Appendix 21: Toxic Contaminants

1. Introduction

A range of potentially toxic chemical contaminants enter the Waikato River from natural geothermal activity, wastewater discharges and indirect diffuse source inputs. Geothermal sources result in high concentrations of mercury, arsenic and boron. The river receives background geothermal contaminants from Lake Taupoo with additional natural inputs downstream. A major input of geothermal contaminants enters the river from the Wairaakei Geothermal Power Station. As a result of these upstream inputs geothermally contaminated sediment has accumulated in the bottom of Lake Ohakurii. At certain times of the year conditions in the lake lead to re-release of these contaminants into the overlying water.

A major point-source discharge of pulp and paper wastewaters occurs in the mid-river section at Maraetai. Historically this had significant concentrations of both mercury and dioxin in addition to resin acids and other organic material. However, improved treatment systems have markedly reduced contaminant concentrations.

The most significant urban contaminant inputs are from Cambridge, Hamilton and Huntly, with associated industrial inputs along this lower river reach. The Waipa River drains a wide agricultural area and receives the run-off and wastewater discharges from Te Kuuiti, Otorohanga and Te Awamutu. Numerous discharges of stormwater run-off occur from agricultural and urban areas. The Hamilton City discharges are elevated in contaminants (particularly metals) particularly during storms.

Run-off results in input of DDT (a synthetic pesticide) and other insecticides, as a legacy of past agricultural practices. Increases in zinc inputs are occurring because of the high usage for facial eczema control. The cumulative inputs of dairy processing wastewaters may result in toxic conditions in tributary streams (largely from ammonia) but not in the Waikato River.

A number of other significant point source discharges occur to the river, including municipal wastewaters, power station cooling tower discharges and various industrial wastewater and stormwater discharges. The individual and cumulative effect of contaminants derived from these discharges has not been assessed.

The contaminants in the river are of concern for two reasons: they can reach levels at which there will be an ecological effect with toxicity affecting some organisms and plants, and there can be human health risks associated with drinking untreated river water and consuming fish and invertebrates from the river.

2. Ohakurii sediment toxicity

Geothermally derived arsenic (As) and mercury (Hg) accumulate in the sediments of Lake Ohakurii. It is estimated that more than 380 tonnes of arsenic and 0.5 tonne of mercury may have accumulated in the lake sediments since its formation in 1961 (N. Kim, Environment Waikato, pers. comm.). Ohakurii has the highest sediment concentrations of any of the Waikato River lakes, with arsenic and mercury concentrations exceeding sediment quality guidelines for ecological protection (Rumbsy and Coombes, 2008; ANZECC, 2000). Other downstream lakes also have elevated concentrations which exceed sediment quality guidelines; however, Ohakurii is regarded as a major 'sink' for these contaminants as it is the first large, deep lake downstream of inputs at Wairaakei and Oraakei Koorako. This accumulation within Lake Ohakurii is also of concern as this lake can become anoxic, under which conditions contaminants are mobilised from the sediments.

A preliminary toxic risk assessment for these sediments could be made by comparing the sediment concentrations with the sediment quality guideline value (ANZECC, 2000). Exceedance would trigger the need for further investigation. In Lake Ohakurii, the average exceedance is about eight times the guideline value (with a maximum exceedance of 31 times). Sediment pore-water concentrations of the most toxic form of arsenic (AsIII) are known to be elevated and released to the overlying water when dissolved oxygen conditions in the lake drop (Aggett and Kriegman, 1988). This can potentially result in toxic conditions for both sediment-dwelling organisms and those living in the lake waters. Similarly, mercury concentrations will be elevated in pore waters and release to the overlying waters. These elevated in situ concentrations of geothermal contaminants pose a significant toxic hazard to key native species inhabiting sediments (particularly kooura (freshwater crayfish) and kaaeo/kaakahi (freshwater mussels)) and the overlying waters.

Previous studies have shown marked accumulation of geothermal contaminants in Waikato River kaaeo/kaakahi (Hickey et al., 1995). The highest flesh and shell concentrations were in the upper Waikato River associated with geothermal inputs. The sensitivity of the larval glochidial life-stage or juvenile mussels to geothermal contaminants has not been determined. However, the field observations have shown marked declines in kaaeo/kaakahi at river sites downstream of upper Ohakurii (Roper and Hickey, 1994).

