FINAL REPORT

ASSESSMENT OF THE EFFECTS OF COMBUSTION OF WASTE OIL, AND HEALTH EFFECTS ASSOCIATED WITH THE USE OF WASTE OIL AS A DUST SUPPRESSANT

Prepared for

Ministry for the Environment
Wellington

7 August 2000

Woodward-Clyde (NZ) Ltd
A division of URS Corporation
Bank Direct Centre, 13-15 College Hill, PO Box 821, Auckland, New Zealand
Ph 0-9-355 1300●Fax 0-9-355 1333

AA25080036

Table of contents

Tables **Page**

Figures

Appendices

PROJECT OBJECTIVES

Woodward-Clyde (New Zealand) Limited has been commissioned by the Ministry for the Environment (MfE) to:

- Determine the environmental appropriateness of burning used oil and to identify any parameters (e.g. fuel specifications) within which used oil might be burned;
- Determine the environmental impact and health effects of road oiling, and to identify any parameters within which road oiling might be undertaken with minor effects on the environment and human health.

This information on the nature and scale of environmental and health effects associated with the reuse of used oil will be used by the MfE to determine the need for national or regional level controls on burning used oils or applying used oils to roads.

To meet the project objectives, tasks therefore comprised:

- Categorising the composition of New Zealand used oils;
- Evaluating the effects of burning used oil, and recommending appropriate controls;
- Evaluating the effects of road oiling and recommending appropriate controls.

There are a large number of collectors, processors and suppliers of used oil in New Zealand. Each of these companies collect used oil, process it and supply it to one of the large or small combustion systems as a source of fuel. The major companies, their locations and the main combustion system they supply are provided as follows.

CONTRACTOR/PROCESSOR	LOCATION	SUPPLIES TO
Salter Cartage	Auckland	Milburn Cement
United Environmental Limited	Auckland	Fulton Hogan
Waste Petroleum Combustion	Auckland	Hot houses
Marine Oil Services Limited	Mt Maunganui	Tasman Pulp and Paper Kinleith
Bens Oils	Nelson	South Island Boiler installations
Chemwaste	Christchurch	Boiler installations and regional road oiling, Fulton Hogan
South Oil	Invercargill	Fulton Hogan

The composition of the used oil varies extremely widely depending on the sources, mixes and processing that takes place. Milburn Cement is required to analyse the untreated used oil used to fuel their Cape Foulwind plant. The oil is a mix of lubricating oils and marine slops. The data collected over a period from 1996 to 1999 shows that metal concentrations are highly variable. In general lead concentrations have decreased (following the withdrawal of leaded petrol) and there has been a corresponding increase in zinc.

Additional data on used oil composition has been supplied by a range of oil processors for the purposes of this study. The results are for “one-off” tests (with the exception of some data supplied by United Environmental which is an average of 10 samples). The results show that there is a considerable range of contaminants in what is classified as processed used oil. No significant quantities of PCBs were found in any of the samples.

In general, road oiling is carried out using used oil collected from service stations.

In New Zealand the main oil combustion systems are atomising and vaporising burners.

Atomising burners atomise the fuel using air. In New Zealand they range from 500 kW to 2.5 MW with the majority of boilers on the smaller end of the scale. The burners are very tolerant of a range of used oil compositions.

The large atomising burners in New Zealand are located at Milburn Cement (Cape Foulwind) and Tasman Pulp and Paper (Kinleith). There are also a number of asphalt plants (at least three with two more in the process of applying for consents) which use atomising burners. The use of used oil for asphalt manufacture is becoming more common as it is a relatively cheap source of fuel.

Vaporising burners are the most basic form of burner that either drip or pump the oil onto a heated base plate which cause the volatile components of the fuel to vaporise. These burners tend to be used by garages and workshops. The vapour combines with air drawn through the side of the burner and then combusts. Because of inefficient combustion, this process generates relatively high concentrations of PAHs.

Based on information supplied for this project, the two large atomising burners at Milburn Cement and Tasman Pulp and Paper account for approximately 60% of the used oil (including ship slops) combusted in New Zealand.

There are no New Zealand emission factors available for used oil combustion. The United States Environmental Protection Agency (US EPA) emission characteristics have therefore been used in this study. With the exception of sulphur, the average contaminant levels in used oils in New Zealand are lower than those reported from the US EPA which means the US EPA emission factors will generally provide an overestimate of emissions occurring here.

To identify the impacts of low temperature used oil burning, three scenarios were modelled:

1. Small vaporising burner;
2. Medium sized atomising burner;
3. Asphalt plant using used oil as a fuel.

Each of these scenarios were evaluated for diesel or light fuel oil as well as processed used oil.

The key assumptions for each of the three modelling scenarios are presented as follows.

ASSUMPTION	**Small Vaporising unit**	**Medium Atomiser Unit**	**Asphalt Plant**
Fuel rate (L/h)	4	50	1000
Stack Height (m above ground)	3	10	12
Velocity (m/s)	11.7	13	14
Temperature (Celsius)	400	200	60
Discharge Rate (g/s)	1	1	1
Diameter (m)	0.15	0.15	0.95
Distance to Residences (m)	20	100	20
Terrain effects	None	None	None

It was assumed that all of the emissions were discharged directly to the atmosphere. This is accurate for the small and medium units but all of the asphalt plants currently operating with used oil in New Zealand are fitted with scrubbers. The predicted results for the asphalt plant will therefore provide an overestimate of actual emissions.

