MINISTRY OF HEALTH
MANATŪ HAUORA

New Zealand Government

The Environmental Case Management of Mercury-Exposed Persons

July 2021

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1 Introduction

1.1 Background

These guidelines provide practical advice for the investigation and environmental case management of mercury-exposed cases. They are intended to assist the public health units in achieving a tolerable level of mercury in the environment of exposed children and/or adults, so limiting any adverse effect on people's health. Making their environment 'mercury safe' will also protect people who might otherwise be exposed to the same mercury hazards in the future. Although the guidelines focus on secondary prevention, increasing evidence of the toxicity of mercury strengthens the importance of primary prevention (Debes et al 2016; Grandjean et al 2014).

The current average blood mercury levels of children and adolescents across a range of developed countries are in the range of 0.23-1.7 µg/L (Ruggieri et al 2017). A New Zealand survey (samples taken from 2014 to 2016) reported a geometric mean blood mercury concentration for adults (19+ years, n = 304) of 1.65 µg/L and for children (5–18 years, n = 191)[1] of 0.86 µg/L ('t Mannetje et al 2021). Equivalent geometric mean concentrations for the United States population, for the period 2011–2016, were in the range 0.81–0.86 µg/L for adults (20+ years) and 0.26–0.41 µg/L for adults (20+ years) and children (1–19 years) (CDC 2018). United States blood total mercury concentrations show a downward trend over time.

1.2 Purpose of the guidelines

These guidelines are intended to support public health units to manage health risks from exposure to mercury in non-occupational settings. People may be exposed to mercury in non-occupational settings, primarily in and around the home.

Properly applied, the guidelines will assist with determining:

- the risk of a mercury hazard
- appropriate processes for managing the risk, including risk communication.

The guidelines will normally be used in the context of 'secondary prevention', when a person has already been, or is suspected to have been, exposed to mercury. They are not intended for primary prevention of hazards arising from mercury (for example, inspection, risk assessment and risk reduction from mercury in dwellings regardless of a resident's blood mercury levels), although many of the basic procedures, sampling and abatement methods would be similar.

[1] While the adult cohort could be considered to be random, a variety of mechanisms were used to establish the child cohort, including recruiting children of recruited adults and friends of the recruited children. The resulting cohort was heavily geographically biased to the lower North Island.

The investigation of mercury-exposed people should evaluate the contribution of all potential sources and media to cumulative mercury exposure. Sources include broken thermometers and fluorescent light bulbs, dental amalgam, mercury-based cosmetics and medicines, and mercury in food and drinking-water, particularly seafood.

Accordingly, these guidelines assist public health units to identify all contributory mercury hazards and (open) exposure pathways, using a combination of interview, visual observation and laboratory testing. A management plan, typically incorporating both behavioural (educational) and environmental (abatement) strategies, can then be developed in consultation with exposed people. It must be emphasised that the guidelines aim to provide a 'mercury-safe' environment; this is not the same as a mercury-free environment.

1.3 Exclusions

These guidelines exclude places of work because these are covered by the Health and Safety at Work Act 2015. WorkSafe New Zealand is responsible for enforcing the Health and Safety at Work Act 2015. Note that homes, public buildings and schools may be considered to be places of work if contractors are doing work in them.

Ambient (outside) air is covered by the Resource Management Act 1991. The Ministry for the Environment administers this Act, and it is implemented by regional councils in so far as it relates to discharging contaminants to air. Mercury may occur in ambient air from diffuse sources of exposure, but such sources are not considered within the scope of these guidelines. For example, fuel/energy use, especially geothermal, and to a lesser extent, primary metal production and waste incineration are significant sources of mercury output to the environment. Ambient air inside dwellings and point-source release of mercury around dwellings would, however, be covered by these guidelines.

1.4 Risk analysis

Some sources of mercury exposure encountered in other countries, such as during traditional or non-mechanised recovery of gold, use of mercury-containing skin-lightening treatments and religious/cultural use of mercury, will be rare or of unknown occurrence in New Zealand. Health protection staff are most likely to become involved with mercury contamination when a mercury-containing device, such as a thermometer, has been broken. In such cases, hazard identification and risk abatement will be the most applicable aspects of the risk analysis framework. They are discussed in more detail in the following chapters.

2 Hazard identification

2.1 Introduction

Mercury is a naturally occurring, highly toxic and persistent metal that is released to the environment by natural phenomena, such as geothermal activity, and through human activities, such as the burning of fossil fuels and mining (WHO 2017). However, human activities since the industrial age, have greatly increased potential human exposure. Once in the environment, mercury can pollute the air and water and also bioaccumulate within the food chain. Due to its distribution in the environment and food chain, everyone is expected to have some level of exposure to mercury. Levels of absorption and toxicity depend on the form of mercury, route and rate of exposure, developmental stage and other factors.

Three forms of mercury occur:

- **Elemental or metallic mercury (Hg^0)** is mercury not combined with other elements. Elemental mercury is a silver, odourless liquid that slowly evaporates at room temperature. This form of mercury can be found in natural settings, industrial applications (combustion of fossil fuels, gold mining, incinerators), products (thermometers, dental amalgam, fluorescent light bulbs) and in ethnic folk medicine, such as azogue. Exposure normally occurs via vapour inhalation.
- **Inorganic mercury (Hg^+ or Hg^{2+})** is mercury combined with other chemical elements, commonly forming salts. Exposure can occur via inhalation, ingestion or skin contact. Historical uses of inorganic mercury compounds include as fungicides, skin-lightening creams, topical antiseptic or disinfecting agents. However, their use in many of these applications has been replaced with safer and more effective agents.
- **Organic mercury** is mercury combined with carbon-containing compounds, such as:
  - dimethylmercury (in fungicides and insecticides)
  - ethylmercury (in medical preservatives such as thimerosal and topical antiseptics)
  - methylmercury (MeHg) (microorganisms convert mercury (Hg^0, Hg^+, Hg^{2+}) to its organic form, which bioaccumulates in the environment, most notably in freshwater and saltwater fish species, and constitutes the main source of dietary mercury exposure in the general population)
  - phenylmercury (applied as an antifungal and found in products such as paints, cosmetics, and toiletries. Exposure can occur via inhalation, dermal absorption or ingestion).

2.2 Elemental mercury hazards

Mercury is the only metallic element that is liquid at ambient temperatures and pressures. This explains its historic extensive use in thermometers, barometers, manometers, sphygmomanometers, float valves, switches and relays. These applications made use of the fact that mercury is opaque (can be seen in the instruments' sight glasses), conducts electricity and has nearly linear thermal expansion.

Mercury has been largely replaced in most of these applications by safer materials.

2.2.1 Mercury in switches and temperature and pressure measurement devices

The unique physicochemical properties of elemental (metallic) mercury resulted in its widespread use in switches, thermometers and pressure measuring devices. For example, mercury switches in devices such as irons meant that, if the iron was tipped over, the mercury would shift position, breaking an electrical circuit and turning off the iron to minimise fire risks.

Mercury used for these purposes does not represent a hazard while it remains contained within the device. For example, in a mercury-in-glass thermometer, the mercury is sealed within a length of glass. However, hazards occur when the devices are broken or decommissioned, exposing the mercury to the ambient environment and creating potential for human exposure. Once elemental mercury is released to the environment, the mercury will vaporise over time, and it is this vapour that constitutes the primary human health hazard.

Metallic mercury has unique physical properties that make it highly attractive to children as a play item. Many exposure incidents have been documented from children finding a source of metallic mercury and sharing it with friends, in a residential or school environment. The liquid metal is relatively non-hazardous, with virtually no absorption through the skin from direct contact or gastrointestinal absorption should the mercury be ingested.

