Assessment of Public Health Risk from the Remediation of the former Fruitgrowers Chemical Company site, Mapua, Nelson

Prepared for the Ministry of Health
February 2010

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Executive Summary

This report is a result of the investigation carried out by Nelson Marlborough District Health Board Public Health Service (NMDHB PHS) into possible public health effects resulting from the Mapua contaminated site remediation.

In December 2006 the Ministry of Health (MoH) requested that the NMDHB PHS investigate the public health concerns relating to remediation activities at Mapua that had been referred to the Ministry by the previous Parliamentary Commissioner for the Environment (PCE), Dr Morgan Williams, and report back to the Ministry. The PCE had received a disclosure of information under the Protected Disclosures Act 2000 in late 2006 that alleged poor environmental management related to clean-up activities at the former Fruitgrowers Chemical Company (FCC) contaminated site at Mapua.

The goal was to investigate the possibility of risk to public health from the Mapua site clean-up from the commencement of the decontamination plant operation (October 2004) to November 2006 and the scope of the project was to ascertain if there have been compliance failures with the resource consent conditions that could lead to public health risk; to identify the occurrence of possible public health effects resulting from site emissions or discharges; to clarify, through a literature review and expert opinion, if the particular Mapua site discharges and emissions could have public health effects; and to prepare a report for the MoH on the results of this investigation.

The investigation was divided into an information gathering phase to ascertain possible hazards and public health effects associated with the site. This was followed by a risk assessment of any identified hazards arising from the site and possibly impacting on public health through community exposure. The investigation was expanded after an initial review of the findings determined that further research was necessary. This research was spread across the PCE and the NMDHB PHS investigations.

The purpose of the remediation was to reduce the contaminant concentrations in the soil and marine sediments to levels determined to be acceptable for future use of the Site and surrounding areas because the then existing risks to public health from the contaminated site had been assessed as unacceptable. It was also expected that the reduction in contaminants in the soil on the Site would result in an improvement in the groundwater quality. The main contaminants had been characterised as being organochlorine pesticides (OCPs), mainly DDX and dieldrin, and a few heavy metals. Future uses proposed for the Site after remediation included commercial, recreational (open space) and residential areas. The remediation process carried with it the risk of mobilisation of contaminants, particularly during the remediation, and consequent risk of exposure of the public to discharges and emissions from the Site. This risk was heightened by the decision to remediate the soil on the Site itself, in the middle of a residential area and adjacent to an estuary.

It was expected that public health would be protected during the remediation by the conditions of the Resource Consents, particularly those specifying an ambient air and groundwater monitoring programme and specific control and mitigation activities for identified hazards. Calculation of a monthly Total Hazard Index (THI) was the main mechanism set in place to assess health risk from discharge of chemicals through air in either gaseous or particulate phase. However the limitations of the site characterisation done prior to the consents being granted and the lack of information on the possible by-products of the Mechano Chemical Dehalogenation (MCD) process meant that there were notable omissions to the range of chemicals included in the monitoring programme that may be associated with public health risk, particularly ammonia, arsenic, benzene, chlorobenzene, dioxins, mercury, PCBs and two isomers of DDX.

Remediation was undertaken by excavating the soil, screening it and processing the contaminated “fines” through the MCD plant (soil dryer, followed by passage through the

MCD reactor to dehalogenate the OCPs) before reinstating the soil back on Site. This resulted in piles of soil awaiting processing and reinstatement around the Site and, despite dust mitigation methods being employed, these activities resulted in considerable amounts of dust being discharged from the Site during windy periods.

The MCD plant had not been used on a commercial scale prior to this remediation project and it was evident that higher temperatures, greater quantities of process reagents and changes in the process reagents used, were required to achieve remediation of the soil and to meet the throughput requirements for the project than had been suggested in the information presented at the Resource Consent Hearing. There is evidence that these factors resulted in increased volatilisation of OCPs and the formation of Volatile Organic Compounds (VOCs), including benzene, and dioxins in the dryer, as well as increased fugitive air emissions of ammonia, and discharge of diammonium phosphate, copper and nitrates to groundwater.

Volatilisation of OCPs and other chemicals, thermal decomposition of OCPs to form by-products and possible de novo synthesis of products are of concern because it is clear that at least until November 2005, and possibly for longer, the Air Emissions Control System (AECS) was not functioning optimally. Thus increased concentrations of OCPs and other chemicals, including those not covered in the monitoring programme (particularly dioxins, benzene and PCBs), are likely to have been emitted from the stack.

The limited range of chemicals included in the monitoring programme, methodological issues in the ambient air monitoring undertaken which affected the data being used for the THI and lack of representativeness in the location of the monitoring sites have compromised the ability to assess health risk for the public during and subsequent to the remediation. There appeared to be a lack of appreciation on the part of the Ministry for the Environment (MfE) as Resource Consent Holder that the purpose of the THI was not primarily as a compliance tool but was to assess public health risk.

Many of these issues were identified by the Tasman District Council (TDC) Compliance Officer and were also discussed by the Peer Review Panel (PRP), with resulting recommendations to address the problem or deficiency. However many of these recommendations were either not taken up at all or not implemented in a timely manner by the Resource Consent Holder (MfE). The delays in carbon filter testing and stack emissions tests for dioxins recommended by the PRP and TDC have meant the risk to public health from exposure to dioxins, particularly from November 2004 until March 2006, was unable to be adequately assessed at the time or subsequently.

The risk assessment for OCPs (including DDX, ADL, HCB), chromium, manganese, nickel, arsenic, copper, lead and selenium reported in the September and October 2009 AES reports indicated that adverse health effects are unlikely to have resulted from exposure to these chemicals for people living or working north or west of the Site. There is some uncertainty for people who live south of the Site, due to inadequate monitoring data being available for this area. In particular this applies to people living on the west side of Tahi Street or closer to the Site than 31 Tahi Street for people living on the east side of the street. However this uncertainty is only of concern for possible exposure to OCPs and arsenic. Fugitive emissions from the Site were a significant component in the total OCP emissions from the Site and the THI calculations showed that the largest contributor to potential public exposure to OCPs was via the dust ingestion pathway

There is evidence that members of the public were likely to have been exposed to dioxins discharged from the Site during the remediation. However in the absence of exposure information from ambient air monitoring, along with the uncertainty regarding the dioxins emission rate used in the dioxins dispersion and deposition modelling, no conclusion can be reached on the health risk, if any, associated with possible dioxins exposure.

It seems likely that low levels of ammonia discharged from the Site may have caused some of the many odour complaints and short term, localised symptoms of eye and throat irritation but this level of exposure is unlikely to have caused lasting or serious adverse health effects. PCBs and benzene are both chemicals of concern that the public may have been exposed to

as a result of discharges from the Site but, as there is no monitoring data for PCB and limited monitoring data for benzene, no conclusion can be made on health risk.

There is considerable uncertainty about the number of days the public was exposed to PM_{10} levels that breached the National Environmental Standard value due to lack of robust exposure data and the non-representative location of the Tahi Street monitoring site for assessment of exposure for residents to the south of the Site. However it is likely that PM_{10} levels breached this standard on numerous occasions and consequently that there was an increased risk of adverse health effects from inhalation of dust during the remediation. The lack of robust exposure data means the extent of the public health risk is uncertain but it is likely to be low to medium.

The Site Auditor reported there is potential for ammonia gas to be generated from the Site and recommended soil gas testing and the development of a management plan depending on the results. He also recommended resampling or reanalysis of archived samples for DDX to clarify the risk of isolated exceedances in contaminants in the residential soils in the capping layer of the Site.

Monitoring of bore water showed DDT, dieldrin and lindane frequently exceeded resource consent threshold concentrations during the remediation in the on Site bores and dieldrin in the off Site bores and that DDX and dieldrin contamination has persisted in some bores. Groundwater to the south of the Site and under the Site is not potable and it remains unclear whether there is health risk from consumption of produce irrigated with bore water.

There was ongoing contamination with OCPs in both the Eastern and Western estuary sediment during the remediation and in shellfish in the Western estuary and this has persisted. Given that signs were put in place warning the public not to collect or consume shellfish from the foreshore, consumption of shellfish is not considered likely to be, or have been, a cause of adverse health effects.

Close neighbours, including those working in commercial businesses, were exposed to repeated episodes of unpleasant odour, dust, noise and vibration over the three year period of the remediation. This caused significant stress and anxiety for some people.

There was non-compliance with some of the conditions in the Resource Consents that may have led to public health risk or compromised the ability to assess whether there was any public health risk. These included the following: the soil dryer did not have an automatic cut-off if the temperature at the dryer inlet exceeded 120˚C, TSP/PM_{10} monitoring during the PoP trials/first month of operation was not completed as specified, the location of the ambient air monitoring sites were not as specified, dust was discharged from the Site at levels that were at the very least offensive and objectionable and may possibly have been noxious, and the PRP did not meet at least quarterly during the first two years of the remediation. Other factors, such as the AECS and the process reagents used, were considered substantially different by the PCE[1] from what was presented to the Resource Consent Hearing in the 2003 AEE, meaning that these may also be considered matters of non-compliance.

Assessment of public health risk resulting from the Mapua Site remediation has been complicated by information gaps particularly on possible Site emissions and discharges as well as in the quality and range of the monitoring data. However it is clear that the public health risk associated with Mapua relates predominantly to the air emissions and discharges from the Site during the remediation. Use of the deposition pattern calculated for the dioxins dispersion and deposition modelling indicates that it is possible around 60-70 properties may have been affected by such discharges. Whether there is a health risk associated with a particular discharge however is very dependent on the level of exposure and the nature of the contaminant.

The delay in adding specialist air quality expertise to the PRP impacted on the identification, investigation and formulation of recommendations on issues that arose during the remediation concerning Site emissions and discharges and this limited the ability of the PRP and the Consent Holder to assess risk to public health during the remediation.

It is now apparent that for a complex project such as this remediation the assessment of public health risk in a changing environment was a significant challenge and, in hindsight, a specialist public health expert on the PRP would have been of benefit.

This investigation into public health risk is limited by the lack of exposure data for members of the public living or working in close proximity to the Site during the remediation to several chemicals that remain of concern, namely dioxins, benzene, PCB and, for those living south of the Site only, OCPs and arsenic.

The deposition modelling from the AES dioxins dispersion and deposition modelling report could be used to clarify those properties where exposure would have been highest to these chemicals. For dioxins the period of concern is limited to the 18 month period from November 2004. However for OCPs and benzene the fugitive component of these emissions means that the period of concern covers the time the MCD plant was operating and it is likely that this is the same for PCBs and arsenic.

Given the half life of dioxins, PCBs and OCPs in people and the environment it may be possible to clarify dioxins, PCBs and OCP exposure through biological and environmental testing. Further investigation is required to clarify who would have been most at risk of exposure to these chemicals and to better characterise the risk of any such exposure. However as the half life of benzene and arsenic in people is very short there is no ability to test for historic exposure.

Recommendations

Recommendations to the Ministry for the Environment

1. For future similar remediation projects the Ministry for the Environment should advise Regional Councils and/or Unitary Authorities that in the consent process:

    - a Peer Review Panel is established to oversee the project
    - the Peer Review Panel should include the local Medical Officer of Health or their representative(s) to ensure the protection of public health is included in deliberations of the panel
    - for contaminated sites adjacent to residential areas greater consideration should be given to the potential for fugitive emissions with either detailed attention to the options for management of these emissions, or offsite remediation
    - a statutory review condition should be inserted in all consents issued for remediation projects similar to this that includes reviewing monitoring requirements placed on the consent (eg, monitoring sites, contaminants monitored, type of monitoring)

2. Where new technology is “trialled” robust Proof of Performance testing should be undertaken using normal operating procedures and reviewed before the remediation proceeds.
3. It is specifically recommended that MfE should seek expert opinion on undertaking soil sampling for contaminants that may have been discharged onto residential properties in close proximity to the Site as follows:

    - dioxins and non dioxin-like PCBs in residential properties in close proximity and downwind to the Site
    - OCPs and arsenic in residential properties south of the Site, particularly those on the west side of Tahi Street or closer to the Site than 31 Tahi Street for properties on the east side of the street

4. Subject to the outcome of the expert opinion recommended in point 3 above, soil sampling is undertaken for the contaminants listed.

Recommendations to the Tasman District Council

1. Groundwater from under the Site or south of the Site should not be used for drinking water and current property owners/residents should be advised of this. In addition this advice should be recorded in the Land Information Memorandum (LIM).
2. A review of the current TDC Resource Management Plan should be undertaken as soon as possible in respect of new bores on Site or south of the Site.
3. A public health risk assessment on the use of groundwater for irrigation of produce grown on the Site and south of the Site should be undertaken and the findings discussed with the NMDHB PHS.
4. Pending discussion of the assessment noted in point 3 above, ground water from under the Site or south of the Site should not be used for irrigation of produce.
5. Any future changes in the recommendations concerning groundwater use on or south of the Site should be reviewed in conjunction with the NMDHB PHS.
6. Appropriate controls to maintain the integrity of the capping layer in all areas of the Site should be in place before any further development of the Site takes place.
7. Information on the potential health risk of breaching the topsoil/capping layer should be recorded on relevant Local Authority property files.
8. Soil gas testing for ammonia should be carried out as recommended by the Site Auditor (final audit) and a management plan developed as necessary.
9. Resampling or reanalysis of archived samples to clarify if there is any risk of isolated exceedances in DDX concentrations in residential soils on Site should be undertaken as recommended by the Site Auditor (final audit).
10. Warning notices advising the public not to collect or consume shellfish from the foreshores adjacent to the Site should be in place until ongoing monitoring confirms levels of contaminants are below the NZFSA residue values (as recommended in 2007) and that these levels remain low in a subsequent testing regime developed in conjunction with the NMDHB PHS.
11. Monitoring of biota further up the food chain should be undertaken.

Recommendations to the Ministry of Health

1. To clarify the possibility of significant dioxins exposure to residents (including off Site workers) in close proximity and downwind of the Site, arising from the remediation over the period of concern (November 2004 - February 2006 inclusive) the Ministry of Health should seek expert advice on undertaking biological testing for dioxins.
2. To clarify the possibility of significant PCB exposure to residents (including off Site workers) in close proximity and downwind of the Site, arising from the remediation over the period of MCD plant operation the Ministry of Health should seek expert advice on the feasibility of biological testing for non dioxin-like PCBs.
3. To clarify the possibility of significant OCP exposure to residents (including off Site workers) in close proximity and south of the Site, arising from the remediation over the period of MCD plant operation the Ministry of Health should seek expert advice on the feasibility of biological testing for OCPs.

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1. Introduction

This report is a result of the investigation carried out by Nelson Marlborough District Health Board Public Health Service (NMDHB PHS) into possible public health effects resulting from the Mapua contaminated site remediation.

In December 2006 the Ministry of Health (MoH) requested that the NMDHB PHS investigate the public health concerns relating to remediation activities at Mapua that had been referred to the Ministry by the previous Parliamentary Commissioner for the Environment (PCE), Dr Morgan Williams, and report back to the Ministry.

The PCE received a disclosure of information under the Protected Disclosures Act 2000 in late 2006 that alleged poor environmental management related to clean-up activities at the former Fruitgrowers Chemical Company (FCC) contaminated site at Mapua. After an initial investigation the PCE formally referred information that related to potential public health impacts to the MoH and worker issues to the Department of Labour (DoL). It was agreed between the three agencies that a coordinated approach would be taken during the investigation. Further consultation between the agencies early in 2007 recognised that the reports would be separate but that the public health investigation would be informed by the scientific review being carried out by the PCE and that the PCE would share information and work together with the NMDHB PHS and the MoH where appropriate to do so.

1.1 Project Goal

Based on the briefing paper provided by the PCE and initial scoping of the remediation project the following project goal[a] was agreed on by the NMDHB PHS and the MoH:

> "To investigate the possibility of risk to public health from the Mapua site clean-up from the commencement of the decontamination plant operation (October 2004) to November 2006"

The November 2006 date was selected based on the planned end date for the remediation.

The goal was later modified to include the time period from commencement of remediation activities on the site by Thiess Services Ltd (the initial Consent Holder) and to cover any ongoing risk from the site post-remediation resulting in the following modified goal:

To investigate the possibility of risk to public health as a result of the Mapua site clean-up from the commencement of the decontamination process.

1.2 Project Scope

The scope of the project[a], agreed on by the NMDHB PHS and MoH, is as follows:

> "To ascertain if there have been compliance failures with the resource consent conditions that could lead to public health risk.
>
> To identify the occurrence of possible public health effects resulting from site emissions or discharges.
>
> To clarify, through a literature review and expert opinion, if the particular Mapua site discharges and emissions could have public health effects.
>
> To prepare a report for the Ministry of Health on the results of this investigation."

[a] Published on the MoH website at http://www.moh.govt.nz/moh.nsf/indexmh/mapua-site-remediation

The scope excludes[b] :

"Health effects prior to the commencement of the site remediation in 2004 Environmental concerns (covered by the PCE investigation) Occupational health concerns (covered by the DoL investigation) Other agrichemical dump sites"

[b] Published on the MoH website at http://www.moh.govt.nz/moh.nsf/indexmh/mapua-site-remediation

2. Investigation process

The investigation was divided into an information gathering phase to ascertain possible hazards and public health effects associated with the site. This was followed by a risk assessment of any identified hazards arising from the site and possibly impacting on public health through community exposure. The investigation was expanded after an initial review of the findings in conjunction with the PCE investigators in June 2007. Further research and work found to be necessary as the investigation proceeded is listed below in Section 2.2.

2.1 Initial Information gathering

Initial information was gathered on the following:

2.1.1 Local residents' health effects/concerns

- Invitation to the local community to bring personal health concerns they thought may be associated with remediation to our attention using:
  - Letter drop to residents in the vicinity of the site
  - Attendance and speaking at the monthly public meeting of the Mapua Residents and Ratepayers Association on 11 June, 2007
  - Phone interviews with respondents using a standardised format for the data collection
- Visit to a General Practitioner (GP) at the Mapua Health Centre
- Letter to all Nelson Tasman GPs requesting information on any health concerns (in patients) they thought may be associated with the site remediation project
- More detailed interviews with specific individuals
- Review of complaints registers held by Tasman District Council (TDC) and the Ministry for the Environment (MfE) – the latter was maintained by Environmental Management Services (EMS)
- Liaison with DoL staff

2.1.2 Site emissions/discharges

- Discussions with TDC Compliance Officer
- Review of Resource Consents
- Collection of base data – maps, site visit, photos, details of remediation process
- Review of historical reports about the site
- Review of Proof of Performance (PoP) Report and Mechano-Chemical Dehalogenation (MCD) plant process
- Review of raw monitoring data, site reports re discharges/emissions and Peer Review Panel (PRP) reports in conjunction with the PCE investigators
- Review of the PCE analyses of the monitoring data
- Review of the Total Hazard Index (THI)

2.1.3 Literature review

- Literature review using national government agency sites [e.g. MfE, MoH], international agency sites [e.g. United States Environmental Protection Agency (USEPA), World Health Organization (WHO)]
- Review of PRP minutes, TDC Compliance Reports, MfE monthly remediation project reports

- Review of reports related to the Mapua Site already produced for or by other agencies, prior to remediation, during remediation and post-remediation activities.[c]

2.2 Further information

The following issues led to further information being commissioned by NMDHB PHS or becoming available from other agencies.[d]

- Lack of monitoring data for some chemicals known to be of concern
- Lack of monitoring data for PM_{10}
- Methodology issues with air monitoring so results may be underestimated
- Incomplete site characterisation so additional chemicals that may be of concern were not included in the monitoring programme
- Changes in process reagents used which may have led to other discharges
- Heating of the soil may have led to formation of new products due to thermal decomposition or *de novo* synthesis
- The dehalogenation process in the MCD reactor may have led to formation of new products
- Lack of temperature control in the rotary dryer and incomplete records for dryer temperatures
- Poorly functioning Air Emissions Control System (AECS) for approximately 18 months of the site remediation
- Not all exposure pathways were addressed in the THI calculations
- Extensions to the original timeframe for this investigation into possible public health risk led to further reports becoming available
- Gaps in worker health monitoring

Additional consultant reports produced or commissioned/requested by various agencies are:

1. Peer Review Panel
    - Review of Total Hazard Index Calculations for the Mapua FCC Remediation Project, 2007 - Dr Craig Stevenson
    - Further Considerations of Total Hazard Index Calculations for the Mapua FCC Remediation Project, 2007 - Dr Craig Stevenson

2. Parliamentary Commissioner for the Environment
    - Review and Assessment of Air Monitoring and Emissions Data for the Former Fruitgrowers Chemical Company Site, Mapua - Dr Bruce Graham (Graham Environmental Consulting Ltd) June 2007
    - Former Fruitgrowers Chemical Company Site, Mapua: Assessment of the Possible Releases to Air During Soil Processing – Dr Bruce Graham February 2008
    - PCE Report: Investigation into the remediation of the contaminated site at Mapua, - PCE July 2008

3. Nelson Marlborough District Health Board Public Health Service and Tasman District Council
    - Further revision of THI calculations by Dr Craig Stevenson.

