greatly contributed to dioxin awareness throughout the world. Researchers identified dioxin to be the most potent carcinogen tested to date in rats (Kociba and Keyes 1978). Shortly after the Italian accident in Britain, the cover-up of a 1968 dioxin trichlorophenol chemicals plant accident, exposing 70 workers to dioxin, began to leak to the public. A journalist covering the story called dioxin "the most deadly poison known to man" (Cox et al. 1986).

Public chemophobia was enhanced by statements linking dioxin to Agent Orange and about dioxin being "the most deadly poison known to man". Concern was generated about dioxin being a compound that would bio-cumulate in the environment like DDT and being a hazard to human and animal health at low doses. Greenpeace reported that the U.S. EPA determined that no safe level of dioxin exposure could be demonstrated on the basis of available information (Van Strum and Merrell 1987). The difficulty in establishing a complete cause and effect relationship between dioxin and health also contributed to the public perceiving limitations in the scientific method.

Linking Dioxin to the Pulp Industry

In Canada in the late 1970s, dioxin was found in fish and herring gull eggs around the Great Lakes (Norstrom and Simon 1983; Hallett 1984). Dioxin was measured in human adipose tissue in people living east of the Great Lakes (Boddington et al. 1983). In the mid-1980s, whale kills were associated with dioxins (Boddington 1984). Dioxin was found in chicken livers from flocks housed on wood shavings previously treated with pentachlorophenol (Boddington et al. 1983). Discussions on dioxin/furans in Canada were formulated under the National Research Council of Canada, investigating both the analytical developments and environmental/human health effects (NRCC 1981). Increased interest by various agencies and the public can be attributed to confusion with 2,4-D herbicide issue (Maybury et al. 1982), dioxin findings by Agriculture Canada (Cochrane et al. 1981), and the noted environmental of dioxins (Jones 1973).

In 1983, early federal government initiatives, based on the Minister's Expert Advisory Committee Report recommendations, were aimed at controlling contamination with dioxin/furans and federal waste combustion operations (Health and Welfare Canada 1983; Muller 1990). In response to public concern, the federal government issued two directives. Firstly, the National Sampling Program was established to determine scope and extent of dioxin/furans in fish and sediments around pulp and paper mills and to take appropriated action where public health was at risk. Secondly, measures were developed to control the release of dioxin/furans by pulp and paper mills and federal incinerators. Background concern over health impacts of dioxins influenced the Canadian pulp and paper industry to act independently of government regulations to take steps to eliminate dioxin and the associated furans, once they were determined to be present in pulp mill effluent.

With improved analytical equipment, i.e., gas chemotography/mass spectrometers, lower levels of dioxins became more easily detected. Although many studies indicated high levels of dioxins in indicator wildlife populations near pulp mills using bleaching, establishing a cause and effect relationship with pulp mills was difficult because of other incidental industrial sources. Dioxins were not factually attributed to the pulp mill industry until 1986. Concern had been expressed in May 1986, in the U.S., regarding the possibility that dioxins may be present in pulp and paper mill sludge, impacting the industry's land application programs (Swanson et al. 1988). The U.S. National Dioxin Study reported in February 1987 that previously undetected levels of dioxin/furans had been found in fish downstream of pulp and paper mills, where no other known source existed (Amendola 1989). In late 1987, the Swedish Forestry Industries Waste and Air Pollution Research Foundation found similar results. These reports were significant in that subsequent research on dioxin shifted from primarily studying incinerators as a main dioxin source to investigating the bleached pulp and paper industry.

In 1986, the U.S. EPA and pulp and paper industry agreed to conduct a joint screening of a small groups of mills (The 5 Mill Study) aimed at determining the source of dioxin/furans and quantifying untreated/treated wastewater effluent and sludge concentrations (Amendola 1989). National Council of Paper Industry for Air and Stream Improvement (NCASI) concluded that 2,3,7,8-TCDD and 2,3,7,8-TCDF were the principal dioxin/furans formed as trace contaminants during bleaching kraft hardwood and softwood pulps using chlorine and chlorine derivatives. Also, it concluded that amounts varied between mills, but were consistent within each mill in bleached pulp, effluent, and sludge.

In 1987, the Canadian Council of Resource and Environment Ministers (CCREM) sponsored a workshop on dioxins, in which senior scientific and policy-making staff of both federal and provincial government met to review the issues concerning environmental and health. A dioxin sub-committee, reporting to the Toxic Substance Advisory Committee was formed to provide overall coordination for four dioxin-working groups on communication, regional, regulatory and scientific priorities. In August 1987, a Greenpeace report, "No Margin of Safety" linking the pulp industry with dioxins, was widely publicized across North America (Van Strum and Merrell 1987). Greenpeace criticized the slow progress of the U.S. EPA chlorine-based pulping investigation and the apparent lack of dioxin control regulations. Subsequent to the release of "No Margin of Safety", Greenpeace called for a Congressional investigation into the U.S. EPA delays, held protests at British Columbia MacMillan-Bloedel's Harmac mill, and released other industry documents reporting dioxin in paper products.