Elemental mercury vapour is the primary hazard. Any condition that leads to a build-up of the air mercury concentration will increase the potential for adverse human health effects. Conditions that may increase the elemental mercury concentration include the following.

- Increased ambient temperatures, such as by building heating, will increase the vapour pressure of metallic mercury.
- Confined and/or poorly ventilated spaces will facilitate a build-up of mercury vapour.
- Dispersal of the metallic mercury into fine particles, with a higher surface area to volume ratio will increase the rate of vaporisation.

2.2.2 Mercury in fluorescent lamps

Fluorescent lamps, either strip lights or compact 'energy saving' lamps contain a small amount of elemental mercury, mercuric oxide or mercury amalgams. Fluorescent lamps are electrical discharge lamps that contain low-pressure mercury vapour and an inert gas, usually argon. The inside of the glass is coated with a fluorescent film made with phosphor powder. The mercury vapour is 'excited' by an electrical current between two electrodes and emits ultraviolet (UV) light. The UV light causes the phosphor coating to fluoresce and emit visible light.

As with the devices discussed in the previous section, mercury in fluorescent lamps does not represent a hazard while contained within the lamp. Fluorescent lamps contain relatively small amounts of mercury, and it is likely that most fluorescent lamps used in New Zealand will contain less than 20 mg of mercury (TERA 2008).

While the New Zealand Energy Efficiency and Conservation Authority (EECA) has previously advocated the use of compact fluorescent lamps (CFLs), it currently advises people 'choose LEDs[2] over CFLs when buying new light bulbs. LEDs provide a better quality light, last longer and use even less energy than CFLs'.

When fluorescent lamps are broken it is unlikely that any spilled liquid mercury will be visible, due to the very small volume of mercury present, and any spilled mercury would form minute droplets on impact. The phosphor powder can separate from the glass when the lamp is broken, and some mercury will be associated with this powder. Due to the highly dispersed nature of the mercury of fluorescent lamps, the resulting air mercury concentrations generated are higher than would be generated by a droplet of metallic mercury of the same total weight. However, the amount of mercury released will depend on the age of the lamp, as newer lamps will release more mercury than used lamps.

While air mercury concentrations increase rapidly after breakage of fluorescent lamps, they can also reduce rapidly. After removal of lamp material and ventilation of the affected space, air mercury concentrations have been reported to return to acceptable levels after approximately two hours (Johnson et al 2008).

2.2.3 Mercury in dental amalgam

'Silver' dental amalgam is used to fill cavities in decayed teeth. It contains approximately 50 percent elemental mercury, with the remainder including metals such as silver, copper and tin. The resulting amalgam is strong and durable and the least expensive type of tooth-filling material.

For the general population with amalgam fillings, these fillings represent the major source of mercury body burden. Amalgam fillings have been estimated to contribute up to 10 µg/day to mercury intake. Dietary mercury intake in New Zealand is of a similar order of magnitude.

2 Light-emitting diodes.

Release of mercury from amalgam fillings appears to increase during non-steady-state activities, such as tooth brushing, eating, chewing gum, drinking hot beverages and bruxism (teeth grinding). Mercury may be released from amalgam as vapour, ions or fine particles, and the amount of mercury released will depend on the number of amalgam fillings.

Replacing amalgam fillings with non-mercury-containing materials has been shown to result in a rapid reduction in the amount of salivary mercury. Exposure to mercury from this source will be via the gastrointestinal tract, with little of the mercury absorbed. A New Zealand study found no significant associations between dental amalgam and a range of nervous system and kidney disorders (Bates et al 2004).

2.2.4 Other sources of elemental mercury exposure

Mercury is used in religious practices associated with some Latin American and Caribbean communities. While the particular religions, such as Voodoo, Santeria and Espiritismo, are unlikely to be common in New Zealand, public health officials should be aware that such practices exist. Metallic mercury, sometimes known as azogue in these communities, may be sprinkled on the floor of a dwelling or car, mixed with soap and water to wash floors or left in an open container in a dwelling to ward off evil spirits.

Of more likely concern is the inclusion of mercury, either metallic mercury or mercury salts, in folk medicines from Asia and Central America. The medicines may contain up to 50 percent mercury and may be applied topically or ingested.

Artisanal and small-scale gold mining (ASGM) is estimated to involve more than 14 million people worldwide, mainly in Africa, Asia and South America. ASGM operations often use mercury to extract gold from ore. The mercury may then be discharged to the environment or vaporised when the gold-mercury amalgam is 'roasted'. While this is unlikely to occur in New Zealand, the possibility can't be excluded.

2.3 Inorganic mercury hazards

Inorganic mercury refers to salts of mercury, such as oxides, chlorides and sulphates. These salts are generally non-volatile and non-intentional and non-occupational exposure is likely to be due to the use of medicinal or cosmetic products containing mercury salts.

2.3.1 Mercury in skin-lightening preparations

Skin-lightening products may take the form of creams, milks, oils, ointments or soaps. The terms 'skin-lightening', 'skin-bleaching' and 'skin-whitening' are all used to describe such products. These products may contain a range of active ingredients, including mercury, hydroquinone, topical corticosteroids (TCs), hydrogen peroxide, kojic acid, arbutin, nicotinamide, tretinoin, azelaic acid, salicylic acid, phenols and solvents. Mercury inhibits production of the skin pigment melanin in epidermal melanocytes by inactivating sulfhydryl mercaptan enzymes, leading to inactivation of tyrosinase, an important catalyst in melanin production.

Skin-lightening products have a legitimate dermatologic role in the treatment of hyperpigmentation disorders, such as melasma and post-inflammatory hyperpigmentation. However, such products are also commonly used in a number of African, Asian and Latin American countries and amongst dark-skinned populations in North America and Europe to produce a general cosmetic lightening of the skin.

Mercury may be present in skin-lightening products as ammoniated mercury, mercury iodide, mercurous chloride, mercurous oxide or mercuric chloride. Products have been reported to contain mercury at concentrations as high as 30 percent, although concentrations in the range of 1–6 percent are more common (Cressey 2014).

While the route of exposure will be principally dermal, following direct application of the skin-lightening product, furniture, bedding and surfaces in the user's dwelling can become highly contaminated, and a study of households of women using skin-lightening products found elevated urinary mercury concentrations in some non-users in the same household (Copan et al 2012). It was uncertain what the exposure route was for these non-users, but it was likely to include dermal and oral exposure.

The limited amount of information available on dermal absorption of mercury from skin-lightening products suggests that 1–4 percent of the applied dose may be absorbed.

It is unknown how common the use of skin-lightening products is in New Zealand.

2.3.2 Mercury in medicines

As mentioned above, mercury may be included, either as metallic mercury or mercury salts, in folk medicines from Asia and Central America. Products may contain up to 50 percent mercury and may be applied topically or ingested.

2.4 Organic mercury

Organic mercury usually refers to alkylmercury compounds (methylmercury or ethylmercury) but may also refer to compounds such as phenylmercury and thimerosal. Methylmercury is the main form of mercury found in fresh fish and is the main dietary form of mercury that people are exposed to. Phenylmercury and, in particular, thimerosal have been used as preservatives. Thimerosal was used as a preservative in some pharmaceutical products, including vaccines. However, its use for this purpose has been largely discontinued in developed countries, and it is not used in vaccines on the New Zealand National Immunisation Schedule (Ministry of Health 2020b).

2.4.1 Mercury in fish

Mercury in the marine environment undergoes microbial methylation to become methylmercury and is taken up by fish and other marine organisms. Methylmercury concentrations in fish tend to increase with trophic level, with large predatory species, such as sharks, having the highest concentrations in their flesh.