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c These are all included in the References or Bibliography

d These issues are covered in detail in the PCE Report and the October 2009 AES Report

This revision was jointly funded by the above organisations. Further work was then commissioned by NMDHB PHS, resulting in the two final reports as set out in point 5 below.

4. Tasman District Council
    - Snail and sediment testing reports – ongoing monitoring to meet resource consents and additional testing requested by NMDHB PHS
    - Soil test for mercury in residential soils on the West FCC – TDC 2008 (result of recommendation in the PCE report)

5. Nelson Marlborough District Health Board Public Health Service
    - Calculations of Hazard Indices and Cancer Risks for the Mapua FCC Contaminated Site Remediation Project (further revision and expansion of earlier THI reports) – Dr Craig Stevenson, Air and Environmental Sciences Ltd (AES) October 2009
    - Calculations of Hazard Indices and Cancer Risks for Additional Metals for the Mapua FCC Contaminated Site Remediation Project – Dr Craig Stevenson (AES) September 2009
    - Toxicological Profiles of Chemicals of Concern at Mapua – Dr Leo Schep (ToxInform Ltd) 2009
    - Screening Dispersion, Deposition and Exposure Modelling Assessment of Possible Dioxin Emissions from the Mapua FCC Remediation Project – Dr Craig Stevenson (AES) 2009
    - Report on toxicological considerations of the TDC Snail and Sediment Report - New Zealand Food Safety Authority (NZFSA) 2007

The majority of this work was funded by the MoH.

6. Ministry for the Environment
    - Site Validation Report for the Former Fruitgrowers Chemical Company Site, Mapua - Sinclair Knight Merz (SKM) 2008
    - Audit of the remediation of the Former Fruitgrowers Chemical Company Site, Mapua - Pattle Delamore Partners Ltd (PDP) 2009

2.3 Risk Assessment

Site activities, discharges and emissions were determined using the information gathered as outlined above. Chemicals known or thought to be discharged or emitted from the site were considered to be “chemicals of concern”.

For chemicals of concern covered by the THI, the final THI report is used as the risk assessment.

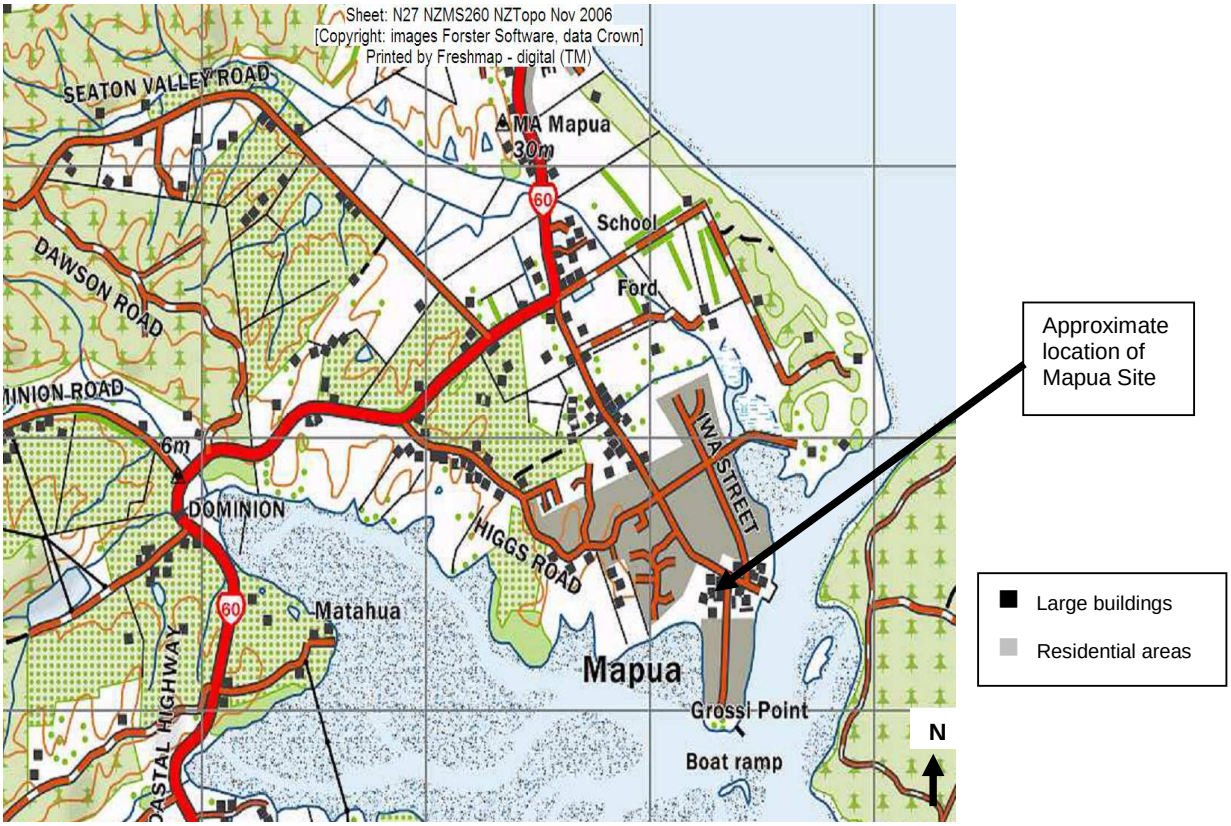
The need for a risk assessment for other chemicals identified as being of concern was determined by assessing the information available on potential community exposure. Where this information was not known or exposure appeared to be likely, a toxicological review followed by risk characterisation was undertaken to complete the risk assessment.

3. Background

3.1 Mapua

Mapua is a coastal township located between Nelson and Motueka at the mouth of the Waimea Estuary at the top of the South Island. It originated as a small holiday settlement but over the years, particularly since the FCC plant closed in 1988, it has become more urbanised. According to Statistics NZ in the 2006 census it had a population of approximately 1875 people (this includes Seaton Valley and Ruby Bay).

Figure 1: Mapua settlement prior to removal of buildings from former FCC site



3.2 History of Fruit Growers Chemical Company & site activities

From 1932 until 1988 the site referred to in this report as “the Site” was home to a pesticides factory operated by the FCC, a mineral processing plant operated by Mintech (formerly Lime and Marble) and a private landfill used by both companies. The 5.06 hectare Mapua Site borders the Mapua Channel and is surrounded by residential and commercial (including tourist) properties.

The Mapua Site was left orphaned when the FCC factory closed. Tasman District Council (TDC) inherited some of this land, along with reclaimed land next to the original FCC site, from the Nelson Harbour Board in the 1980s and took ownership of the rest of the FCC and Mintech sites in July 1996.

Figure 2: Location of Mapua Site

Activities at the Site by FCC and Mintech (Lime and Marble), had resulted in contamination of soil, marine sediments and groundwater by organochlorine pesticides (OCPs), heavy metals and other chemicals. The landfill on the Site contained waste from the two factories and contaminated stormwater, groundwater and dust from the Site had discharged to the Waimea Inlet. This had resulted in contamination of marine sediments and seawater in close proximity to the Site. Soil on some neighbouring properties had also been contaminated.

Concern about the contamination resulted in several investigations during the 1990s in an attempt to characterise the nature and extent of contamination and a government decision to remediate the Site was made following this. The details of the history of the Site remediation, including site characterisation and choice of remediation technology, are covered in the PCE Report 2008.[1] Several locations for the site remediation treatment plant were considered before the decision was made to treat the contaminated soil on the Site itself. The impacts of additional vehicle movements to and from the Site, including haulage of contaminated soil through the Mapua community, and concerns about the potential environmental impact on the proposed separate treatment sites were the main reasons put forward to support treatment on the Site.

3.3 Site characterisation

An audit of the Site was done by Woodward Clyde in 1992[2] in which they reviewed historical records and photos, and conducted a Site inspection and interviews with past employees to identify the nature and extent of ground contamination of the FCC and Mintech sites. Their report recommended a sampling programme with proposed locations for soil and groundwater sampling.

This sampling programme and various other studies were undertaken by Woodward Clyde to assess the degree and extent of contamination, the resulting risks to human health and the environment, and the remediation options. These reports are the basis for the Woodward Clyde report *Assessment of Environmental Effects,*[3] prepared in 1996 to accompany applications for resource consents required for the implementation of the remediation strategy they had developed for TDC. This report includes the analytical results of the sampling programme.

Further site characterisation investigations were carried out in 2001, with the aim of refining the quantity and extent of material requiring remediation. A 15-20 metre grid pattern with samples being taken at a range of depths was used. As the remediation was targeted at OCPs the sampling was largely confined to testing for OCPs.[4]

The spatial limitations of pre-remediation sampling (large grid and limited depth sampling) may explain why hotspots and unexpected chemicals were found during the remediation. This opinion was supported in discussions at the Site visit in January 2007 with the MfE's Site Manager, EMS (personal communication with John Roosen, EMS).

The PCE report[1] notes that "contamination was typically found in areas used for chemical handling and bulk storage, and within storm water drains and low-lying areas." It is of note that the various sampling programmes concentrated on areas thought likely to be contaminated and the number of samples was far higher for chemicals thought more likely to be present at high levels. The lack of a more extensive sampling regime for the site characterisation was noted as a shortcoming by Dr Bruce Graham in his report prepared for the PCE. [5] However it was these sample results, from 1992 – 2001, that were used as the basis for the human health and environmental risk assessments pre-remediation and for the subsequent choice of chemicals to be included in the monitoring programme during remediation.

Baseline soil and groundwater sampling was also carried out in September and October 2004 prior to remediation with soil sampled from 10 known "hotspots" and 10 random sites and groundwater from six onsite wells and four residential bores.[6] These confirmed the presence of chemicals such as PCBs in the soil but the decisions on ambient air and stack emissions monitoring required for the resource consents had been made prior to this testing and no further changes were made to these requirements.

3.4 Assessment of public health risk if Site left unremediated

Several assessments of public health risk were carried out, based on the presence of chemicals found in the site characterisation.

3.4.1 Woodward Clyde Report 1996

An assessment of existing and potential public health risk from the contamination at the Site was part of the Woodward Clyde *Assessment of Environmental Effects* discussed in Section 3.3.[3] This assessment was based on the site characterisation already carried out.

As a result of the site characterisation the only hazards considered to be human health risks were OCPs.

Exposure pathways identified and results of risk assessment for OCPs were:

- Dermal contact with and ingestion of contaminated soil – risk assessed as unacceptable

- Ingestion of produce grown in contaminated soil – potential for exposure assessed as zero so assessed as no risk
- Inhalation of contaminated dust and vapours – risk assessed as well within acceptable limits
- Contact with contaminated stormwater – exposure pathway not considered to be significant (because exposure would not be prolonged)
- Dermal contact with, and ingestion of, contaminated groundwater – dermal contact exposure considered unlikely so risk was not assessed; risk from ingestion assessed as unacceptable
- Dermal contact with, and ingestion of, contaminated sediment in the Waimea Inlet – risk assessed as acceptable
- Ingestion and dermal adsorption of tidal water while swimming - risk assessed as acceptable
- Ingestion of contaminated fish and shellfish – risk from ingestion of mudsnails assessed as unacceptable but note is made that it was considered unlikely anyone would collect and eat these from this site. Ingestion of cockles, oysters, mussels and fish – risk assessed as likely to be acceptable.

However Woodward Clyde also carried out a Site specific human health assessment using a methodology developed by the US EPA. This showed that human health risks posed by the highest concentrations of chemicals in marine sediments, tidal waters and shellfish were unacceptable and that, of the individual exposure pathways, "the carcinogenic risk associated with the ingestion of shellfish is the most significant" health risk.[3]

3.4.2 Egis Consulting Report 2001

The Egis report, *Derivation of Risk-based Acceptance Criteria for Human Health and the Environment Revised Report,* [7] was commissioned by TDC to derive risk-based acceptance criteria for the contaminated soils, house dusts and sediments, based on protection of human health and the environment. This was a preparatory step to planning remediation and management of the Site but the report also provides an assessment of the health risks from the contaminants considered to be of concern on the Site.

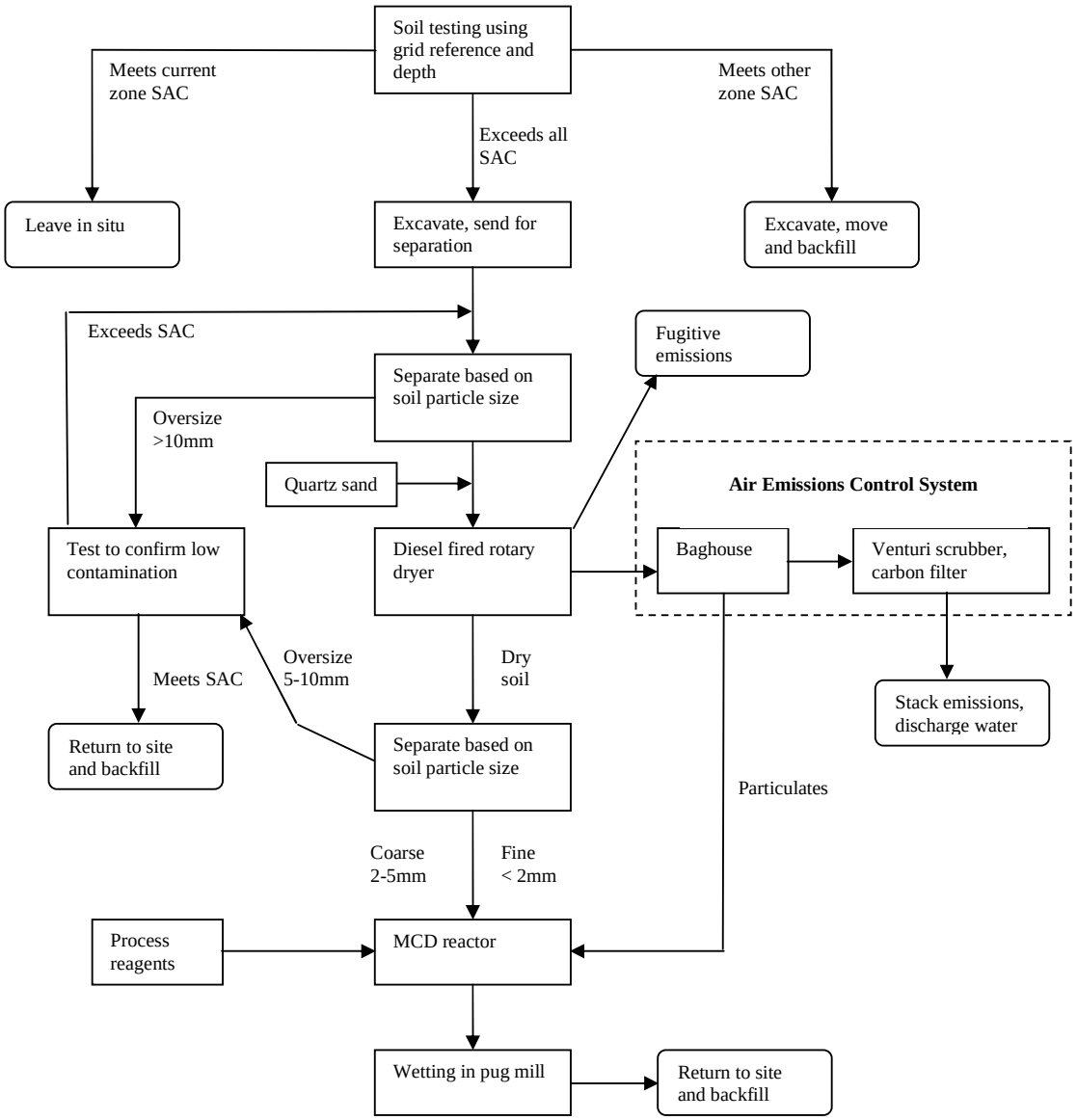
The report starts with the premise that only the OCP contamination is widespread and therefore the focus of the risk assessment was DDX (DDT and its breakdown products, DDD and DDE) and dieldrin. It recognises a number of areas of uncertainty relating to the Site at this time, including insufficient sampling in some areas of the Site to fully characterise the extent of contamination as well as the actual contaminants present. It recommended further sampling of crabs, fish and birds in order to be able to ascertain the acceptance criteria necessary for marine sediments to protect both human health and the environment. Although a study was done by Landcare Research [8] (2001 – 2002) this appears to have been limited to identifying suitable sites and biota to monitor the effects of the remediation on the OCP contamination.

3.5 Remediation project

3.5.1 Remediation process

The purpose of the remediation was to reduce the contaminant concentrations in the soil and marine sediments to levels determined to be acceptable for future use of the Site and surrounding areas, while ensuring that unacceptable discharges during and following the remediation did not occur. This was undertaken by processing any contaminated soil through a MCD reactor. Before the soils could be processed in this way it was necessary to dry the soil using a rotary dryer. The Site was divided into residential, recreational or commercial use zones with different Soil Acceptance Criteria (SAC) for each zone. A schematic representation of the remediation process is in Figure 3.

Figure 3: Flow chart summarising the remediation process



Potential emissions and discharges resulting from the remediation process were influenced by:

1. The process reagents used in the MCD reactor:
    - Initial process reagents used were granulated slag and urea.
    - Final reagents were copper sulphate (this replaced the slag in early 2005), diammonium phosphate (definitely used by May 2005 and possibly earlier in the same year), and urea. The amount of each reagent used varied according to how contaminated the infeed soil had been on pre-remediation sampling. Increasing use of these reagents resulted in elevated levels of ammoniacal nitrogen, nitrates and copper in groundwater monitoring wells (especially on the southern boundary), and the release of ammonia gas from the MCD reactor and piles of remediated soil ("fines") as fugitive emissions.[19]

- Quartz sand was added to the soil before it entered the rotary dryer. It is not clear if this was used to aid in the drying of heavier clay soil, as a grinding agent in the reactor process or to provide a source of oxygen ions to the dehalogenation process.