On the basis of the above summary, it is apparent that there is a major information gap around the toxicity of arsenic (and to a lesser extent mercury) in the upper Waikato River. This gap could be most addressed by undertaking sediment toxicity tests, including multi-species sediment toxicity tests (e.g., with amphipods, fingernail clams, oligochaetes and juvenile kooura) and short- and long-term water toxicity tests with arsenic (e.g., with cladocerans, amphipods, iinanga (whitebait) and bullies). Additional information on chemical contamination, sediment physical characteristic and benthic community structure would be required to properly interpret test findings. Some studies on benthic macroinvertebrates have shown that animals in Lake Ohakurii appear to be affected by both chemical contaminants and the nature of the sediment (i.e., organic/muddy enrichment) (Hickey and Martin, 1996). Further investigations would be needed to provide a comprehensive assessment of the level of toxicological impacts, together with a characterisation of the sensitivity of a range of key species to arsenic exposure.

Such a study would cost (including report documentation and communication of study objectives and findings) about $220,000.

3. Health risks

Elevated concentrations of arsenic (As) in the river mean that untreated river water exceeds the water quality guidelines for drinking-water at all river sites downstream of Aratiatia. However, arsenic is substantially removed by most conventional drinking-water treatment systems (e.g., 90 percent reduction of arsenic is achieved after treatment of Hamilton drinking-water; N. Kim, Environment Waikato, pers. comm.).

The risk from consuming food collected from the river is only poorly understood for a few contaminants and food species. Mercury is of particular concern because it can biomagnify through the food-chain. This can result in concentrations that could adversely affect people eating kai (food) from the river. Surveys of trout in 1998 found that mercury concentrations exceeded health regulations in only 11 of the 285 fish sampled; however, comparison with accepted daily intake values indicated that some sites *"could conceivably pose some threat to human health"* (Mills, 1995). Arsenic levels in fish were low and below health regulation limits at all sites. Previous studies have shown marked accumulation of geothermal contaminants in Waikato River kaaeo/kaakahi (Hickey et al., 1995). The highest flesh and shell concentrations were in the upper Waikato River associated with geothermal inputs.

Since 1996–97 an estimated 4,200 elvers (juvenile tuna) have been transferred to Lake Ohakurii (Boubée, NIWA, pers. comm.). The introduction of tuna to Lake Ohakurii poses a significant risk for accumulation of high mercury concentrations from the contaminated sediments. This in turn poses a risk to people who eat large quantities of tuna from the lake. No information is available on the contaminant concentrations in Ohakurii tuna.

Some species of aquatic plants are ‘hyper-accumulators’ of water and sediment-derived arsenic. Watercress is among the species which strongly accumulates arsenic (Robinson et al., 2006). A health assessment of watercress from Lake Ohakurii has indicated that regular consumption of 16 grams of fresh watercress a week from Lake Ohakurii would be sufficient to exceed the tolerable daily intake (Robinson et al., 2006). While watercress occurs in some locations in the upper Waikato River main stem, its distribution is limited in extent and collection would largely occur from the less contaminated tributary streams. Health risk is therefore probably minimised by the low availability and suitability of river sites for regular collection. Watercress is an accumulator of a number of other metal contaminants (especially copper).

Previous fish and mussel monitoring studies have measured DDT, PCB (polychlorinated biphenyl), dioxin and other pulp and paper related contaminants at low tissue concentrations (Hickey et al., 1997; Burggraaf, 1996). Although the use or discharge of many of these contaminants would be far less now than it has been in the past, some legacy areas of sediment contamination may still contain these persistent chemicals. DDT and PCBs have had multiple potential sources throughout the river. The dioxins have historically been associated with the pulp and paper mill discharge to Lake Whakamaru.

Different species of fish are harvested for consumption from the lower Waikato River. The major harvested fisheries would be for mullet and whitebait. The whitebait would generally be considered of low risk to human health as their short time in the river does not provide sufficient time for chemical contaminant accumulation. There is no contaminant information available for mullet.

Kooura occur throughout the river system but currently there is no information available on their distribution or abundance, nor on contaminant concentrations in their tissue.

To assess the health risk associated with a ‘food basket’ of the most commonly eaten species, it is necessary to have robust data on the concentrations of contaminants in a range of species. From the above, contaminants of most interest are heavy metals (especially copper, arsenic and mercury), methyl mercury, PCB, DDT and dioxin. Species of most relevance are tuna, mullet, kaaeo/kaakahi, trout, whitebait and kooura. Information to help understand factors controlling contaminant uptake into these food species is also needed (e.g., animal size, age and condition, lipid content, and stable isotope analysis to understand food-chain routes).

