Appendix 1

Review of the report on toxicity assessment of a pulp mill effluent for the proposed Tasmanian pulp mill

Prepared for
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September 2006

Executive Summary

This document reviews Ecotox 2005 report "Toxicity Assessment of a Pulp Mill Effluent for the Proposed Tasmanian Pulp Mill" and has been prepared on request from the Tasmanian Fishing Industry Council, Northern Tasmania Development and Dorset Council**.** The Ecotox 2005 report gives results for a limited toxicity testing without replication in time. The longest test was 96 hours, all tests were static (non-renewal). No chemical analyses of the effluents tested were reported. Some of the knowledge gaps identified are: no subchronic or chronic tests done on effluents, no genotoxicity tests, no immunotoxicity tests, no endocrine disruption tests, no bioaccumulation tests, no sediment toxicity tests, no fish residue tests with appropriate detection limits, lack of information on chemical composition of the effluent tested and lack of information on proposed monitoring of the toxicity of the effluent and effects of the effluent on marine life

The main recommendations of this review are:

1. Analytical methods with enough sensitivity to at least detect Food Standard Maximum Levels are available and should be used for chemical testing (including residues in fish and sediment). For each type of analysis only laboratories NATA registered for the specific analysis should be used.

2. Subchronic toxicity testing on equivalent pulp mill effluent should be undertaken.

3. Sediment toxicity should be evaluated.

4. Detailed monitoring program should be available for assessment before the pulp mill is approved.

5. Residue monitoring (fish, crustaceans, molluscs, including samples from aquaculture facilities) should be clearly outlined in the monitoring program, this monitoring should have two components - one focusing on protecting consumers (commercial fishing catch, recreational fishing catch and aquaculture product should be included) and another one on protecting environment.

6. No dredging activities should be undertaken in Tamar river or estuary as part of pulp mill construction or activities without detailed assessment of toxicity of the sediments and their potential impact on water quality, aquatic life and existing aquaculture facilities.

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Scope

The scope of this project is to provide a critical review of the report "Toxicity Assessment of a Pulp Mill Effluent for the Proposed Tasmanian Pulp Mill" Ecotox (2005) as provided by the Tasmanian Fishing Industry Council. This review is a desktop study based on the report, available literature and expertise of the author. In particular, the Tasmanian Fishing Industry Council asked for comments on:

- the robustness and completeness of the testing
- the appropriateness of the assessment and the conclusions drawn

In addition, questions specifically posed by Tasmanian Fishing Industry Council on behalf of other stakeholders are addressed.

Methods

Ecotox 2005 report "Toxicity Assessment of a Pulp Mill Effluent for the Proposed Tasmanian Pulp Mill" as provided by Tasmanian Fishing Industry Council was fully reviewed. In addition, other sections of Bell Bay Pulp Mill Draft Integrated Impact Statement Gunns Ltd were consulted to ensure that the information missing from the Ecotox 2005 report was not provided in other reports. These included Ecotox 2006 report, Executive Summary, Human Health Risk Assessment - Bell Bay Pulp Mill Effluent, Marine Ecological Monitoring Program, Marine Biological and Pollutant Survey at the Proposed Outfall Site, Erratum 3 August 2006 and Erratum 15 September 2006. Scientific literature was searched using ISI Web of Knowledge (in particular Web of Science and Current Contents). The scientific literature used focused on information for Elemental Chlorine Free (ECF) and Total Chlorine Free (TCF) pulp mills. All references cited are listed in the reference list at the end of this document and a copy of a full reference can be provided on request.

The robustness and completeness of the testing

Sample tested

Two samples of pulp mill effluent were tested, one on each occasion. The first one was a 24-h composite sample of final effluent from Thai pulp mill (Ecotox, 2005). The second was a 24-h composite sample of secondary treated effluent from a pulp mill from South America (Ecotox, 2006). This is a limited testing and the results are only for the two samples tested (each from a different pulp mill without replication in time so no conclusion can be drawn on how variable the toxicity of the effluents is). No chemical analyses of the effluents tested were reported, so it is impossible to compare the effluents with the information on chemical composition of the effluent from the proposed pulp mill provided in Table A1.3 (Toxicos, 2006).