2. Temperature in the rotary dryer

- Drying of the soil was critical to the process as the moisture content of the contaminated soil had to be controlled for maximum remediation rates in the MCD reactor. Hence the soil moisture content affected throughputs.[4] However it was also known that a high temperature in the rotary dryer (thought to be above 250˚C) could cause volatilisation and/or breakdown of the OCPs and other chemicals to form intermediaries. Such intermediaries could include dioxins, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs) and acidic gases, particularly hydrogen chloride (HCl). Volatilised OCPs and other chemicals formed would then enter the AECS. In addition direct exposure of the soil to the diesel burner flame could give rise to *de novo* synthesis of dioxins. [1 5 10]
- In recognition of these risks a condition of the Resource Consents required the burner to have an automatic cut-off if the temperature at the dryer inlet exceeded 120˚C (Condition 22 of Consent RM030523). This automatic cut-off had been suggested in the Tonkin and Taylor report, *Assessment of Effects of Discharges to Air from Site Remediation Fruitgrowers Chemical Company Site, Mapua*[11] to avoid volatilisation of organic compounds in the soil. (This report had been commissioned by Thiess to assist in obtaining Resource Consents for the remediation.)
- It was noted that there was no automatic cut-off installed on the dryer as of the PRP meeting of August 2005.[12] This was not compliant with the condition noted above or with the information presented in the 2003 AEE.[11] The MfE reported to the PRP in December 2005 they wanted a variation of the consent so the cut-off at 120˚C would be at the outlet of the rotary dryer.[13] It seems likely that there was an automatic cut-off at the outlet (but not the inlet) by this date but the date this was installed is not specifically recorded in the PRP minutes.
- The Compliance Officer reported that from October 2004 to March 2005 Environmental Decontamination Ltd (EDL) was having difficulty successfully treating the soil and were “still experimenting, trying to get the treatment method right” and that the Site Manager had reported to her that on at least one occasion the dryer had been run so hot it blistered the paint.[14]
- A heat shield and kae wool was installed in the dryer infeed area after high OCP levels were recorded in the emissions stack testing in April 2005. The MfE June 2005 monthly report notes this is “to reduce the high level of gaseous organochlorine being produced”[15] – this supports the premise that dryer temperatures were thought to be high enough for volatilisation of OCPs (at least 200˚C). If the shield was only intended to prevent direct exposure of the soil to the diesel burner flame, and therefore prevention/reduction of *de novo* synthesis of dioxins, installation of the shield would have been expected to reduce high levels of both particulate and gaseous phase dioxins (Section 5.2.5 also discusses this).
- Stack testing results from November 2005 – March 2007 show that the OCP emissions from the dryer were predominantly in the gaseous phase[16].

3. Functioning of the Air Emissions Control System:

- The AECS was expected to control emissions to air from the soil drying process. The system was not installed as described during the resource consent process and the AECS carbon filter failed, or performed suboptimally, on numerous occasions for at least the first year of plant operations.[1 10 17]

- Modifications to the AECS were carried out between July and September 2005 and a review of the system arranged. Despite these modifications the filter failed again one month after completion of the modifications and before the report of this review, containing recommendations for best practice, was completed. Then a month later the filter failed again.[9] [10] Although these recommendations were not adopted the carbon in the filter was changed monthly from November 2005 and other changes were also made to address the acidic corrosion problems that had caused complete disintegration of the carbon filter on several occasions.[9] Despite these changes carbon filter analysis carried out in January 2006 showed that the carbon filter was saturated and therefore would not be functioning correctly.[18] In the PCE report the issue of complete failure of the AECS on a number of occasions was raised.[1] The PRP minutes of May and August 2006[19] [20] record ongoing discussion about whether the AECS was functioning efficiently, particularly given the risk of VOCs and dioxins emissions and that these chemicals were not part of the stack testing or ambient air monitoring programme. Suggestions for how to assess when the carbon filter became saturated or channelling had developed were discussed and it was agreed to continue to change the carbon monthly to reduce the possibility of either occurring. There were no further reports of AECS malfunction or failure in subsequent PRP minutes.
- During times of the AECS malfunction or failure there was a risk of elevated OCP and dioxins emissions from the rotary dryer if this malfunction also coincided with dryer temperatures high enough for OCP volatilisation and/or dioxins formation. The PCE report suggests elevated emissions of OCPs, dioxins and possibly other chemicals may have occurred on a number of occasions.[1]
    - The three monthly stack emission test results from February, April and July 2005 show elevated OCPs[21] however, as dioxins were not tested for, it is unknown whether dioxins were present and/or elevated. The DDX concentrations recorded for these three stack emissions tests range between 50,000 – 230,000 ng/m^3, considerably higher than the average level of approximately 5000 ng/m^3 recorded during the PoP trial period in 2004.[22]
    - The Compliance Officer noted in her February 2006 report that the November 2005 stack tests were done with new carbon in the filter, clean sacks in the baghouse and a low concentration of DDX along with aldrin, dieldrin and lindane (ADL) in the infeed soil (half the concentration of that during the PoP trials). However the stack emissions tests were said to have readings 20 times the total concentration of OCPs when compared with the concentration recorded during the PoP trials.[23]

4. Back pressure issues

- The PCE report states there were back pressure issues with the MCD plant during the first year of its operation that may have led to fugitive emissions from the rotary dryer. Such emissions are likely to have been into the storage shed for the contaminated soil awaiting infeed to the rotary dryer or into the surrounding open air. There is no record available of any monitoring done in these areas to assess if these emissions were occurring.[1] These emissions may have been OCPs, intermediaries such as dioxins or any other compound in the soil that was volatilised in the rotary dryer.

5. Concentration of OCPs in the infeed soil

- Air dispersion modelling reports were produced by SKM for MfE.
    - In April 2005 the report noted that the predicted ground level concentrations for OCP contaminants for January and February 2005 were lower than, and did not correlate well with, the ambient air monitoring results for the same months.[24]

- The next report noted that although the predicted levels from modelling in July 2005 were lower than those from February 2005, the ambient monitoring results measured in July 2005 were even higher than those measured in February 2005.[25] The report suggested several reasons for this lack of correlation such as lower OCP concentration in the infeed soil during the stack test period than the average for the rest of the month, a lower temperature in the dryer during the test period than the rest of the month, and OCPs in any fugitive emissions not being measured by the stack test – this is presented in more detail in Section 5.2.2

3.6 Assessment of public health risk if Site remediated

3.6.1 Hazards associated with remediation relevant to human health

The hazards identified in the Egis report were limited to chemicals and were listed as DDX, ADL, lead, mercury, tin, sulphur, nickel and chromium.[7]

To support its application for resource consent for the proposed remediation, Thiess contracted Tonkin and Taylor to prepare a series of reports collectively known as the 2003 AEE.[4] The AEE included assessments of environmental effects, air quality, groundwater, marine ecology, noise, and vibration. The report identified potential hazards relevant to human health risk and proposed methods to avoid or mitigate exposure to these hazards. The hazards identified were:

- Total Suspended Particulate (TSP) and PM_{10}.
- Organochlorine pesticides - ADL, DDX, heptachlor, chlordane
- Ammonia
- Heavy metals - arsenic, cadmium, chromium, manganese, nickel, copper, mercury, lead, zinc
- Selenium, aluminium, magnesium, and titanium (these latter three are included based on their presence in slag as it was planned to use slag as a process reagent)
- Other chemicals that would be present on Site as a result of the combustion process - carbon monoxide, nitrogen dioxide, sulphur dioxide
- Dioxin was not expected to be a risk due to low levels found in the soil sampling and was not evaluated further
- Odour
- Noise and vibration

In its evidence to the TDC Resource Consent Hearing[26] in 2003, NMDHB PHS drew attention to public health issues around hazards associated with noise, air quality and water. Air quality hazards identified as having human health or nuisance risk were fugitive dust from the Site and transport activities, dust from drying and treating the soil, combustion products from drying soil, odour, organochlorine emissions from the drying plant and discharge of metals in fugitive dust. Water hazards identified as having human health risk were groundwater, roofwater and stormwater. In addition contamination of marine sediments and mudsnails (which may be a food source) were identified as hazards.

The final Resource Consent conditions recognised the potential hazards in the applicant's 2003 AEE (listed earlier in this Section) as having public health risk.

3.6.2 Potential routes of human exposure to hazards (exposure pathways)

During the Site remediation it was possible the public may be exposed to the identified hazards through:

- Air emissions or discharges of chemicals and dust leaving the Site as a result of:

- stack emissions – gaseous and particulate
- fugitive emissions from the rotary dryer and/or MCD reactor – gaseous or particulate
- fugitive emissions from treated or untreated soil onsite (especially when soil was in piles) – gaseous or particulate
- once off the Site the potential exposure pathways from air emissions were: soil or dust ingestion, dermal exposure to soil or dust, inhalation of chemicals in gaseous or particulate phase, inhalation of PM_{10}, ingestion of produce grown in contaminated soil or produce that has absorbed chemicals directly from air or dust deposition, roofwater in water storage tanks used for drinking or irrigation of vegetables

- Groundwater becoming contaminated as a result of onsite chemicals being leached from soil which may result in exposure occurring through the:
  - use of bore water for drinking
  - use of bore water for irrigation
  - contamination of marine sediment
- Stormwater from the Site contaminating:
  - soil in surrounding properties
  - marine sediment
- Marine biota that have become contaminated by either ingestion of contaminated sediment (e.g. mudsnails) or ingestion of such contaminated biota by other species higher up the food chain (e.g. fish):
  - consumption of contaminated biota by humans

After the Site remediation is completed the public could be exposed to contaminants from:

- contaminants remaining in soil, both on the Site and possibly off Site, by ingestion of soil or dust, dermal exposure to soil or dust, ingestion of produce grown in contaminated soil
- ingestion of water if contaminated sludge remains in roofwater storage tanks
- ingestion of contaminated groundwater through drinking bore water
- ingestion of contaminated marine biota or dermal absorption from contaminated marine sediment

3.7 Protection of public health

The protection of public health from exposure to the above mentioned hazards was addressed through general and specific conditions in the Resource Consents.

The NMDHB PHS evidence[26] to the Resource Consent Hearing conditionally supported the Thiess application to remediate the Site. The PHS made specific comments and recommendations that included:

- Support for a Site Auditor during the remediation, particularly to confirm that the SAC were compatible with the proposed land use and to review the groundwater monitoring data as it was produced to verify assumptions made in the AEE and risk modelling
- Support of the proposals in the applicant's 2003 AEE as being adequate for the control of construction noise and vibration. These proposals were adopted in the resource consents.
- As the discharged dust may contain a significant portion of PM_{10}, an initial study of TSP and $PM_{10,}$ using High Volume (HiVol) filters, should be undertaken to enable

direct comparison between the readings. The trigger value selected for TSP concentration was to be determined by the proportion of PM_{10}.

- It would be preferable to use a real-time method for monitoring dust emissions so that immediate information is available to assist dust mitigation efforts.
- The rotary dryer temperature should be controlled (up to 120˚C but should be less than the temperature at which expected contaminants will volatilise)
- Monitoring of metals in dust should be undertaken
- It was important to establish that a risk assessment had been done on the use of groundwater for irrigating vegetables
- Monitoring of rainwater from roofs in water storage tanks after remediation to confirm the Maximum Acceptable Value (MAV) was not exceeded
- The depth of excavation required for the marine remediation is confirmed by increased sediment sampling
- There is monitoring of shellfish
- There is monthly monitoring of groundwater
- The Site Management Plan must ensure that any disturbance of waste or transportation in the Landfill area is controlled to avoid contamination of vehicles or workers.

In essence the final Resource Consents addressed these issues. There were also several key mechanisms to support a flexible approach in dealing with emergent issues during the remediation:

- A review condition under Section 128 – 133 of the Resource Management Act (RMA). This condition included a clause that monitoring requirements placed on the Consent could be reviewed on the first working day of every second month.
- The appointment of a Site Auditor to provide independent advice during the remediation
- The appointment of a PRP
- A Council Compliance Coordinator who was given a specific decision-making role under certain of the conditions
- Decision-making responsibility being given to the Council Compliance Coordinator in some specific conditions to approve or alter the parameters for ongoing sampling or monitoring

Other general conditions of the consents which helped protect public health included the establishment of a process for community liaison, a complaints register, a regular reporting process and defined SAC.

As part of the general conditions management plans were required covering a range of issues. Examples of plans relevant to public health included having an Environmental Management Plan that would include procedures specifying methods to mitigate the adverse effects of dust, noise and vibration and an Emergency Response Management Plan. The latter was to be prepared before any works were commenced and was to include procedures to address site emergencies such as chemical spills and damage to neighbouring property.

Specific conditions found in the seven consents covered Site, coastal marine, air, water, sediment discharge, stormwater and groundwater issues.

Apart from the requirement for a THI, these consents have an environmental compliance focus. However, in addition to the health protection focus of the THI, some of the other conditions also protected public health. These conditions were not grouped together as specific health protection conditions in a single consent; rather the public health issues were addressed by the range of conditions imposed in some or all of the seven consents.

Conditions required by the consents in relation to issues that could impact on public health are outlined below.

3.7.1 Air Emissions control, testing and discharge monitoring

- Rotary dryer to be fitted with a temperature monitor and control system to maintain the dryer inlet temperature at less than 120˚C and if the temperature exceeds 120˚C then the dryer shall be automatically shut down.
- Stack emissions testing during the PoP and/or first month of operation
  - During the first month of testing the plant to be processing the most heavily contaminated soils and to be operating at least 75% of its maximum capacity
  - Stack testing to be carried out at weekly intervals for the first month of operation or until completion of the PoP
  - PoP stack testing to consist of no less than three "runs" of not less than six hours
  - Stack testing for:
    - lindane, aldrin, dieldrin, DDE, DDD, DDT, heptachlor, manganese, chromium, nickel
    - three samples for: unintentionally produced Persistent Organic Pollutants (POPs), including dioxins, furans, PCBs, and hexachlorobenzene
    - three samples for: particulate fractions of PM_{10}
  - Daily TSP during the first month to also include PM_{10} on at least 10 days of maximum Site remediation operations. If PM_{10} > 30% of TSP then an ongoing sampling programme required as determined by the Compliance Officer
- Ambient air monitoring after the first month or when PoP complete
  - Three monitoring sites to be in the general locations of:
    - One site north/east and one site south/west of the Site boundary and to be representative of the closest residential neighbours and approved by the Compliance Officer
    - Third site to be in a vicinity that best represents ambient conditions and approved by the Compliance Officer
  - Daily TSP < 80 $\mu g/m^3$ above background as a 24 hour average
  - Filter and deposition gauge samples to measure ambient concentrations and deposition rates for lindane, aldrin, dieldrin, DDE, DDD, DDT, heptachlor, manganese, chromium, nickel and particulates
- Stack emissions testing after the first month or when PoP complete
  - three monthly testing when the plant was operating at normal load for gaseous and particulate fractions - lindane, aldrin, dieldrin, DDE, DDD, DDT, heptachlor, manganese, chromium, nickel
  - POPs including dioxins – only required if concerns after the first month of testing as determined by the Compliance Officer
- Dispersion modelling assessment of the effects of the discharge at the end of the first month of operation and thereafter six monthly

3.7.2 Groundwater control and monitoring

- Take all practicable steps to limit the discharge and migration of contaminants in groundwater
- Monitoring prior to commencement of remedial works and thereafter:

- on a monthly basis at monitoring locations as shown in the AEE
- on a three monthly basis at four private bores in Tahi Street

- Minimum parameters to be analysed:
  - Organochlorine pesticide suite
  - Acidic herbicides
  - A metals suite
  - pH, alkalinity, electrical conductivity
  - Other chemical analyses determined by the Consent Holder in consultation with the Compliance Officer
- Based on results of baseline sampling revise the provisional environmental threshold values (trigger levels for corrective action)

3.7.3 Stormwater control and monitoring

The Consent Holder was required, as far as practical, to minimise surface discharge of stormwater and to avoid discharging stormwater from the remedial works area to remediated coastal sediment areas. Stormwater discharges were to be monitored and were not to exceed specified criteria for contaminants and suspended sediments.

3.7.4 Marine sediments and shellfish sampling

- Macroinvertebrate (mudsnails) and marine sediment sampling required
- Timing of sampling to be before commencement of the remediation of the marine areas and at 12, 24 and 36 months following completion of works

3.7.5 Dust control

The Consent Holder was required to adopt the best practicable options (BPOs) to minimise the discharge of fugitive dust from the Site that is noxious, dangerous, offensive or objectionable. BPOs included wet suppression, minimising the height of stored soil piles, use of temporary covers, use of mobile windbreaks at working faces and restrictions on vehicle speeds.

3.7.6 Odour control

The Consent Holder was required to adopt the BPOs to minimise odour and no odour considered noxious, dangerous, offensive or objectionable was permitted to go beyond the Site boundary.

3.7.7 Noise control

Noise limits were set in the resource consents with lower sound levels before 0730 hours and after 1800 hours as measured at dwellings in the residential areas. No noise generating activities were to occur on Saturday evening or Sundays and Public Holidays.

Limits were set on the hours heavy traffic could enter or leave the Site.

Noise attenuation barriers were to be used close to an identified noise source where practical to do so.

The MCD plant was to be operated so as to minimise any special audible characteristics.

3.7.8 Vibration control

Threshold levels for continuous and transient vibrations were set and corrective measures required if the levels were in exceedance of these thresholds.

Vibration monitoring was to occur weekly during the first month of operation of the MCD plant and in response to any complaints received from neighbouring residents.

3.7.9 Total Hazard Index (THI)

A THI was to be calculated using the TSP monitoring data combined with the measured deposition data for lindane, aldrin, dieldrin, DDX, heptachlor, manganese, chromium and nickel on a monthly basis. This could be reduced to three monthly if the THI was < 0.5 for the first three months.

The calculations were to include "all exposure pathways (including dermal contact)" and must compare background risks to those generated by the Site activities. However the methodology developed for the THI only considered the following exposure pathways:

- Inhalation of organic compounds
- Ingestion of organic compounds
- Inhalation of metals
- Ingestion of metals

Total Hazard Index

Although the name may differ between agencies, the THI [27] [28] [29] is an internationally recognised and relatively widely used approach to assessing human health risk. It is applicable to "threshold compounds", i.e. substances for which there is a threshold below which adverse effects do not occur. It is not applicable to "non-threshold compounds", such as genotoxic carcinogens, which are assessed on the basis of risk.

The THI is a way of expressing the potential for adverse health effects from exposure to a group of substances at the same time (cumulative effects).

The steps in calculating the THI are:

1. Calculate an intake factor for each exposure pathway, e.g. inhalation or ingestion

2. Calculate the Chronic Daily Intake of each substance (the average amount that a person would be exposed to each day) using the intake factor and the concentration in the appropriate environmental media, e.g. in air for inhalation exposure.

3. Identify the appropriate toxicity factor from published data (e.g. World Health Organization). The toxicity factor is expressed as a Tolerable Daily Intake

4. Divide the Chronic Daily Intake by the Tolerable Daily Intake for each substance. The result is known as the Hazard Quotient.

5. Add the individual Hazard Quotients together to give the THI.

If the individual Hazard Quotient for a substance is less than 1, then the exposure to that substance is "acceptable", i.e. it is unlikely to cause any adverse effects on health.

If the THI (i.e. the sum of all the individual Hazard Quotients) is less than 1, then the cumulative exposure to all the substances is unlikely to cause any adverse effects on health.