The dispersion of the emissions for used oil and diesel for each of the three scenarios was modelled using AUSPLUME. The artificial meteorological data set "Metsamp" was used which contains all of the worst case conditions.

The predicted contaminant loads (in g/s) were compared with the New Zealand Ambient Air Quality Guidelines (1994) and the currently proposed changes to this guideline. In cases, where there was no available New Zealand air quality guideline, either the Victorian Environmental Protection Agency Air Quality guidelines (1995 and 1998) or the New Zealand Workplace Exposure Standards (1992) were used.

The results of the analysis showed that for all three modelling scenarios:

- All predicted offsite metal concentrations were significantly lower than acceptable guideline values;
- Predicted "combustion emissions" (including sulphur dioxide, VOCs, Carbon Monoxide and PAHs) were significantly lower than acceptable guideline values;
- With the exception of sulphur dioxide, diesel produced greater combustion emissions than used oil;
- Used oil produced greater metals emissions than diesel.

On the basis of the modelling completed, combustion of processed used oil does not generate any significant adverse impacts on atmospheric quality.

IDENTIFYING "WORST CASE"

There are three main areas that road oil is used in New Zealand:

- Dust suppression on roads around residences with relatively high seasonal use;
- Dust suppression on roads with commercial vehicles;
- Dust suppression on private roads.

In most situations the oiling is carried out in areas directly surrounding the residents. For example the Queenstown Lakes District Council pay for dust suppression to be carried out on roads for 1 km on either side of residences on one occasion during the summer period.

To identify the impacts of road oiling, three scenarios were investigated, a low use, medium use and commercial use non-sealed road. The assumptions for each of these scenarios are provided as follows.

ASSUMPTION	Low use Road	Medium Use Road	Commercial Road
Vehicle movements (per day)	20	200	50
Vehicles	Cars/Light vans	Cars/Light vans	Trucks
Rainfall (days per year)	120	120	120
Effectiveness of road oiling (%)	90	90%	90%
Surrounding landuse	Horticultural/Farming	Horticultural/Farming	Horticultural/Farming

On the basis of modelling a range of exposure pathways (for example oil contaminated dust settling on crops, oiled particulates in the runoff entering streams) it was determined that the "worst case" or maximum potential for oil entering the adjacent environment arose from the middle scenario – a medium use road. A detailed analysis on the specific exposure pathways was therefore completed using this scenario, on the basis that this would predict the highest volume of dust generated by vehicle movement and hence the greatest potential environmental and human exposure.

Similarly a range of data on the chemical composition of used oil to suppress dust on the roads was compared to select the "worst case", or most contaminated oil. These concentrations were used as the input data for all exposure pathways. Results of the assessment therefore represent "worst case" potential environmental impacts using the most contaminated oil applied to the road with conservative assumptions for loss to the environment.

In each case, contaminants assessed were lead, copper, naphthalene, pyrene, benzo(a)pyrene (toxic equivalency factor) and total polycyclic aromatic hydrocarbons (PAHs). These chemicals were selected for the following reasons:

- Lead and copper were selected due to their elevated levels in the 'worst case' used oil sample.
- Naphthalene was selected because it is the predominant organic compound present in the Confidential sample provided to Woodward-Clyde. Furthermore, environmental and health-based guidelines exist for this compound.
- Pyrene was selected because it is representative of the less volatile, non-carcinogenic PAHs. The concentration of this contaminant in the various environmental media used in the health risk assessment was based on a sum of the concentrations of all non-carcinogenic PAHs detected in the used oil.
- A toxic equivalency factor for benzo(a)pyrene was selected because it is representative of the carcinogenic PAHs. Benzo(a)pyrene and other carcinogenic PAHs were found to have concentrations of less than the detection limit in the used oil. For the assessment, the concentrations of each compound were assumed to be equal to the limit of detection. Estimated concentrations of carcinogenic PAHs, in the various environmental mediums as a result of road oiling, was required for use in the health risk assessment.
- Polycyclic aromatic hydrocarbons (PAHs) were summed to provide a total concentration for PAHs. Due to their low individual concentrations it was not considered practical to assess each compound individually. Furthermore, environmental and health-based guideline values exist for total PAHs.

EXPOSURE PATHWAYS

There are two main pathways by which the contaminants in the used oil can enter the adjacent environment from an oiled road surface:

- Attached to dust particles blown into the surrounding atmosphere;
- Attached to sediment particles in stormwater runoff.

Once entering the atmosphere, contaminated dust may settle on crops, adjacent soil and grazing pasture, adjacent surface waters and sediments, or be inhaled by humans.

In runoff, the oil particles may enter adjacent surface waters or sink to the sediment layer of a stream bed.

Grazing pastures contaminated directly with oily dust particles, or indirectly through stormwater, could then be ingested by cows and contamination of milk supplies could occur.

The dermal absorption of contaminants from soil during gardening may also occur.

The exposure pathways for used oil on roads are presented in Figure 6-1. To predict total exposure to humans and the environment, each of these exposure pathways was modelled using a range of worst case assumptions.

DUST DEPOSITION

Contaminant levels in the dust

The quantity of dust emitted from each of the roads was determined using US EPA emission estimates. The emissions were modelled on the basis that oiling achieved at least a 90% reduction of the road dust.