Total mercury concentrations in marine molluscs and cephalopods are usually less than 0.1 mg/kg (part per million) (Brooks et al 1976; Love et al 2003; Sadhu et al 2015; Vlieg et al 1991). Herbivorous fish species also usually have total mercury concentrations less than 0.1 mg/kg. For predatory species, age, size and trophic level may all contribute to mercury content. Large predatory fish may contain mercury concentrations greater than 1 mg/kg. Food processing and cooking appears to have little impact on mercury content.

Bioaccumulation of mercury by biota may also occur in freshwater environments. Trout from freshwater geothermally-influenced lakes in the Taupō Volcanic Zone (TVZ) have been shown to contain mercury levels that exceeded maximum recommended levels for consumption (Verburg et al 2014). New Zealand's geothermally influenced lakes are mainly found in the North Island, and elevated mercury concentrations are unlikely to be found in lakes in other areas of the country.

The Ministry for Primary Industries is responsible for managing mercury in foods, including fish. Its website has useful information about mercury in fish and emphasises the potential risks from consuming fish with high mercury content for pregnant women and their developing babies. More information can be found at the Ministry for Primary Industries website.[3]

[3] See the Ministry for Primary Industries webpage *Food and pregnancy* at: **www.mpi.govt.nz/food-safety-home/food-pregnancy/** (accessed 15 March 2021).

2.5 New Zealand hazard limits for mercury

Regulations and guidelines exist for mercury concentrations in various environmental media.

Workplace exposure standards (WES) exist for mercury vapour (as Hg), inorganic compounds and alkyl compounds (WorkSafe New Zealand 2018). The standards are expressed as time-weighted averages (TWAs; exposure considered across an 8-hour day and 40-hour work week). WES TWAs for the three forms of mercury are: 0.025, 0.025 and 0.01 mg/m^3 respectively.

The *Drinking-water Standards for New Zealand 2005 (Revised 2018)* specify a maximum acceptable value (MAV) for inorganic mercury of 0.007 mg/L (Ministry of Health 2018).

The Ministry for the Environment has established soil contaminant standards for health (Ministry for the Environment 2011). These include values for inorganic mercury (all expressed on a dry weight basis):

- Rural residential / lifestyle block / standard reside (25 percent produce) 200 mg/kg
- Rural residential / lifestyle block / standard reside (10 percent produce) 310 mg/kg
- Rural residential / lifestyle block / standard reside (no produce) 510 mg/kg
- High-density residential 1,000 mg/kg
- Recreational 1,800 mg/kg
- Commercial / industrial outdoor worker / maintenance 4,200 mg/kg

The Ministry for the Environment has also established ambient air quality guidelines (annual average) for inorganic and organic mercury of 0.33 and 0.13 µg/m^3 respectively (Ministry for the Environment 2002).

The Australia New Zealand Food Standards Code includes limits for mercury in salt (0.1 mg/kg) and in fish, crustacea and molluscs.[4] The limits depend on the seafood species, and both mean and maximum limits are included for specified numbers of samples.

4 For more details on the code, see the Australian Government webpage *Federal Register of Legislation* at: **www.legislation.gov.au/Details/F2017C00333** (accessed 30 November 2020).

3 Dose response, exposure assessment, risk characterisation and risk communication

3.1 Health effects

The toxicology of mercury is complex due to the different states that the element can occur in (elemental, inorganic and organic), the different routes of exposure (mainly inhalation and ingestion) and the distinctly different pathological effects over different time courses (acute or chronic). Further complicating the picture is the fact that mercury has adverse effects on many organic systems, including the brain, the kidneys and the skin.

3.1.1 Elemental mercury

Inhalation is the most likely route of exposure for elemental mercury. Approximately 74–80 percent of mercury in inhaled vapour is absorbed by the lungs (ATSDR 1999). While elemental mercury may occasionally be ingested, absorption from the gastrointestinal tract has been estimated to be less than 0.05 percent, with the majority of the ingested mercury excreted in faeces (JECFA 2011). Dermal absorption of vapour is also considered to be a minor route of exposure, with absorption through the skin estimated to be about 2–3 percent of the amount absorbed by the lungs (ATSDR 1999).

Following absorption, elemental mercury is oxidised to divalent (inorganic) mercury in the red blood cells, the lungs and, possibly, the liver. Divalent mercury can be reduced to monovalent or elemental mercury. Elemental mercury may then be excreted by exhalation.

Elemental mercury can readily cross the blood-brain and placental boundaries. After oxidation to inorganic mercury, it primarily accumulates in the kidneys.

Exposure to high concentrations of elemental mercury vapour can be lethal, with death usually occurring as a result of respiratory failure. The specific lethal dose from inhalation has not been reported.

Acute health effects of non-lethal exposure to elemental mercury vapour are also respiratory in nature and may include pneumonitis, bronchiolitis and pulmonary oedema. Chronic exposure to mercury vapour can cause neurobehavioural effects, including mood changes and tremors. Chronic exposure may also cause hypertension and nervous system dysfunction.

The Centers for Disease Control and Prevention (CDC) clinical description for elemental mercury is:

> … Acute toxicity might result in fever, fatigue, and clinical signs of pneumonitis. Chronic exposure results in neurologic, dermatologic, and renal manifestations. Signs and symptoms might include neuropsychiatric disturbances (e.g., memory loss, irritability, or depression), tremor, paresthesias, gingivostomatitis, flushing, discoloration and desquamation of the hands and feet, and hypertension.[5]

Children are considered to be at greater risk from exposure to elemental mercury vapour, due to their higher respiration rate, their larger lung surface areas relative to body weight and their likelihood to be engaged in activities closer to the floor, where mercury vapour concentrations are higher.

3.1.2 Inorganic mercury

Ingestion is the most likely route of exposure to inorganic forms of mercury. Studies of humans and animals indicate that approximately 10–30 percent of inorganic mercury is absorbed from the gastrointestinal tract. Studies of rats have suggested that monovalent mercury may be absorbed less well than divalent mercury, probably due to lower solubility.

Inorganic mercury may be reduced in vivo, in a similar manner to divalent mercury released from elemental mercury.

Inorganic mercury reaches all organs but accumulates primarily in the kidneys. It accumulates in the brain and in foetus to a lesser extent than other forms of mercury.

The lethal dose of inorganic mercury following acute oral exposure has been estimated to be 29–50 mg/kg, with death attributed to renal failure, cardiovascular collapse and severe gastrointestinal damage (ATSDR 1999).

[5] From the CDC webpage *Chemical Emergencies; Case definition: Mercury (Elemental)* at: **https://emergency.cdc.gov/agent/mercury/mercelementalcasedef.asp** (accessed 2 June 2021).

The CDC clinical description for inorganic mercury is:

> … Signs and symptoms might include profuse vomiting and diarrhea (both can be bloody), followed by hypovolemic shock, oliguric renal failure, and possible death. Survivors of acute poisoning or persons chronically exposed to inorganic mercury might develop neurologic, dermatologic, and renal manifestations that might include neuropsychiatric disturbances (e.g., memory loss, irritability, or depression), tremor, paresthesias, gingivostomatitis, flushing, discoloration and desquamation of the hands and feet, and hypertension.[6]

As could be expected, the chronic effects of inorganic mercury poisoning are the same as those for elemental mercury poisoning since elemental mercury is metabolised to inorganic mercury following absorption.

3.1.3 Organic mercury

Although ingestion of organic mercury is the most typical route of organic mercury toxicity, toxicity also might result from inhalation and dermal exposures, particularly with dimethylmercury. While no direct evidence is available, it is likely that organic mercury compounds will be readily absorbed through the lungs. Organic mercury is readily absorbed following oral exposure, with indirect evidence suggesting as much as 95 percent of methylmercury being absorbed (ATSDR 1999). Selenium is known to reduce the toxicity of methylmercury through formation of a bismethylmercury selenide complex. While there is negligible information on the dermal absorption of methylmercury, analysis of a case involved in a laboratory accident, where dimethylmercury was spilt onto the back of the hand, suggests near-complete absorption (ATSDR 1999).