It is important to note that the THI methodology is used to assess long term (chronic) health effects. The tolerable daily intakes (which are used in the THI calculation) are described by the World Health Organization as "an estimate of the intake of a substance over a lifetime that is considered to be without appreciable health risk". It is generally accepted that short term exposure exceeding the Tolerable Daily Intake is not a cause of concern provided the intake over time does not appreciably exceed the level set.

3.7.10 Peer Review Panel

Under the resource consents the Consent Holder (initially Thiess, then MfE) was to request TDC to appoint a PRP, which was to include a nominated representative of the Environment and Planning Manager of the Council (TDC) and to be funded by the Consent Holder. The panel was to consist of a range of experts in some or all of the following: Noise, Air Quality, Vibration, Pesticide Contamination (including POPs), Water Resources and Coastal Ecology.[e]

The role of the PRP was to "review, comment and make recommendations on the management plans" during the PoP and to continue this activity in regard to any changes to the management plans and monitoring reports. Recommendations were to be made to the TDC's Environment and Planning Manager and the Council's Compliance Officer. The PRP was required to meet at least three monthly.

3.7.11 Complaints Register

A complaints register relating to noise, dust, odour, vibration and other nuisances from the Site was to be maintained by the Consent Holder for the duration of the Site remediation. Details of the nuisance, the most likely cause of the nuisance and any corrective actions taken to mitigate the nuisance were to be recorded in the register and provided to TDC's Compliance Officer within 24 hours of receipt of any complaints.

3.8 Timeline of activities related to the remediation project

The following table highlights the timeframe for important events relevant to the remediation project.

2001	
	Thiess Services Pty Ltd awarded the contract to remediate the FCC site with EDL as a subcontractor offering MCD technology
	Thiess commences preliminary investigation to identify contaminated soil and quantities of soil requiring treatment
2002	
January	Round One of demonstration MCD plant operation (2 days)
	Round Two of demonstration MCD plant operation (3 days)
2003	
February	Thiess submits application and AEE to TDC for FCC site remediation
November	Resource consents granted by TDC. Following appeal by two parties the Environment Court confirms consents with amendments
2004	
February	First Peer Review Panel Meeting. PRP does not include a specialist air quality expert
Feb - April	Proof of Performance Testing and first month of operation
August	Thiess withdraws from the project
	MfE becomes Consent Holder and takes over management of project from Thiess
September	Work begins on Site including clearance of vegetation, excavation of soil "cells" and screening of soil

[e] The Site Auditor (remediation) is also recorded as attending, or giving apologies for, most PRP meetings from April 2005.

October	EMS appointed site manager by MfE
November	MCD plant starts operating and processing contaminated soil full time
December	Carbon filter losing integrity and repaired with chicken wire
2005	
	Slag replaced by copper sulphate, and diammonium phosphate added, as process reagents in the MCD reactor early in the year
January	HiVol monitors replaced by PUF samplers
March	Complete failure of carbon filter reported for first time
July	MCD plant shutdown late in month for modifications to the AECS
September	Modifications to the AECS completed
October	
November	Monthly changes of filter adopted as standard practice
December	Specialist air quality expert joins PRP (Dr Craig Stevenson)
2006	
March	Records of rotary dryer temperature available
September	Dioxin tests on activated carbon from the filter
2007	
March	Dioxins tested in stack emissions
September	MfE issues EDL a certificate of practical completion
2008	
June	TDC signs off the certificate of practical completion
July	PCE report Investigation into the remediation of the contaminated site at Mapua released
November	Report on the Site Validation by consultants SKM released by MfE
2009	
July	Report of the Audit of the Remediation of the former FCC site by consultants PDP released by MfE

"Period of Concern"

(AECS mal functioning and/or no temperature records for rotary dryer)

4. Community Health Concerns

Health concerns reported in local residents helped to inform the NMDHB PHS investigation as they provided another source of information on potential hazards and possible human health effects resulting from the remediation.

4.1 Complaints Register

A review of the complaints register for the period of the remediation showed that the majority of complaints largely came from people who lived or worked adjacent to the Site. The complainants came from at least 27 household or work locations[30] - this is approximately 10% of the 300 households reported by MfE as estimated to be in the potentially impacted area.[31]

The most commonly reported complaint was odour, closely followed by dust, then noise and vibration. For the odour complaints many reported a chemical smell, several reported that they thought they could smell ammonia and at least five people reported that the smell was of cleaning or dry cleaning fluid. All complaints related to hazards that had been identified during the Resource Consent process.

4.2 Information reported to the Public Health Service

Information about health concerns was recorded from approximately 30 local residents who responded to the request to contact the NMDHB PHS.

Health effects thought to be associated with the Site that were raised by residents are:

- Upper respiratory tract irritation, usually reported as being temporally associated with odour and/or dust
- Nose bleeds - evidence was available from the EMS investigation of one complaint (involving several people and occasions) that for several people these were associated with increased dust episodes from the Site. A review by the NMDHB PHS of the TSP readings from the closest ambient air monitoring site to the complainants also supports this association.
- Eye problems – streaming, glaucoma
- Wheezing
- Thyroid disorders
- Tinnitus and/or headaches – usually associated with noise and vibration
- Nausea – associated with vibration
- Feeling stressed – associated with ongoing odour, noise, dust and vibration
- Anxiety – worry about effects of vibration on house, possible long term effects on health of self or children
- Other – hypertension, cancer

The most common health complaints reported to the NMDHB PHS were upper respiratory tract irritation, eye symptoms, stress and anxiety.

Health effects thought to be associated with the Site and reported by GPs were:

- Two patients who worked at the same location, close to the Site, found to be hypothyroid in 2006 and to have a sterile non-specific haematuria
- Odour and vibration were the most common concerns reported to the Mapua Health Centre
- No patterns of symptoms or illness were identified by GPs among patients attending the Mapua Health Centre

A number of anecdotal reports about third parties with health concerns were also received and in this situation it was requested that those parties contact the NMDHB PHS directly.

5. Risk Assessment: Air Emissions

5.1 Chemicals included in the THI

The THI was the risk assessment method required for air emissions of the chemicals listed as of concern in the Resource Consents. Further investigation (by the PRP and NMDHB PHS) led to several revisions of the exposure pathways and chemicals included in the THI. The resulting final two reports were commissioned by the NMDHB PHS, the *Recalculation of Hazard Indices and Cancer Risks for the Mapua FCC Contaminated Site Remediation Project* [32] and the *Calculation of Hazard Indices and Cancer Risks for the Additional Metals for the Mapua FCC Contaminated Site Remediation Project* [33] (AES 2009 Reports). These reports may be found in full in Appendix 1 and Appendix 2 respectively.

These final reports covered the following chemicals:

- Organochlorines as required by the Resource Consents:
  - o,p'-DDT
  - p,p'-DDT
  - p,p'-DDE
  - p,p'-TDE (DDD)
  - aldrin
  - dieldrin
  - lindane (gamma-HCH)
  - heptachlor
- Additional organochlorines for which monitoring data was also available:
  - alpha-chlordane
  - gamma-chlordane
  - HCB
  - alpha-HCH
  - beta-HCH
  - heptachlor epoxide
- Metals as required by the Resource Consents:
  - chromium
  - manganese
  - nickel
- Additional metals considered to be of concern for which monitoring data were also available:
  - arsenic
  - copper
  - lead
  - selenium

In Section 3.6.2 it was discussed how these chemicals may be discharged from the Site as:

- stack emissions
- fugitive emissions from the rotary dryer or the MCD reactor

- fugitive emissions from treated or untreated soil

These emissions could be in either the gaseous or particulate phase. Therefore exposure to these chemicals by the public [or by remediation project staff working off Site in the EDL laboratory (EDL Lab) or in the EMS offices] could occur through inhalation, soil ingestion, currently depositing dust ingestion, dermal uptake from soil, dermal exposure through air, ingestion of contaminated roof water and consumption of local produce. It was reported to the NMDHB PHS that workers and iwi monitors on Site were protected from exposure by the use of Personal Protective Equipment (PPE) as required by the various contractors and DoL.[34] [35]

In general the potential of an adverse health effect resulting from chemical exposure occurs with long term (chronic) exposure, unless the short term exposure has been to levels sufficient to cause acute poisoning. Therefore sporadic higher readings from ambient air monitoring in any particular month are not a predictor of health risk unless the elevated level was sufficient to cause acute poisoning. Thus the average reading over the course of the remediation is the most useful predictor of health risk.

The detailed reports on the THI calculations are in Appendix 1 and 2. The calculations are dependent on the Site monitoring data, external reference data and ensuring that all relevant exposure pathways are included. Site monitoring stations were located at 14 Aranui Road (outside the EDL Lab), at 10 Coutts Place and at 31 Tahi Street. In the PCE report methodological issues with the sampling done for the ambient air monitoring programme during the remediation were identified.[1] The PCE also noted deficiencies in the range of chemicals measured, particularly identifying dioxins and mercury as chemicals of concern. Since the Resource Consents were granted in 2003 MfE has published new guideline values for organochlorine exposures. In undertaking recalculation of the THI it was decided to incorporate all chemicals tested as part of the monitoring programme but not previously reported on and to use the most conservative international guideline values for Tolerable Daily Intake (TDI). The TDI values selected as "most conservative guideline values" for this purpose were reviewed and the choice supported by an independent toxicologist.[36] Unfortunately the chemicals monitored did not include dioxins or mercury. The methodological issues in the monitoring programme identified by the PCE have been addressed in the September and October 2009 AES reports and adjustments made, using a conservative approach where there was uncertainty.

Cancer risk from exposure to the air emissions has also been calculated in the AES 2009 reports using a non-threshold approach. A conservative (worst case scenario) approach was used where there was uncertainty on carcinogenicity for any chemical or metal.

The average THI value for OCPs calculated over the life of the project for a 3 year old child, using the most conservative TDI values, ranges from 0.11 – 0.44 for the three monitoring sites. For adults the range for the average THI is 0.035 – 0.162. The highest THIs result from emissions recorded at the EDL Lab site and the largest contributions to the THI are from DDX and dieldrin. Although some individual months had THI readings over 0.5, ranging up to 1.11, these exposure levels are not sufficient to cause acute health risk. The biggest contributor to the THI for OCPs calculated for adults and a three year old child at all monitoring sites was from the dust ingestion pathway (70 – 82%).

The average THIs over the life of the project calculated for the metals are well below 0.5 at all monitoring sites, excluding several monthly results (September 2005 and June 2006) that were considered to be obviously unreliable data (See the reports in Appendix 1 and 2 for more detail). Although it was decided to include all metals with monitoring data available in the revised THI and cancer risk calculations the PCE had reported that arsenic was the only metal not originally included in the monitoring programme that perhaps should have been,[1] and it was noted in the AES 2009 Report that the inclusion of manganese, chromium and nickel in the calculation of THI values for the remediation project was debatable (See Appendix 1 for discussion). The highest average THI calculated for any of the metals over the lifetime of the project was 0.15 for arsenic.

The cancer risks calculated over the period of the remediation project were all less than the most commonly accepted level of incremental cancer risk from exposure to an environmental carcinogen of 10 per million for both a three year old child and adults.

The overall conclusion from these two detailed reports on the THI calculations (See Appendix 1 and 2) is that adverse health effects are unlikely to have resulted from exposures to any of the contaminants included in the AES 2009 reports (see list on previous page) at the three ambient air monitoring sites for the remediation project.

However this statement must be qualified as follows:

- The THI can only provide a risk assessment for those chemicals for which monitoring data are available
- Collection of this data had methodological flaws that have been adjusted for, using a conservative approach, in these revised calculations but this has required several assumptions
- The data collected were dependent on the location of the ambient air and deposition gauge monitoring sites
    - The prevailing winds for the Site are northeast (NE) and southwest (SW).
    - The three sites used were located west of the Site close to the Site boundary (10 Coutts Place); north to northeast of the Site close to the boundary (EDL Lab); and south of the site approximately nine properties depth back from the Site (31 Tahi St)
    - 31 Tahi Street was originally intended as the "background" monitoring station
    - By April 2005 the PRP panel recognised that the location of the air samplers did not pick up all the contamination reaching Tahi Street residents and proposed using personal air monitors to assess the Site environment, and possibly these neighbouring properties for gaseous and particulate contaminants[37]
    - In August 2005 the Compliance Officer reported to the PRP that the meteorological data collected over the past eight months from Mapua indicated that the location of the monitoring sites did not meet the intent of the Resource Consents and that this affected both the TSP readings and the data going into the THI.[38] The PRP recommended that the monitoring sites were not changed but that personal air monitoring pumps were used in addition to the existing sites. However the PRP did suggest that as the 31 Tahi St site sampler may have to be moved for other reasons this could be moved to 18 Tahi St, just beyond the Site boundary and closer to SW of the Site.[12] This did not occur.
    - In the Compliance Officer's report to the December 2005 PRP meeting it was noted that the dispersion modelling showed that the SW side of Tahi Street was the most exposed to the stack emissions and that this was not being monitored for air quality. It was also reported that MfE had not adopted the previous PRP recommendation that mobile pumps be used and that TDC was considering purchasing a mobile pump for this purpose. It was reported that 18 Tahi Street would be the most representative of "close" neighbours to the SW of the Site.[9]
    - During the remediation two additional deposition gauges were installed in response to dust complaints from nearby residents.[39] The additional gauge at 13 Tahi Street was moved in January 2006 to 20 Tahi St.[40] However there was no monitoring for OCPs at this location but, as it was noted to be high for deposited particulates, it was suggested that this location should also be monitored for OCPs. Although a specific unit to monitor for OCPs was apparently on order the author could not find any record that this monitoring eventuated.[40]

- The Compliance Officer has since reported that MfE declined to support TDC in the use of a mobile monitor to assess these close neighbouring properties in Tahi Street for OCP levels and that TDC did not proceed with this monitoring.[41]

The location of the monitoring sites and direction of prevailing winds means that, while it is reasonable to rely on the THI calculations to assess the risk of adverse health effects from exposures to these contaminants for those people living west or north of the Site, there is more uncertainty that the THI can be relied on to assess the risk for those people living south of the Site, particularly those on the west side of Tahi Street or closer to the Site than 31 Tahi Street for those living on the east side of the street. This is approximately 30 residences if using the deposition pattern calculated for the dioxins dispersion and deposition modelling (see Figure 4). Although the deposition modelling for OCP emissions from the Site carried out by SKM throughout the Site remediation could potentially be used to predict exposure for these properties south of the Site it has been shown that this modelling significantly underestimated the actual Site emissions recorded by the PUF samplers at the monitoring sites. The reasons for this are further discussed in Section 5.2.5, but it is relevant to note that the peer reviewer of the AES 2009 reports concurs that there was a "significant fugitive emission component in total OCP emissions from the Site." [42]

During the investigations the results of the monitoring programme of blood OCP levels in the Site workers and iwi monitors were reviewed and discussed with the DoL investigator. The use of this data to infer potential exposure of the public living or working close to the Site was also considered in a discussion with the DoL and PCE investigators. As the Site workers and iwi monitors used PPE while on Site it was decided that it would not be valid to extrapolate this monitoring data to the public who were not protected by PPE.

5.2 Other chemicals

Other chemicals of concern that may have been discharged from the Site were identified in the PCE Report[1] and in the author's discussions with members of the community and review of the Complaints register. These are dealt with separately below in two parts depending on whether a risk assessment was carried out (Part I) or not (Part II). The chemicals are arranged alphabetically in each part.

Part I: Other chemicals - risk assessment

5.2.1 Ammonia

Ammonia occurs naturally in the environment, and humans are regularly exposed to low levels of ammonia in air, soil, and water.[43] It is essential for the biological functioning of mammals.

It is rapidly "recycled" from soil and water being taken up by plants and micro-organisms. For instance fertilizer application may result in ammonia concentrations of 2 – 3000 ppm with levels dropping to 2 – 850 ppm after five days.

Ammonia has a strong, irritating odour – people can smell it in air if the concentration is > 50 ppm.[43]

The most common route of intake from environmental exposure is by inhalation and most ammonia is exhaled after breathing it in. If it enters the body from food or water it rapidly changes into other substances that are not harmful to humans and the remainder is excreted in urine within a few days.

Ammonia causes immediate irritation to the nose and throat in humans with levels > 50 ppm but studies have shown that people repeatedly exposed to ammonia develop tolerance. Studies of chronic exposure to levels < 25 ppm showed little effect on lung function and odour sensitivity in workers at some factories but other studies showed an association between exposure to pollutants, including ammonia and dust, and an increase in respiratory

symptoms such as bronchial reactivity and asthma symptoms, cough and/or a decrease in lung function. However the contribution of ammonia to these symptoms was unclear.[43]

It is slightly irritating to human eyes in brief exposures of 100 ppm and immediately irritating at about 700 ppm but exposure to an air concentration of 250 ppm is bearable for most people for 30 – 60 minutes.[43]

The skin is very sensitive to airborne ammonia or ammonia dissolved in water. The severity of damage is proportional to the concentration and duration of exposure. [43]

In short-term inhalational exposure ammonia is almost completely retained in the nasal mucosa regardless of its concentration in air (up to 500 ppm). Increased ammonia in the body (in various forms) is generally not seen following inhalation or dermal exposure, even when there has been massive exposure.[43]

The Agency for Toxic Substances and Disease Registry (ATSDR) states that "Toxic levels do not develop as a result of chronic inhalation exposure because the body has multiple effective mechanisms for detoxifying and excreting it" and that there is no evidence that children are more susceptible to effects of ammonia than adults.[43]

People who are hyper-reactive to other respiratory irritants or who are asthmatic, would be expected to be more susceptible to ammonia inhalation effects. There is evidence that ammonia inhalation can exacerbate existing symptoms including cough, wheeze, nasal complaints, eye irritation, throat discomfort and skin irritation.[43]

Ammonia was known to be a fugitive discharge from the MCD reactor. Ammonia was reported to the PRP to have "wafted" across Tahi Street from a high pile of treated fines in September 2006.[44] The Compliance Officer also reported that there was ammonia discharge from the treated fines after processing of highly contaminated infeed when "surplus urea" was added to the MCD reactor and that this odour could travel onto Aranui Road or Tahi Street and cause eye or throat irritation to members of the public.[45] Possible ammonia emissions were also raised as a cause of odour coming from the Site by some community members who reported health concerns to the NMDHB PHS. On direct questioning (by the author) of people with respiratory tract or eye health concerns, only a few of these people had been aware of an ammonia odour. The people questioned all thought they would have recognised an ammonia odour.

Personal dosimeters were used onsite for some workers and at selected locations around the Site to test for emissions of some chemicals, including ammonia, not included in the formal stack testing and ambient air monitoring programme. It was reported to the PRP that ammonia was detected on Site next to the pug mill [44] and one reading was recorded as 175 ppm.[20]

The NMDHB PHS requested any monitoring results (for ammonia) from EMS but these were not provided. However the NMDHB PHS was advised verbally that worker and Site perimeter levels measured by the personal monitors were negative or "low".[34] Additionally, in May 2007, following ongoing complaints of eye and nasal irritation associated with acrid odour, the Site Manager placed a Gastec ammonia dosimeter adjacent to 17 Tahi Street. This was said to have been left for 10 hours and it was reported to NMDHB PHS that no ammonia was detected (detection limit 2 ppm). The Site Manager planned to obtain an ammonia detector to monitor in real time (detection limit of 1 ppm) but various delays occurred and the NMDHB PHS was informed that the detector was not received.[46]

It seems likely that there may have been regular exposure to low levels of ammonia by residents adjacent to the Site resulting in some of the odour complaints and symptoms of eye and throat irritation.