A health risk assessment for food consumption would also need to be undertaken for different risk categories (e.g., river iwi, the general population, women of child-bearing age and children) and for realistic levels of consumption which reflect actual amounts consumed (e.g., moderate and high consumers). Such analysis would help to show if there are health risks associated with ‘normal’ consumption levels or if guidance needs to be provided to limit consumption.

If significantly elevated concentrations of multiple chemical contaminants were found to occur, a cumulative health risk approach could be used to assess the risk for all of the contaminants present (Barnes and Dourson, 1988). Such a study would cost in the vicinity of $290,000.

4. Restoration

There are legitimate concerns for arsenic and mercury contamination occurring in the water and kai of the Waikato River, although there are many unknowns and further study is needed before specific restoration actions can be confirmed. There are also initiatives underway that will address some of the existing problems. For example, geothermal contaminant inputs from the Wairaakei Geothermal Power Station discharge will be managed through their resource consents. Similarly, although untreated river water is high in arsenic this can be substantially removed by most conventional large-scale drinking-water treatment systems. The most likely restoration action that could be undertaken would involve capping or fixing arsenic and mercury in the sediments of Lake Ohakurii. This would have the benefit of limiting arsenic and mercury release from the lake sediments into the overlying water. While this action is not being recommended at this time it has been costed for future reference.

There is considerable uncertainty regarding other contaminants in the river and it is presently impossible to assess if or when a problem might arise. This is clearly a significant information gap, but of major interest to river iwi (tribes).

There are other discharges to the river that may have an ecological impact. These include stormwater discharges and dairy wastewater discharges to streams. Although it is recognised that these effects may be occurring, they are of limited extent and are of low priority in the scheme of restoration actions.

Abatement costs have been developed for three options for restoration in Lake Ohakurii: core cost, anticipated treatment and whole-lake treatment (see Table 1).

Figure 1 shows total abatement costs of reducing arsenic and mercury, and improving sediment ecology for each of three actions: core cost, anticipated treatment and whole-lake treatment. Abatement potentials differ amongst actions (e.g., the whole-lake treatment action is most costly for improving sediment ecology, but at the same time generates maximum benefits for sediment ecology (e.g., 100 percent)). If the objective is to reduce both mercury and arsenic, and improve sediment ecology at the same time, then the whole-lake action has to be implemented. Improving sediment ecology is positively correlated to costs: the higher the improvement the higher the cost. The most cost-effective way to reduce arsenic is by implementing the core cost action, at a total cost of $1,505,000. Mercury can only be reduced by implementing the whole-lake treatment action.

Table 1: Benefits and costs of action components for reducing toxic contaminants.

Components	Description	Details	Benefit	Cost	Options		
					1	2	3
1	Laboratory testing of Ohakurii sediments and calibration of dosage	Validation of various product options ranging from alum (binding only phosphorus and As) to Aqua-P (binding P, As, and Hg).	Capping dose and product selection established. Proof of As (and Hg) binding efficiency.	$110,000			
2	Field efficacy trial in Whirinaki arm	Field trial of Aqua-P applied to 74 ha of arm at 200 g/m^2 (148 tonnes). Application cost estimate at 30% product cost. Monitoring allowance for As and P in and out of arm ($50k). Contingency of $75k for higher dosing rate if required.	Field efficacy established for arm of lake known to deoxygenate. Can be used to validate suitability of application method.	$585,000			
3	Alum lake dose for As removal	Base alum dose calculation (480 tonnes). Contingency of 50% for possible higher dose requirement.	Peak As (and phosphorus) removed from export to downstream lakes and water supplies.	$660,000			
4	Aqua-P lake dose for As removal	Base Aqua-P dose calculation (960 tonnes). Contingency of 50% for possible higher dose requirement.	Peak As (and phosphorus and mercury) removed from export to downstream lakes and water supplies.	$4,110,000			
5	Whole lake treatment for As and Hg removal	Base Aqua-P dose calculation (1600 tonnes). Contingency of 50% for possible higher dose requirement.	Peak As (and phosphorus and mercury) removed from export to downstream lakes and water supplies.	$6,900,000			

Table 1: (cont.)