A Swedish study reporting furans in milk cartons surprised the pulp and paper industry, and initiated extensive studies in several countries (Ryan et al. 1988). A second NCASI investigation of all U.S. mills (The 104 Mill Study) using chlorine-bleaching processes found dioxins/furans (Whittemore et al. 1990). Other U.S. investigations into milk cartons and other food packages determined that dioxins/furans contamination levels depended upon food fat content, storage temperature, contact time, and container barrier coating (LaFleur et al. 1990). The Ontario Ministry of Environment reported 2,3,7,8-TCDD in 17 of 47 samples of fish downstream of kraft operations in levels greater than the Ontario consumption guideline of 20 parts per trillion and dioxin/furans were in sludge from nine bleached Kraft pulp mills (Clement et al. 1989).

The shellfish industry near coastal pulp mills (Woodfibre, Port Mellon, Prince Rupert), and seven other coastal areas in B.C. were closed in 1988 and 1989. Health and Welfare Canada (1989) issued health advisories for nine recreational and native shellfish coastal sites, for four inland B.C. locations and for one Quebec (La Tuque mill) inland location. Between 1987 and 1990, the Alberta Government found unacceptably high levels, i.e., greater than 20 ppt, of dioxin and furans, in fish samples near an older pulp mill on the Athabasca River and another on the Wapiti River and released an advisory to limit consumption (Alberta Environment 1989, 1990). The federal government assessment under the Canadian Environmental Protection Act (CEPA), "Effluents from Pulp Mills Using Bleaching", concluded that Kraft pulp mill effluent was toxic, even without dioxins and was being released into the environment in a quantities sufficient to cause immediate and long term harmful effects (Environment Canada 1991).

In 1988, the Pulp and Paper Institute of Canada found oil-based additives to be a source of dioxin/furans in Kraft bleach plants and when removed, dioxin/furan was undetectable before and after chlorination (Allen 1989). Eight NATO countries accepted a standard set of International Toxicity Equivalency Factors rating the toxicity of dioxins and furans (NATO 1988) and chlorine dioxide substitution effectively prevented the formation of dioxin/furans (Axegard et al. 1989; Berry et al. 1989; Kitunen et al. 1989). Biological treatment of effluents was also indicated to be effective in reducing dioxin levels in the final effluent (McCubbin 1992). Mills began to implement these process changes reducing dioxin/furans average discharge by over 98% with the dioxin reduction technology and 20 to 25% by biological effluent treatment. By 1991, 60% of the Kraft bleach lines operated with the new techniques, compared to 33% in 1989. Quantities were so small as to become non-measurable[2]. For AOX, bleach plant changes accounted for 50 to 60 % reduction and biological treatment reduced AOX levels by 40 to 55% (McCubbin 1992).

Legislation controlling dioxin and AOX

In both the United States and Canada, legislation controlling pulp mill effluent was modified in the late 1980s and early 1990s. In the United States, the pulp and paper effluent guidelines were first created in 1974 and updated in 1977 and 1982 under the US Clean Water Act and the National Pollutant Discharge Elimination System for navigable waters. More recent permits for discharge, issued by EPA or a state environmental agency, required effluent monitoring for BOD, COD, chlorinated organic compounds, temperature, and aquatic toxicity. In addition to the Clean Air Act - Air Quality Standards controlling carbon monoxide, nitrous oxides, sulphur oxides, and particulate matter. The Cluster Rule for the pulp and paper mills, first proposed in late 1993 by EPA, sets levels for pollution parameters and best available technologies (BAT) for effluent treatment and maximum achievable control technologies (MACT) for air emissions. The Cluster Rule contains effluent limitations on total suspended solids, biochemical oxygen demand, chlorinated organic compounds, a "non-detect" limit for dioxin and AOX.

Pulp mills in Canada have been regulated by both provincial and federal legislation. Prior to 1992, pulp mills were required to follow the 1971 federal Fisheries Act Pulp and Paper Effluent Regulations. In 1992, the Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations, and the Pulp and Paper Mill Defoamer and Woodchip Regulations, both under Canadian Environmental Protection Act, required that chlorine bleaching pulp mills implement process changes to prevent the formation of dioxins and furans. The Fisheries Act - Pulp and Paper Effluent Regulations (PPER), were revised to require all mills to pass acutely toxic tests and implement secondary treatment. Although specific limits for AOX were not set, mandated in-plant processes and secondary treatment would drastically reduce AOX and eliminate many of the AOX compounds, particularly the lower molecular weight toxic chlorinated compounds. The Pulp and Paper Effluent Regulations also required mills to conduct Environmental Effects Monitoring studies every 5 years to measure the impact of effluent on fish and fish habitat, measuring a wide range of substances and characteristics of receiving water quality.