The derived emission rates were used in the Fugitive Dust Model (FDM) to predict the dispersion of dust from the road. A full year meteorological data set from the Auckland region was used for the modelling exercise. The model predicted both deposition rates and ambient dust concentrations for each of the three road scenarios.

The contaminant concentrations in the dust were predicted using:

- the model output (presented as dust concentrations in $g/m^2/s$),
- an application rate of 2 L/m^2 and an oil density of 0.9,
- application over a square metre of unsealed road for atmospheric dispersion calculations and over a 1m wide x 3m long strip from the centreline of the road to the verge for the runoff calculations.

RUNOFF

Predicted contaminant concentrations in the runoff

To assess the volume or mass of particulates that could potentially become entrained in stormwater runoff from the road, the Universal Soil Loss Equation (USLE) was used. This equation includes factors such as erosion potential, slope length and steepness, and vegetative cover and rainfall (a two year, six hour duration event). The equation estimates the sediment yield in tonnes/hectare/year.

The volume of water generated was assessed using the Rational formula and was equal to $0.15m^3$ for a 1 in 2 year storm over 6 hours. In addition, for the purposes of this assessment it was assumed that a single storm event contributed the entire particulate and water load to the grass verge.

ENVIRONMENTAL CONCENTRATIONS

Contaminant concentrations in Soil

The contaminant concentrations in soil were derived from inputs of deposited dust and runoff from stormwater. To estimate the volume of particulates and water retained or trapped in the grass verge, the verge was assumed to be 1m wide and 5m long and was vegetated by grass, weeds or small shrubs. The verge was assumed to retain 75% of the water and particulates in the runoff. The remaining 25% was assumed to enter the adjacent watercourse. To calculate the annual contaminant load due to the storm event and dust deposition it was assumed that the dust and runoff were mixed through the top 10cm of soil in the grass verge.

The resulting concentrations in the soil at the verge after an annual contaminant load and after 70 years of historic accumulation were below the ANZECC (1992a) and MfE Gasworks (1997) guidelines, with the exception of naphthalene. The assumptions do not make any allowance for contaminant loss via the variety of processes in soil and hence over-estimate the resulting concentration.

The concentrations of runoff and dust derived contaminants in the soil were used for the uptake by grass, consumption by cows and excretion into milk exposure pathway discussed below. The concentrations of contaminants associated with dust deposition only were used for the root crop and gardening assessment.

Contaminant Concentrations in Sediment

The remaining 25% of the contaminants in the stormwater runoff were assumed to pass over the 5m long strip of grass verge and enter a single square metre area of the adjacent stream. The stream was assumed to be 30cm deep and the water was not flowing. Thus the runoff mixed with 0.3m^3 of water in the stream. Dust was also assumed to enter the watercourse and either settle to the sediment of the stream bed or remain suspended in the water column.

The sediment concentration in the stream was estimated assuming that the 100% of the particulates settled to the stream bed and mixed with a 2cm layer of sediment already in the stream. To estimate the accumulation of contaminants in the sediment layer after 70 years, 70 annual runoff particulate loads were assumed to be retained in the stream bed.

The total annual contaminant concentrations in the sediment as a result of the dust deposition and particulate laden runoff were all below the lower guideline values given in both the draft ANZECC (1999) and NOAA (1995) guidelines, with the exception of naphthalene.

The 70 year historic accumulation does not allow for further mixing, erosion, flooding, dilution with clean sediment or degradation of the organic species. Thus the assessment over-estimates the expected 70 year concentrations. Despite this, the concentrations of most organic species significantly exceeded the relevant guideline values. Consequently, over a period of 70 years, accumulation of organic compounds in the sediment layer is expected to adversely effect benthic biota.

Contaminant Concentrations in Water

To calculate the concentration of contaminants in the water, the volume of water in the stream was combined with the runoff volume. 100% of the contaminant load in the runoff and in the deposited dust was assumed to remain suspended in the stream water. The stream was assumed to be 30cm deep and the water was not flowing. Thus the dust and runoff mixed with 0.3m^3 of water in the stream.

A 70 year loading of suspended contaminants in the water column was not undertaken given that mixing of the water column was likely within the stream.

A comparison of the estimated water borne contaminant concentrations as a result of annual dust deposition and runoff to the stream with the ANZECC guidelines (1992 and 1999) shows that both sets of guideline values are exceeded if the annual load is deposited in the stream at once. The expected flow of the stream and additional inputs from rain are expected to mix and further dilute the contaminant load.

The practice of oiling roads with used oil to reduce dust volumes is expected to have an adverse effect on the quality of water in a stream lying between 5m and 7m from the road (5m and 7m are the length of the grass verge and the distance from the road with the highest deposition rate, respectively).

FOOD CHAIN CONCENTRATIONS

Contaminant Concentrations in Root Crops

To calculate the uptake of contaminants from soil by root crops, bioconcentration factors were used. The assessment of root vegetable uptake was based on the concentration of contaminants in the soil as a result of dust deposition.

The annual mass of each contaminant was mixed with the top 10cm of soil as this was representative of the soil mixing as a result of typical gardening activities. The uptake by crops after exposure to the soils with 70 years of historically accumulated contaminants was also assessed.