Evidence suggests that, following absorption, methylmercury is converted to inorganic mercury, specifically divalent mercury. However, this process may not be rapid as mercury found in the brain has been ascribed to organic or elemental mercury, which can pass the blood-brain barrier, rather than inorganic mercury, which does not to the same degree.

Organic mercury distributes throughout the body, but of the three forms of mercury, organic mercury shows the greatest accumulation in the kidneys. As with elemental mercury, organic mercury can cross the blood-brain and placental barriers and accumulate in the brain and foetus.

The CDC clinical description for organic mercury is:

> … Symptoms of toxicity can be delayed for weeks after organic mercury exposure and usually involve the central nervous system. These symptoms might include paresthesias, headaches, ataxia, dysarthria, visual field constriction, blindness, and hearing impairment.[7]

6 From the CDC webpage *Chemical Emergencies; Case definition: Mercury (Inorganic)* at: **https://emergency.cdc.gov/agent/mercury/mercinorgcasedef.asp** (accessed 2 June 2021).

7 From the CDC webpage *Chemical Emergencies; Case definition: Mercury (Organic)* at: **https://emergency.cdc.gov/agent/mercury/mercorgcasedef.asp** (accessed 2 June 2021).

With respect to chronic exposure, studies in populations with high fish consumption in the Seychelles and Faroe Islands identified that the most sensitive life stages for methylmercury exposure were the embryo and the foetus. In the Faroe Islands study, prenatal exposure to methylmercury was associated with impaired neurodevelopment (Grandjean et al 1999). This impairment has been found to persist through to at least adolescence but to not increase (Debes et al 2006, 2016).

3.2 Dose response

3.2.1 Elemental mercury

A minimal risk level (MRL) for metallic mercury by the inhalation route of exposure of 0.0002 mg/m^3 (0.2 µg/m^3) was derived by the United States Agency for Toxic Substances and Disease Registry (ATSDR) based on a mean lowest observed adverse effect level (LOAEL) of 0.026 mg/m^3 for increased frequency of hand tremors in occupationally-exposed male workers (ATSDR 1999).

3.2.2 Inorganic mercury

ATSDR derived an acute duration MRL for inorganic mercury by the oral route of exposure of 0.007 mg/kg bw/day (7 µg/kg bw/day) based on effects seen on the kidneys in rat studies (ATSDR 1999).

ATSDR derived an intermediate duration MRL for inorganic mercury by the oral route of exposure of 0.002 mg/kg bw/day (2 µg/kg bw/day) based on effects seen on the kidneys in rat studies (ATSDR 1999).

The Joint Food and Agriculture / World Health Organization Expert Committee on Food Additives (JECFA) derived a chronic provisional tolerable weekly intake (PTWI) of 0.004 mg/kg bw/day or 0.0006 mg/kg bw/day based on effects seen on the kidneys in rat studies (JECFA 2011).

3.2.3 Organic mercury

Chronic duration exposure limits for methylmercury by the oral route of exposure of 0.0002 and 0.0003 mg/kg bw/day (0.2 and 0.3 µg/kg bw/day) have been derived based on neurodevelopmental effects in humans (ATSDR 1999; JECFA 2007).

3.3 Exposure assessment

Knowledge of exposure is essential for environmental epidemiology and hazard control. The measurement of a person's exposure to mercury can be determined by absorbed dose. The sources of exposure can be determined by exposure characterisation based on questionnaires, interviews, inspections, historical records and/or exposure simulations.

Exposure to mercury may be accidental (for example, spilling elemental mercury, breaking mercury-containing items), intentional (for example, using skin-lightening products or mercury-containing folk medicines or using mercury for religious purposes) or incidental (absorbing mercury as a result of eating fish). Each of these exposure types will have different mercury exposure characteristics.

3.3.1 Accidental exposure

Accidental mercury exposure is most commonly associated with inhaling the vapour form of elemental mercury, following the breakage of a mercury-containing item, such as a mercury-filled thermometer or a fluorescent lamp, or the spillage of container-stored mercury. In such cases, affected individuals will be exposed to mercury in relation to:

- the concentration of mercury vapour
- time spent in the mercury-affected environment
- their respiration rate.

The mercury vapour concentration will in turn relate to:

- the amount of mercury released
- the ambient air temperature
- the size and ventilation characteristics of the affected space.

The vapour pressure of elemental mercury will increase with increasing temperature, and it is important that contaminated areas are not heated and that any heating in the space is turned off as soon as possible. Also, normal vacuum cleaners should not be used to clean up mercury spills as they will be contaminated and will help disperse mercury from the floor into the breathing zone.

3.3.2 Intentional exposure

Intentional exposure can involve elemental or inorganic mercury. For elemental mercury sprinkled into an environment for religious purposes, the contributors to exposure will be the same as for accidental exposure. For mercury in personal care products or medicines, the amount of exposure will depend on:

- the mercury concentration of the product used
- the rate of use (that is, the number of units of medication taken in any one instance or the proportion of the body that the products, such as skin-lightening products, are applied to. Absorption of mercury will be greater for a product that is applied to the whole body rather than, say, just to the face)
- the frequency of use
- the duration of use.

3.3.3 Incidental exposure

Incidental exposure to mercury from eating fish or other seafood will depend on:

- the concentration of mercury in the edible fish tissue (which, in turn, depends on species, fish size, fish age and trophic level)
- portion size
- frequency of consumption.

It is generally assumed that food consumption is a lifelong activity, and it is only the frequency with which a person consumes mercury-containing seafoods that varies over time. This contrasts with medicines and personal care products, which may be used for a particular period of time to achieve a particular objective.

Exposure to mercury from mercury-containing amalgam fillings may also be considered incidental. In such cases, exposure to mercury is likely to be due to:

- the number of amalgam fillings or, more accurately, the exposed surface area of amalgam fillings
- how often a person who has amalgam fillings consumes acidic foods or the frequency of bruxism events or other activities that stimulate the release of mercury from amalgam.

3.4 Risk characterisation

Risk characterisation combines the information obtained from the hazard identification, dose-response assessment and exposure assessment to estimate the risk associated with each exposure scenario being considered and present uncertainties in the analysis. However, this process can be simplified since information on hazard identification and dose-response assessment are usually generic while information on exposure assessment is situation specific.

Exposure can be assessed through information on the various factors outlined in the previous section or using an appropriate clinical biomarker, such as the concentration of mercury in blood, urine or hair. **There is currently no biomarker notification level for mercury poisoning defined for New Zealand.**

Clinical management of the exposed individual can be related directly to cumulative exposure since this determines the severity of health effects and may indicate whether treatment (for example, chelation therapy) is necessary. Assessing the chemical form of mercury involved in the exposure is also important. Advice can be sought from a medical toxicologist at the National Poisons Centre if needed.

Environmental management may involve adjusting the physical environment or changing an affected person's behaviours to decrease or eliminate mercury exposure. Behavioural changes are likely to be most effective where the source of the mercury is fish consumption. For other mercury sources, it is essential that mercury hazards be removed wherever possible. This may include removing sensitive individuals from the contaminated environment while it is being cleaned up.

3.4.1 Clinical characterisation of mercury exposure

Although mercury poisoning is not a notifiable disease under the schedule of notifiable diseases of the Health Act 1956 (Ministry of Health 2020c), the notifiable disease category 'Poisoning arising from chemical contamination of the environment' may be interpreted to include environmental mercury exposures. Alternatively, mercury poisoning may be notified as a hazardous substance injury under the Hazardous Substances and New Organisms Act 1996 (HSNO Act). Notifications should be recorded in the Hazardous Substances Disease and Injury Reporting Tool (HSDIRT).