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2 The term measurable is a set level, below which samples are considered non-measurable due to equipment inaccuracies and background levels. An effluent sample may have a detectable level of 2 to 5 ppq, but is not considered measurable because it is below the set 15 ppq limit.

In 1988, the Alberta government in setting out both best available technology and water quality standards to regulate pulp mills may have been one of the first agencies in North America to control chlorinated organics (MacKenzie et al. 1989). In-plant processes, based on worldwide research/progress, were required for all Kraft mills: modified continuous cooking, extended delignification, oxygen delignification, and high chlorine dioxide substitution. In addition to setting strict licensed effluent parameter standards, all mills were required to implement primary and secondary effluent treatment systems (Nagendran et al. 1988). Although the earlier Clean Water Act and other older environmental regulations were consolidated into the Alberta Environmental Protection and Enhancement Act, the province still implements a best available technology and strict effluent parameter approaches for the pulp mill industry.

In 1992, British Columbia government enacted the Pulp & Paper Mill Liquid Effluent Control Regulations, setting strict AOX limits over a series of stages to eliminate chlorinated organic effluent compounds within 10 years. Pulp mills had to reduce their actual AOX discharge limit and could follow one of two approaches to eliminate AOX before 2003, ensuring the elimination of chlorine and chlorine dioxide bleaching processes. The industrial waste branch of B.C.'s Ministry of Environment, Lands and Parks claimed that the new regulation represented a "precautionary" approach to the pulp mill effluent problem, since only about 10% of pulp mill effluent 30,000 different products had been identified (Van Nijnatten et al. 1997).

KEY ISSUES

Precautionary Principle

In 1983, the United Nations General Assembly established the World Commission on the Environment and Development to study the relationship between economic development and the global environment, resulting in Bruntland’s 1987 Our Common Future and the legacy of sustainable development. This Commission and growing public concern about environmental effects of chlorinated organics set the stage for environmental legislative changes in Europe. The precautionary principle developed in concert with a number of European pulp mill pollution programmes during the same time period.

Arising from 1980s German environmental policy, the notion of precautionary principle meant to apply controls in advance of complete scientific understanding of suspected harmful agents. Bans on dumping of toxic substances in the North Sea arose from heightened concerned about pulp mill releases of chlorinated organics into marine receiving waters. The Second International Conference on the Protection of the North Sea (1987) created the underlying concept of the precautionary principle, i.e., "in order to protect the North Sea from possibly damaging effects of the most dangerous substances, a precautionary approach is necessary". In 1988, the Baltic Marine Environment Protection Commission recommended pulp and paper reduce toxic slow-degrading substances and nutrients using best available technology. In 1988, Finland established the Water Protection Programme to reduce toxic wastewaters, especially chlorinated organics and improving effluent treatment technology (Hynninen and Vuoriranta 1989). These precautionary measures were taken even though the causal effect chlorinated organics on environmental degradation had not been established.

The public concern about the uncertainty of dioxin impacts has facilitated the acceptance and implementation of the Precautionary Principle by regulatory agencies and suggests a new approach for environmental science. Gaining wide spread support among environmental groups globally, the precautionary principle was added to a number of international agreements, namely, the 1992 Principle 15 of the Rio Declaration by the UN Conference on Sustainable Development, 1992 Climate Change Convention, 1992 Treaty on European Union, 1992 Convention for the Protection of the Marine Environment of the North-East Atlantic, 1992 Convention on Biodiversity, and 1992 Helsinki Convention protecting the Baltic Marine Environment (Biomatics International 2001). More recently the Precautionary Principle has become enshrined in EU law and is currently being adopted by North American environmental agencies. One of the more recent definitions states that the Precautionary Principle can be summed up as “When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically” (Science and Environmental Health Network 1998).

Appell (2001) points out that science may never have the answers for the enormously complex environmental problems we face today and precautionary action may take precedent over clinical cause and effect experimental method. In the face of inherent uncertainty in managing natural resources, policy makers and government decision makers are shifting the burden of proof away from those advocating protection toward those proposing development that may cause harm. The implementation of the precautionary principle obliges researchers to advance a different kind of science with a broader skills set to handle multifaceted data from complex interactions among a number of systems and to elicit a stronger social consciousness, putting ethics back into science. In cases where insufficient data makes uncertainty considerable and difficult to adequately express, the full implementation of precautionary principle implies scientific advice based on inference and not necessarily statistically valid experiments repeatable by other scientists. Since this is not science by definition, it becomes more like art, moving decisions away from science into politics, which is more inclined to public values. The challenge facing agencies is to apply the precautionary principle with common sense, ethical power, and scientific rigor when making environmental and public health decisions.