The concentrations of the contaminate in the roots crops varied between 1 x 10^{-5} and 1 x 10^{-3} mg/kg for the annual contaminant load from dust being deposited in soil to between 0.002 and 0.5 mg/kg for crops grown in soil after 70 years of historic accumulation.

Contaminant Concentrations in Apples

The concentration of contaminants in dust that accumulates on apples was estimated assuming:

- That apples were exposed on the trees for six months of the year.
- That the apples during those six months, were fully grown, that is, approximately 8cm in diameter.
- That during this six month period, no dust was washed from the apples by rainfall.
- That 75% of the surface of the apple was exposed to, and accumulated, dust.
- That up to three apples were then eaten daily for a period of three months.

The above assumptions were designed to be conservative in terms of dust accumulation. The potential washing of the apples by rainfall was excluded from the calculation, as was the growth rate of the apples on the trees.

The mass of contaminants in the apples varied between 0.002mg to 0.15mg depending on the contaminant.

Contaminant Concentrations in Cows Milk

The uptake of contaminants from soil by grass, consumption by cows and the excretion into cows milk was assessed for the organic components of the used oil only. The organic contaminants have typically low water solubility and are predominantly partitioned into the fat and milk of a cow. The contaminant concentrations in the soil were take to be the total of the runoff and dust deposited scenarios. This would represent the situation where cattle were able to graze the grass verge of the oiled road.

However, to take a conservative approach, the BCF values used in the uptake of contaminants by root crops were applied to the uptake by grass. It was also assumed that the translocation of the organic fraction from the root to the leaf/stem was 0.2 time the BCF for root crops (MfE and MoH, 1997). For the purposes of this assessment cows were assumed to eat only grass and consume approximately 15 kg of dry matter each day.

The excretion into milk was calculated using McLachlans model (1994). To calculate the concentration in milk produced on a daily basis it was assumed that each cow typically produced 10L of milk each day.

The concentrations of the contaminants in cows milk varied between 1×10^{-5} to 2×10^{-3} mg/L/day for the soil containing the annual contaminant load and between 7×10^{-4} and 0.16 mg/L/day for the soil containing 70 years accumulated contaminants.

HUMAN HEALTH RISK ASSESSMENT

The results from the above environmental and food chain analysis of exposure pathways were used to predict the worst case human exposure. It was assumed that all potential human exposures are cumulative and both adults and children were assessed. The exposure pathways included:

- Consumption of crops grown in contaminated soil as a result of deposited dust;
- drink unpasteurized milk from a cow who had eaten grass exposed to contaminated stormwater runoff and deposited dust;
- inhale contaminated dust while travelling along the oiled road.
- eat apples covered with contaminated dust which are grown in an orchard adjacent to an oiled road.
- Garden in soil contaminant with deposited dust.

The analysis was completed using toxicity factors derived from both the USEPA and the Australian National Health and Medical Research Council – which is referred to as the ANZECC approach.

The sum of the nonthreshold carcinogenic risks from individual exposure pathways, using 1 year contaminant concentrations, is 5.17×10^{-5} and 5.57×10^{-5}, for a child and adult respectively. These respective risks increase to 6.53×10^{-5} and 8.81×10^{-5} when using 70 year historic contaminant concentrations. In both cases, the risk to human health is considered unacceptable given that the risk is greater than the acceptable level risk of 1×10^{-5} used in New Zealand guideline documents.

The sum of threshold noncarcinogenic risks (Chronic Hazard Index) from individual exposure pathways, using 1 year contaminant concentrations, is 1.94 and 0.420, for a child and adult respectively. These respective risks increase to 3.10 and 0.943 when using 70 year contaminant concentrations. The hazard to a child receptor, as a result of exposure to the individual pathways, is unacceptable given that the hazard index is greater than 1. The hazard to adults is less than 1 and is therefore acceptable.

For each scenario it is the exposure to dust on apples that is primarily responsible for the risk associated with the carcinogenic compounds and this applies to both children and adults. When the risk calculated for apple consumption is excluded from the calculation, the total carcinogenic risk for both children and adults from the annual contaminant load is 2.34×10^{-7} and 5.57×10^{-7} respectively, and is acceptable. Exposure to 70 years of historic accumulation increases the child and adult risk to 1.38×10^{-5} and 3.29×10^{-5} respectively and remains unacceptable.

RECOMMENDATIONS

Based on the used oil combustion assessment presented in this report Woodward-Clyde makes the following recommendations.

That if used oil combustion is to continue the following conditions should apply:

- Oil conforms to US EPA requirements or similar including an appropriate guideline value for sulphur.
- Combustion equipment is properly installed and operated and meets the Regional Air Plan requirements for the region in which it is installed
- Consideration should be given to limiting fuel usage or the size of plant that used oil can be combusted in without the need for mitigation measures. Above this size appropriate mitigation measures such as scrubbers may be required to achieve acceptable environmental outcomes.