If mercury poisoning is suspected, verification by clinical testing may be recommended. However, the choice of test is best considered in the context of the duration of exposure (acute or chronic) and the likely form of mercury involved. Table 1 summarises the recommended test matrices for various combinations of exposure duration and chemical form. Table 2 summarises the action levels in blood and urine suggested in a review carried out for the Ministry of Health (Fowles and Curtis 2018).

Table 1: Preferred biological matrices for testing for mercury based on the duration of exposure

Mercury form	Duration of exposure	
	Acute	Chronic
Elemental	Blood	Urine
Inorganic	Blood or Urine	Urine
Organic*	Blood**	Blood, Hair

* Organic mercury is primarily excreted in the faeces; therefore, urinary analysis is inappropriate.

** Ingestion rarely presents an acute phase and instead results in a latent period followed by neurological toxicity.

Table 2: Suggested action levels for mercury in clinical matrices

Matrix	Proposed notification level	Proposed intervention level
Blood	5 μg/L	15 μg/L
Urine	7 μg/L	25 μg/L

Source: Fowles and Curtis 2018

While the suggested action levels in Table 2 do not have legal standing in New Zealand, concentrations in excess of these levels and a case history of mercury exposure should provide a sufficient basis for notifying the case as poisoning arising from chemical contamination of the environment, under the Health Act or as a hazardous substances injury under the HSNO Act.

3.5 Risk communication

Community perception of risk is not based on technical risk assessment alone. Public recognition of risk, in contrast to risk assessment based on probabilities prepared by experts, includes intuitive risk perception. The characteristics of such perceptions appear to be related to concepts of fairness, familiarity, future and present 'catastrophic potential', and outrage at involuntary exposure to hazards not of their making.

Mercury hazards at home, where people expect to be safe, are hazards that will be perceived by the public in a context wider than that of scientific risk assessment.

Effective risk communication is more likely to be achieved if:

- a careful and sensitive explanation is given to assist and improve the level of understanding of the risk
- the feelings of dread towards mercury poisoning are recognised and efforts are made to assist a person to come to terms with those feelings before decisions are made
- there is an appropriate urgency and level of response to hazards that may affect a large number of people (especially children).

Bear in mind that certain general points hold.

- Younger adults and better educated individuals tend to have more technical, scientific and medical knowledge about hazards.
- Women (particularly women with young children) and older people tend to express the most concern about risks.
- People tend to simplify complex and uncertain information into 'rules of thumb'.
- People attempt to impose patterns on patternless events.
- People overestimate the frequency of rare events and underestimate the frequency of common events.

- Individuals who take risks voluntarily tend to be overconfident and believe they are not subject to the same risks as other individuals.
- Individuals who are forced to take a risk will involuntarily overestimate the risk and will generally be unwilling to agree to 'acceptable risk' criteria set out by national and international agencies.
- People tend to relate past-life experiences to new situations, affecting their perception of the new situation.

Risk communication needs to be a two-way process, as described in some detail in *Risk Communication in Action: The risk communication workbook* (Reckelhoff-Dangel and Peterson 2007). It needs to be done in such a way that people are well informed and guided in the actions they can take, while knowing that the experts are also taking account of, and acting on, people's concerns.

Specific situations may arise that require a proactive response from a public health unit. For example, a school may be identified as being mercury contaminated as a result of a thermometer breakage or elemental mercury spill. It is important to recognise that parents and caregivers are likely to become very concerned once they become aware of raised mercury levels in the school environment. Information needs to be provided directly to parents and caregivers, through information sheets and/or public meetings and via appropriate media channels. This information should acknowledge the concerns but place them in the context of the children's overall exposure.

The World Health Organization (WHO) have developed a series of key facts concerning mercury that may be useful when communicating the risks:

- Mercury is a naturally occurring element that is found in air, water and soil.
- Exposure to mercury – even small amounts – may cause serious health problems and is a threat to the development of the child in utero and in early in life.
- Mercury may have toxic effects on the nervous, digestive and immune systems, and on lungs, kidneys, skin and eyes.
- The WHO considers mercury to be one of the top 10 chemicals or groups of chemicals of major public health concern.
- People are mainly exposed to methylmercury, an organic compound, when they eat fish and shellfish that contain the compound (WHO 2020).

4 Risk abatement

Priorities for managing risk should be based on the risk assessment but should also consider public perception of risk. The range of risk abatement alternatives must be evaluated, including the social, economic and cultural implications of options. This could be achieved along two lines: controlling actions and events that could translate a mercury hazard into a mercury risk and removing or nearly permanently containing the mercury hazard.

Mercury exposures in non-occupational settings may vary greatly. A protocol for managing such exposures should aim to provide a response that is graded according to the likely harm. Exposures are likely to be an order of magnitude less than current permissible workplace exposures (WorkSafe New Zealand 2018).

4.1 Principles of risk abatement

Risk abatement for mercury exposures involves eliminating or controlling mercury hazards. In particular, safe abatement of mercury spills is based on recognising that spilt mercury will continue to produce mercury vapour for a long time, constituting a hazard to all permanent and transitory users of the contaminated environment. The goal of (safe) abatement is therefore the long-term, sustainable elimination of interior reservoirs of mercury contamination.

To achieve this goal, a set of general principles for safe abatement has been developed, which apply to all abatement strategies.

Principles of safe abatement

1. Minor contamination events (<¼ teaspoon) may be abated by the property owners or occupants, with appropriate direction. Major contamination events (≥¼ teaspoon) should be dealt with by specialists in hazard substances abatement.
2. Isolate the affected area and ventilate to the outdoors. Turn off any heating source.
3. Carry out abatement activities to minimise the spread of mercury contamination.
4. Contain and safely dispose of all mercury-contaminated material generated during the abatement process.
5. Protect occupants during the abatement (temporarily relocate preschool children, pregnant women and pets; restrict site access for those vulnerable groups until the environment is made mercury safe).

4.2 Abatement of spilt or released elemental mercury

It should be remembered that the primary hazard associated with elemental mercury is the mercury vapour generated rather than the liquid mercury particles. However, liquid mercury will generate mercury vapour over time.

4.2.1 Initial measures to isolate the affected site and decrease the hazard

Spills of elemental mercury or release of mercury from broken fluorescent lamps will usually be confined to a particular defined area; usually a single room. It is important that the contamination is confined as much as possible to this area. This will require controlling people and pets access to the affected area. Temporary relocation of people and pets not involved in the abatement process will assist entry control.

The temperature of the affected area should be kept as low as possible to minimise the mercury vapour pressure. Practically, this will involve turning off any heating devices in the affected area (including central heating to the area).

The spread of mercury or mercury vapour to other parts of the building should be prevented or minimised. Any air-conditioning device that can transfer air from the affected area to other parts of the building should be turned off. However, any devices that ventilate the affected area to the outdoor environment should be maintained or even turned up.

Contaminated clothing and shoes worn by those involved in the abatement process should not be worn beyond the contaminated area. Those involved in the abatement should remove any contaminated clothing and shoes at the point of exit from the contaminated area.

4.2.2 Personal protection during abatement

For small spills in a domestic environment, special personal protective equipment should not be required. Those carrying out abatement should wear rubber or latex gloves and old clothes and shoes that can be easily disposed of if they become contaminated.

Respiratory devices should not be necessary for small spills, where the affected area has been well ventilated to the outdoors. However, such devices may be used if this gives greater assurance to those carrying out the abatement.

4.2.3 Removing gross contamination

Where the contamination involves a broken mercury-containing vessel, such as a thermometer or fluorescent lamp, visible pieces of glass should be collected, wrapped in newspaper and secured in a plastic bag or 'double bagged' for disposal in accordance with local regulations.