Risk Assessment

Examining the precautionary principle and dealing with uncertainty has become predominant components of risk assessment. Harrison and Hoberg (1994) analyzed how Canada and the United States assessed risks of dioxins, when effects on humans were uncertain and where exposure was difficult to isolate and measure. While chloracne, nausea, headaches, depression, sexual dysfunction, reproduction problems and cancer were considered dioxin-exposure symptoms, these responses had only been reported from high concentration exposures from industrial accidents. While dioxin causes cancer at large doses in laboratory animals in both acute and chronic studies, the toxicity varied among species. Dioxin has been recognized as a cancer promoter, but its cancer initiator properties are still being debated. Harrison and Hoberg (1994) indicate that because the mechanism by which dioxins cause cancer is scientifically uncertain, governments' regulatory approaches reflect cultural, legal, and political issues. Using the safety factor approach, Health and Welfare Canada originally estimated an acceptable daily dioxin intake to be 1700 times greater than the US EPA's virtually safe dose derived using a linear mathematical model. Other levels of government and scientific agencies released more cautious than Health and Welfare Canada, contributing to the over all uncertainty. In the early 1990's scientists concluded that dioxin acts through a receptor-mediated mechanism and consistent with the existence of a threshold. While the US reconsidered its original safe dose, concern is increasing with respect to potential reproductive and immunological effects of dioxin.

Harrison and Hoberg (1994) go on to discuss the role of science in determining dioxin risk. Scientific opinion was split on the differences between the safety factor and linear mathematical modelling approaches. This debate and the variance in acceptable risk suggest that governments operating in an adversarial political environment, like the one surrounding dioxin, rely heavily on explicit risk assessment for its decisions. Risk assessment was not the only factor influencing standards. Highly published dioxin/pulp mill controversy lead opinions in both countries to converge. Regulators concluded that strict regulatory controls for pulp mills were warranted, especially for high-risk subpopulations, overriding economic factors. Even though risk assessment estimates varied between the two countries, Environment Canada went on to require non-detectable dioxin concentrations in pulp mill effluent, which influenced comparable requirements in the United States. Harrison and Hoberg (1994) concluded that dioxin risk assessment indicated an example of how scientific debate played out in the political arena, setting strict regulatory pulp mill standards in the face of publicised concern about dioxin.

Endocrine Disruption and Dioxins

Endocrine disruption, associated with pesticides, heavy metals, and chlorinated pulp mill compounds, has become another related political environmental debate. Although studies have failed to establish a causal relationship between trace levels of certain contaminants and human illness, some scientists and many activist groups maintain concern due in part to the increasing ability to detect lower chemical concentrations in the environment and the public's collective fear of chemical exposure (American Council on Science and Health 1999). Endocrine disruption asserts that low levels of chemicals interfere with hormonal and endocrine system functioning, causing a range of illnesses and reproductive defects. Public's concern about environmental poisoning and the related endocrine disruption has been advanced by a series of publications ranging from "Silent Spring" (Carson 1962) to the more recent "Our Stolen Future" (Colburn 1997).

The debate rages not only in the public arena, but in the scientific community as well. Data uncertainties lead to different judgements among expert scientific panels when interpreting agents of concern and environmental variables related endocrine disruption. A variety of opinions are expressed in government and research agency publications, including, the American Council on Science and Health (1999), U. S. National Research Council (1999), Health Canada (2000), and EU Scientific Committee on Toxicity, Ecotoxicity, and the Environment (1999).

Most agree that high doses of toxins negatively affect human and animal health, as documented by industrial accidents and widespread use of pesticides. However, while chemicals in high doses may cause cancer in laboratory animals, they do not necessarily cause cancer in humans, who are normally exposed to significantly lower doses. After key research findings were retracted or not reproduced, no consistent association between industrial chemical low-level exposures and disruption of the endocrine system has been found. Most agencies agree that more research and environmental monitoring is required to ascertain more conclusive results. However, environmental sectors are moving to implement the precautionary principle by decreasing industrial contaminants suspected of being endocrine disrupters. Endocrine disruption, often associated with chlorinated pulp mill constituents, presents an example of how intricate science complicated by confounding factors fails to provide policy makers with clear resolution of public environmental fears.