Components	Description	Details	Benefit	Cost	Options		
					1	2	3
6	Lake monitoring programme, public presentations and reports	Lake biota and chemical monitoring associated with treatments. Report documentation and presentations.	Monitoring to show no adverse effects of treatments. Full documentation of remediation process. Long-term monitoring will show whole-lake benefits.	$150,000			
			1 Core cost	$1,505,000			
			2 Anticipated treatment	$4,955,000			
			3 Whole-lake treatment	$7,745,000			

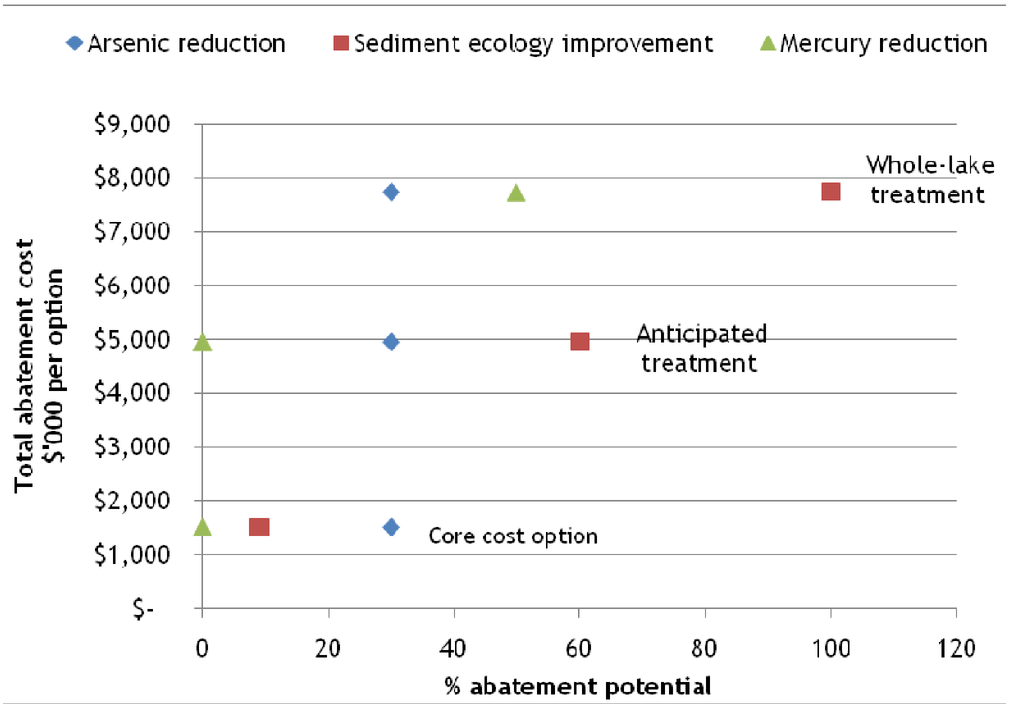

Figure 1: Abatement costs for three toxic contaminant reduction actions.

Each action has co-benefits; for example, if the objective is to reduce arsenic, the core cost option is most cost-effective and also has the additional benefits of improving sediment ecology (although at a higher cost than the other two options). Abatement potentials differ for each action. Therefore it is useful to construct another graph analysing unit costs which shows that the whole-lake option is the most cost-effective way to improve sediment ecology. Figure 2 shows the unit abatement cost per unit of reduction in arsenic and mercury, and per unit of improvement for sediment ecology for each action.

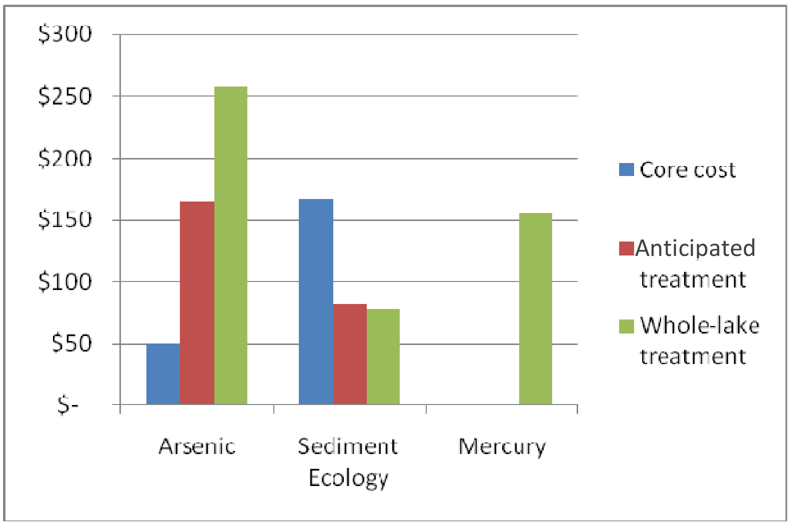

Figure 2: Unit costs for reducing toxic contaminants for all three actions.