This level of exposure is unlikely to have caused lasting or serious adverse health effects.

5.2.2 Atrazine

Atrazine is a herbicide and was detected in soil samples. As it is more persistent than other herbicides found on Site such as simazine and amitrole, the PCE suggested perhaps this should have been included in the monitoring.[1]

Atrazine has low acute toxicity to humans and there is limited evidence of any health effects related to chronic exposure. It degrades once in contact with the soil (within a year under normal application regimes) and does not bioaccumulate in the food chain.[36]

It is possible that residents were exposed to low levels of atrazine during the remediation but it is unlikely that any low level exposure would cause any adverse health effects.

5.2.3 Benzene

Benzene is an aromatic hydrocarbon and is a natural component of crude oil. It is a component of products derived from coal and petroleum and is found in gasoline and other fuels. It may be produced by burning natural products. Benzene has a characteristic sweet odour and most people can begin to smell benzene in the air at approximately 60 ppm and recognise it as benzene at 100 ppm (approximately 320 mg/m^3).[47]

Benzene is toxic to humans with inhalation the most usual route of exposure but ingestion and skin contact are also possible routes.[48] Once inhaled about 50% of the benzene enters the bloodstream and may be temporarily stored in the bone marrow and fat and about 20% is exhaled unchanged. [49] Benzene is metabolised in the liver or bone marrow and most of the metabolites leave the body within 48 hours of exposure.[47] Short term exposure to low levels may cause eye irritation and higher level exposure may cause drowsiness, rapid heart rate, confusion and unconsciousness. Chronic exposure to low levels may cause anaemia and cancer (particularly various types of leukaemia).[48] Most information on health risk comes from studies of workers with long term exposure to high levels of benzene when it was used as a solvent in some work places.[47 49] Members of the public are exposed to benzene daily at much lower levels from sources such as exhaust fumes, petrol fumes at filling stations and tobacco smoke. [47 49]

Benzene was not recorded as being a chemical known to have been on site from historic records but it was detected in carbon filter testing in January 2006.[18] Benzene had been identified as a possible by-product from the dehalogenation process prior to the remediation[1] and also as a possible by-product of thermal decomposition of OCPs during the PCE investigation.[5] In February 2006 the PRP raised the concern of possible ambient air emissions of benzene from the Site. Benzene monitoring was recommended by the PRP using personal dosimeters (badge monitors) at the location of three of the deposition gauges (EDL Lab, Coutts Place and 20 Tahi Street) to assess possible Site emissions.[18]

In May 2006 it was reported to the PRP that monitoring for benzene had not been undertaken and that the level being discharged had been calculated, based on the carbon filter tests, as 72 µg/m^3 and that the New Zealand ambient air guideline at the time was 10 µg/m^3. (It is unclear to the author whether the calculated concentration is an annual average, as is the ambient air guideline value.) At this meeting the PRP again recommended monitoring using badge monitors but in two locations only – 20 Tahi Street and near the MfE site office/site boundary. [19] It was reported that the only place VOCs such as benzene were detected, apart from in the EDL Lab, was on Site next to the pug mill. The PRP minutes state the monitoring for VOCs was done using a photo-ionisation detector (PID) and records discussion that these badge monitors may not detect low enough levels. Different monitors were recommended.[20] No further information was found in the PRP minutes in relation to this.

In the absence of ambient air monitoring or emission testing and the disagreement over whether the limited data available from the badge monitors were robust, it is unknown if the public was exposed to benzene.

Therefore no conclusion can be reached on any public health risk associated with possible benzene exposure from the remediation of the Site.

5.2.4 Chlorobenzene

Chlorobenzene is used as a solvent for some pesticide formulations, as a degreaser and to make other chemicals, including DDT. It is a liquid, evaporates readily and has an almond-like odour. It does not occur naturally in the environment and does not build up in the food

chain. It is slowly broken down if released to air, but is broken down rapidly by bacteria if released to soil, although some may evaporate into the air or filter into groundwater.[50]

Animal studies suggest that chlorobenzene can affect the liver, kidney and central nervous system but there is limited data on human health effects apart from that on workers exposed to high levels of chlorobenzene in the air. This is reported to have caused complaints of headaches, nausea, sleepiness, numbness and vomiting but this may have been due to other contaminants.[50] Chronic exposure of humans to chlorobenzene may affect the central nervous system causing numbness, increased sensation and muscle spasms.[51] No information is available on the carcinogenic effects of chlorobenzene in humans.[50]

Chlorobenzene was identified in the PCE report as a possible by-product of the dehalogenation of OCPs. The report also noted that chlorobenzene had been detected in the 2005 baseline investigation and may have been present due to natural microbial breakdown of OCPs and/or historical use as a solvent on Site.[1] There was no record of chlorobenzene being on Site in the Woodward Clyde 1992 report.[2] However it was detected in groundwater in both the East and West FCC sites as reported in the Woodward Clyde 1996 Report. The sampling location on the West FCC Site was in the vicinity of the solutions mixing plant whereas the sampling location on the East FCC Site was in the vicinity of the prills and pesticide manufacturing buildings and the finished goods store. Soil testing results in the same report record did not indicate the presence of chlorobenzene but sampling was limited to the West FCC site.[3] Further studies were advised in the Soil technical annex of the PCE report to "identify the nature, concentration and potential environmental impact of chlorobenzene in real MCD-treated, pesticide-contaminated soils" but this was not mentioned in the main body of the report.[1]

The presence of chlorobenzene in "soil and groundwater" was noted at the February 2006 PRP meeting by an MfE representative when benzene monitoring was being discussed but there was no further discussion recorded[18] or reference to this in the minutes of subsequent meetings. A review of the Tonkin and Taylor 2005 baseline investigation showed chlorobenzene as being detected in several groundwater and soil samples but not above the ecological screening level.[6] The levels recorded in the 2006 annual groundwater sampling were all below the threshold concentration.[52]

It appears likely that chlorobenzene was used historically on Site and may also have been a by-product of the MCD process. Any chlorobenzene in the soil would have been readily broken down, with some evaporating into air or filtering into groundwater. As the levels of chlorobenzene in groundwater and soil were either low or below the detection level in the sampling done in 2005 and 2006, and it had been recommended that groundwater not be used for drinking, it is unlikely that the public were exposed to elevated levels of chlorobenzene. Therefore it is unlikely there was a health risk associated with chlorobenzene exposure.

5.2.5 Dioxins

The term "dioxins" is generally used to refer to a group of chemicals that share similar chemical structures and properties. These belong to three related families – the polychlorinated dibenzo-*p*-dioxins (PCDDs), the polychlorinated dibenzofurans (PCDFs) and certain of the polychlorinated biphenyls (PCBs).[53] Dioxins are usually formed as by-products of human activities such as combustion and industrial processes, although they may also be formed naturally as a result of geological processes and natural combustion or in sewage sludge, forest soils and compost.[36 53] They usually exist in the environment as mixtures, are environmentally persistent and accumulate in the tissues of animals.[53 54]

Toxicity among the 17 dioxins considered to pose health or environmental risk varies with the most toxic being 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD).[36 53] Toxic equivalency factors (TEFs) are assigned to each of the toxic dioxins based on relative potency with TCDD. This allows the toxicity of any mixture of dioxins to be determined by summing the toxicity weighted concentration of each dioxin in the mixture to give a single concentration known as a Toxic Equivalency Quotient (TEQ).[36 55]

In general humans may be exposed to dioxins in food, air, soil and water. Uptake is most likely by ingestion, inhalation or dermal routes. The predominant source of exposure in countries such as New Zealand has been through consumption of meat, dairy products, eggs and fish. [36 53]

Dioxins are known to produce biochemical changes such as enzyme induction in humans and animals but the clinical significance of this is unclear. The response in an exposed individual appears dependent on level and length of exposure as well as individual susceptibility. [36 53] Exposure to high doses of TCDD, or equivalent other dioxins, can cause a severe skin condition, known as chloracne, within one week to several months after exposure. Mild but transient liver injury may also be associated with such exposures. [36 53]

Most international authorities regard TCDD as a carcinogen (cancer-causing) but there is disagreement over how strong this association is and whether a threshold approach to risk assessment is appropriate. [36] As well as chloracne, soft tissue sarcoma, non-Hodgkin's lymphoma, Hodgkin's disease and chronic lymphocytic leukaemia (including all chronic B-cell leukaemias) have all been assessed by the US Institute of Medicine (National Academy of Sciences) as having "sufficient evidence" of association with dioxin exposure. Some other cancers, cardiovascular diseases, neurological diseases, spina bifida and also Type 2 diabetes have been assessed as having "limited or suggestive evidence" of association. [36 53]

Although animal studies show immune, reproductive and developmental effects, there is a lack of relevant evidence available for humans.[53] However there have been several studies that assessed the possible association between TCDD exposure and developmental effects in humans, none of which showed a significant association between a particular birth defect and exposure. [36]

Dioxins could form during the remediation process in two ways:

- high temperatures in the rotary dryer (in the 200-400˚C range) could cause thermal decomposition (breakdown) of the OCPs with dioxins as one by-product. Dioxins formed in this way would be emitted in the gaseous phase[56 57]
- *de novo* synthesis of dioxins from direct exposure of the soil to the diesel burner flame or if the soil temperature was above 250˚C. Dioxins formed in this way could be emitted in both gaseous and particulate phases.[56] Copper is known to be a strong catalyst for this process[58] and would have been present in any soil being retreated as copper sulphate was a process reagent.

There is limited evidence that dioxins were formed and emitted from the stack of the rotary dryer:

- During the PoP trials dioxins were included in the stack emission tests – four tests while soil was being processed and one when no soil was being processed through the rotary dryer and MCD reactor ("dry run"). Results showed dioxin levels for three of the tests were indistinguishable from the "dry run" but the fourth test results recorded dioxin levels of 0.56 ng TEQ/m^3, with almost all the dioxins being in the gaseous phase. EDL suggested that this elevated emission was due to overheating of the dryer consequent to frequent stoppages of the outlet auger and that new procedures put in place meant this would not recur.[22]
- Ongoing problems with functioning of the AECS, uncertainty about the temperatures in the rotary dryer and high levels of OCPs in the stack emissions testing led to the PRP recommending further stack emissions testing for dioxins in 2005. The MfE did not agree to this until 2007. The results were well below the dioxin emission limit of 0.1 ng TEQ/m^3 set by the European Commission Waste Incineration Directive.[59] The average temperature in the chamber of the dryer at the time of this test was less than 250˚C. This was lower than typical temperatures reported during the period for which temperatures were recorded (mid February 2006 – July 2007) of 250 - 400˚C, [56] and the average temperature of 310˚C for the period August 2006 – July 2007.[1]

- Dioxin tests were also carried out on the activated carbon removed from the filter in September 2006. This carbon had been in place for one month. Concentrations were compared from a range of depths throughout the filter. The results estimated the average concentration of the dioxins entering the filter as 0.018 ng TEQ/m^3 and those leaving the filter as negligible. The efficiency of the carbon filter was estimated to be 95-99.5%.[60] Dryer temperatures were in the 250 – 300˚C range throughout the test month but the OCP throughput for this month is recorded as almost the lowest throughput for the year to date.[60] This was discussed by the PRP and thought to indicate an acceptably low level of dioxin emissions being "about the same as Christchurch winter air emissions".[61]

However these latter two tests do not provide information about formation and emission of dioxins during periods of the remediation when:

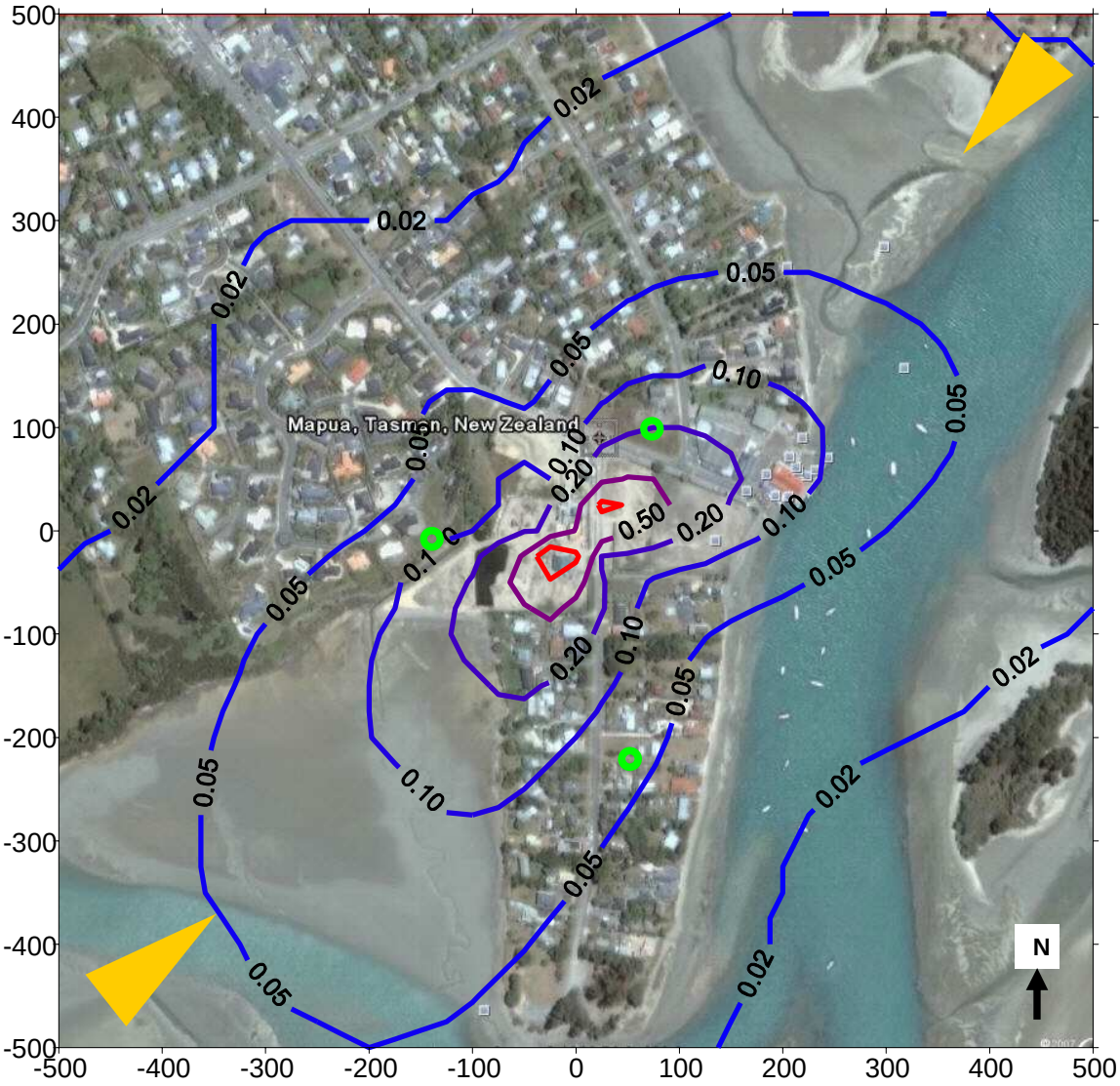
- Dryer temperatures were higher or unknown
- Infeed OCP concentrations were high (particularly during the first year of MCD plant operation when the most contaminated soil was being processed)
- The AECS was malfunctioning or had failed completely.

In an attempt to address this uncertainty the NMDHB PHS commissioned a report from Dr Craig Stevenson that would model a "worst case scenario" for dioxins exposure during the remediation and use this information to characterise the risk. The resulting report[59] can be found in Appendix 3.

After reviewing all information available at the time on dioxins formation in the dryer, stack emissions and the AECS operation, a dioxins emission rate of 0.5 ng TEQ/m^3 was chosen. This was based on what was considered to be a "one off" high emission concentration recorded during the PoP trials. For the purposes of the model it was assumed that this concentration of dioxins was emitted whenever the MCD plant was operating during the period of November 2004 – October 2005. The period chosen for the modelling was specifically identified as being of concern in the PCE report.[1] A period of a year was used to allow for comparison of the predicted concentrations with the annual average concentrations of dioxins measured at a number of locations around New Zealand under the MfE Organochlorines Programme during 1996/97. [59]

These concentrations were then used to predict annual deposition rates to feed into the exposure assessment. The deposition rates were likely to have been overestimated because, for this purpose, all of the dioxins were assumed to be in particulate phase which would give a higher rate than if allowance had been made for the proportion of dioxins being in the gaseous phase (which do not deposit as readily). The deposition rates are shown in Figure 4.[59] This figure can also be used to indicate the deposition pattern for any of the chemicals emitted from the Site and is thus a useful tool in assessing the representativeness of the locations of the ambient air and deposition gauge monitoring sites (See the last paragraph of section 5.1).

Figure 4: Predicted annual deposition rates (wet and dry) of dioxins (ng TEQ/m^2) for 1 November 2004 - 31 October 2005



A multi-pathway exposure assessment was then used to estimate overall dioxins exposures for people living at the residential property most affected by the modelled emissions. This assessment used conservative assumptions such as that all residents in the house were present at the property throughout the modelled year, obtained all their drinking water from the roof of their house and grew 100% of their consumption of above ground produce (e.g. lettuce, tomatoes), chicken and eggs. For an adult this would result in an incremental intake of dioxin of 0.02 pg TEQ per kg of bodyweight per day. For a three year old child the incremental intake of dioxin would be 0.06 pg TEQ per kg of bodyweight per day. These are both less than 8% of the typical New Zealand dietary intake, as determined in 1997.[59] However, because the emission rate of 0.5 ng TEQ/m^3 was used for both the particulate and gaseous exposure pathways in this assessment, the report notes that this will have resulted in an overestimation of intakes from particulate sources as almost all the dioxins in the high

test were emitted in the gaseous phase. In the report the largest contributor to incremental dioxin intakes was assessed as being from particulate exposure pathways.[59]

Since this report was prepared additional information has become available that suggests there is increased uncertainty about some of the assumptions used to determine the dioxins emission rate used in the modelling.