Best Available Technology and Monitoring

In the face of uncertainty, environmental jurisdictions have previously implemented the combination of best available technology and strict control of effluent contaminants, especially AOX. This approach has been criticized because it does not reflect physical environmental impacts and the efficacy of selected technology. In recent years, agencies have begun to emphasis industrial environmental monitoring. The 1992 Fisheries Act - Pulp and Paper Effluent Regulations Environmental Effects Monitoring (EEM) program was created to ascertain actual environmental impacts from pulp mill effluent across the nation (Environment Canada 2001).

Canadian pulp mills are required to evaluate impacts on fish, fish habitat and the use of the fisheries resource by collecting in-stream data in 3 to 4 year cycles. Cycle 1 ended in April 1996 and Cycle 2 data was submitted in April 2001. The monitoring data include samples of:

- Health of fish populations, measuring liver weight, gonad weight, and weight to length ratio and condition factor of both sexes of two resident species;
- Indicators of fish habitat quality by measuring abundance and diversity of various species combinations in benthic invertebrate communities;
- Dioxin/furan concentrations and tainting of fish tissue to indicate usability, measuring levels against human health consumption guidelines; and
- Effluent toxicity by measuring sublethal effects on fish, invertebrates, and plant species.

Cycle 1 fish population data acted as a baseline for information collected under the subsequent Cycle 2 monitoring (Environment Canada 2001). While some mills had logistical problems collecting Cycle 1 data, about 50% mills indicated statistically increased liver weight, increased condition factor, and decreased gonad weight as well as reporting affects from other non-pulp mill sources. Mills reporting levels of chlorinated dioxin/furan congeners in fish tissue below health consumptions in Cycle 1 or not receiving public complaints of off-flavours fish were not required to sample for dioxin/furans in Cycle 2. Since the major of chlorine mills indicated low levels in Cycle 1, six of the ten reporting mills reported levels of dioxin/furans above Health Canada fish consumption guidelines. In Cycle 2, many mills reported lower Ceriodaphania dubia sublethal toxicity after installing superior effluent treatment systems.

In Alberta, the 5 mills on the Athabasca River system collected Cycle 2 EEM data jointly in a basin wide study (Stantec Consulting Inc. 2000). While over all effects on fish populations were considered neutral, some fish indicated increased growth, reproductive capacity, and energy stores from increased nutrients, especially in the upstream mills. The majority of mills reported significant differences between benthic communities above and below effluent outfalls, indicating nutrient enhancement. The Athabasca River mills were not required to report tainting in Cycle 2 data. In Cycle 2, no mills indicated sublethal toxicity for fathead minnows, two mills showed some survival effects for Ceriodaphnia dubia toxicity, and four mills reported improved survival of Selenastrum capricornutum. Two mills detected low level chlorinated phenolics and dioxin/furans congeners above and below the mill locations which was attributed to natural upstream sources, i.e., forest fires. Contradicting findings of the earlier Northern River Basin Study Board (1996), there was no evidence of basin-wide cumulative pulp mill effects on fish populations.

In addition to data required by the federal EEM program, Alberta Environment requires pulp mills to monitor rivers for other parameters (Stantec Consulting Inc. 2000). To determine bottom sediment quality, Kraft mills must sample for a combination of nutrients, chlorinated phenolics, resin/fatty acids, metals, and dioxin/furans. To determine surface water quality, all mills must sample for a combination of nutrients and metals. Only one mill is required to sample for macrophytes.

Over time, these long-term site-specific monitoring data will provide a better understanding of pulp mill impacts on Canadian aquatic ecosystems. Rolling up the data or finding general conclusive results may prove more challenging due to the extreme variability of pulp mill technology and characteristics of receiving environment. In-plant and effluent treatment technology are unique to each pulp mill. Meaningful generalities from mills comparisons in each type are next to impossible. Receiving environment characteristics are also high varied, making each river system and locations along the rivers unique. While providing statistically significant trends with acceptable variation from the national data base may prove difficult, the wide spread publication of pulp mill data may be enough to encourage poor performers to implement best available technology specifications like secondary treatment systems.

CONCLUSIONS

Along with the management of other industrial chemicals, the development of AOX controls in pulp mill effluent presents an interesting environmental policy case study. While industry and government agencies proactively responded to the discovery of dioxin in pulp mill effluent, public fears over rode the influence of science in the minds of government decisions makers. Even today, public concern about pulp mill chlorinated organics continues as part of the complex endocrine disruption debate. Integrated research and long term strategies are required to resolve the conflict between public fear and scientific fact in environmental policy development. One of the most significant steps will be to have science professions accept that fear sometimes does have a stronger influence than causal relationships and shift their perspective on how to better include the public in environmental decision making.

