ENVIRONMENTAL RESPONSE TO DECREASED DIOXIN AND FURAN LOADINGS FROM BRITISH COLUMBIA COASTAL PULP MILLS

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1.0 Introduction

Eleven pulp mills discharge effluent into the coastal waters of British Columbia (Figure 1). Monitoring by federal government agencies beginning in 1988 documented elevated dioxin and furan levels in edible fish and shellfish tissue from sites near nine coastal kraft mills.

The federal government responded by issuing restrictions on various crab, clam, prawn, shrimp, and oyster fisheries; implementing a monitoring program with the cooperation of the pulp and paper industry; and introducing legislation to control dioxin and furan discharges. Industry responded by implementing mill process changes that dramatically reduced effluent dioxin and furan loadings by over 97%[1].

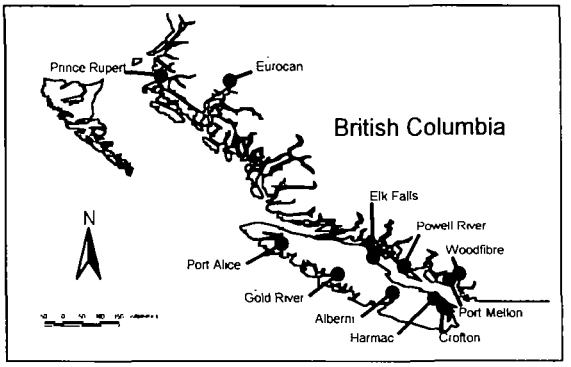

Figure 1: British Columbia pulp mills discharging to the coastal environment.

This paper presents a brief overview of the environmental improvements documented by the Dioxin and Furan Trend Monitoring Program conducted by coastal pulp mills as directed by the Department of Environment (DOE) and the Department of Fisheries and Oceans (DFO). Original data are described in annual consultant reports (e.g., Dwernychuk et al. [2),3),4),5),6),7)], IRC Inc.[8)], and G3 Consulting Ltd.[9)])

2.0 Dioxin and Furan Trend Monitoring Program

A Dioxin and Furan Trend Monitoring Program was prescribed by the federal government in 1990 following initial data collection in 1988 and 1989. Although a variety of organisms and tissues have been sampled from over 200 sites, sampling has focussed on key species and tissues: whole mussel and oyster, prawn, and shrimp muscle, crab muscle and hepatopancreas, and finfish muscle and liver. Sediments have been sampled at over 70 sites. In total, over 1,200 samples have been analysed for dioxin and furan content to date. Sampling locations, species, and numbers of samples in tissue pools are specified annually by DOE to each mill.

Analyses have been conducted via ultra-trace high resolution gas chromatography/high resolution mass spectrometry, although some data generated in the 1980's was low resolution and is not reported here. Quality assurance and quality control (QA/QC) procedures including the number of blanks and duplicate samples, and the level of surrogate recovery are specified by DOE[10].

3.0 Dioxin and Furan Trends in the Coastal Environment

3.1 Sediment:

Dioxin and furan toxicity equivalence (TEQ)[11] declined an average of 51 % at 22 of 23 sediment sites monitored in both 1990 and 1994. Values in 1994 samples ranged from 3% to 99% of 1990 levels.

While 1994 levels were lower than those of 1990, year to year variations were large at some locations. When data from sediment sites nearest mill discharge points were examined, fjord and embayed areas showed definite downward trends (Fig. 2). More exposed, open coastlines showed more variable results (Fig. 3) than sheltered locations.

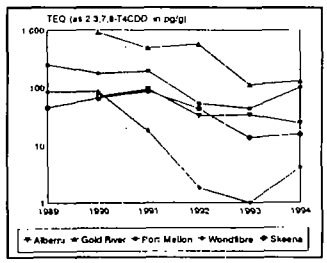

Figure 2: Dioxin and furan TEQ in sediment at pulp mill outfall sites on fjords and embayments.

Site-specific physical and chemical factors which can alter dioxin and furan levels in sediment include: initial effluent TEQ and solids concentration; effluent dispersion; sediment resuspension and transport; and sediment characteristics (e.g. particle size composition, organic content). For example, Discovery Passage has very high tidal currents (> 7 knots) and consequently has relatively coarse sediments. As a result of discharging into this high energy environment, the sediment TEQ levels adjacent to the Elk Falls mill are very low (3 pg/g), however there are widespread, discontinuous areas of dioxin and furan contamination associated with this mill.

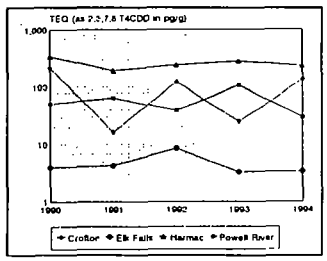

Figure 3: Dioxin and furan TEQ in sediment at pulp mill outfall sites located on exposed coasts.

Bioturbation, or the biological mixing of sediments, is another factor in how long the sediments will take to recover from contamination. Even if the contaminant source is eliminated, bioturbation will act to prolong contact of contaminated

sediment with biota. The half life of sediment contamination is dependent on the thickness of the mixing layer and the sedimentation rate, and may be about 10 years at a typical B.C. coastal fjord site[12].

3.2 Dungeness Crab (*Cancer magister*) Hepatopancreas:

Dungeness crabs generally bioconcentrate higher levels of dioxins and furans in their hepatopancreas than other crab species, and higher levels than expected on a lipid-normalized basis[13]. Dioxin and furan TEQs in hepato-pancreas declined an average 71% at 28 of 29 Dungeness crab hepatopancreas sites monitored in both 1990 and 1994. TEQ results in 1994 ranged between 3% and 63% of 1990 levels.