Based on the assessment of the environmental effects and human health risk assessment for road oiling the following are recommended:

- That the application rate for used oil should not exceed 2 l/m^2;
- The oil should not be applied within 10m of a watercourse to protect both the water and sediment quality.
- Cows should not be permitted to graze grass within 10m of an oiled road. This would reduce the impact of runoff associated contaminants trapped in the grass verge on cows milk.
- Apples and other pip and stone fruit should be washed before consumption.
- To minimise runoff of free oil product the used oil should only ever be applied:
    - to a dry road
    - when 2-3 days of fine weather is forecasted.
- The water content in the oil should be minimised as far as practicable. If the oil is to remain in the tanker for a number of hours prior to discharge to the road, the separated water should be bled off prior to the oil being spread on the road surface.
- Benzo(a)pyrene is the main contributor to the unacceptable risk for the combined exposure pathways. If possible the benzo(a)pyrene concentration should be measured in the oil and the oil only applied to the road if the concentration is less than a specified value. A sensitivity analysis could be undertaken to determine this value.

To achieve these ends it may be necessary for MfE to formulate a guideline or standard similar to that promulgated by the US EPA.

Woodward-Clyde has been commissioned by the Ministry for the Environment (MfE) to prepare a technical report on the potential environmental effects of the use of used oil. The report focuses on two areas:

- Determine the environmental appropriateness of burning used oil and to identify any parameters (e.g. fuel specifications) within which used oil might be burned;
- Determine the environmental impact and health effects of road oiling, and to identify any parameters within which road oiling might be undertaken with minor effects on the environment.

This information on the nature and scale of environmental and health effects associated with used oil will be used by the MfE to determine the need for national or regional level controls on burning used oils or applying used oils to roads.

To meet the project objectives, tasks therefore comprised:

- Categorising composition of New Zealand used oils;
- Evaluating the effects of burning used oil, and recommending appropriate controls;
- Evaluating the effects of road oiling and recommending appropriate controls.

Woodward-Clyde would like to acknowledge the assistance of all those companies that made information available for this report.

This report has been set out in a number of sections. The areas covered in each of these sections are:

- Section 2 Composition of New Zealand Used and Treated Oils
- Section 3 Used Oil Combustion Devices
- Section 4 Used Oil Combustion Emissions
- Section 5 Road Oiling Emissions
- Section 6 Estimation of Effects from Road Run off
- Section 7 Human Health Risk Assessments
- Section 8 Report Recommendations

A review of the major oil collectors and processors in New Zealand, the type of treatment processes that they carry out, and the compositions of used oils in New Zealand, is presented below. It also includes information on a range of oils used in combustion and road oiling, as well as presenting information on the quantities used in the various areas. One of the issues that has become apparent in the course of this investigation is that there is a significant variation in terms of what is defined as treated oil. For the purposes of this report Woodward-Clyde has defined treatment as a process which removes contaminants other than water and particulate matter, these two processes being defined respectively as dewatering and filtration.

2.1 INTRODUCTION

The potential sources and components that go to make up the used oil stream in New Zealand have been reviewed previously for MfE by Worley Consultants (Worley 1999). To avoid repetition, this information has not been replicated in this report. There is one oil source that is not covered in the Worley report, which is marine slops. This consists of fuel oil used in ships together with small amounts of lubricating oil. This type of oil was not included in the inventory of used oil, prepared by Worleys, as it is not imported for use here. However, it does make a significant contribution to the quantity of used or treated oil combusted in New Zealand.

2.2 USED OIL SUPPLIERS

Information on oil suppliers is presented geographically, and includes information on the major oil collectors, processors and suppliers. There appear to be a number of other small companies who collect and supply used oil which is reused locally. Generally these smaller companies do not appear to have any treatment or processing capability.

There also appears to be a significant variation between the different suppliers as to the level to which dewatering and filtration are carried out. This variation has the potential to result in poor performance or damage to equipment operated by users of used oil when switching from one supplier to another.

2.2.1 Salter Cartage Limited

Salter Cartage appear to be one of the largest of the used oil collectors in New Zealand. They have a main depot in Auckland, where they store used oil and carry out some blending operations. They also process the used oil to reduce the free water content.

All of the used oil collected is supplied to Milburn Cement for combustion at their Cape Foulwind plant. Based on information supplied by Milburn Cement to Woodward-Clyde, they collect 5 to 6 million litres per annum.

2.2.2 United Environmental Limited

United Environmental operate a used collection and treatment service in Auckland. Part of their operation involves treating used oil to produce a fuel oil, suitable for combustion. Their process involves dewatering, and chemical treatment to remove contaminants.

They are currently supplying Fulton Hogan, with several million litres per annum of treated oil for use in their Auckland asphalt plant for heating purposes.

2.2.3 Waste Petroleum Combustion

Waste Petroleum Combustion operate a used oil treatment plant in Pukekohe. Their process produces a light fuel oil used extensively in the South Auckland area in combustion systems for greenhouses.

They are currently processing in the vicinity of 5 million litres per annum.

2.2.4 Alpine Oils

Alpine Oil operates in Matamata, and carry out a blending and filtration operation. All of the product is supplied to medium sized combustion systems either for use in boilers or heating systems for greenhouses.

Based on information supplied they are processing approximately 1.5 million litres per annum.

2.2.5 Marine Oil Services Limited

Marine Oil Services are based in Mt Maunganui. They operate a dewatering, distillation, blending and filtration operation. Production is based primarily on marine slops,

In the last year they processed approximately 360,000 litres of lubricating oil.

2.2.6 Thurline Transport

Thurline Transport operate in the lower North Island region and collect used oil. This is supplied to Milburn Cement for combustion.