When the breakage has occurred over a hard surface, use stiff paper or cardboard to brush together and scoop up any remaining glass, powder (from fluorescent lamps) and large particles of elemental mercury. Secure in screw-top container, zip-lock bag or equivalent for disposal in accordance with local regulations.

Do not use a vacuum cleaner or brush/broom, as these items will become contaminated and have the potential to further disperse the mercury.

Disposed of all contaminated material in accordance with local regulations. It will probably be necessary to contact the local council to determine if any and what special conditions may apply for disposing of mercury-contaminated material.

All material for disposal should be stored outdoors until appropriate permanent disposal in accordance with local regulations.

4.2.4 Removing residual contamination

Use an eyedropper or sticky tape to pick up small beads of mercury or remaining mercury dust. Shine a torch across the floor surface to help detect remaining beads of mercury or glass. Secure the resulting material (in a screw-top container or zip-lock bag) and dispose of as above.

Wipe the area with a damp disposable rag or paper towel. Secure used rags or towels for disposal in accordance with local regulations.

If available, the affected area may be sprinkled with powder sulphur (flowers of sulphur). Sulphur will react with mercury to produce stable mercuric sulphide. The mercuric sulphide should be collected and disposed of as for mercury.

4.2.5 Abatement of soft surfaces

For rugs, carpets and covered furniture, as far as possible, clean up mercury in the manner described above. Rugs and furniture may be disposed of or placed outside for several days to allow residual mercury to volatilise. For carpets, if the affected area can be defined, this area of carpet may be cut out and disposed of in the same way as other mercury contaminated items described above. Otherwise, all carpet in the affected area may need to be disposed of in accordance with local regulations.

4.2.6 Post-abatement activities

The affected area should be ventilated to the outdoors for at least 24 hours, and people and pets should not be allowed into the area during this time.

If access to a mercury air monitoring device is available, the affected area's air mercury concentrations may be measured to determine when mercury levels are no longer detectable.

Clothing worn during the abatement process that has not had direct contact with mercury may be washed normally. Clothing that has been contaminated or thought to be contaminated can be discarded (local regulations for deposing contaminated items may apply).

4.3 Abatement of inorganic mercury contamination

Domestic environments may be contaminated with mercury, for example, through using cosmetic products such as mercury-containing skin-lightening products. In such cases, the contamination has the potential to be widespread. For example, mercury-containing products applied to the skin may contaminate clothing and subsequently washing machines and clothes storage areas, and furniture may be contaminated from contact with mercury-treated skin.

4.3.1 Environmental assessment

If an initial investigation suggests that a domestic environment may be contaminated with inorganic mercury, a mercury vapour survey should be carried out to identify the extent and severity of contamination. Vapour surveys are also useful in helping identify 'hot spots' of mercury contamination.

While no domestic air limits for mercury are specified for New Zealand, the United States Environmental Protection Agency and ATSDR have identified two action levels for air mercury:

- 1 $\mu g/m^3$ – indoor air concentrations below this level are considered safe for residential occupancy without abatement
- 10 $\mu g/m^3$ – at indoor air concentrations above this level, it is recommended that residents be isolated from exposure or evacuated.

At concentrations from 1 to 10 $\mu g/m^3$, abatement is recommended but without requiring evacuation.

While these limits are primarily applicable to elemental mercury spills, they have been used to assess environments where mercury-containing skin-lightening products had been used. In addition, contamination of clothing and other items has been assessed by placing the item in a plastic bag, placing the plastic bag in the sun for about 10 minutes and then measuring for mercury vapour in the bag.

4.3.2 Abatement measures

Much less information is available on the abatement of inorganic mercury contamination than elemental mercury contamination (Copan et al 2012). Measures used include:

- removing the source of contamination
- heating and ventilating affected areas (after residents have been evacuated)
- decontaminating expensive contaminated items and washing machines with powdered sulphur.

The second and third steps listed above were repeated until air mercury concentrations had reduced to acceptable levels.

These processes should be carried out by specialists rather than the residents or property owner.

5 Risk reduction – behaviour modification

5.1 Introduction

While abatement is directed towards elimination or control of mercury hazards, in some instances, behavioural measures can be used to reduce exposure to these hazards, and diet can affect the absorption and toxicity of ingested mercury. Environmental, behavioural and dietary strategies are complementary processes, and their relative efficacy depends on the cause and extent of mercury contamination and the vulnerability of the receiving population. Environmental controls are most effective when contamination is extensive. In most other situations, behavioural adjustment will be effective on its own, although obvious mercury hazards should always be abated.

Environmental and behavioural strategies in reality merge into one another, and some interventions include elements of each.

In relation to mercury, behavioural strategies are likely to fall into two groups:

- personal cosmetic and religious practices
- dietary habits.

5.2 Personal cosmetic and religious practices

With situations where mercury exposure is from the use of mercury-containing cosmetics, such as skin-lightening products, or use of mercury in religious practices, individuals will be encouraged to modify a behaviour that they see as beneficial.

5.2.1 Mercury-containing cosmetics

In New Zealand, regulation of cosmetic products is covered by the Cosmetic Products Group Standard 2017 under the Hazardous Substances and New Organisms Act 1996 (see EPA 2017). Under the standard, cosmetic products must not contain mercury and its compounds, except for use as a preservative in eye make-up and eye make-up remover. The permitted mercury compounds are thimerosal and phenylmercuric salts, to a maximum concentration of 0.007 percent mercury.

While public health officials should endeavour to identify the source of mercury-containing cosmetics for future action, meaningful behavioural change is more likely to occur through education. Affected individuals should be given information on the adverse effects that exposure to mercury may have on them and their friends and family.

Depending on the function of the cosmetic, safe alternatives should be identified.

5.2.2 Religious uses of mercury

While it is a highly uncommon practice in New Zealand, elemental mercury is used in some Latin American and Caribbean religions, such as Voodoo and Santeria. The most concerning aspects of its use in these religions is when it is sprinkled around a space to ward off evil spirits.

In such instances, behavioural modification is only likely to be effective through education; providing information on the adverse effects of exposure to mercury to people and their pets.

5.3 Dietary habits

Diet can have a significant influence on mercury exposure, as methylmercury exposure occurs through the diet. However, dietary factors can also protect against the toxic effects of mercury, particularly the presence of sufficient levels of selenium in the diet.

5.3.1 Managing methylmercury exposure

People are exposed to methylmercury through the consumption of fish. While the methylmercury content of individual fish cannot be well predicted, higher methylmercury content is generally associated with large predatory fish species. The *Food and Nutrition Guidelines for Healthy Pregnant and Breastfeeding Women* (Ministry of Health 2006) and New Zealand Food Safety offer advice for safe fish consumption with respect to methylmercury (New Zealand Food Safety 2020b).

New Zealand Food Safety currently recommends that pregnant women, or women consider pregnancy limit their consumption of some fish species due to their mercury content. In particular: cardinalfishes, dogfish (excluding rig), lake trout from geothermal regions (especially Lake Rotomahana trout), school shark, striped marlin, southern bluefin tuna and swordfish should not be eaten more than once every 1 to 2 weeks (New Zealand Food Safety 2020a).

However, there are also benefits to eating fish since it is a good source of protein, iodine, selenium and omega-3 fatty acids. For this reason, any behaviour changes associated with fish consumption should seek to limit methylmercury exposure in particular rather than limiting fish consumption in general.

5.3.2 Selenium

While the exact mechanism is unknown, there is significant evidence that selenium can react with mercury in some way to alleviate mercury's toxicity. The Ministry of Health's *Eating and Activity Guidelines for New Zealand Adults* (Ministry of Health 2020a) provides information on selenium, adequate intakes and sources of selenium in the diet.