Chemophobia is deeply rooted in western culture. Although probably a natural part of human psyche, it was accentuated in the 1960s and 1970s by a series of industrial chemical accidents and government cover-ups. Steeped in the cause and effect paradigm, science professionals did not recognize the validity of public fears. They thought that if the pubic only knew the facts their irrational fears and lack of distrust would dissipate. The un-addressed public fears were vaulted into the political arena by activist and wide spread publication of controversial papers suggesting doubt in the scientific method. Government leaders responded with the precautionary principle by superseding industrial science advice and setting best available technology criteria, strict effluent parameter standards, and ongoing environmental monitoring provisions. These stipulations were established with limited consideration of the industrial financial burden, scientific necessity, or improved environmental protection. Without adequate dialogue about government, industry, and public underlying intentions this condition will continue into the future, placing environment policy development under the influence of politics and away from science based decision-making.

The solution is complex and systemic in nature. Public fears have to be recognized on par with causal relationships in the development of environmental policy. The reality is that causal relationships may never be established in complicated ecological systems and the best that science professionals can do is manage the inherent uncertainty when producing wealth from natural resources. There may never be the “facts”, only inference based on expert knowledge. Extensive meaningful participatory land use planning in conjunction with increasing trust in science professional judgement may provide government leaders with confident decision-making. Research is required to investigate the systemic barriers to achieving these two directives and the ultimate preparation of legislative mechanisms that sustainably manage industry and effectively protect the environment.

REFERENCES

Alberta Environment 1989. Winter water quality in the Athabasca river system 1988-89. Environmental Quality Monitoring Branch, Environmental Assessment Division, Alberta Environment. August 1989. Pp. 1-1200.

Alberta Environment 1990. Press release kit, Alberta Environment, July.

Allen, L.H. 1989. Evidence that oil-based additives are an indirect source of the TCDD and TCDF produced in kraft bleach plants. Chemosphere 19, No 1-6. pp. 741-744.

Amendola, G. 1989. The occurrence and fate of PCDDd and PCDFd in 5 bleached Kraft pulp and paper mills. Chemosphere 18, No. 1-6. pp. 1181-1188.

Appell, D. 2001. The new uncertainty principle. Scientific American. Available online at: www.sciam.com/2001/0101issue/0101scicit1.html

Axegard, P., and Renberg, L. 1989. The influence of bleaching chemicals and lignin content on the formation of polychlorinated dioxins and dibenzofurans. Chemosphere 19, No 1-6. pp. 661-668.

Barnes, D.G. 1985. Recent US EPA actions related to dioxins. Chemosphere 14, No 6/7. pp. 755-766.

Berry, R.M., Fleming, B.I., Voss, R.H., Luthe, C.E., & Wrist, P.E. 1989. Toward preventing the formation of dioxins during chemical pulp bleaching; ways to decrease tcdd and tcdf without reducing quality. Pulp and Paper Canada, 90, No. 8. pp. 48-58.

Biomatics International 2001. International frameworks. Available at website: http://www.bioint.org/biosafety/legalandadvisoryframeworks/frameworks/internationalframeworks/internationalframeworks.html

Blair, E.H. (ed). 1973. Chlorodioxins - origin and fate. Adv. Chem. Ser., 120, 1973, 144 pp..

Boddington, M.J., Douglas, C.E., Duncan, M., Gilbertson, D.L., Hallett, D., McDlelland, L., Roberts, J.R., Sing, J.,& Whittle, M. 1983. Dioxins in Canada. Chemosphere 12, No 4/5. pp. 477-480.

Boddington, M.J. 1984. The dioxin issue - an overview. Chemosphere 14, No. 6/7. pp. 721-727.

Brundtland G H 1987. Our Common Future. World Commission on Environment and Development. Oxford: Oxford University Press

Carson, R. 1962. Silent spring. Houghton Mifflin Company, Boston.

Cattabeni, F., Cavallaro, A., & Galli, G. (eds). 1978. Dioxin: toxicological and chemical aspects, SP Medical and Scientific books: New York. 222 pp..

Clement, R.E., Tashiro, C., Suter, D., Reiner, E., & Hollinger, D. 1989 Chlorinated dibenzo-p-dioxins (cdds) and dibenzofurans (cdfs) in effluents and sludges from pulp and paper mills. Chemosphere 18, No 1-6. pp. 1189-1197.

Cochrane, W.P., Singh, J., Miller, W., Wakeford, B., & Scott, J. 1981. Analyses of technical and formulated products of 2,4-dichlorophenoxyacetic acid and for the presence of chlorinated dibenzo-p-dioxins. In Hutzinger, O., Frei, R.W., Merian, E. & Pocchiari, F. (eds). Chlorinated Dioxins and Related Compounds on the Environment. Pergamon Series on Environ. Sci., 5. pp. 209-213.

Colburn, T., Dumanoski, D., Peterson-Meyers, J. 1997. Our stolen future. Plume, New York.