2.2.7 A & G Burroughs Ltd

A & G Burroughs operate in the Taranaki region, and collect used oil which is mostly supplied via Salter Cartage to Milburn Cement. They also carry out some road oiling in the region. The road oiling is carried out using “clean” used oil gathered from known sources

2.2.8 Ben’s Oils Ltd

Ben’s Oils Ltd is located in Nelson. They operate a used oil treatment plant that uses chemical treatment and filtration to produce a fuel oil.

This is supplied to a number of medium to large boiler installations for combustion purposes in the South Island. They process approximately 3 million litres of oil per annum.

2.2.9 Chemwaste

Chemwaste operate a blending, dewatering and filtration plant in Christchurch.

They supply a number of large and small users in the Canterbury region, as well as a small quantity to the Otago region for use in road oiling.

2.2.10 South Oil

South Oil operate a used oil collection service in Southland. Most of the oil is supplied to Fulton Hogan Invercargill for use in their asphalt plant for heating purposes. On this basis they collect at least 0.5 million litres per annum.

2.3 OIL COMPOSITION

Woodward-Clyde has been supplied with a large amount of information with respect to the composition of used oil processed by the companies discussed in Section 2.2. Based on a review of this information it was found that most companies are only regularly monitoring parameters such as flashpoint, calorific value, and water content which directly affect their ability to market their product and/or the enduse of product. There are smaller number of companies that undertake regular or irregular monitoring of the other contaminants in their products. Available data on contaminant monitoring is presented in Table 2-1 and Table 2-2.

This section is arranged in three subsections associated with the different uses that are made of the oil. The information in this section is in summary form. The Milburn Cement information has been included separately as for the most part the oil is used untreated. Full details of the oil compositions from the various sources are included in Appendix A.

2.3.1 Milburn Cement – Combustion of Untreated Used Oil

Milburn Cement combust untreated used oil at their Cape Foulwind cement plant.

Milburn Cement are required to take an analysis of all oil supplied to them in batches for use in their Cape Foulwind plant. They are supplied from various sources with a mixture of lubricating oils and marine slops. Contaminant levels are monitored in the used oil and are presented for the years 1996 to 1999 in Table 2-1 in the form of average concentration and range. In 1999, of the total of 11,150 tonnes delivered (approximately 12.4 million litres) approximately 8,500 tonnes (9.4 million litres) was lubricating oil and the remainder marine slops.

The data in Table 2-1 shows that oil contaminant concentrations have changed with time, especially lead. The reduction in lead concentrations following the withdrawal of leaded petrol, has been mirrored by an increase in the concentrations of zinc. This is shown graphically in Figure 2-1. This may be due to an increase in the use of aluminium-zinc alloys in engine componentry. It is also likely that although lead is no longer used in petrol, it will continue to be present in used oil, due to its use in engine components.

It was noted that the Milburn data shows high concentrations of chlorides compared to other analyses available. Although some of the highest concentrations are associated with ships slops, which can be presumed to be contaminated with seawater, there are also high concentrations associated with other used oil sources. These high concentrations in used oil may be associated with seawater contamination during transportation from Auckland, or could be an indication that the used oil may be being contaminated with chlorinated wastes.

Table 2-1
Oil Analysis at Milburn Cement

Compound	1996 (mg/m^3)	1997 (mg/m^3)	1998 (mg/m^3)	1999 (mg/m^3)
Number of Samples	48	62	70	85
Pb	215 (20 - 1080)	112 (15 - 775)	109 (15 – 405)	56 (10 – 160)
As	<50	<50	<50	55 (<50 - 60)
Al	297 (<100 – 500)	209 (<100 – 800)	243 (<100 – 1000)	145 (10 – 300)
Cd	<15	10 (<10 – 10)	17 (<10 – 20)	10 (<10 – 10)
Cu	36 (<10 – 150)	21 (<10 – 40)	36 (<10 – 120)	31 (<10 - 165)
Cr	23 (14.5 – 35)	<20	39 (<10 –80)	13 (<10 – 20)
Hg	<10	<10	<10	<10
Zn	319 (108 – 1011)	430 (120 – 990)	685 (165 – 2500)	664 (310 – 3670)
Sulphur (%)	1.5 (0.44 – 2.4)	1.2 (0.6 – 2)	1.0 (0.3 – 2.8)	0.83 (0.1 – 2)
Cl	2045 (602 - 4500)	1690 (300 – 4900)	1734 (300 – 7600)	1152 (400 – 2900)
PCBs	<10	<10	<10	<10

