POLE 1 DEONSTRUTION, BENMORE SUBSTATION

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1. Introduction

The Benmore and Haywards substations are owned by Transpower New Zealand Limited (Transpower). The substations are at either end of the main electricity link between the South and North Islands. Benmore (South Island) and Haywards (North Island) host the AC/DC conversion technology. During a recent upgrade, new High Voltage Direct Current (HVDC) converters were installed at both substations. The new converter equipment is known as Pole 3 and replaces the Pole 1 equipment at both substations.

The Benmore substation is located in south Canterbury, directly below the dam which creates Lake Benmore and approximately 4 km north of Otematata. The Benmore Pole 1 facility was comprised of a large concrete structure. The conversion technology used mercury arc valves which were in a below-ground basement area, with offices and workshops in first floor and ground level.

2. The Project

Because the Pole 1 facility was excess to needs, deconstruction of the building was determined to be the best course of action. It was planned to deconstruct the building to just below ground level, with the basement remaining in place. Following mercury cleaning and asbestos removal, the deconstruction material (largely concrete and metal) was separated, with metal removed and shipped off-site for recycling, and the concrete crushed on site and used as fill material in the basement of the building.

The fill material was compacted and covered with cleanfill material, so the area could be reused if required in the future. Prior to placement of the concrete fill material, holes were drilled into the basement floor to allow water to drain through the structure. Wells were installed in the basement within the fill material to monitor leachate.

The objectives of the project were to:

- Ensure employee health and safety were protected during cleaning and deconstruction;
- Ensure environmental protection during cleaning, deconstruction;
- Provide for environmental protection in longer term by cleaning to allow draining of the backfilled basement; and
- Minimise off-site disposal

3. The Challenges

3.1 Mercury and Asbestos

The Pole 1 facilities at Benmore and Haywards used identical mercury arc valve technology. Historic maintenance of the mercury arc valves resulted in mercury contamination within the Pole 1 buildings. Early investigations using a mercury vapour indicator (MVI), x-ray fluorescence (XRF) machine, visual inspection, and concrete sample analysis, detected elemental mercury.

The mercury arc valves were removed and shipped to Germany for proper recycling and disposal. Other materials and equipment removed from the building were cleaned as required, and recycled or disposed.

Mercury is a liquid at room temperature and easily evaporates (volatilises), forming mercury vapour when it is exposed to air. Rates of evaporation increase with increasing temperature. Mercury vapour is colourless, odourless, and toxic.

Mercury vapours are readily absorbed into the human body through the lungs and (at high concentrations) can go on to affect the nervous system, causing neurological and behavioural disorders. Once in the body, elemental mercury can oxidise to inorganic mercury and be retained in body tissues, including the brain and kidneys.

At the Benmore substation there were also asbestos containing tiles and adhesive present. Some of the doors, the building entrance, and other areas also contain asbestos which needed to be removed. Asbestos tiles and adhesives are usually removed by scraping and/or grinding. However, these mechanical methods generate heat, which can volatilise any mercury which might be present, such as between the tiles and adhesive.

Asbestos is a naturally-occurring silicate mineral with good fire-retardant properties. It is fibrous in nature and can release fibres into the air when it is friable. Small asbestos fibres can be deposited in the airspaces deep within the lungs or migrate to other parts of the body. Asbestosis, lung cancer, and mesothelioma are diseases associated with exposure to friable asbestos. Under New Zealand regulations, Asbestos Containing Materials (ACM) must be removed before building demolition in most circumstances.