6 Roles and responsibilities

The New Zealand Government plans to ratify the Minamata Convention on Mercury. Ratification is awaiting the announcement of regulations under the Waste Minimisation Act 2008 (banning the manufacture and sale of specific mercury products) and the Imports and Exports (Restrictions) Act 1988 (controlling the trade of mercury and regulating the import and export of specific mercury products). Details of the intended changes can be found in *Mercury and Mercury Products: New Zealand's approach to ratifying the Minamata Convention: Consultation document* (Ministry for the Environment 2020).

6.1 Role of public health units

Public health units become aware of instances of mercury exposure as a result of incidents (for example, mercury spillage) or being informed by people who have a raised blood or urine mercury level.

Public health units have a particular role in managing cases of mercury exposure. This includes:

- carrying out a risk assessment to identify contributory sources of mercury (mercury hazards) and (open) pathways of exposure to mercury (including collecting environmental samples for laboratory analysis and interpreting laboratory results)
- designing an appropriate abatement (source elimination) and management (exposure control) strategy in consultation with affected individuals, the general practitioner, public health nurses, the territorial authority and other parties as appropriate
- advising affected individuals on the process for implementing the abatement strategy, including precautions to take
- ensuring key abatement processes are implemented
- evaluating the effectiveness of the risk reduction plan, including clearance (post-abatement), environmental testing if appropriate (and take corrective action as necessary)
- liaising with local authority officers, local WorkSafe New Zealand officers and other environmental agencies as required.

6.1.1 Health Act 1956

Section 74 of the Health Act 1956 requires health practitioners to notify the medical officer of health of cases of listed notifiable diseases, and Schedule 2, Section B – Other conditions includes 'poisoning arising from chemical contamination of environment' as a notifiable disease. The Act requires health practitioners to report to medical officers of health about any poisoning arising from chemical contamination of the environment. This reporting of notifiable diseases is critical so that the medical officer of health can analyse the reported incidents and decide whether any public health action is required.

Poisoning, chemical and contamination are not defined in the Act, so the ordinary meaning of these words must apply.

- The *Oxford English Dictionary* defines 'poisoning' as 'any substance that can impair function, cause structural damage, or otherwise injure the body'. Poisoning does not need to be fatal or require admission to hospital.
- The same dictionary defines 'chemical' as 'any substance used in or resulting from a reaction involving changes to atoms or molecules'.
- 'Contamination' is defined as the act or process of contaminating or the state of being contaminated. To 'contaminate' is to 'make impure especially by touching or mixing; pollute'.

An incident is considered to be notifiable if it meets the definition for 'poisoning', 'chemical' and 'contamination' as described above. Any incident where 'poisoning arising from chemical contamination of environment' is identified must: involve the chemical (mercury), contaminate the environment and that contamination must lead to poisoning. If the incident does not meet any one of these three requirements, then it does not fit the description of 'poisoning arising from chemical contamination of environment'.

6.1.2 Hazardous Substances and New Organisms Act 1996

The purpose of the Hazardous Substances and New Organisms Act 1996 (HSNO Act) is to protect the environment and the health and safety of people and communities by preventing and managing the adverse effects of hazardous substances and new organisms.

In exercising all functions, powers and duties under the HSNO Act, the Environmental Protection Authority (EPA), or other responsible agency, must take into account public health. Under the HSNO Act, the EPA is responsible for:

- deciding which hazardous substances are approved for use in New Zealand
- the classification, labelling, safety data sheets and packaging hazardous substances
- regulating class 9 (ecotoxic) substances in both the workplace and non-workspaces
- disposing of hazardous substances in non-workplaces.

The HSNO Act empowers the EPA to make notices that set controls on hazardous substances to ensure they are safely managed. The EPA also has power to set tolerable exposure limits (TEL) under section 77B of the HSNO Act. A TEL is a limit on the concentration of a substance (or any element or compound making up the substance) with toxic properties in an environmental medium, as set in accordance with section 77B or an EPA Notice. Environmental medium means air, water or soil, or a surface that a hazardous substance may be deposited onto. To date the EPA have not set TELs and environmental exposure limits (EELs) for any form of mercury.

Section 13 of the HSNO Act on General Duty, requires that no action or omission by any person will cause a hazardous substance to adversely affect any other person or the environment. This duty is not of itself enforceable; however, a compliance order may be served on any person under section 104, by an enforcement officer, to cease or prohibit that person from doing anything that relates to hazardous substances if, in the opinion of that officer, there is a risk to the health and safety of people or the environment. The enforcement action would be done by other agencies' HSNO enforcement officers as this power is not issued to PHU HSNO officers.

In December 2005 an amendment to the HSNO Act was made that requires all health practitioners, in addition to hospitals, to report injuries caused by hazardous substances to the medical officer of health as required under section 143 of the HSNO Act. This notification requirement includes mercury health-related incidents.

Under section 144 of the HSNO Act, every person in charge of a hazardous substance resulting in death, notifiable injury or illness as defined by section 23 of the Health and Safety at Work Act 2015 or serious environment damage must, unless an enforcement officer attended the incident, report the incident to an enforcement officer. No person is obliged to report the incident to an enforcement officer under the HSNO Act where the incident is required to be reported under any other act.

If a case is notified arising from occupational exposure, consent is needed from the individual to notify identifiable information to WorkSafe New Zealand. If the case meets the definition of 'serious harm', the employer is required to inform WorkSafe New Zealand under the Health and Safety at Work Act 2015 and HSNO Act. The medical officer of health should inform the case (and the employer if the case agrees) of this obligation.

6.2 Role of the health protection officer

The skills of the health protection officer are necessary for the following tasks.

1. **Initial response and preliminary assessment**
    - Receive, record and interpret queries and concerns.
    - Identify the cause of concern or complaint, location and associated parties.
    - Provide initial response and support to concerned people.
2. **Inspection, hazard evaluation and risk assessment**
    - Identify person(s)/ groups at risk.
    - Identify compounding risks (eg, occupational exposure to mercury).
    - Identify sources and forms of mercury implicated, hazards, open pathways of exposure.
    - Collect samples and send to an approved laboratory for analysis if appropriate.
    - Interpret laboratory results if appropriate.
    - Seek advice from the medical officer of health and others if necessary (eg, epidemiologists, toxicologists).
    - Assess the likely health risk from the information collected.
3. **Information and risk communication**
    - Explain how the risks should be managed, in consultation with other relevant agencies.
    - Consult with property owners and occupiers.
    - Refer information to the regulatory agency with statutory authority to bring about remedial action.
4. **Management plan**
    - Assist other agencies to determine appropriate actions, including, if necessary, the design of appropriate abatement and exposure control strategies.
    - Subject to the approval of the regulatory agency, advise property owners and occupiers on the implementation of the management plan.
    - Monitor the implementation of the public health aspects of the plan.
    - Maintain communication and cooperation with the other agencies and parties (recognising privacy).
    - Evaluate the effectiveness of the management plan.
5. **Enforcement**
    - Encourage enforcement by the appropriate regulatory agency.

The public health unit may also consider health promotion initiatives aimed at increasing awareness of the safe use of mercury-containing devices and the hazards associated with mercury.

6.3 Responding to media

Unless other arrangements have been made, media liaison should be carried out by the medical officer of health or an experienced health protection officer in consultation with other agencies as appropriate. Media updates should be made in accordance with PHUs procedures and policy for dealing with the media and should include notifying the Ministry of Health in advance.