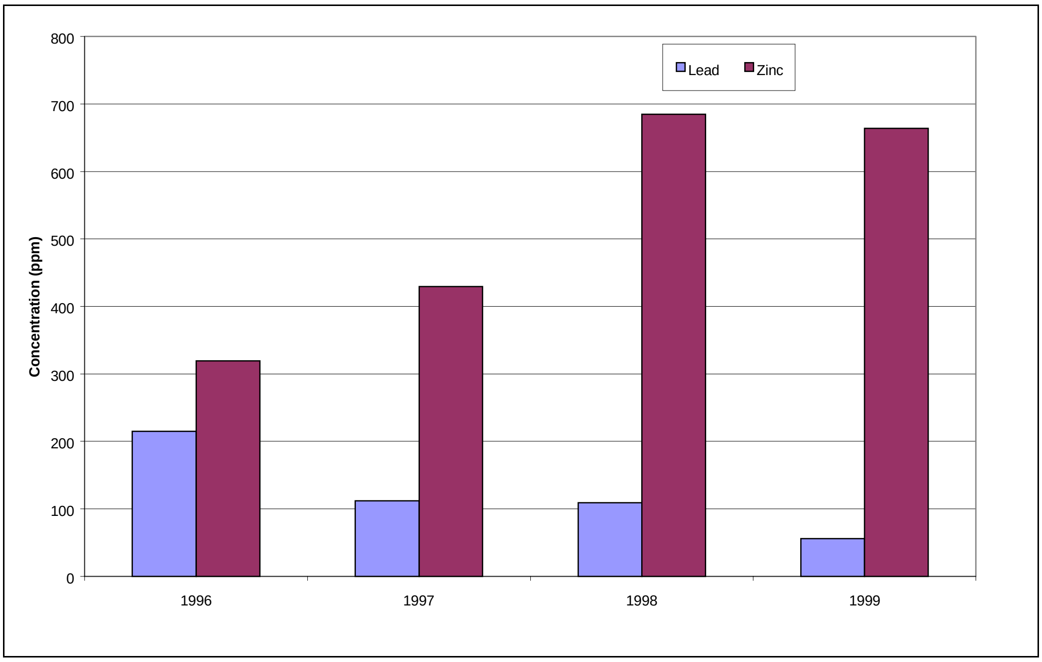


Figure 2-1
Metals in the Milburn Used Oil Stream

2.3.2 Combustion Suppliers

Table 2-2 provides details of the concentrations of contaminants in various “fuel oils” supplied by the main used oil processors. The information apart from the “Confidential data” has been supplied by used oil processors in the form of chemical analysis undertaken at recognised testing laboratories. The results apart from those supplied by United Environmental are for one off tests. The United Environmental results are an average derived from 10 samples. All of the test results have been included in Appendix A. The used oil sample for the confidential supplier was provided to Woodward-Clyde and the analysis carried out for this report, again at a recognised testing laboratory.

The table indicates that there is a considerable range in the concentrations of contaminants in what is classified as processed used oil.

These analyses also indicate that there are no significant quantities of PCBs in the oils.

Table 2-2
Combustion Fuel Oils
(all concentrations in mg/kg except sulphur)

	UEL[1]	**NZ Marine Services**	**Confidential**	**Burroughs**	**Chemwaste**	**Bens**
Pb	50	18.2	71[2]	8	41	31
As			<0.5	3		
Al	<10	66			21	10
Cd	0.37		0.5	1		
Cu	21	12.8	42	21	12	6
Cr	3.2	4.3	1.8	2	2.1	1
Hg			<1	1		
Zn		11.3	180	572	164	
Sulphur (%)		1.3	0.5		0.8	2.24
Cl	500		56		485	
PCBs	<20		<0.5			
Napthalene			79	9.7		
Total PAH			169	30.3		
Ash Content		1.33			0.3	0.4

[1] UEL – United Environmental based on average of 10 samples.

[2] The lead value is taken from another analysis for the same source. The lead concentration reported with the rest of the sample was anomalously high.

2.3.3 Road Oiling

From discussions with various companies involved in road oiling, it appears that most of the oils are collected locally. The companies involved all state that they only use “clean” used oil collected from known service stations. By this they mean that it is only used lubricating oil, which has not been contaminated with other waste materials. Information collected for this report is contained in Table 2-3. The confidential concentrations listed below are typical of the type of untreated used oil that could be used for road oiling, the concentrations labelled Burroughs are for a batch of oil used for dust suppression on a private road.

---

[1] UEL – United Environmental based on average of 10 samples.

[2] The lead value is taken from another analysis for the same source. The lead concentration reported with the rest of the sample was anomalously high.

Table 2-3
Road Oiling Concentrations
(all concentrations except sulphur in mg/kg)

Source	Confidential	Burroughs
Pb	71	8
As	<0.5	3
Cd	1	1
Cu	105	21
Cr	4.6	2
Hg	1	1
Sulphur	0.425	
Cl	184	
PCBs	<0.5	
Napthalene	125	9.7
Total PAH	204	30.3

This section presents information on combustion units currently used in New Zealand for used oil.

3.1 INTRODUCTION

Woodward-Clyde has investigated the various types of combustion systems that are being used for used oil. Based on discussions with various suppliers of both combustion equipment and used oil, there appear to be a wide variety of systems in use.

The largest number of combustion systems appear to be atomising burners used in boilers or in systems supplying heat to horticultural sites, and asphalt plants. However, the total combustion usage for these systems in New Zealand is dwarfed by the usage of the two large used oil users; Milburn and Tasman Pulp and Paper. Another type of combustion system, commonly used in New Zealand, is the vaporising burner.

Each of the systems is described below.

3.2 VAPORISING BURNERS

Vaporising units are generally used for heating, for example, a garage may have a unit which it uses to heat the workshop in winter, using used oil collected in-house.

Vaporising burners are the most basic form of burner, and either drip or pump the oil onto a heated base plate. This causes the volatile components of the fuel to vaporise. This vapour combines with air drawn through the side of the burner and then combusts (see Figure 3-1). Because of the design of this type of burner and its relatively inefficient combustion, it generates relatively high concentrations of PAHs. This can be seen by comparing the emission data presented in Table 4-2 for the vaporising and atomising burners.