The core cost option is the most cost-effective at reducing arsenic, whereas the whole-lake action is the most cost-effective at improving sediment ecology and also has the added benefit of reducing mercury. The costs of reducing mercury for the first two actions are effectively zero as they do not have the ability to reduce mercury.

5. Information gaps

This review has highlighted many information gaps which need to be addressed before restoration recommendations can be developed further. Specific studies that are recommended include:

1. Monitor arsenic and mercury levels in tuna, kooura, and kaakahi throughout river to assess contaminant levels and monitor arsenic levels in water and watercress.
2. Undertake a full Health Risk Assessment (HRA) for mercury including food chain accumulation and species/amount consumed to gauge the seriousness of the

problem and identify priorities and where effort needs to be focused.

3. Investigate arsenic mobilization mechanisms in Lake Ohakurii to determine how big an issue it would be if the ‘worst case’ scenario occurred of lake deoxygenation.
4. Investigate sediment arsenic toxicity to establish how big an issue it is and determine the sensitivity of key native species (including juvenile kooura and kaaeo/kaakahi).
5. Undertake trials on sediment capping in Lake Ohakurii and assess its effectiveness at immobilisation of arsenic and mercury.
6. Investigate DDT, PCB, arsenic, zinc and copper levels in potential food organisms.
7. Undertake monitoring (at five-yearly intervals) for emerging contaminants which may affect the river.
8. Monitor seasonal anoxia (oxygen depletion) in the hydro-lakes, especially Lake Ohakurii. (This is a fundamental measure of both the input of organic run-off, internal lake productivity and the potential of generation of sediment-associated arsenic.)

6. References

Aggett, J.; Kriegman, M.R. (1988). The extent of formation of arsenic (III) in sediment interstitial waters and its release to hypolimnetic waters in Lake Ohakuri. *Water Research 22*: 407–411.

ANZECC (2000). Australian and New Zealand guidelines for fresh and marine water quality. Canberra, Australia, National Water Quality Management Strategy Paper No. 4, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Barnes, D.G.; Dourson, M. (1988). Reference dose (RfD): Description and use in health risk assessments. *Regulatory Toxicology and Pharmacology 8*: 471–486.

Burggraaf, S.; Langdon, A.G.; Wilkins, A.L.; Roper, D.S. (1996). Accumulation and depuration of resin acids and fichtelite by the freshwater mussel Hyridella menziesi. *Environmental Toxicology and Chemistry 15*: 369–375.

Depree, C.; Franklin, P.; Hickey, C.; Hudson, N.; Martin, M.; van Houte-Howes, K.; Wells, R. (2008). Monitoring of Lakes Maraetai and Waipapa in compliance with Environment Waikato Resource Consent 961348 No. CHH08201, *HAM2008-206. NIWA client report* for Carter Holt Harvey Limited, pp. 231.

FSANZ (2004). Mercury in Fish – Further Information. Food Standards Australia New Zealand. 2008.

Hickey, C.W.; Buckland, S.J.; Hannah, D.J.; Roper, D.S.; Stüben, K. (1997). Polychlorinated biphenyls and organochlorine pesticides in the freshwater mussel Hyridella menziesi from the Waikato River, New Zealand. *Bulletin of Environmental Contamination and Toxicology 59*: 106–112.

Hickey, C.W.; Martin, M.L. (1996). Lake Ohakuri monitoring: 1994/96. *No. EVW60204.* Prepared for Environment Waikato, pp. 54.

Hickey, C.W.; Roper, D.S.; Buckland, S. (1995). Metal concentrations of resident and transplanted freshwater mussels Hyridella menziesi (Unionacea: Hyriidae) and sediments in the Waikato River, New Zealand. *The Science of the Total Environment 175*: 163–177.

Mills, G.N. (1995). Mercury and arsenic in Waikato River fish. *No. SCJ129/06.* Environment Waikato, Hamilton. 47 p.

Robinson, B.; Kim, N.; Marchetti, M.; Moni, C.; Schroeter, L.; van den Dijssel, C.; Milne, G.; Clothier, B. (2006). Arsenic hyperaccumulation by aquatic macrophytes in the Taupo Volcanic Zone, New Zealand. *Environmental and Experimental Botany 58*: 206–215.

Roper, D.S.; Hickey, C.W. (1994). Population structure, shell morphology, age and condition of the freshwater mussel Hyridella menziesi (Unionacea: Hyriidae) from seven lake and river sites in the Waikato River system. *Hydrobiologia 284*: 205–217.

Rumsby, A.; Coombes, L. (2008). Investigation of Lake Ohakuri. Report prepared for Environment Waikato by Pattle Delemore Partners Ltd.