Mercury releases into the environment have the potential to impact on ecosystems as a result of direct contact, and due to bioaccumulation and biomagnification through the food chain (Harding 2005, USEPA 1997). Plants and animals can be exposed to mercury by direct contact with contaminated material or through ingestion of contaminated water or food (USEPA 1997). Mercury can be readily transformed from its elemental and inorganic forms to its most toxic and bioavailable methyl mercury form by anaerobic bacteria, either in soil or water. As mercury is toxic at low levels and is typically slow to be excreted through natural biological processes, high concentrations of mercury in both people and wildlife have been associated with developmental and behavioural abnormalities, impaired reproduction and survival, and in some cases with direct mortality (USEPA 1997). A recent study investigating the risk to humans associated with consuming wild food (including trout, eel, whitebait, and freshwater crayfish) from a number of geothermal lakes within the Rotorua district identified mercury levels in trout and koura that exceeded food safety guidelines (Phillips, 2014).

3.2 Mercury Regulations and Guidelines

In order to evaluate potential methods for removing mercury and ACM from the Pole 1 building, an evaluation of national standards, regulations, and guidelines was conducted. The goal of the evaluation was to determine which standard or guideline value is most appropriate to elemental mercury in concrete within the context of the project.

The National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (NES Soil) provides soil contaminant standards (SCS) for eight priority contaminants, including inorganic mercury. For commercial land use, the SCS is established at a concentration of 4,200 mg/kg. However, the contamination present is mercury in concrete, rather than in soil, and soil disturbance, change in land use, subdivision, soil sampling, and underground storage tank removal works were not part of this project. In addition, an outline plan of works was not required for demolition. Therefore, the NES Soil is not applicable.

An alternative approach is provided through the control of discharges of leachate from landfills. The MfE has landfill classification guidance that applies to hazardous waste and municipal waste landfills (MfE, 2002b). Class A landfills are lined, have leachate collection systems, and are closely monitored. Class B landfills are not typically lined nor is leachate collected. The Class A hazardous waste screening criteria value for mercury is 4 mg/kg with a 0.2 mg/L concentration in leachate using toxicity characteristic leaching procedure (TCLP) analysis. The concentrations are ten times lower for Class B landfills (i.e., total of 0.4 mg/kg and TCLP value of 0.02 mg/L). This reflects the difference in the level of environmental protection associated with each type of landfill. The Class B value is the concentration below which a release to the environment from an uncontrolled landfill will have a less than minor effect on the environment.

This classification system does not include consideration of industrial monofills or construction and demolition wastes without the putrescible material normally associated with municipal landfills. The guidance states "the acceptable standard for these sites depends on the range of wastes being accepted at the site. It is recommended that the acceptable standard be developed on a site-by-site basis." It also states that waste acceptance criteria should be determined through the resource consent process. Therefore, the on-site reuse of the material would be determined by Regional Council requirements.

As described above, the proposed treatment of the Benmore Pole 1 facility following decontamination of mercury containing areas was to dispose of the cleaned deconstruction concrete material as fill within the former basement structure before covering it with additional cleanfill material. Water would be able to drain through the structure and into underlying substrate through drilled drainage holes. Therefore, the potential risk to surrounding ecosystems would be if mercury-contaminated water percolated into sediment and groundwater, and ultimately into the surface water of the nearby Waitaki River. International standards and guidelines were also reviewed for applicability; however, standards for mercury in concrete were not available.

3.3 Selection of Trigger and Remediation Values

Instead of applying guideline values, it was determined that a risk-based approach is most appropriate, with evaluation of potential effects to human and ecological receptors. Because of its bioaccumulative properties and the industrial nature of the site, the ecological receptors are considered the most sensitive with human health protected through implementation of WorkSafe New Zealand standards and environmental protection.

For worker protection from mercury in ambient air, the criteria and guidelines are very straight-forward. The WorkSafe New Zealand TLV/TWA of 0.025 mg/m^3 and the National Ambient Air Quality Guideline (NAAQG) of 0.33 $\mu g/m^3$ in ambient air are appropriate guideline values for the proposed project.