Tests used

The following tests were used:

- Microtox assay
- 72 h micro-algal growth inhibition test
- 72 h macro-algal germination assay

- sea urchin fertalisation success test
- 72 h larval development test for sea urchin
- 48 h larval development test for doughboy scallop
- 96 h survival test for juvenile amphipod
- 96 h larval fish imbalance test

A wide range of acute toxicity tests was used to evaluate toxicity of pulp mill effluents from Thailand and South America (Ecotox 2005, Ecotox 2006). However, no subchronic or chronic tests were done. All tests used were static, non-renewal tests. The Microtox test, 72 h micro-algal growth inhibition test and 72 h macro-algal germination assay were evaluated for testing of pulp mill toxicity previously (Stauber et al 1994). The sensitivity of Microtox and macro-algal germination tests was evaluated as medium, whereas the sensitivity of micro-algal growth inhibition test was determined to be high (Stauber et al 1994). The reproducibility was high for the Microtox and 72 h micro-algal growth inhibition test, however the 72 h macro-algal germination assay had only low-medium reproducibility (Stauber et al 1994).

Duration of toxicity tests

The toxicity testing for the proposed pulp mill focused only on acute (short term) tests. The longest exposure duration was 96 hours (Ecotox 2005, Ecotox 2006). However, it would be more appropriate to run subchronic trials, which test toxicity over longer period of time, as the effluent will be released over longer time than just a few days. Acute testing is not appropriate for effluents containing trace contaminants, which are persistent and are more likely to cause subchronic or chronic than acute effects. The effects on aquatic life will be related not only to the concentration of toxicant (in water but also in sediment and diet) but also to the duration of exposure. At least subchronic toxicity tests should be included in the toxicity assessment.

Type of tests

The reported toxicity testing focused on static, non-renewal tests. In general, static non-renewal tests can underestimate toxicity. A more realistic approach, to reflect continuous discharge of effluent into environment would be to use flow-through toxicity tests or at least renewal tests (semi-static).

Routes of exposure

These toxicity tests focused on aqueous exposure (effluent added to water). However, aquatic life will be exposed to chemical compounds from the effluent accumulated in the sediments and diet. Effects of these routes of exposure have not been tested.

The appropriateness of the assessment and the conclusions drawn

Some of the conclusions are overstated. For example, the conclusion in both toxicity reports is "Assuming that the effluent from the pulp mill proposed for Bell Bay is the same as that sampled and tested (...), then based on the results presented herein, no acute or sub-lethal toxicity would be expected to be

observed at the edge of the mixing zone" (Ecotox 2005, Ecotox 2006, similar statement used in Executive Summary page 26). I agree that if the effluent is the same as tested there should be no acute toxicity. However, it is possible that exposure longer than 96 hours would result in subchronic or chronic effects, so the statement that no sublethal toxicity would be expected is incorrect. Additionally, aquatic life will not only be exposed to the effluent being released at any point in time, but also to contaminants which originated from the effluent but accumulated in sediments and biota. Toxicity of marine sediments would increase with the duration of effluent release.

Furthermore, it is also stated that there is "a significant difference in flows between the South American Mill (43m^3/Adt) and Gunns Mill (25m^3/Adt) which indicates (a) the Gunns Mill is more water efficient and (b) that the effluent from the Gunns proposed mill is likely to be in a more concentrated form than the South American Mill" (Ecotox 2006, page 12). If the effluent from the proposed mill is in a more concentrated form it suggests that it will contain greater concentration of toxins and will be more toxic than South American effluent. This does not support the assumption that the effluent from the proposed pulp mill is the same as tested in the Executive Summary of the same report (Ecotox 2006, page 4, cited in the previous paragraph).

Specific questions (as provided by TFIC)

1. Does the report address all potential marine areas on which the Gunn's mill effluent could have impact?

The Ecotox report focuses only on toxicity tests, which addressed short-term (acute) toxicity to particular marine species. There is no evaluation of the effects of longer term exposure, exposure to contaminated sediments or formation of residues in aquatic animals. No ecosystem or fishery impacts were investigated.

2. Is the monitoring process detailed in the report adequate for now and into the future?

No, it is not. Very little information is provided for the monitoring, therefore it is impossible to assess it. The limit of detection proposed for monitoring of residues is too high and more sensitive methods should be used.