- The concentrations of the OCPs in the soil used for the PoP trials was considerably lower than those in the soils being processed during the period November 2004 – October 2005.[23]
- There are no temperature records for the dryer for 2005 but there is both circumstantial and anecdotal evidence that the dryer was operated at high enough temperatures to cause dioxin formation:
  - The elevated levels of OCPs in stack tests in 2005 suggest that temperatures were high enough to cause volatilisation of OCPs in the dryer (see Section 3.5.1)
  - Compliance Officer comments that one EDL staff member believed in "roasting" the soil to achieve successful treatment (see Section 3.5.1)
  - The emissions from the plant stack were often highly acidic causing severe corrosion to the structure of the carbon filter, the stack itself and the roof. Hydrogen chloride was one source of this acidity which is likely to be present due to thermal breakdown of OCPs[10 18 56 5] – this supports the contention of the occurrence of high dryer temperatures.
- SKM suggested that the lack of correlation between their dispersion modelling results, which were based on the stack emissions testing, and the ambient air monitoring results during 2005 where the modelling gave lower results for deposition of OCPs at monitoring sites (see section 3.5.1), may be due to three reasons: [24 25]
  - Variations in the concentrations of OCPs in the infeed soil [presumably this means between the infeed soil OCP concentrations during the stack tests and the average for the rest of the month]
  - Changes in the plant operating parameters and its efficiencies [one parameter clearly known to be linked to changes in OCP emissions is temperature – if lower than usual during the stack test compared with the rest of the month this would account for the lack of correlation]
  - Modelling not taking into account fugitive emissions from the MCD plant, soil piles and other dust from the Site
- Almost all the dioxins measured in the elevated PoP trial test were in the gaseous phase, indicating precursor synthesis from thermal breakdown of OCPs and not *de novo* synthesis.[56] *De novo* synthesis requires a temperature of at least 250˚C but it is thought that thermal breakdown of OCPs may occur at lower temperatures (200-400˚C).[5] Thus dioxins might form at a lower temperature than considered in the modelling assumptions.[56]
- There is no information that suggests the AECS was not functional during the PoP trial test that resulted in the elevated dioxins reading, apart from a statement that it was "shut down".[22] An expert opinion is that the only powered part of the system would have been the venturi scrubber fan and that shutting this down would be expected to reduce the gas flow rate to the stack and hence should have been noticed by the stack tester.[56] The stack tester's log for 5 April, 2004 in the PoP report records that the "venturi was off for half an hour, kiln feed rate was 5 tph".[22] There are no other entries recording a shut down of the AECS. An expert opinion is that it is unlikely shutting off the venturi scrubber fan would significantly reduce the efficiency of the carbon filter.[56] Therefore it can be assumed the majority of any dioxins formed during this test trial should have been removed by the AECS (the carbon filter was later tested and found to be 95-99.5% efficient[60]). This

suggests that the concentration of dioxins formed in the dryer during the PoP trial resulting in the elevated dioxins reading may have been up to 200 times higher than the level used in the dioxins dispersion and deposition modelling report.[59]

All of these factors suggest that there is considerably more uncertainty as to the possible concentrations of dioxins that may have been emitted from the stack and dispersed from the Site than the dioxins dispersion and deposition modelling report[59] concluded. This concentration may have exceeded the high dioxins emission rate measured during the PoP trial.

There is reasonable evidence that members of the public in the vicinity of the Site were exposed to dioxins discharged from the Site during the remediation. Most of any dioxins discharged are likely to have been in the gaseous rather than the particulate phase. There were no cases of chloracne reported to the NMDHB PHS during the investigation, suggesting that any exposure was not likely to have been to a high level of TCDD, or equivalent other dioxins.

In the absence of ambient air monitoring, along with the uncertainty regarding the dioxins emission rate used for the modelling exercise, the extent of exposure is unknown. However the duration of exposure was most likely limited to the period when elevated dryer temperatures coincided with a poorly functioning AECS which was for approximately 18 months. Whether the concentration of dioxins or duration of exposure was sufficient to result in a public health risk is unknown.

5.2.6 Pentachlorophenol (PCP)

PCP is a fungicide and was identified by PCE as a chemical that possibly should have been included in the monitoring regime. However PCE did not appear to consider this a high risk chemical of concern.[1]

PCP is a potent skin, eye and upper respiratory tract irritant. The most significant exposure route is usually skin[53] and almost all reports of human toxicity have occurred after direct skin exposure and absorption. [36] Chloracne may occur following exposure to high doses, but this is now thought to be caused by the frequent presence of dioxins contaminants in earlier formulations of PCP. [36]

There is no evidence from the Complaints Register or reports of health concerns from the community or GPs that skin complaints were a problem associated with the Mapua Site remediation.

Although there is uncertainty about exposure of the public to PCP due to the lack of ambient air monitoring, significant exposure seems unlikely due to lack of opportunity for direct skin contact. Therefore it is unlikely that PCP presented a health risk during the remediation.

5.2.7 Polychlorinated Biphenyls (PCBs)

PCBs were widely used in transformers and capacitors, lubricants, paints, plasticisers and as pesticide extenders. Commercial preparations usually contained a mixture of PCBs. There are 209 different congeners (different structures) of PCBs of which 12 cause similar toxic responses to those elicited by TCDD and hence are referred to as dioxin-like PCBs. Dioxin-like PCBs have been considered in this investigation as part of the “dioxins”. PCBs are known to have adverse health effects including carcinogenicity and can persist in the environment as well as bioaccumulate. They can form dioxins when burned. [36] Although adverse health effects have generally been associated with high concentrations, it has been suggested that developmental and reproductive effects may occur at lower levels.[62] Most research has been limited to studying the toxicity of the dioxin-like PCBs but more recent studies suggest that at least some of the non dioxin-like PCB congeners may cause endocrine dysfunction, neurotoxicity, immunotoxicity or be associated with adverse effects on the liver independently of the effects from dioxin-like PCBs.[63]

PCBs had been recognised as being onsite during site characterisation and were sampled as part of the stack emissions testing during the PoP trials as per the Resource Consents. The

only results discussed in the body of the PoP report were for the dioxin-like PCBs only and these values were added into the other dioxins results. However the concentrations for some individual non-dioxin-like congeners ranged up to 5.7 ng/m^3 (3.2 ng/ m^3 if the test is excluded when the auger jammed). [22] This is significantly higher than the mean concentration for the highest individual congener recorded during the ambient air sampling done in1996-1997 at Nelson Lakes National Park by MfE of 5.89 pg/m^3 (0.006 ng /m^3) or the mean concentration of 0.0145 ng /m^3 recorded for the highest individual non dioxin-like PCB recorded in Christchurch during the same sampling programme.[64]

Elevated levels of PCBs were also found during baseline soil and groundwater sampling in September and October 2004 prior to remediation starting. 21 sampling sites were used in FCC East and West Sites with total PCBs found above the level of detection in 13 of these sites. Non dioxin-like PCBs were detected at all 13 sites but dioxin-like PCBs were only detected at five of these sites. The highest concentrations were found in soil in the vicinity of the workshop and Landfill with values ranging up to 0.27 mg/kg for individual non dioxin-like congeners.[6] This can be compared with the maximum concentration for an individual non dioxin-like congener measured in the 1998 Organochlorines programme of 2.68 µg/kg (0.00268 mg/kg) in a metropolitan centre and that PCBs were not found above detection level in most grassland or agricultural soils.[65]

This testing confirmed the presence of PCBs in the soil at levels well above what appears to be usual for both rural and metropolitan areas in New Zealand but the decision to omit PCBs from the ongoing ambient air and stack monitoring had already been made in the Resource Consents. There is no record that this condition was reviewed by the PRP or Compliance Officer. In an annex to the PCE Report this lack of monitoring was raised as a concern but no recommendation was made in the report itself regarding this issue.[1]

In the absence of monitoring data no conclusion can be reached on likely exposure and therefore on health risk from PCB exposure.

5.2.8 Stearate

The Complaints Register recorded a concern about a white dust blowing off-site in December 2005. The Register records that the MfE Site manager said this was stearate and that he used a soap solution to manage the dust. Stearate is reported to degrade very quickly in the environment.[67] The Compliance Officer reported that a small amount of a similar powder had been found in a test pit in the same area of the FCC Site during the late 1990s. This powder was hydrophilic and, after discussion with two former FCC scientists, this was identified as stearate. Stearate, a non-conductor, had been used for some experiments being done in the past in the FCC workshop to do with electrical cables. As the white powder unearthed during site excavations in December 2005 was from the same location and was also hydrophilic (it was unable to be hosed down, hence had to be dispersed using a soap solution) the Compliance Officer felt this was almost certainly stearate.[66]

No adverse health effects other than potential adverse effects such as eye and respiratory tract irritation associated with dust exposure are likely to have occurred as a result of this incident.

Part II: Other chemicals – no risk assessment

5.2.9 Amitrole

Amitrole is a herbicide and was reported in the initial site audit as being on the FCC Site but having a persistence of less than three months.[2] No sampling was done for amitrole during the site characterisation but there is anecdotal evidence of an amitrole spill on site in 1975.[1] However the principal investigator for the PCE advised that amitrole would have decomposed in the soil prior to remediation.[67]

Therefore residents would not have been exposed to amitrole during the remediation and hence a risk assessment was not carried out.

5.2.10 Asbestos

Asbestos material was a component of some of the buildings historically on the Site. These buildings were demolished in the 1990s and there were reported to be problems with the demolition process of one building in 1996 with the result that there was loose asbestos on the ground around the building. The DoL was involved in following this up.[68] No asbestos fibres were found during sampling by Thiess in 2001 and the PCE did not recommend any further action.[1]

Therefore residents would not have been exposed to asbestos during the remediation and hence a risk assessment was not carried out.

5.2.11 Mercury

Mercury is a heavy metal that was historically used in the formulation of many pesticides known as organomercury compounds. The PCE investigation identified that there could have been some small hotspots of mercury contamination on the Site, especially in the Landfill area. The report noted that mercury would not be treated by the MCD process but the AECS should have effectively prevented the emission of mercury as dust. The PCE also noted that "any soil containing elevated mercury should pose a minimal risk if reburied beneath the cover layer" but they were concerned that there was a possibility that mercury was in the capping layer.[1]

Subsequent to the release of the PCE Report TDC did specific sampling for mercury in the capping layer of the West FCC Site in August 2008 and the results were well under the residential soil criterion.[69] The report of the Site Auditor (final audit) confirmed that heavy metals (which include mercury) were unlikely to be of concern in soil on the Site.[70]

Based on the PCE findings, exposure of residents to elevated levels of mercury during the remediation appears very unlikely and the Site Auditor (final audit) confirms that exposure of the public to mercury in the soil is unlikely to be a concern post-remediation. Therefore, as discussed in Section 2.3, a risk assessment was not carried out.

5.2.12 Phenothiazine

Phenothiazine is an insecticide and was detected in soil samples from two different sampling cells in November 2004 and this was discussed at the Site Management meeting in November 2004.[71] There is no further reference to this chemical being found. The PCE principal investigator advised that phenothiazine would have been broken down in the MCD process. [67]

It is unlikely that residents were exposed to phenothiazine during the remediation. If they were, the levels would have been very low and hence a risk assessment was not carried out.

5.2.13 Simazine

Simazine is a herbicide and was detected at low levels in the baseline soil testing by Tonkin and Taylor 2005.[6] These low levels were reported to reflect the limited half-life of this chemical[1] and the PCE principal investigator advised that simazine would decompose in the soil.[67]

It is unlikely that residents were exposed to simazine during the remediation. If they were, the levels would have been very low and hence a risk assessment was not carried out.

5.3 Odour

At the time of the Resource Consent Hearing odour effects were expected but considered likely to be a nuisance rather than causing an adverse health effect.[26]

Odour complaints were assessed by a team of three (TDC Compliance Officer, Site Manager and EMS staff member) who decided if there was a chemical or acrid component to the odour in which case the odour was considered non-compliant. Concerns about non-

compliant odour were reported to the PRP. Approximately 40% of the complaints recorded on the Complaints Register by June 2007 were about odour.[31]

The Compliance Officer report for the PRP in December 2005 noted that "since October" (presumably meaning October 2005) the stack discharge had smelt strongly of chemicals and that when this plume descended onto neighbouring properties it was unpleasant.[72] Specific ambient air monitoring was reported as being in place for the detection of some chemicals at the February 2006 PRP meeting and it was proposed that PIDs and a range of personal monitors be used to assess the Site environment (and possibly neighbouring properties) for other air contaminants, such as ammonia, benzene and HCB.[18]

After use of these monitors to measure levels of VOCs and other chemicals around the Site it was reported that ammonia was detected by a personal monitor next to the pug mill at around 175 ppm.[20] However there was discussion at the PRP that the particular monitors used for VOCs may not detect low enough levels for benzene and a different monitor was recommended for this purpose.[20] No further information was found by the author in PRP reports in relation to whether this testing eventuated. The NMDHB PHS was advised verbally that worker and Site perimeter levels were negative or "low" for ammonia.[34] No information was obtained as to any other chemicals being identified as potential sources of odour beyond the Site boundary.

There is reasonable evidence that ammonia was one cause of odour as follows:

- Replacement of the spray bowl system with a pug mill for mixing the treated fines was reported to the PRP in August 2005 as helpful in reducing odour, as was replacement of the carbon in the filter - resulting in fewer complaints.[38]
- The Compliance Officer reported that there was ammonia discharge from the treated fines after processing of highly contaminated infeed when "surplus urea" was added to the MCD reactor and that this odour could travel onto Aranui Road or Tahi Street and cause eye or throat irritation to members of the public.[45]
- Ammonia off-gassing from piles of treated fines appears to have been temporarily reduced by controlling the OCP concentration in infeed soils so that the quantity of process reagents used could be reduced.[45]

Adverse health effects due to odour may be stress associated with experiencing an unpleasant smell and also any direct chemical effects from the chemical causing the odour. The latter are assessed under Sections 5.1 and 5.2

It does seem clear that close neighbours were exposed to repeated episodes of unpleasant odour and that this caused significant stress for some people. This was a factor, along with also experiencing vibration, noise and dust, for some people requesting relocation during the remediation. (This relocation was arranged on a temporary basis for one household.)[9 13]

6. Risk Assessment: Dust and Direct Soil Exposure

6.1 During remediation

Dust, due to its physical properties alone, was recognised as a potential health hazard during the remediation and specific mitigation steps were undertaken including a high fence with misting sprinklers on a timer at adjacent residential properties, use of a mobile water tanker, tarpaulins and PVA paste on piles of soil as dust suppressants.

The health risk (generally of respiratory, including bronchitis and asthma, and cardiac illness and increased cardio-respiratory mortality) is greater from the inhalable fraction (PM_{10}) than from larger particles.

Dust was discharged from the site as a result of the excavation and earthmoving activities as well as from the piles of material awaiting screening or treatment and from the piles of treated fines. These various activities were noted to result in large amounts of soil sitting in piles, as bare dirt or exposed to the air and wind as it was being treated in the machinery.[73] Initially, treated fines exiting from the plant went into a spray bowl but this led to ammonia, diammonium phosphate (DAP) and dust being emitted from this area. These fugitive emissions were reduced by replacing the spray bowl with a pug mill in mid- 2005.[38]

Dust monitoring was by daily TSP readings using the filter in the polyurethane foam (PUF) samplers and monthly dust deposition rates using the dust deposition gauges. A real time method of monitoring was not used.

PM_{10} was not monitored during the remediation as a decision was made after the PoP trials and first month of operation that only TSP would be measured with a threshold level of 80 $\mu g/m^3$ used to identify exceedances. During the first month of operation PM_{10} sampling, along with simultaneous TSP sampling, during the MCD plant operation was recorded for six days with the PM_{10} percentage of TSP over 30% on five out of the six events, thus exceeding the Resource Consent threshold requiring consideration of ongoing monitoring. The decision to not continue to monitor PM_{10} appeared to be based on the fact that PM_{10} was a similar proportion of TSP on days when the MCD plant was not operating during this period and that total TSP and PM_{10} values were low, with PM_{10} values well below the New Zealand Ambient Air Guidelines[74] 24 hour average value of 50 $\mu g/m^{3.}$ [This same value has been a National Environmental Standard (NES) since 2004.[75]]

The Resource Consents had also specified that analysis of the TSP filters to determine the percentage of TSP that was PM_{10} should occur on at least 10 days of "maximum site remediation operations". However there is no record that any excavation and earthmoving activities occurred during the PoP period. TDC reports that there were only a few piles of treated and untreated soil on Site at this time.[41] It appears unlikely that excavation and earthmoving were occurring as the Compliance Officer reported to the December 2005 PRP meeting that soil excavation and screening had started sometime after September 2005.[76] It was also reported that the soil used in the PoP trials and first month of operation was from a supply that TDC had arranged for the demonstration trials.[66] Therefore it is likely that the dust emissions from the Site during the sampling period for simultaneous TSP and PM_{10} was not representative of the Site emissions once full Site activities commenced. Thus there was non-compliance with the number of days required for this proportional TSP testing and with the fact that there were not maximum Site operations.

The change to PUF samplers, in place of the HiVol filters specified in the Resource Consent, early in 2005 was made to better assess the gaseous emissions to air[1] but no discussion in the PRP minutes or MfE monthly reports was found that indicated that the decreased effectiveness of these samplers for monitoring particulates was considered. Because the PUF sampler filters are not as effective for measuring TSP as the HiVol filters, this meant that 80 $\mu g/m^3$ was no longer a suitable threshold value as the PUF filter readings would record mainly PM_{10} and therefore underestimate TSP.[57] Three air quality experts consulted by the NMDHB PHS agreed that it was likely that the PUF filter TSP readings would have been made up of 75% PM_{10}.[57 77 78] This means that the TSP readings recorded may have

underestimated the health risk from inhalation of fine particulates. This issue is also discussed in the AES 2009 report in Appendix 1 and in Section 5.1.[32]

A recalculation of the TSP readings using an estimation that the particulate matter captured on the PUF filter would have been made up of 75% PM_{10} shows PM_{10} is likely to have exceeded the NES for PM_{10} (24 hour average of 50 $\mu g/m^3$)[75] on at least 33 occasions during the remediation (33 months). Most of the breaches (29) are calculated as occurring at the EDL Lab monitoring site.

This number of exceedances can be compared to Nelson City Council's (NCC) records for the city's yearly PM_{10} readings. In 2008 there were 25 exceedances in airshed B (Nelson South), down from 81 in 2001, and 11 in airshed A (Tahunanui). It should be noted that NCC has been taking active steps to reduce the number of exceedances as there are known adverse health effects associated with exposure to elevated levels of PM_{10}. TDC records for PM_{10} readings in central Richmond for 2008 show 20 exceedances. The NES[75] sets a maximum of one exceedance of the 24 hour average per year.

The TSP readings were also dependent on the location of the ambient air monitoring sites. As has already been noted in Section 5.1 the prevailing winds for the Site are northeast (NE) and southwest (SW) and the three ambient air monitoring sites used were located west of the Site close to the Site boundary (10 Coutts Place); north to northeast of the Site close to the boundary (EDL Lab); and south of the site, approximately nine properties depth back from the Site at 31 Tahi St. Number 31 Tahi Street was originally intended as the "background" monitoring site but it quickly became apparent that subtracting these TSP readings from the two other site readings could result in negative readings. The results of the deposition modelling for dioxins emissions indicate that deposition of particulates to the south of the Site would have been better represented by having an ambient air monitoring site on the west side of Tahi Street close to the Site boundary (see Section 5.2.2). Therefore TSP readings from 31 Tahi Street would have under-represented exposure of many people in the street to dust. This was noted as a concern in several reports to the PRP by the Compliance Officer.[38] [40]

There is considerable uncertainty about the number of days the public was exposed to PM_{10} levels that breached the NES for PM_{10} due to lack of robust exposure data and the non-representative location of the Tahi Street monitoring site for assessment of exposure for residents to the south of the Site. However it is likely that PM_{10} levels breached the NES for PM_{10} on numerous occasions. Therefore it is likely that there was an increased risk of adverse health effects from inhalation of dust during the remediation, particularly respiratory complaints such as cough, worsening asthma and increased incidence of bronchitis.

The public would not have been directly exposed to soil while it remained on the Site during the remediation therefore there would be no risk of adverse health effects from contaminants in the soil by this exposure pathway. (Exposure to soil contaminants leaving the Site as fugitive emissions is covered under Section 5 - Air Emissions.)