The question of which clean-up or trigger value is appropriate with regard to elemental mercury in concrete was somewhat more difficult to answer. Therefore, in order to recommend the most appropriate guideline value, a conceptual site model (CSM) was developed to evaluate potential risk. Initially, all potential pathways were considered. The CSM was then re-evaluated in the context of the completed project. In the re-evaluation, only completed pathways were considered, with primary long-term risk identified as being to groundwater and the river, with human users and aquatic species being the most likely receptors. Volatilisation to air was not considered to present an undue risk to site workers or visitor to the site and area based on the data obtained to date and air quality analysis conducted by URS (2008).

In order to reach the river, mercury would need to be mobilised by infiltrating rainwater, travel vertically through the soil to groundwater, and then laterally to the tail race. Once it enters the tail race, it could adhere onto sediments or be further mobilised in the water.

A geotechnical report conducted indicated that groundwater is approximately 8 m bgs. Assuming the basement bottom is 4 m bgs, mercury would still need to travel several metres before reaching groundwater. In addition, the edge of the basement closest to the tail race is approximately 150 m away at its closest point.

While placement of the processed concrete material is not considered to be a landfill, based on the conceptual site model, the final configuration is expected to behave in a manner similar to a Class B (unlined) landfill (i.e., with rainwater infiltrating through processed material and potentially travelling to groundwater). However, a Class B landfill typically accepts municipal, organic, and domestic waste, as well as inert wastes such and demolition wastes.

The hazardous waste screening criteria are based on protection of groundwater, and the TCLP analysis is used to simulate municipal landfill conditions and acidic leachate generated in the presence of putrescible waste material.

At the Benmore Pole 1 facility, the concrete fill material is not expected to contain organic matter. Conditions are not expected to be acidic as concrete is alkaline. Therefore, it was proposed that the Synthetic Precipitation Leaching Procedure (SPLP) be used in place of the TCLP method. The SPLP is less acidic, representing waste open to rainwater and is a conservative approximation of expected conditions within the concrete-filled basement. The SPLP results are compared with Class B Landfill TCLP criteria for both leachate from concrete samples (as clean-up criteria) and from infiltrated water (leachate) samples collected from within the basement (for future monitoring).

The results of the field screening conducted at both Benmore and Haywards, combined with concrete sampling, demonstrated that mercury "hot spots" could be qualitatively identified through the use of XRF machine. The higher XRF readings generally corresponded to areas where visible elemental mercury was present or where mercury in concrete concentrations were elevated. Therefore, it was determined that the XRF machine would be suitable for use to identify areas which require cleaning prior to deconstruction. In order to use the XRF machine, however, a specified concentration was required to allow the cleaning contractor to readily determine which areas required cleaning, as well as determining in the field when the area was likely to be clean or required additional work. Based on comparison of XRF, MVI, and laboratory tests, an XRF value of 50 mg/kg was established as the concentration level to be used as a "yes/no" indicator by the contractor. Once levels were below this field criteria, concrete sampling was undertaken to confirm the clean-up effectiveness in the lab.

There are also guidelines for protecting aquatic ecosystems from the impacts of toxicants such as mercury. These are provided by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000). The guidelines specify "trigger values" for a range of environmental indicators, including mercury. The trigger values are intended as indicators of the potential for adverse effects on aquatic biota due to the contaminant. For example, the guidelines set a trigger value of 0.06 micrograms of inorganic mercury per litre of water (µg/L) to protect 99% of freshwater species in slightly-moderately disturbed New Zealand ecosystems, and 0.6 µg/L for 95% species protection. Due to the potential for mercury to bioaccumulate and biomagnify the Guidelines recommend the application of the higher, i.e. 99% species protection, guideline. However, it can be difficult to find analytical laboratory facilities able to report the presence of mercury to such low levels. Therefore, it was considered appropriate to establish a trigger level of "greater than the laboratory reporting limit". Note that these are trigger values which indicate the need for some type of evaluation and are not considered clean up goals.

4. Pilot Test

As an early stage of evaluating options for management of the Pole 1 buidlings, mercury surveys were conducted and included an XRF and MVI screening surveys, along with concrete sampling that evaluated total mercury in concrete at various depths within the concrete. Concrete samples were also analysed using the SPLP method to evaluate mercury leachability.