3. Does the report address potential long term impacts throughout Bass Strait with reference to coastal ecology?

No, it does not. Only acute toxicity tests (up to 96 hours) were performed.

4. Will there be insignificant impacts beyond the 1km mixing zone?

This question requires definition of "insignificant". However, even without the definition there is not enough information in the report to predict impacts beyond the 1 km mixing zone.

5. Will your review identify data gaps and uncertainties and make recommendations for further work, if required?
Yes. Please refer to previous answers and recommendation sections.

6. Are the data generated suitable to support the assessment of effects of the proposed Bell Bay Pulp Mill?
No, the toxicity data are very limited and address only acute toxicity. For example, longer term toxicity of the effluent, residue formation in aquatic animals or genotoxicity of the effluent has not been studied.

7. Does the toxicity assessment address spatial ecological impacts?
No, it does not.

8. Could the toxins in effluent reaching the Tamar estuary from both the proposed ocean outfall and also leaching from the site itself into the Tamar River affect existing aquaculture industry?
There is an abalone farm, a seahorse farm and a salmon farm which are in the area of Tamar river or Tamar estuary. The most likely ways the existing aquaculture industry could be affected would be through release of toxic substances from Tamar river sediments during any construction or dredging activities, leaching from landfills, incidental spills or discharges into Tamar or aerial drift of contaminants. The main effluent discharge (ocean outfall) is located some distance away from these facilities. Any effects on the farmed animals would be more likely to be sublethal than mass mortalities and may occur over longer time. Residues of heavy metals and dioxins in the farmed animals are another potential risk, which could be significant due to their potential impact on market access, consumer perception and consumer health.

Additional issues

Chemical composition of the effluent

Information on chemical composition of the effluent from the proposed pulp mill is provided in Table A1.3 (Toxicos, 2006). Substituting chlorine dioxide for chlorine does not reduce emissions of resin acids (Soimasuo et la 1995). The presence of resin acids and in particular retene is of concern because of their tendency to accumulate in sediments and their known genotoxic effects on marine life (please see below).

Genotoxicity of the effluent

Resin acids can cause teratogenicity in fish larvae (Brinkworth et al 2003) and are genotoxic to mussels (Gravato et al 2004). Exposure of mussels to abietic acid and dehydroabieteic acid resulted in a decrease in hepatopancreas DNA activity (Gravato et al 2005). Eels exposed to dehydroabieteic acid for 3 days showed significant increase in erythrocytic nuclear abnormalities (Pacheco and Santos 1997), these results were confirmed in further laboratory and field studies

(Pacheco and Santos 1998). Short term (6 hours) exposure to low concentrations of retene (3.08 µg/L) or bleached kraft pulp mill effluent (1%) induced genotoxic effects in sea bass, including erythrocytic micronuclei and nuclear abnormalities (Gravato and Santos 2002). UV radiation has been shown to increase the toxicity of retene, for example newly hatched larvae of whitefish did not show any mortality on exposure to low concentrations of retene but when they were treated with UV radiation the resulting LC50 was 13.3 µg/L (Häkkinen et al 2003). Retene has been reported to induce blue sac syndrome in trout larvae (Brinkworth et al 2003). The concentration of retene in pulp mill effluent is listed as 5 µg/L in the effluent of the proposed pulp mill and 0.5 µg/L in the initial dilution zone in Table A1.3 'Chemicals of interest' in Bell Bay effluent (Toxicos, 2006, page 142). Resin acids accumulate in sediments and become bioavailable to fish (Oikari et al 2002).

Potential immunosuppression in fish as a result of exposure to pulp mill effluent

Immunosuppression has been reported in fish experimentally exposed to pulp mill effluent. For example, whitefish exposed for 30 days to 1.3% bleached kraft pulp and paper mill (low chlorine) effluent had depressed concentration of plasma immunoglobulin (Soimasou et al 1995). Furthermore, 3 weeks exposure to 20% of either primary or secondary-treated effluent from a pulp and paper mill using ECF/TCF bleaching had adverse effects on immune response of roach, in particular decreased the number of antibody secreting cells (Aaltonen et al 2000). These effects could result in an increased susceptibility to infectious diseases. These potential effects were not investigated in the Ecotox toxicity studies.