6.2 Post-remediation

The Site Auditor (final audit) assessed that the proposed commercial and recreational areas of the remediated Site should not result in direct soil exposure (and hence exposure to residual chemicals) by members of the public. He also noted there is potential for ammonia gas to be generated from the treated soil in the former FCC East site and the former Landfill. The potential uses of the proposed commercial area means there is the possibility of human health effects if exposure to ammonia gas occurs and a programme of soil gas testing was recommended by the Site Auditor. The Site Auditor also recommended that as long as the former Landfill area is only used for recreational use, without erection of buildings or excavation, there is no risk of human health effects from day to day use as open space.[70]

The Site Auditor (final audit) also reports that, "on average the soil quality [in the proposed residential area] complies with the SAC, and in particular meets the ADL and DDX SACs". Some uncertainty around detection limits for DDX and possible isolated local exceedances is also noted. This means that there is uncertainty as to whether there is any exposure risk and

the Site Auditor recommended a programme of resampling or reanalysis of archived samples to clarify this. [70] If DDX levels were raised there would be a potential exposure pathway to these contaminants from direct soil contact if digging below the 150 mm topsoil layer (which is imported soil). Further, the Site Auditor notes that, although the results of the further sampling of the capping layer of the proposed residential area for mercury undertaken by TDC (as recommended in the PCE Report[1]) showed low concentrations of mercury, arsenic and lead, the absence of hotspots in the capping layer "cannot be absolutely guaranteed" but are "unlikely to exist".[70]

Four residential properties in Tahi Street were remediated and the remediated soil validated. In two of the properties the validation was based on soil sampling carried out in 2001 and 2002.[70] For the other two properties validation sampling was carried out as part of the remediation project. In each of these properties the area requiring remediation varied from a small patch (5 by 2.3 metres) to almost 50% of one property. [70] Although the Site auditor accepted the validation sampling as meeting the SAC for residential soil it is possible that the soil on these and other properties adjacent to the Site may have become contaminated or re-contaminated particularly as a result of Site air emissions and discharges. The deposition of contaminants into soil and resulting exposure pathways of dust/soil ingestion or consumption of locally grown produce is discussed in detail in the AES 2009 reports (See Appendices 1 and 2) and the probability of significant exposure to OCPs and metals through consumption of root vegetables during the remediation was assessed as very small. As there is no source to cause an increase in the levels of any of these contaminants above the water table it is considered unlikely there would be a health risk from the consumption of locally grown root vegetables post-remediation.

7. Risk Assessment: Groundwater and Stormwater Discharges

Contamination of groundwater from the Site during remediation extended to the Waimea Inlet and bores/wells on neighbouring properties to the south of the Site.[1]

7.1 Bore water (during remediation)

7.1.1 Organochlorines

Groundwater monitoring of bore water showed DDT and lindane frequently exceeded Resource Consent threshold concentrations.[1] However residents had been advised by TDC not to use bore water as drinking water during the remediation so this should not have been an exposure pathway. Although people had been advised by TDC that the bore water was suitable for irrigation purposes it does not appear that a formal risk assessment for human health was done as proposed in the NMDHB PHS evidence at the Resource Consent Hearing.[26] The threshold values in the Resource Consents were based on ecosystem trigger values, not guidance values based on human health risk from consumption of produce irrigated with this groundwater. The PCE report notes that the "suitability of groundwater for irrigation with respect to DDX was not assessed, because the Australian and New Zealand Environment and Conservation Council (ANZECC) 2000 does not provide guideline values for pesticides in irrigation water".[1] The PCE report goes on to note that the Site Auditor (remediation) did not propose any criteria for the purpose of assessing the suitability of groundwater for irrigation during the remediation and that it appeared that "because there were no criteria and hence no exceedances, the AEE implicitly did not consider DDX in irrigation water to be a significant risk to nearby users".[1]

Groundwater monitoring showed exceedances of the MAV, as set out in the Drinking Water Standards for New Zealand 2000 and 2005,[79] [80] for dieldrin at most on Site, and some off Site, monitoring bores and for DDX and lindane at some on Site bores during the remediation.

The PCE report notes that contaminants had exceeded consent thresholds since April 2005, including discharge into nearby residential wells, and that MfE had taken no effective action to reduce these discharges or determine their source despite requests from TDC and advice from the Site Auditor (remediation) and the PRP.[1] In the Water quality technical annex to the PCE report it is suggested that the Site Auditor (final audit) should consider if there is any significant risk in using groundwater for domestic irrigation at residential properties south of the Site (on Tahi Street) as well as on Site (FCC West) after completion of the remediation.

The Site Auditor (final audit) states that the groundwater in existing bores is of an "adequate quality" for irrigation use and for new bores on Site (FCC West) is "probably suitable for irrigation use." [70] There is no evidence presented in this report that indicates a risk assessment, as suggested in the PCE Report, has been undertaken.

7.1.2 Nitrates and ammoniacal nitrogen

Groundwater monitoring showed nitrates and ammoniacal nitrogen exceeded Resource Consent threshold concentrations and the New Zealand drinking-water MAVs in monitoring bores both on and off Site. These chemicals appear to have arisen from the process reagents used during the MCD plant operation.[1]

As residents had been advised not to use the water for drinking, these chemicals should not have caused adverse health effects in humans. (The only potential exposure pathway was the use of the water for irrigation of produce and there is no health risk associated with elevated nitrates and nitrogen in irrigation water).

7.2 Marine environment (during remediation)

7.2.1 Sediment

There was ongoing contamination with OCPs in both the Eastern and Western estuary sediments, with an increase in the contamination levels in the Western side, after remediation of the foreshore.[81] This apparent recontamination was thought to be due to poor housekeeping practices with stormwater run-off from the Site to the estuary area during the remediation.[70]

Sediment contamination is not considered a direct exposure pathway with potential for adverse health effects for the public by the Site Auditor (final audit),[70] although this must be qualified by acknowledging that there would be a potential health risk for those who compulsively consume soil (a form of pica), particularly children.

7.2.2 Shellfish

During the remediation project, but after the foreshore remediation, follow up monitoring showed that there was ongoing contamination with dieldrin/aldrin and DDX in mudsnails (*Amphibola*) in the Western estuary.[81] The NZFSA report arranged by NMDHB PHS advised that snails from the Western estuary should not be consumed.[82] Further remediation was done on the West foreshore, followed by further monitoring which showed higher levels of contamination in the mudsnails from some locations.[83] The NMDHB PHS recommended that the TDC erect signs warning the public not to take shellfish for human consumption, undertake ongoing monitoring and consider testing higher up the food chain (e.g. fish). As far as the NMDHB PHS is aware this latter testing has not been implemented.

Given that signs were erected warning the public not to collect or consume shellfish from the area this contamination is not considered likely to be a cause of adverse health effects.

7.3 Post remediation

7.3.1 Bore Water

The report of the Site Auditor (final audit) identified that there is residual groundwater contamination beneath the remediated Site and extending to the south and that this is likely to be ongoing for some years. The contaminants of concern are DDX, dieldrin, and nutrients such as nitrates and ammoniacal nitrogen.[70]

It is noted that bores for the extraction of small quantities of water for domestic purposes are a permitted activity under the TDC Resource Management Plan.

There is potential exposure to these hazards from bore water extracted from residential properties south of the Site (Tahi Street) or from new on Site (FCC West) residential properties, and therefore a risk of potential adverse health effects, if:

- there is use of bore water for drinking
- bore water is used for irrigation of produce

See Section 6.1.1 for further discussion on health risk assessment.

7.3.2 Marine environment

The Site Auditor (final audit) reports there is ongoing contamination of marine sediments and shellfish with OCPs but notes the decreasing trend. The most recent sampling available for snails shows ongoing exceedance of the recommended safe dieldrin/aldrin level for human consumption at one sampling site in the Western estuary and a borderline reading at a second site in the same area, although the trend does appear to be downwards,[84] and the DDX concentrations in the mudsnails are now below the recommended safe level for human consumption. Potential exposure pathways to these contaminants are through consumption

of shellfish and direct contact with marine sediment.[70] As there has not been recent testing further up the food chain it is unknown if there is risk associated with consumption of other biota.

Sediment contamination is not considered an exposure pathway with potential for adverse health effects for recreational users of the foreshore.[70] As in Section 6.2.1 this must be qualified by acknowledging that there would be a potential health risk for those who compulsively consume soil (a form of pica), particularly children.

Given that signs remain warning the public not to collect or consume shellfish from the foreshore, consumption of shellfish is not considered likely to be a cause of adverse health effects.

8. Risk Assessment: Noise and Vibration

At the time of the Resource Consent Hearing effects from noise and vibration were expected to be issues but controlled by the proposals set out in the AEE.[26]

8.1 Noise

Noise resulting from remediation activities at the Site was expected to be of nuisance value, and not at a level to risk damage to hearing.[26] However the 2003 AEE[4] recognised that noise might be disruptive to residents and businesses in the vicinity of the Site and the Resource Consents had a number of conditions to address this.

Mitigation was by use of sound barriers e.g. hay bales and modifications of machinery in addition to ensuring compliance with consent conditions in relation to the hours of noise generating activities. Such modifications included:

- The installation of a "muffler" box next to the induction fan in the AECS.[85]
- Improvements in the soil screening process to reduce the amount of oversize stone fraction going through the plant[85]
- better maintenance of the augers in the MCD plant[86]

There were several instances of noise generating work occurring on a Sunday or out of allowable hours.

Approximately 25% of the complaints recorded on the Complaints Register by June 2007 were about noise.[31]

On occasion the noise generated from the Site was clearly a nuisance and irritating to some people. The noise levels were insufficient to cause adverse health effects with the exception of causing stress to some people living in adjacent properties. This is particularly so given that the remediation continued for approximately three years.

8.2 Vibration

Vibration was recognised as an issue arising from Site operations both as a nuisance and a concern regarding possible effects on dwellings for some residents close to the Site. The vibration was mitigated by various changes in the MCD plant and operations, such as:

- reducing the number of steel balls replaced in the MCD reactor at any one time[87]
- turning off the vibrator mode on the compactor roller[88]
- ceasing to use a large rotary screen as part of the soil screening process[89]

Approximately 25% of the complaints recorded on the Complaints Register by June 2007 were about vibration.[31]

Vibration is unlikely to have caused any adverse health effects with the exception of causing stress and anxiety due to residents' concerns about damage to their properties. This is particularly so given that the work continued for approximately three years. The NMDHB PHS has not seen the results of any post-remediation assessment undertaken of off Site buildings looking for possible structural damage due to vibration from the Site operations.

9. Discussion and Conclusions

The purpose of the remediation was to reduce the OCP concentrations in the soil and marine sediments to levels determined to be acceptable for future use of the Site and surrounding areas. It was also expected that the reduction in contaminants in the soil on the Site would result in an improvement in the groundwater quality. The then existing risks to public health from dermal contact with, or ingestion of, the contaminated soil; ingestion of contaminated groundwater; or ingestion of contaminated mudsnails had been assessed as unacceptable (Section 3.6.1). Future uses proposed for the Site after remediation included commercial, recreational (open space) and residential areas. Remediation of the soil was chosen over the original proposal to cap and contain the Site because it had the advantage that future use of the land was not limited to open space along with the possibility of some commercial use.[1] However this process carried with it the risk of mobilisation of contaminants, particularly during the remediation, and consequent risk of exposure of the public to discharges and emissions from the Site. This risk was heightened by the decision to remediate the soil on the Site itself, which is in the middle of a residential area and adjacent to an estuary.[1]

It was expected that public health would be protected during the remediation by the conditions of the Resource Consents. This was to be achieved by an ambient air and groundwater monitoring programme and specific control and mitigation activities for identified hazards (Sections 3.6 and 3.7). Monthly assessment of health risk from discharge of chemicals to air in either gaseous or particulate phase was by use of the THI (Section 3.7.9). It also appears inherent in the Consent conditions that the Compliance Officer would consider adjusting the monitoring programme after the PoP trials or first month of operation in certain specified instances and that the PRP would make recommendations if required (Section 3.7). However the limitations of the site characterisation done prior to the consents being granted, and the lack of information on the possible by-products of the MCD process, meant that there were notable omissions from the range of chemicals included in the monitoring programme that may be associated with public health risk, particularly ammonia, arsenic, benzene, chlorobenzene, dioxins, mercury, PCBs and the “missing” two isomers of DDX.

Remediation was undertaken by excavating the soil, screening it to separate out the “fine” contaminated material, and processing any contaminated soil through the MCD plant to dehalogenate the OCPs before reinstating the soil back on Site. The soil awaiting processing and reinstatement was stored in piles around the Site. These activities resulted in considerable amounts of dust being discharged from the Site during windy periods despite dust mitigation methods being employed (Section 7.1).

The MCD plant had not been used on a commercial scale prior to this remediation project.[4] Before the soils could be processed it was necessary to dry the soil using a rotary dryer and to then add a variable amount of process reagents to the MCD reactor to enhance the dehalogenation process. It is evident that higher temperatures, greater quantities of process reagents and changes in the process reagents used, were required to achieve remediation of the soil and to meet the throughput requirements for the project. These parameters differed from the information presented at the Resource Consent Hearing (Section 3.5.1). There is evidence that these factors resulted in increased volatilisation of OCPs and the formation of VOCs , including benzene, and dioxins in the dryer, as well as increased fugitive air emissions of ammonia, and discharge of DAP, copper and nitrates to groundwater (Section 5.2).

Volatilisation of OCPs and other chemicals, thermal decomposition of OCPs to form by-products such as dioxins and benzene and possible de novo synthesis of dioxins would not have been of such concern if the AECS had been functioning as outlined in the resource consent application. However it is clear that at least until November 2005, and possibly for longer, this was not the case and chemicals, including those not covered in the monitoring programme (particularly dioxins, benzene and PCBs) may have been emitted from the stack (Sections 3.5.1, 5.1, 5.2.3, 5.2.5 and 5.2.7).

As well as the limited range of chemicals included in the monitoring programme, there were methodological issues in the ambient air monitoring undertaken which affected the data

being used for the THI. Adjustments have been made in the revision of the THI calculations since completion of the remediation to address these issues, but the quality of the data weakened the value of the THI for monitoring immediate risk to public health during the remediation. Further, the location of the monitoring sites did not adequately assess risk to the public south of the Site and also appears to be contrary to the Resource Consent conditions (Sections 5.1, 5.2.2 and 7.1).[90]

Many of these issues were identified by the Compliance Officer and were also discussed by the PRP, with resulting recommendations to address the problem or deficiency. However many of these recommendations were not taken up by MfE either at all or in a timely manner[1] (see Sections 5.1, 5.2.2, 5.2.8 and 7.1). The rationale behind MfE's decision in declining to support TDC to undertake OCP testing at a residence close to the Site not covered by the location of the ambient air monitoring sites is unknown. Similarly the rationale behind MfE's decision to not undertake the dioxins stack emission testing, proposed by the PRP and TDC in November 2005, is unclear, although it appears from comments in the review of the role and actions of MfE during the remediation that MfE did not wish to support an approach they considered would create unnecessary concern over dioxins.[91] The delays in carbon filter testing and stack emissions tests for dioxins recommended by the PRP and TDC have meant the risk to public health from exposure to dioxins, particularly from November 2004 until March 2006, was unable to be adequately assessed at the time or subsequently.

The focus of the monitoring appeared to be more for compliance and environmental protection than protection of public health. Although there was a comment from a member of the panel at one PRP meeting (August 2005) that "it would be good to have the air and groundwater results reported in context of human health risk",[12] this is contrasted by the response from a MfE representative when declining to fund further recalculations of the THI in 2007:

"From the Ministry's perspective, the THI is used for compliance and is calculated regularly for this purpose." [92]

The MfE response suggests a lack of appreciation that the purpose of the THI was to assess public health risk. This recalculation had been suggested to address recognised inadequacies in the THI for assessment of public health risk.

The PRP also did not have a specialist air quality expert until December 2005. This date was after the PRP had reviewed the PoP trial report and Compliance Officer's report indicating that the location of the ambient air monitoring site in Tahi Street had been shown to not be representative of the exposure for some people living south of the Site. Review of all PRP minutes suggests a noticeable change in approach to discussing and/or investigating some issues, particularly concerning air emissions and discharges, after the addition of the air quality specialist to the PRP, and somewhat improved acceptance on the part of MfE to act on the subsequent recommendation(s).

The risk assessment for OCPs (including DDX, ADL, HCB), chromium, manganese, nickel, arsenic, copper, lead and selenium reported in the September and October 2009 AES reports indicates that adverse health effects are unlikely to have resulted from exposure to these chemicals for people living or working north or west of the Site. There is some uncertainty for people who live south of the Site, due to inadequate monitoring data being available for this area (See Section 5.1), particularly for those on the west side of Tahi Street or closer to the Site than 31 Tahi Street for those living on the east side of the street. Due to the very low THIs calculated for the metals at all monitoring sites, along with the debate as to whether manganese, chromium and nickel should have been part of the monitoring programme (See Section 5.1), the uncertainty raised by the location of the Tahi Street monitoring site is only a concern for OCPs and, to a lesser extent, arsenic. Therefore the THI cannot be relied on as an assessment of the health risk from possible OCP or arsenic exposure for people living at those properties identified above. This is approximately 30 properties if using the deposition pattern calculated for the dioxins dispersion and deposition modelling (see Figure 4). It is of note that the THI calculations have shown that dust ingestion was the largest contributor to potential public exposure to OCPs and that the

ambient air monitoring results, along with the stack emissions testing, indicate that fugitive emissions were a significant component in the total OCP emissions from the Site (See Section 5.1).

There is evidence that members of the public were likely to have been exposed to dioxins discharged from the Site during the remediation. However in the absence of exposure information from ambient air monitoring, along with the uncertainty regarding the dioxins emission rate used in the dioxins dispersion and deposition modelling undertaken by AES, no conclusion can be reached on the health risk, if any, associated with possible dioxins exposure (Section 5.2.5).

It seems likely that low levels of ammonia discharged from the Site may have caused some of the many odour complaints and symptoms of eye and throat irritation but this level of exposure is unlikely to have caused lasting or serious adverse health effects (Section 5.2.1).

PCBs and benzene are both chemicals of concern that the public may have been exposed to as a result of discharges from the Site. However there is no monitoring data for PCBs and hence no conclusion can be made on health risk (Section 5.2.7). For benzene there is evidence that benzene was formed in the dryer and also discharged from the MCD reactor. It was reported to the PRP that based on the concentrations detected in the carbon filter, the levels being discharged from the Site may be well above the ambient air guideline value for benzene.[74] Although subsequent testing using PIDs at various locations round the Site were reported as not showing benzene apart from next to the pug mill, there was disagreement recorded in the PRP minutes over the accuracy of this testing.[20] It is possible that the public may have been exposed to benzene arising from the Site due to stack emissions, particularly during the period when the AECS was malfunctioning, and also due to fugitive emissions from the MCD reactor. No conclusion can be made on health risk due to the lack of robust monitoring data (Section 5.2.3).

There is considerable uncertainty about the number of days the public was exposed to PM_{10} levels that breached the NES [75] due to lack of robust exposure data and the non-representative location of the Tahi Street monitoring site for assessment of exposure for residents to the south of the Site. However it is likely that PM_{10} levels breached the NES[75] on numerous occasions. Therefore it is likely that there was an increased risk of adverse health effects from inhalation of dust during the remediation. The lack of robust exposure data and health data means the extent of the public health risk cannot be determined with certainty but is likely to be low to medium.

The Site Auditor (final audit) assessed that although the commercial and recreational areas of the remediated Site should not result in direct soil exposure by members of the public there is potential for ammonia gas to be generated. Therefore the Site Auditor recommended soil gas testing and the development of a management plan depending on the results.

There is uncertainty as to whether there may be isolated exceedances in DDX concentrations in residential soils on Site. If present this would mean there is a small risk of exposure from direct soil contact if people were to dig below the 150 mm topsoil layer. The Site Auditor (final audit) has recommended resampling or reanalysis of archived samples to clarify this risk. It is very unlikely there is any health risk from exposure to mercury in the soils on the remediated Site.