Cox, E.A., and Finnecy, E.E. 1986. Dioxins and waste disposal: the UK experience. Chemosphere 15, No 9/12. pp. 1543-1548.

Environment Canada 1991. CEPA Priority substances list assessment report no. 2 – effluents from pulp mills using bleach, En 40-215/2E, ISBN 0-662-18734-2 pp. 1-60.

Environment Canada 2001. Environmental effects monitoring – cycle 2 reports are in. National EEM Office, Environment Canada, available online at: www.ec.gc.ca/eem

Esposito, M.P., Teirnen, T.O., and Dryden, F.E. 1980. Dioxins, U.S. Environmental Protection Agency, EPA-600-80-197. 351 pp..

EU Scientific Committee on Toxicity, Ecotoxicity, and the Environment 1999. CSTEE opinion on human and wildlife health effects of endocrine disrupting chemicals, with emphasis on wildlife and on ecotoxicology test methods. available online at http://europa.eu.int/comm/food/fs/sc/sct/index_en.html .

Fortunati, G.U. 1984. The Seveso Accident. Chemosphere 14, No. 6/7. pp. 729-737.

FRG (Federal Republic of Germany) 1985. Sachstand Dioxin - Stand November 1984. Umweltdunesamt und Bundesgesundeitsamt. 385 pp..

Hallett, D. 1984. Dioxin in the Great Lakes Ecosystem - A Canadian Perspective. Chemosphere 14, No. 6/7. pp. 745-753.

Harrion, K. and Hoberg, G. 1994. Risk, science, and politics – regulating toxic substances in Canada and the United States. McGill-Queen's University Press, Montreal, Quebec.

Health and Welfare Canada 1983. Report of the minister's expert advisory committee on dioxins. Minister of Supply and Services, Ottawa.

Health Canada 2000. Human health and exposure to chemicals which disrupt estrogen, androgen and thyroid hormone physiology. Environmental and Occupational Toxicology Division, Ottawa Canada and available at http://www.hc-sc.gc.ca/ehp/ehd/bch/env_contaminants/endocrine.pdf

Hutzinger, O., Frei, R.W., Merian, E. & Pocchiari, F. (eds) 1983. Chlorinated dioxins and related compounds, Chemosphere, 12, No 4/5. pp. 425-790.

Hutzinger, O., Crummett, W., Karasek, F.W., Merian, E., Regiani, G., Reissinger, M., and Safe, S. (eds) 1986. Chlorinated dioxins and related compounds - 1985. Chemosphere, 15, No. 9-12. pp. 1079-2132.IARC (International Agency for Research on Cancer). Chlorinated Dibenzodioxins. In IARC Monographs on the evaluation of the Carcinogenic risk of Chemicals to Man, 15. pp. 41-102.

Hynninen, P. & Vuoriranta, P. 1989. Present trends of pulp and paper industry effluent treatment in finland environmental aspects of pulping operations and their wastewater implications, Conference Proceedings, Edited by H. Edde and D.W. Smith, Edmonton, Alberta, July 28-29. pp. 207-218.

Jones, H.R. 1973. Pollution control and chemical recovery in the pulp and paper industry, Noyes Data Corporation, New Jersy. pp. 1-335.

Kay, M. 1989. Overcoming chemophobia: A Key Factor in Solving the Missouri Dioxin Problem. Chemosphere 18, No. 1-6. pp. 1177-1180.

Kinbrough, R.D. 1984. The epidemiology and toxicology of tcdd. Bull. Environ. Contam. Toxicol., 33. pp. 636-647.

Kitunen, V.H., and Salkinoja-Salonen, M.S. 1989. Occurrence of PCDDs and PCDFs in pulp and board products. Chemosphere 19, No 1-6. pp. 721-726.

Kleopfer, R.D. 1984. 2,3,7,8-TCDD Contamination in Missouri. Chemosphere 14, No. 6/7. pp. 739-744.

Kociba, R.J. and Keyes, D.G. 1978. Results of a two-year chronic toxicity and oncogenicity study of 2,3,7,8-TCDD in rats. Toxicology and Applied Pharmacology 46: 279-303.

LaFleur, L., Bousquet, T., Ramage, K., Brunck, B., Davis, T., Lukesemburg, W., and Peterson, B. 1990. Analysis of PCDD and PCDF on the ppq-levels in milk and food sources. Chemosphere 20, No. 10-12. pp. 1657-1662.

Lindsay, K. and Smith, D.W. 1995, Factors influencing kraft pulp mill effluent treatment in Alberta, Journal of Environmental Management, 44: 11-27.