6.4 Role of territorial authorities

In a non-occupational settings, territorial authorities will normally be the regulatory agency with statutory authority to bring about a remedy. Territorial authority enforcement officers may collaborate with the other agencies, and the public health unit should provide the territorial authority with information and advice. Territorial authorities have duties and powers to prevent or control mercury hazards to the environment and to public health. The main legislations includes:

- **Health Act 1956**

  The Health Act 1956 includes provision for territorial authorities to:

  - improve, promote and protect public health
  - cause steps to be taken to abate nuisances or to remove conditions likely to be injurious to health or offensive
  - enforce regulations under the Act
  - make bylaws for the protection of public health
  - issue cleansing orders or obtain closing orders.

  Section 29 of the Act defines health 'nuisances' and generally includes matters 'likely to be injurious to health'. Particularly relevant are references to:

  - accumulations or deposits
  - situation or state of premises
  - conduct of any trade, business, manufacture or other undertaking.

  Enforcement is determined by the District Court if a nuisance is not abated voluntarily, except where immediate action is necessary. Works undertaken by a territorial authority to abate a nuisance may result in costs being recovered from the owner or occupier. It should be noted, however, that any person can lay information regarding a nuisance. A nuisance has to exist before any action can be taken and, accordingly, is not an effective means of preventive action.

Under section 41 of the Act, the territorial authority may serve a Cleansing Order on the owner or occupier, specifying the work to be carried out and the time in which to complete it. A Closing Order made under sections 42 or 44 can be issued as a last resort to protect the occupants, but such action will not, of course, resolve any mercury contamination issues.

- **Building Act 2004**

  The Building Act 2004 includes provision for territorial authorities to:

  - require work to be done to prevent buildings from remaining or becoming dangerous or unsanitary
  - take measures to avert danger or rectify insanitary conditions
  - issue project and land information memoranda revealing (*inter alia*) known hazardous contaminants.

  Project Information Memoranda (PIM) issued by territorial authorities must include information identifying special features of the land relating to the likely presence of hazardous contaminants where it is:

  - relevant to the design and construction or alteration
  - known to the territorial authority
  - not apparent from the operative district plan.

  Section 44A of the Local Government Official Information and Meetings Act 1987 allows for an application for a LIM (Land Information Memorandum). Section 44(2) states that included in the LIM there must be information concerning the 'likely presence of hazardous substances'.

  PIMs are required for a Demolition (Building) Consent. The PIM will advise if any restriction on demolition, for example, a Heritage listing, exists in the City or District Plan.

  Sections 121 to 124 and 129 to 130 deal with dangerous or insanitary buildings. It is possible that the presence of mercury could lead to a building being considered 'dangerous' or 'insanitary' for the purpose of the Act. In determining whether or not a building is insanitary, consideration must be given to:

  - size of the building
  - complexity of the building
  - location of the building in relation to other buildings, public places, and natural hazards
  - intended use of the building, including any special traditional and cultural aspects of the intended use
  - expected useful life of the building and any prolongation of that life
  - reasonable practicality of any work concerned
  - in the case of an existing building, any special historical or cultural value of that building
  - any matter that the territorial authority considers to be relevant
  - provisions of the building code.

Enforcement action is by way of formal notice requiring a remedy. An application for a Court Order authorising the Council to do required work at the owner's expense may be made on default.

An offence is committed if a building is used for a purpose for which it is not safe or sanitary.

- **Resource Management Act 1991**

  Section 15 of the Resource Management Act 1991 prohibits the discharge of contaminants into the environment except where some form of authority or consent exists. Section 17 requires every person to avoid, remedy or mitigate adverse effects on the environment.

  Enforcement orders (Environment Court) or abatement notices (enforcement officer) may be issued requiring a person to cease, or prohibiting a person from commencing, anything that is or likely to be noxious, dangerous, offensive, or objectionable.

  Similar action may require a person to do certain things to avoid, remedy or mitigate adverse environmental effects.

  The Resource Management Act 1991 also includes provision for territorial authorities to make plans and rules that deal with hazardous substances. The health protection officer should be aware of the appropriate provisions of plans, since advice given in the absence of such knowledge could create difficulties.

- **Local Government Act 1974**

  Part XXXI of the Local Government Act 1974 provides for local authority refuse collection and disposal services. Disposal must be undertaken so as not to be a nuisance or injurious to health. Work generally must be to the satisfaction of the Medical Officer of Health. Bylaws may also be made prohibiting or regulating the deposit of refuse of any specified kind.

  Clean-up material containing mercury will almost certainly arrive at council disposal sites. Service managers will need to determine strategies to deal with this issue to ensure environmental risk and councils' liability are minimised.

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Appendix 1: Mercury sampling and analysis

Environmental testing for mercury

Mercury can be analysed in a range of environmental matrices, as for other metals. The general process includes decomposition of the matrix, reduction of the mercury to its elemental form and analysis by a technique such as cold-vapour atomic absorption spectroscopy (CVAAS) or inductively-coupled plasma-mass spectrometry (ICP-MS). Due to the volatility of elemental mercury and the predominant hazard via the inhalation route of exposure, it is often desirable to measure the concentration of mercury in air in situ.

A range of direct air mercury meters are available.

- The Jerome® J405 mercury vapor analyser is a gold film sensor.[8] When a mercury-rich air sample passes over a thin gold film, the mercury is deposited on the gold and changes the electrical resistance of the foil. This change in resistance is directly proportional to the mass of mercury vapor taken from a known volume of air, which can be calculated in mg/m^3.
- The Lumex mercury analyser RA-915M uses atomic absorption spectroscopy to measure mercury in a range of environmental matrices, including ambient air.[9]
- The Jerome J505 atomic fluorescence spectroscopy mercury vapor analyser uses portable atomic fluorescence spectroscopy.[10]

While these analysers have mainly been used to measure mercury concentrations in ambient air, they have also been used to assess contamination of personal items (Copan et al 2012). Items were placed in a sealed plastic bag and placed in the sun for about 10 minutes. Analysers were then used to measure mercury in the headspace within the plastic bag.

Testing of the mercury concentration in air is usually carried out in the breathing zone for an adult (approximately 1.5 m above ground level) and at ground level to approximate the breathing zone of a crawling infant (Copan et al 2012).

8 For more information, see the Brookfield Ametek® webpage *Jerome® J405* at: **www.azic.com/jerome/j405/**.

9 For more information, see the Lumex Instruments webpage *Mercury analyzer RA-915M* at **www.lumexinstruments.com/catalog/atomic-absorption-spectrometry/ra-915m.php**.

10 For more information, see the Brookfield Ametek® webpage *Jerome® J505* at: **www.azic.com/jerome/j505/**.

Appendix 2: Summary of standards and background values for mercury in the environment

Guideline value for mercury in air (Ministry for the Environment 2002)

Annual mean (inorganic)	0.33 μg/m^3
Annual mean (organic)	0.13 μg/m^3

Workplace exposure standard (WES) (WorkSafe New Zealand 2018)

Time-weighted average (TWA):	
Mercury vapour (as Hg)	25 μg/m^3
Inorganic compounds (as Hg)	25 μg/m^3
Alkyl compounds (as Hg)	10 μg/m^3

Biological exposure index (BEI) (WorkSafe New Zealand 2018)

Mercury in urine (before shift)	20 μg/g creatinine

Maximum acceptable value (MAV) for mercury in drinking-water (Ministry of Health 2018) 0.007 mg/L

Soil contaminant standard (health) for inorganic mercury (Ministry for the Environment 2011)

Rural residential / lifestyle block 25 percent produce	200 mg/kg
Rural residential / lifestyle block 10 percent produce	310 mg/kg
Rural residential / lifestyle block no produce	510 mg/kg
Standard residential 25 percent produce	200 mg/kg
Standard residential 10 percent produce	310 mg/kg
Standard residential no produce	510 mg/kg
High-density residential	1,000 mg/kg
Recreational	1,800 mg/kg
Commercial/industrial (outdoor worker/maintenance)	4,200 mg/kg