Potential endocrine disruption in fish as a result of exposure to pulp mill effluent

Pulp mill effluents have been reported to affect reproductive physiology of fish through endocrine disruption. Effluents from pulp and paper mills show androgenic activity which results in masculanisation and sex-reversion of female fish. For example, extracts of treated effluent from totally chlorine free pulp mill in Sweden induced male biased sex ratio and intersex fish in zebrafish exposed from 10 to 38 days post-hatch under laboratory conditions (Örn et al 2006). Male bias was present in eelpout embryos collected in the vicinity of chlorine free bleaching pulp mill (Larsson and Förlin 2002). So far the chemicals responsible for these effects have not been identified. Multiple ligands to a fish androgen receptor were present in effluent from total chlorine free bleaching kraft pulp mill in Sweden, their amount was reduced but not eliminated by biological treatment of the effluent (Larsson et al 2006). These potential effects were not investigated in the Ecotox toxicity studies.

Residues in fish

Residues form as a result of exposure over time to some toxicants. Even exposure to low concentrations of toxicants (below detection limit) can result in formation of residues in fish. Fat soluble (lipophilic) compounds may be at levels below detection limit in the water, but at detectable levels in sediment and fish.

Many contaminants such as dioxins are lipophilic which makes them extremely persistent in the marine environment (Tanabe 1988). Sensitive methods must be used for testing residues in fish. Use of sensitive methods can be expensive but is crucial for monitoring. Methods used for residue testing (baseline) could not detect Maximum Level or Generally Expected Level because they were not sensitive enough (Aquenal 2005, report on outfall ecology page 54). Residues can be reported on the basis of wet weight, lipid weight or dry weight, unless more information (water and fat content) is provided they can be difficult to interpret. For polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) and dioxin-like polychlorinated biphenyls (PCBs) residues are often reported as Toxic Equivalent concentration. Each congener concentration (upper bound basis) is first standardised to its 2,3,7,8-Tetra Chlorinated Debenzo Dioxin (TCDD) Toxic EQuivalent (TEQ) concentration. The dioxin and dioxin-like TEQs are calculated by multiplying the concentration of each congener by its World Health Organisation (WHO) 2,3,7,8-TCDD Toxic Equivalence Factor (TEF) value (Van den Berg et al., 1998). Each of these individual TEQs is then summed to calculate the total TEQ.

Sediments toxicity in Tamar

Sediments from some areas in Tamar river have been shown to contain high levels of toxicants (Mondon 2000), which resulted in immunotoxic effects on greenback flounder (Mondon et al 2000). Exposure to contaminated sediments and diet sourced from Tamar river inhibited growth and induced pathological changes in greenback flounder (Mondon et al 2001). Therefore, there is a potential risk of an increased exposure of marine life in Tamar river to the contaminated sediments during any dredging activities or other activities resulting in resuspension of the sediments. This exposure could result in adverse effects on aquatic life.

Monitoring

Effluent can have very low level (even below detection limit) of toxicants, however due to a discharge of large volume of effluent there is high risk that these contaminants will partition into sediment and biota and that the residues in sediments and biota will increase over time. Water analyses alone are not adequate as some of the substances of concern are lipophilic (fat soluble) and will not remain in water. It is important to analyse lipid content of any biological samples so the residues of lipophilic compounds can be interpreted correctly. Choice of fish tissue or organs for analysis is crucial. If the main reason for monitoring is health of consumers, fish flesh should be analysed. However, if environmental contamination and its effects on aquatic life are investigated organs which are most likely to accumulate or contain toxins of interest should be sampled. For example, resin acids and their metabolites are usually present in bile. Furthermore, artificial sampling devices (containing matrix attractive to lipophilic compounds such as solvent or lipid) can be used. Residue monitoring will not provide all information needed. Ecological surveys and toxicity screening

should be also undertaken. The proposed monitoring program does not contain enough detail to be critically assessed. It is not obvious what mitigation will be put in place if the results of monitoring show toxicity or presence of residues.

Chlorine toxicity

Chlorine toxicity "Chlorine itself is not toxic ..." in Section 5.3 Key Messages in V1a_part5.pdf IIS Public Consultation. Chlorine is toxic to humans and other animals (including fish), for example in humans it can cause mild irritation of mucous membranes at 1-3 ppm and death after 30 minutes exposure to 430 ppm (Evans 2004).