As there is no source to cause an increase in the amount of OCPs or metals already discharged from the Site to soil on adjacent properties or in soil remaining on Site above the water table it is unlikely there would be a health risk from the consumption of locally grown root vegetables post-remediation.

Monitoring of bore water showed DDT, dieldrin and lindane frequently exceeded Resource Consent threshold concentrations during the remediation in the on Site bores and dieldrin in the off Site bores. DDX and dieldrin contamination persists in some bores. There was no risk of exposure to these contaminants by ingestion during the remediation as residents were advised not to drink this water. However groundwater guideline values for protection of human health from consumption of produce irrigated with this groundwater are not available

for DDX and dieldrin. Therefore it is unknown if the bore water is suitable for irrigation of produce. In the absence of such information the health risk from consumption of home produce irrigated with bore water is unknown (Sections 6.1 and 6.3.1). It is noted that new bores on residential properties are currently a permitted activity under the TDC Resource Management Plan. Groundwater to the south of the Site and under the Site is not potable and it remains unclear whether there is any potential health risk from consumption of produce irrigated with bore water. The public health risk of the use of groundwater for irrigation of produce, when the water is contaminated with DDX and dieldrin, needs clarification.

There was ongoing contamination with OCPs in both the Eastern and Western estuary sediments during the remediation and in shellfish in the Western estuary and this has persisted. Sediment contamination is not considered an exposure pathway with potential for adverse health effects for recreational users of the foreshore[70] and, given that signs were put in place warning the public not to collect or consume shellfish from the foreshore, consumption of shellfish is not considered likely to be a cause of adverse health effects. Warning signs advising the public not to collect or consume shellfish from the foreshore areas adjacent to the Site should remain in place and ongoing monitoring of both marine sediment and biota should continue until contamination is at acceptable levels to protect public health. As the Site Auditor (final audit) suggests there may be enhanced leaching of contaminants into the groundwater,[70] monitoring should continue until these levels are clearly stable. It is unknown if there has been contamination higher up the food chain but it is likely that the health risk associated with consumption of other biota is low (Sections 6.2 and 6.3.2).

Close neighbours, including those working in commercial businesses, were exposed to repeated episodes of unpleasant odour, dust, noise and vibration over the three year period of the remediation. This caused significant stress and anxiety for some people. This was a factor, along with also experiencing vibration, noise and dust, for some people requesting relocation during the remediation.

There was non-compliance with some of the conditions in the Resource Consents that may have led to public health risk or compromised the ability to assess whether there was any public health risk. These included the following: the soil dryer did not have an automatic cut-off if the temperature at the dryer inlet exceeded 120°C, TSP/PM_{10} monitoring during the PoP trials/first month of operation was not completed as specified, the location of the ambient air monitoring sites were not as specified, dust was discharged from the Site at levels that were at the very least offensive and objectionable and may possibly have been noxious, and the PRP did not meet at least quarterly during the first two years of the remediation. Other factors, such as the AECS and the process reagents used, were considered substantially different by the PCE[1] from what was presented to the Resource Consent Hearing in the 2003 AEE, meaning that these could also be considered non-compliance.

Assessment of public health risk resulting from the Mapua Site remediation has been complicated by information gaps particularly on possible Site emissions and discharges as well as in the quality and range of the monitoring data. However it is clear that the public health risk associated with Mapua relates predominantly to the air emissions and discharges from the Site during the remediation. Use of the deposition pattern calculated for the dioxins dispersion and deposition modelling (Figure 4) indicates that it is possible around 60-70 properties may have been affected by such discharges. Whether there is a health risk associated with a particular discharge however is very dependent on the level of exposure and the nature of the contaminant.

The delay in adding specialist air quality expertise to the PRP impacted on the identification, investigation and formulation of recommendations on issues that arose during the remediation concerning Site emissions and discharges. This limited the ability of the PRP and the Consent Holder to assess risk to public health during the remediation.

It is now apparent that for a complex project such as this remediation the assessment of public health risk in a changing environment was a significant challenge. The only people

with a public health perspective on the PRP were TDC staff. In hindsight, a specialist public health expert on the PRP would have been of benefit.

This investigation into public health risk is limited by the lack of exposure data for members of the public living or working in close proximity to the Site during the remediation to several chemicals that remain of concern, namely dioxins, benzene, PCBs, and for those living south of the Site only, OCPs and arsenic.

The deposition modelling from the AES dioxins dispersion and deposition modelling report could be used to clarify those properties where exposure would have been highest to these chemicals. The results show a rapid decrease in deposition rates with distance from the Site. The highest predicted annual average dioxins concentration was found for the houses immediately adjacent to the southern Site boundary. For dioxins the period of concern is limited to the 18 month period from November 2004 to March 2006. However for OCPs and benzene the fugitive component of these emissions means that the period of concern covers the time the MCD plant was operating and it is likely that this is the same for PCBs and arsenic.

Given the half life of dioxins, PCBs and OCPs in people and the environment it may be possible to clarify exposure through biological and environmental testing. Further investigation is required to clarify who would have been most at risk of exposure to these chemicals and to better characterise the risk of any such exposure. However as the half life of benzene and arsenic in people is very short there is no ability to test for historic exposure.

10. Recommendations

10.1 Recommendations to the Ministry for the Environment

1. For future similar remediation projects the MfE should advise Regional Councils and/or Unitary Authorities that in the consent process:
   - a PRP is established to oversee the project
   - the PRP should include the local Medical Officer of Health or their representative(s) to ensure the protection of public health is included in deliberations of the panel
   - for remediation of contaminated sites adjacent to residential areas greater consideration should be given to the potential for fugitive emissions with either detailed attention to the options for management of these emissions, or offsite remediation
   - a statutory review condition should be inserted in all consents issued for remediation projects similar to this that includes reviewing monitoring requirements placed on the consent (eg, monitoring sites, contaminants monitored, type of monitoring)
2. Where new technology is "trialled" robust Proof of Performance testing should be undertaken using normal operating procedures and reviewed before the remediation proceeds.
3. It is specifically recommended that MfE should seek expert opinion on undertaking soil sampling for contaminants that may have been discharged onto residential properties in close proximity to the Site as follows:
   - dioxins and non dioxin-like PCBs in residential properties in close proximity and downwind to the Site
   - OCPs and arsenic in residential properties south of the Site, particularly those on the west side of Tahi Street or closer to the Site than 31 Tahi Street for properties on the east side of the street
4. Subject to the outcome of the expert opinion recommended in point 3 above, soil sampling is undertaken for the contaminants listed.

10.2 Recommendations to the Tasman District Council

1. Groundwater from under the Site or south of the Site should not be used for drinking water and current property owners/residents should be advised of this. In addition this advice should be recorded in the Land Information Memorandum (LIM).
2. A review of the current TDC Resource Management Plan should be undertaken as soon as possible in respect of new bores on Site or south of the Site.
3. A public health risk assessment on the use of ground water for irrigation of produce grown on the Site and south of the Site should be undertaken and the findings discussed with the NMDHB PHS.
4. Pending discussion of the assessment noted in point 3 above, groundwater from under the Site or south of the Site should not be used for irrigation of produce.
5. Any future changes in the recommendations concerning groundwater use on or south of the Site should be reviewed in conjunction with the NMDHB PHS.

6. Appropriate controls to maintain the integrity of the capping layer in all areas of the Site should be in place before any further development of the Site takes place.
7. Information on the potential health risk of breaching the topsoil/capping layer should be recorded on relevant Local Authority property files.
8. Soil gas testing for ammonia should be carried out as recommended by the Site Auditor (final audit) and a management plan developed as necessary.
9. Resampling or reanalysis of archived samples to clarify if there is any risk of isolated exceedances in DDX concentrations in residential soils on Site should be undertaken as recommended by the Site Auditor (final audit).
10. Warning notices advising the public not to collect or consume shellfish from the foreshores adjacent to the Site should be in place until ongoing monitoring confirms levels of contaminants are below the NZFSA residue values (as recommended in 2007) and that these levels remain low in a subsequent testing regime developed in conjunction with the NMDHB PHS.
11. Monitoring of biota further up the food chain should be undertaken.

10.3 Recommendations to the Ministry of Health

1. To clarify the possibility of significant dioxins exposure to residents (including off Site workers[f]) in close proximity and downwind of the Site, arising from the remediation over the period of concern (November 2004 - February 2006 inclusive) the MoH should seek expert advice on undertaking biological testing for dioxins.
2. To clarify the possibility of significant PCB exposure to residents (including off Site workers) in close proximity and downwind of the Site, arising from the remediation over the period of MCD plant operation the MoH should seek expert advice on the feasibility of biological testing for non- dioxin-like PCBs.
3. To clarify the possibility of significant OCP exposure to residents (including off Site workers) in close proximity and south of the Site, arising from the remediation over the period of MCD plant operation the MoH should seek expert advice on the feasibility of biological testing for OCPs.

[f] Off Site workers excludes off Site remediation project workers who are included in the DoL investigation

Glossary

<	Symbol used in maths to denote “less than”
>	Symbol used in maths to denote “greater than”
ADL	A collective term used for three organochlorine pesticides; Aldrin, Dieldrin and Lindane
adverse effect	A biochemical change, functional impairment and/or pathological lesions (damage to part of the body) that may affect the performance of the whole organism, or that reduce an organisms ability to respond to an additional challenge
adverse health effect	An adverse effect on human health
AECS	**Air Emissions Control System**. The system used to filter air emissions via a stack from the diesel fired rotating cylinder dryer that was used to dry wet contaminated soil during the remediation
AEE	**Assessment of Environmental Effects:** A mandatory assessment required under the Resource Management Act (RMA) for certain resource consent applications. It outlines the effects that a proposed activity may have on the environment
AES Ltd.	**Air & Environmental Sciences Limited**. An Air Quality and Environmental consultancy
ATSDR	**Agency for Toxic Substances and Disease Registry**, a branch of the US Department of Health and Human Services, Public Health Service
bore/well	A hole from which groundwater is abstracted from subsurface water-bearing formations
breakdown products	Products produced by breaking a larger molecule into smaller parts
carbon filter	A filter in the Air Emissions Control System employing activated carbon to remove particles from the air The chemical nature of activated carbon is such that its high surface area and porosity make it an ideal medium for the removal of organic pollutants from liquid or gas streams
Compliance Officer	The TDC Compliance Co-ordinator as referred to in the Resource Consents
DAP	Diammonium phosphate
DDD (TDE)	Dichlorodiphenyldichloroethane, a breakdown product of DDT
DDE	Dichlorodiphenyldichloroethylene, a breakdown product of DDT
DDT	1,1,1-Trichloro-2,2-bis(4-chlorophenyl)ethane, an organochlorine pesticide

DDX	The sum of DDT and its primary breakdown products
dehalogenation	The reduction or removal of halogens from a chemical compound. Halogens are various non-metallic elements that readily combine with metals. Halogenated compounds are more likely to be toxic
de novo	Latin: to make anew
deposited dust	Dust that settles out of the air and is measured on the basis of the mass per unit surface area over a fixed period of time (eg g/m^2 per 30 days)
dioxin	A group of chemicals that share similar chemical structures and properties, belonging to three related families – the polychlorinated dibenzo-*p*-dioxins (PCDD), the polychlorinated dibenzofurans (PCDF) and certain of the polychlorinated biphenyls (PCBs).
discharge stack	A stack post the Air Emissions Control System that discharges air to the atmosphere following soil treatment in the rotary dryer
dispersion modelling	A computerised technique used for predicting the movement of pollutants through the air.
EDL	**Environmental Decontamination Limited**. Originally a subcontractor to Thiess. When Thiess withdrew the company was contracted to MfE. In addition to operating the MCD plant the company was also responsible for up lifting excavated soil for treatment, assessing pesticide concentrations in the soil before and after treatment and stockpiling treated soils
Egis	**Egis Consulting Australia Pty Ltd** An environmental consultancy company contracted by the Tasman District Council to produce a report in 2001 to develop acceptance criteria for various environmental media eg soil, sediments etc
EMS	**Effective Management Services Ltd.** This Company was contracted by MfE as the site manager following the withdrawal of Thiess. Its role was to oversee and direct site operations including responsibilities for consent compliance, work programming, validation sampling and community liaison
exposure pathway	The physical course of contaminants from their source to people via a medium (air, soil, surface water, or ground water).
FCC	**Fruitgrowers Chemical Company**
fines	Soil and rock fragments less than 2 mm
fugitive emissions	Emissions not caught by a capture system (due to factors such as equipment leaks, evaporative processes and/or wind)
gm/m^3	grams per cubic metre
groundwater	All water which is below the surface of the ground in a saturated zone of the soil

hazard	A source or situation of potential harm
HCB	**Hexachlorobenzene** was used in the past as a pesticide but is more commonly found as a contaminant in other organochlorine pesticides
HCH	**Hexachlorocyclohexane** is an organochlorine and exists in eight chemical forms called isomers. It was used in the past as an insecticide with gamma-HCH (lindane) as the main active ingredient (the product also typically contained some of the other isomers). There were three isomers analysed in the air samples from the Site (alpha, beta and gamma-HCH)
heavy metals	Metallic elements with high atomic weights or density, such as mercury, cadmium, arsenic and lead. Many heavy metals are toxic, and since they do not easily break down tend to accumulate in the food chain
herbicide	Any pesticide used to destroy or inhibit plant growth
inhalable particulate	PM_{10}, particulate matter less than 10 microns in size. Particles of this size are small enough to enter the lungs and cause health effects
lindane	an organochlorine pesticide
MAV	**Maximum Acceptable Value**, the MAV relates to drinking water. It is the concentration of a substance below which the presence of the substance does not result in any significant risk to a consumer over a life time of consumption
MCD	**Mechano Chemical Dehalogenation,** a non incineration, low temperature multistream closed reaction process for treating soil containing persistent organic pollutants (POPs)
MCD Plant	The MCD plant consisted of two main processes, the rotary dryer followed by treatment in the ball mill reactor.
MfE	**Ministry for the Environment**. A Ministry of the Crown (responsible for the administration of the Resource Management Act). It partly funded the FCC site remediation and assumed the role of consent holder after Thiess withdrew in 2004
mg/L	milligrams per Litre
mm	millimetres
µg/L	micrograms per litre
microgram (µg)	1/1,000 of a milligram or 1/1,000,000 of a gram
nuisance dust	Dust particles large enough to be visually apparent in the air and on surfaces, thus causing visual nuisance or offence
OCPs	**Organochlorine pesticides**, Synthetic organic compounds containing chlorine; also known as chlorinated hydrocarbons and includes pesticides such as DDT, aldrin, dieldrin and

	lindane. Found to be toxic in non target species, persist in the environment and have a propensity to accumulate in the food chain
organics	Natural organic materials of waste or non-waste origin, including petroleum products, pesticides, herbicides, solvents, and chemicals from decaying plants and animals
organophosphate	A group of organic compounds consisting of phosphorus bonded with carbon. Organophosphate pesticides break down rapidly when exposed to sunlight, air and soil
PAHs	**Polycyclic aromatic hydrocarbons**, formed at trace levels during combustion
particulates	Sum of all microscopic liquid and solid particles, of human and natural origin, that remain suspended in a medium such as air for some time. Particulate matter may be in the form of fog, fumes, dust, soot or fly ash
PCBs	**Polychlorinated biphenyls,** a class of chemical compounds containing benzene and chlorine atoms. Some are used for pesticides and fire-resistant coatings
pesticides	Chemicals used to kill, control, repel or mitigate any pest; includes herbicides (to control weeds and plants), insecticides (to control insects), fungicides (to control fungi), rodenticides (to control rodents) and germicides (to control bacteria)
PCP	**Pentachlorophenol**, a chemical historically used as an anti-sapstain fungicide for short-term protection of sawn timber surfaces
PM_{10}	**Particulate matter** less than 10 microns in size. Particles of this size are small enough to enter the lungs and cause health effects. Is also known as inhalable particulate
POPs	**Persistent Organic Pollutants**, organic substances that do not break down quickly in the environment and are readily taken in by living organisms through contaminated food or polluted water or air. These pollutants include some pesticides (e.g. DDT, aldrin) and other chemicals (e.g., dioxins, PCBs)
PoP	**Proof of Performance**, testing of the remediation technology and associated processes so as to ensure adequate compliance and outcomes prior to the full site remediation being undertaken
ppb	**parts per billion** denote the number of units of one substance relative to one billion units of another substance
ppm	**parts per million** denote the number of units of one substance relative to one million units of another substance. (1ppm = 1mg/L)
PRP	**Peer Review Panel**, this panel was established under the Resource Consents to review, comment and make recommendations during the remediation

PUF sampler	**Polyurethane Foam** sampler, an air sampler that uses polyurethane foam for capturing organic vapours
pug mill	A device that mixes and grinds clay or other materials to a desired texture, using rotating paddles or blades
reagent	A substance used to react with another substance
risk assessment	A process that identifies hazards, dose response relationships and the actual or potential exposure of people to those hazards and then combines that information to characterise and estimate the risk in order to help determine how best to manage the risk
risk	The probability of harmful consequences arising from a hazard
rotary dryer	A diesel fired rotating cylinder used to heat and dry contaminated soil (also referred to as “dryer” in the report)
Site Management Plans	Site Management plans were a condition of a Resource Consent issued for the site remediation. The consent holder was required to appoint an experienced site manager who was responsible for the preparation and submission of the plans to the Site Auditor (remediation) and the TDC Compliance Co-ordinator for approval
SAC	**Soil Acceptance Criteria** Soil guideline values defining the levels of contaminants that are not considered to pose an unacceptable risk to human health or the environment
Site Auditor (final audit)	Consultants engaged by the MfE to audit the completed remediation. Produced the Final Site Audit report.
Site Auditor (remediation)	Person appointed by TDC and MfE to provide independent advice on the remediation of the Site and associated matters
SKM	**Sinclair Knight Merz** Environmental consultants used by Thiess and MfE.
stack emissions	Emissions to the atmosphere from a stack
TEQ	**Toxic Equivalency Quotient** for any mixture of dioxins is determined by summing the toxicity weighted concentration of each toxic dioxin in the mixture to give a single concentration
TEF	**Toxic Equivalency Factors** are assigned to each of the toxic dioxins based on relative potency with TCDD. This allows concentrations of the less toxic dioxins to be expressed as toxicity weighted concentration (ie equivalent to a similar concentration of TCDD)
THI	**Total Hazard Index** ,the Total Hazard Index is a way of expressing the potential for adverse health effects from exposure to a group of substances at the same time (cumulative effects)
Thiess	**Thiess Services Pty Limited** the Australian Company originally contracted by the Tasman District Council in 2001 to remediate

	the FCC site. The company withdrew in 2004
TDI	**Tolerable Daily Intake** a TDI is an estimate of the amount of a substance in air, food or drinking water that can be taken in daily over a lifetime without appreciable health risk. TDIs are calculated on the basis of laboratory toxicity data to which uncertainty factors are applied
threshold concentration	The concentration of a substance below which no adverse effect is expected to occur
TSPs	**Total Suspended Particulates,** particulates of all sizes present in ambient air
VOCs	**Volatile Organic Compounds**, organic compounds that may evaporate and enter the atmosphere. Occur in nature or be man-made and may be toxic.
venturi scrubber	A device associated with the Air Emissions Control System that removes water soluble pollutants prior to emission to the atmosphere
Well/bore	A hole from which groundwater is abstracted from subsurface water-bearing formations

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