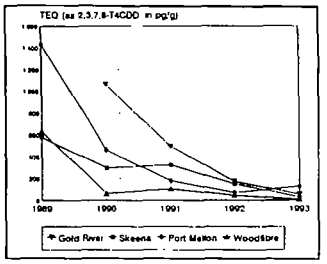

Figure 4: Dioxin and furan TEQ in Dungeness crab hepatopancreas at pulp mill outfall sites--initial high levels.

The nine outfall sites monitored in the program fall into two categories: those where crab hepatopancreas had high dioxin and furan TEQ levels at the start of monitoring in 1989/1990 (600 - 1,400 pg/g) (Figure 4), and those with low TEQs (<200 pg/g) (Figure 5).

A pattern of declining TEQ in crab hepatopancreas is apparent at most mill outfall sites. Levels had declined to under 100 pg/g (as low as 8.6 pg/g at Woodfibre) by 1993. While improvements have been dramatic in all areas that had high TEQ results in 1989 or 1990, a similar improvement in areas with lower initial TEQ levels has occurred only at Harmac. This occurred in spite of high and variable sediment dioxin results from the Harmac area. Results from 1994 are not shown as these data are still under review by Health Canada.

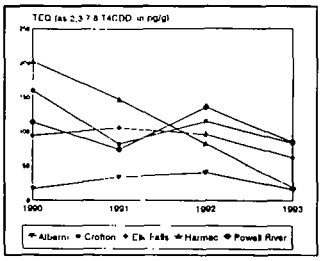

Figure 5: Dioxin and furan TEQ in Dungeness crab hepatopancreas at pulp mill outfall sites--initial low levels

4.0 Fisheries Closures

After dioxin/furan data in fish and shellfish have been submitted by the mills the data are referred to Health Canada for a human health risk assessment. The assessment and subsequent decisions regarding fisheries closures and re-openings are based on a number of factors, including the TEQ, species utilization/consumption patterns, and the type of fishery.

Closures and consumption advisories may be site specific (fish harvesting in one area may be completely prohibited), or they may be tissue specific (consumption advisory for hepatopancreas). Areas with crab hepatopancreas contamination may be subject to commercial harvesting closures but remain open for non-commercial harvesting. In such instances, there would also be an advisory to limit the consumption of the contaminated tissue (eg. hepatopancreas) to amounts of tissue which may be safely consumed. In areas where whole organisms (e.g., oysters) exhibit contamination the area may be closed to all harvesting of that organism.

4.1 Fisheries Re-opening Criteria

In the fall of 1994 the Department of Fisheries and Oceans finalized criteria for the re-opening of contaminated fisheries[14]. Decisions are to be based on the following considerations:

- data are assessed on a species- and area-specific basis;
- re-openings may be partial (e.g., total closure to all crab fishing replaced with a commercial closure coupled with a consumption advisory on hepatopancreas use by non-commercial harvesters);
- re-openings must encompass at least one-half of the closed area or a discrete portion of the habitat;
- re-openings require a minimum of two years of "clean" data (i.e., probable daily intake does not exceed tolerable daily intake) and for which TEQ levels do not appear to be increasing; statistical tests may be applied;
- independent audit and/or confirmatory samples may be collected
- data must meet QA/QC requirements
- areas may remain closed for other reasons (e.g. sewage contamination)

4.2 Fisheries Re-openings

In February 1995, for the first time, areas closed to fishing due to dioxin/furan contamination were re-opened. TEQ trends in areas where application of the re-opening criteria resulted in the opening of previously closed oyster (Powell River, Crofton), shrimp (Howe Sound, Prince Rupert), and prawn (Gold River, Howe Sound) fisheries declined very rapidly (Figure 6). Although the closures were lifted due to declining dioxin/furan levels, sewage or paralytic shellfish poisoning (PSP) related closures remain in effect and prevent shellfish harvesting in some locations.

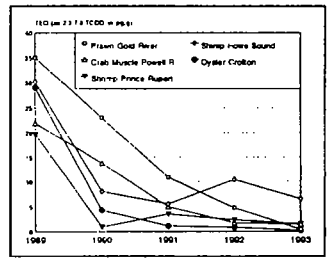

Figure 6: Oyster, prawn, shrimp, and crab muscle TEQ near selected pulp mill outfalls.

Some areas previously closed to all crab harvesting (Gold River, Powell River, Howe Sound) were re-opened to non-commercial fishers, with advisories on hepatopancreas consumption. All crab fisheries closed due to elevated hepatopancreas TEQ levels remain closed to commercial harvesters.

4.3 Areal Extent of Fisheries Closures and Re-openings

The February 1995 re-opening of prawn, shrimp and oyster fishery closure areas affected 236 km^2. Declining contaminant concentrations in crab muscle resulted in a re-opening to non-commercial fishers of 165 km^2 of area previously closed to all crab harvesting. In total over 400 km^2 of coastline was re-opened. The area remaining under closure was about 1200 km^2 as of February 1995. This included 65 km^2 of new area closed to crab harvesting which was previously not sampled.

5.0 Conclusions

The reason for the rapid drop in dioxin and furan levels in crabs, even in areas where sediment values remain relatively high and variable, is not entirely clear. It may indicate that contaminant uptake in crab is related to their consumpsion of filter feeders such as oysters and mussels in preference to sediment-exposed organisms. The rapid TEQ decline in filter-feeder organisms which has resulted in fisheries re-openings tends to support this conclusion.

Regulatory initiatives and a substantial capital investment by the B.C. pulp and paper industry has resulted in lower levels of dioxins and furans within the marine environment contamination and a reduction in fisheries harvesting restrictions. This improved environmental quality can be viewed as the "environmental dividend" of the investments, and as an indicator of the effectiveness of regulations which significantly limit dioxin and furan levels in effluent discharges.

6.0 References

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