Data gaps

No subchronic or chronic tests, including investigations of potential activity of endocrine disruptors or immunosupressants
No genotoxicity tests
No bioaccumulation tests
No sediment toxicity tests
No fish residue tests with low detection limits
Lack of information on chemical composition of the effluent tested
Lack of information on proposed monitoring of the toxicity of the effluent and effects of the effluent on marine life

Uncertainities

I could not find definitions for risk assessment and other statements - for example what is meant by "negligible toxicity" (for example page 43 Executive Summary) or "very low risk" (for example, page 44, Executive Summary). These definitions should be provided so the statements are objective and can be understood by everybody.

As some of the methods used for measuring concentration of contaminants (Aquenal 2005) had high detection limit (greater than Food Standard Maximum Levels) it is not obvious what is meant by the statement that concentrations will be "below detection limits" - if an insensitive method is used a residue or concentration which is biologically significant can be missed if it is under detection limit, it does not necessarily mean that it will not have any effect. Methods proposed to be used in the monitoring also have too high detection limit, for example (Draft Integrated Impact Statement, Bell Bay Pulp Mill, Volume 4: Page 228) arsenic - detection limit listed 5 mg/kg, Food Standard Maximum Level 2 mg/kg, expected detection limit in analytical laboratories 0.02 mg/kg, cadmium detection limit listed 1 mg/kg but should be 0.01 mg/kg.

Most of published research on toxicity, residue accumulation and impacts of pulp mill effluents were done in freshwater environments in Northern Hemisphere. There is less information on effects on marine environments. Salmonids (only in freshwater environment) are the only group of commercially important fish studied in more detail. I could not find any published information on effects of

pulp mills on rock lobster (or equivalent crustacean) or abalone. This makes extrapolation of results difficult.

Recommendations

1. Analytical methods with enough sensitivity to at least detect Food Standard Maximum Levels are available and should be used for chemical testing (including residues in fish and sediment). For each type of analysis only laboratories NATA registered for the specific analysis should be used.
2. Subchronic toxicity testing on equivalent pulp mill effluent should be undertaken.
3. Sediment toxicity should be evaluated.
4. Detailed monitoring program should be available for assessment before the pulp mill is approved.
5. Residue monitoring (fish, crustaceans, molluscs, including samples from aquaculture facilities) should be clearly outlined in monitoring program, this monitoring should have two components - one focusing on protecting consumers (commercial fishing catch and recreational fishing catch and aquaculture product should be included) and another one on protecting environment.
6. No dredging activities should be undertaken in Tamar river or estuary as part of pulp mill construction or activities without detailed assessment of toxicity of the sediments and their potential impact on water quality, wildlife and existing aquaculture facilities.

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Appendix 1
Typographical errors in toxicity reports (Ecotox 2005, Ecotox 2006)
Ecotox 2005 and Ecotox 2006 - glossary of terms, page 9 - LC50 - part of the definition is copied and pasted from EC50. It should say: "LC50 is the median lethal concentration. That is it is the concentration of material in water (eg., mg/L) that is estimated to be lethal to 50% of all test organisms. In most instances the LC50 and its 95% confidence limits are statistically derived ...", not "LC50 is the median effective concentration. That is it is the concentration of material in water (eg. mg/L) that is estimated to be lethal to 50% of all test organisms. In most instances the EC50 and its 95% confidence limits are statistically derived ..."

Ecotox 2005 - almost all results of toxicity tests have a typographical error in the table, which lists "percentage of fertilised eggs" even if the endpoint was different (4.2 page 17, 5.2 page 20, 6.2 page 23, 7.2 page 27)

Ecotox 2006 - the same mistake (incorrect endpoint listed in result table) is repeated in section 4.2 page 17, 5.2 page 20, 6.2 - page 26.

Ecotox 2005 - page 86 and 89 - reports DO for FSW as 1040 mg/L, values for other treatments range from 98.7 to 104.2 mg/L - I am assuming it should be % oxygen saturation not mg/L and that the first number was 10 times lower than reported.

Ecotox 2006 - page 145 - reports DO in a range of 102.8 to 118.9 as mg/L, I'm assuming it is % oxygen saturation, similar mistake on page 148, 151 and 154.