The presence of higher concentrations of mercury in the first 30 to 40 mm of concrete is typical of what has been found in international studies reviewed. This also held true for the concrete samples evaluated at Benmore and Haywards, and indicated that surface cleaning could be effective.

Because the studies described above confirmed the presence of mercury in the concrete at the Benmore Pole 1 facility at concentrations above Class B Landfill criteria, a pilot trial was undertaken to evaluate the best methods of cleaning the mercury from the concrete and removing the asbestos without generating mercury vapour. The pilot trials were informed by research into international experience with the clean-up of mercury arc valve buildings.

A pilot trial was conducted at the Haywards Pole 1 facility in order to evaluate various methods of mercury-in-concrete cleaning and ACM removal. Note that the Haywards and Benmore Pole 1 facilities are essentially identical, and therefore the Haywards pilot trial data was considered valid for selection of cleaning techniques at the Benmore facility. A protocol was developed for the pilot trial by 4Sight Consulting.

The basement area of the Pole 1 facility contains pits which formerly housed mercury arc valves. One of the pits was selected for testing and a containment structure was constructed above the pit. Elemental sulphur was sprinkled on the floor of the pit to evaluate the presence of mercury (the sulphur changes from yellow to grey if elemental mercury is present). The sulphur was then removed using a mercury vacuum. The containment structure was ventilated through an exhaust system with air passing through an in-line HEPA and mercury filter prior to discharge to the outside.

The containment structure was separated into three chambers for evaluation of three concrete decontamination products. Each chamber was cleaned with one of the products by washing the concrete walls and floors with the solution, then sorbing up the solution with clean cloths. Concrete sampling was conducted before and after cleaning to evaluate the mercury concentration in the concrete, and air sampling was conducted to evaluate mercury in air concentrations. The waste generated from the mercury clean-up pilot trial was disposed of off-site as hazardous waste.

The mercury-in-concrete cleaning trial showed a 6% sodium sulphide in water plus alkaline (high pH) degreaser (1 litre degreaser added to 5 litres of 6% solution) being the best option for mercury cleaning because it efficiently removed the mercury and was cost-effective. The Mercon™ product was equally effective, but much more expensive. The 20% sodium thiosulphate solution was the least effective.

Real-time air monitoring was conducted using a MVI and Gastech direct-reading tubes. Ambient air sampling was also conducted in each of the chambers using sampling pumps and sorbent tubes. The sorbent tubes were analysed by RJ Hill Laboratories in Hamilton. The ambient air results were all well below the WorkSafe New Zealand threshold limit value/time weighted average (TLV/TWA) of 25 $\mu g/m^3$, with the highest value being 1.2 $\mu g/m^3$.

Concrete samples were collected to evaluate the effectiveness of the cleaning where the mercury pilot trial had been conducted to evaluate leachability. Samples were analysed for mercury using the SPLP analytical method. Results ranged from 0.00031 to 0.00077 mg/L; well below the Class B landfill TCLP criteria of 0.02 mg/L.

For the ACM removal, a containment structure was constructed which ventilated to the outside through mercury vapour and HEPA filters. Before asbestos removal, the area was checked for mercury and vacuumed with a mercury vacuum.

Advances in the industry have seen the development of a variety of non-toxic solvents that allow for removal of asbestos-containing mastic without grinding. In the United States, these compounds are allowed for removal of non-friable asbestos material (such as tiles and adhesives) without containment.

Two products were trialled in separate areas of a containment structure and both allowed removal of tiles and mastic without grinding. The asbestos containment area was visually inspected by a certified asbestos specialist and air samples were collected in the containment area for laboratory analysis in accordance with WorkSafe New Zealand requirements. The air sampling results were below the laboratory reporting limit with no asbestos detected in any air samples. A demonstration of the process was observed by WorkSafe New Zealand representatives, who concurred that no containment was required. This saved a great deal of time and money while still providing protection for the workers and the environment.