MacKenzie, I., Pentney, A., and Nagendran, J. 1989. The development of effluent standards for pulp and paper mill in alberta. environmental aspects of pulping operations and their wastewater implications, Conference Proceedings, Edited by H. Edde and D.W. Smith, Edmonton, Alberta, July 28-29. pp. 23-36.

Maybury, R., Singh, J., and Riedel, D. 1982. 2,4-D Herbicides: their chemistry, fate and effect on animals and humans, Health and Welfare Canada (draft report), Ottawa.

McCubbin, N. 1992. TECH '92 - Environment Control Course, Text for Environment Professional Development, CPPA, June.

McNelis, D.N., Nauman, C.H., Fenstermaker, L.K., Safe, S., Clement, R.E., Campana, J., Kahn, P., Fingerhut, M., desrosiers, P., Barnes, D.J., Hwliman, F., and Keith, L.H., (eds) 1989. Chlorinated dioxins and related compounds 1987. Chemosphere, 18, No. 1-6. pp. 1-1339.

Moore, J.A., (ed) 1973. Perspective on chlorinated dibenxodioxins and dibenzofurans. Environmental Health Perspectives, 5. 313 pp..

Muller, E.F. 1990. Canada's federal program for the control of chlorinated dioxins and furans, Chemosphere 20, No 7-9. pp. 743-749.

Nagendran, J., Cary, P., MacKenzie, I., and Hamilton, H. 1988. Standard setting approach for mechanical pulp mills in Alberta. Presented at the 1988 Environmental Conference Vancouver BC. pp. 1-16.

NATO (North Atlantic Treaty Organization) 1988. Scientific basis for the development of the International Toxicity Equivalency Factor (ITEF) method of risk assessment for complex mixtures of dioxins and related compounds. Committee on the Challenges of Modern Society, Pilot study on international information exchange on dioxins and related compounds, #186. pp. 1-26.

Norstrom, R.J., and Simon, M. 1983. Preliminary appraisal of tetra-to octachlorodibenzodioxin contamination in eggs of various species of wildlife in Canada. In, J. Miyamoto et al. (ed). IUPAC Pesticide Chemistry, Human Welfare and Environment, Pergamon Press, New York. pp. 165-170.

Northern River Basin Study Board 1996. Northern river basins study report to the Ministers 1996. Edmonton, Alberta.

NRCC (National Research Council of Canada) 1981. Polychlorinated dibenzo-p-dioxins: criteria for their effects on man and his environment, Associate committee on Scientific Criteria for Environmental Quality, NRCC #18574. 251 pp..

Ryan, J.J., Panopio, L.G., and Lewis, D.A. 1988. Bleaching of pulp and paper as a source of PCDD and PCDF in foods. In DIOXIN '88, The 8th International Symposium on chlorinated Dioxins and Related Compounds, August 21-26. Umea, Sweden.

Science and Environmental Health Network 1998. Wingspread Conference on Precautionary Principle. Available online at www.sehn.org/wing.html

Stantec Consulting Inc. 2000. Cycle 2 Environmental Effect Monitoring for Athabasca River basin pulp mills, volumes 1 – Interpretive Report and Volume 2 Unpublished report, available upon request from Golder and Associates, Edmonton, Alberta.

Stalling, D.L., Smith, L.M., Pett, J.D., Hogin, J.W., Johnson, J.L. Rappe, C., and Buser, H.P. 1983. Residues of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Laurentian Great Lakes Fish. In R.F. Tucker et al. (eds). Human and Environmental Risks of Chlorinated Dioxins and Related Compounds, Plenum Press New York. pp. 221-240.

Swanson, S.E., Rappe, C., Malmstrom, J., Kingstad, K.P. 1988. Emissions of PCDDs and PCDFs from the Pulp Industry. Chemosphere 17, No. 4. pp. 681-961.

U.S. National Research Council 1999. Hormonally active agents in the environment. National Academy Press, Washington and available at http://books.nap.edu/html/hormonal_agents

Van Nijnatten, D.L., Leiss, W., And Hodson, P.V. 1997. Fighting battles, waging war: pulp mill effluent regulation in Canada -environment's x-file: pulp mill effluent regulation in Canada. School of Policy Studies, Queens University.

Van Strum, C. and Merrell, P.E. 1987. No margin of safety: a preliminary report on dioxin pollution and the need for emergency action in the pulp and paper industry. Greenpeace. Toronto, Ontario.

Winner, L. 1986. A search for limits in an age of high technology, University of Chicago Press, Chicago. pp. 1-200.

Whittemore, R.C., LaFleur, L.E., Gillespie, W.J., Amendola, G.A., & Helms, J. 1990. USEPA/Paper industry cooperative dioxin study: the 104 mill study. Chemosphere 20, No. 10-12. pp. 1625-1632.