5. Protocol Development

A protocol for full scale asbestos removal and mercury cleaning was developed following completion of the pilot trial. The protocol called for a step-wise approach with evaluation after each step in the process. It also provided for stopping work if results indicate that the protocol was not effective.

For mercury cleaning, the protocol called for vacuuming the area with a mercury vacuum, cleaning the mercury using the selected products, evaluating the area with an XRF and MVI survey, re-cleaning the area if required, and collecting concrete samples for SPLP analysis. If SPLP results were above the selected guideline value, cleaning was repeated and samples re-collected.

For ACM, the area was inspected for mercury using an XRF and MVI, removing the mercury if required, using the selected products to remove the tiles and mastic, re-surveying for mercury, and visually inspecting the area for ACM. Air samples were to be collected throughout the process,.

Where SPLP mercury results were above the selected guideline value, cleaning was to be repeated and the area resampled. In addition, “background” areas of the building were to be sampled for SPLP mercury analysis. The laboratory results were to be compared with Class B Landfill TCLP criteria.

The work was conducted under a health and safety plan which addresses ambient and worker air monitoring, personal protective equipment and decontamination, and overall worker safety.

6. Implementation

The project was initiated with a site induction with Transpower, and contractor staff present. This was key to the project running smoothly, as all project team members had the opportunity to discuss expectations, health and safety, the protocol and procedures, and communication.

Routine meetings continued throughout the project and at key implementation phases, to discuss items such as better cross-contamination control and signage, ACM and mercury removal technique improvements and challenges, and variations to the protocol. For example, the mercury removal technique initially selected was a 6% sodium sulphate solution mixed with an alkaline degreaser and water. This had proven effective during the pilot test; however, on a large scale, hydrogen sulphide was produced in high enough quantities to create a safety hazard. Therefore, a solution of sodium thiosulphate was substituted. While this did not prove to be as effective at removing the mercury, it did not produce harmful gas. Some areas require scabbling to remove the upper 10 to 20 cm of concrete as the sodium thiosulphate cleaning solution was not adequate to remove all of the mercury. Ventilation of the work area using mercury filters was required for this work.

The ACM removal was conducted without containment and all air sample results were free of asbestos. However, as a precaution, all personnel wore full personal protective equipment, including respirators with particulate and mercury vapour filters.

Through laboratory testing for total and SPLP mercury, the XRF field criteria of 50 mg/kg was proven to be an accurate indicator of whether mercury cleaning was adequate. The MVI required skilled use; however, it was a good indicator of mercury in air for monitoring potential employee exposures. It was also used to evaluate the presence of mercury along rails where XRF readings could not be obtained due to interference by the steel rails.

The project was successful due to:

- § Up-front planning, including protocol development and the pilot test which allowed for a step-wise process and development of good field screening criteria;
- § Project induction meeting, which allowed all team members to ask questions and understand expectations;
- § Inspections and meetings throughout the project to allow for quick implementation of improvements;
- § Emphasis on health and safety;
- § Task-specific training regarding cross-contamination, sampling procedures, and decontamination; and
- § Establishing a good working relationship with Environment Canterbury which provided for good communication.

7. Results

The demolition contractor conducted due diligence surveys for asbestos and mercury prior to start of works. No mercury or ACM contamination was identified during these surveys. The demolition proceeded as planned, and metal was separated from the concrete. The metal was taken off-site for recycling and the concrete was crushed on-site. Over 2,000 cubic metres of concrete was used as backfill in the basement.

The wells were emplaced in the basement within the crushed concrete in accordance with the protocol and will allow for future monitoring of leachate, providing an early warning system for protection of groundwater and surface water. Monitoring of groundwater and the tailrace begins in November 2016.

The site has been left in a reusable state while providing for protection of human health and the environment. The project objectives were met and successfully completed.