However, as the fuel is vaporised the heavy non volatile components such as metals are retained on the base plate. This residual material needs to be removed periodically and due to the potentially high concentrations of lead and other heavy metals this material needs to be disposed of in a suitable manner. Ideally the material should be tested, and if non hazardous placed in a sealed container and disposed of at a sanitary landfill. If the material is hazardous it should be disposed of at a landfill capable of accepting hazardous waste.

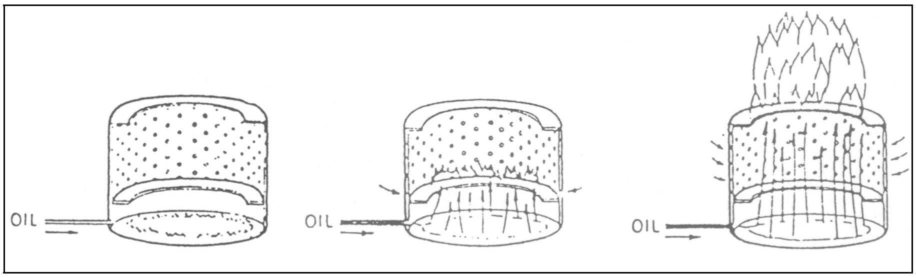


Figure 3-1
Vaporising Burner
Figure shows three stages of combustion i) oil being vaporised, ii) vapour combustion as it comes into contact with air, iii) full combustion

There appear to be few commercial units of vaporising burners currently available in New Zealand. The two main brands that Woodward-Clyde was able to identify were Kroll and Goldspot. The Kroll burners are manufactured overseas and sold through a Hasting based agency. According to the supplier, there are probably about 120 of their vaporising units in New Zealand. There is no available information on how many of these units are still in operation and how many burn used oil as a fuel source. Goldspot burners were manufactured in Christchurch. It is understood that they no longer supply any vaporising burners.

Because of the simplicity of this design, it is possible that there are other home made units being used around the country. However as the fuel flow rates are in the order of 4 to 8 litres an hour, it is unlikely that they make a significant contribution to the amount of used oil combusted.

One of the potential uses of these types of burners has been as frost pots in orchards. Discussions with representatives of the stone fruit growers in Central Otago, indicates that this is becoming a very minor usage, with probably only 1% of growers still using them.

3.3 ATOMISING BURNERS

Atomising burners, as the name suggests, atomise the fuel, usually using air (although some burners use steam), and then inject it into the combustion chamber. There is virtually no difference between the burners that run on diesel or fuel oil and those that operate on used oil derived products. The main difference appears to be that burners used for used oil derived fuels have higher component tolerances to allow for “dirtier” fuel. Figure 3-2 below presents some of the different atomising burners available.

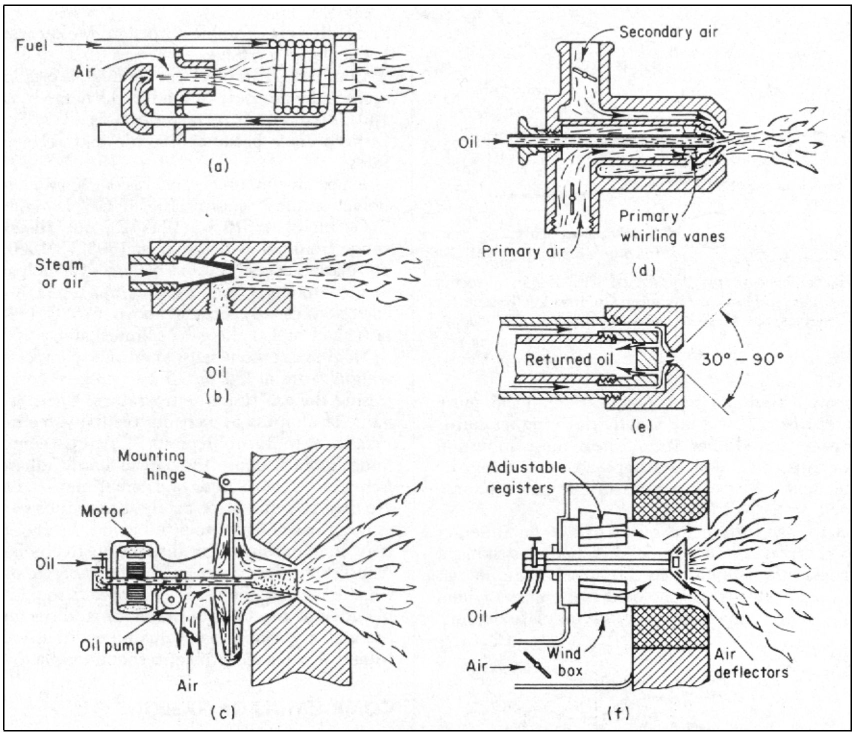


Figure 3-2
Types of Atomising Burners

(a) Pressure atomising burner, (b) High pressure steam or air atomising burner, (c) Horizontal Rotary Cup (d) Low pressure air atomiser, (e) Mechanical or oil pressure atomiser, (f) Complete Mechanical atomiser

Atomising burners are used in a wide range of application from boilers providing process steam, to heaters for horticultural applications. Based on discussions with suppliers of the burners, the size of the units available in New Zealand range from 500 kW to 2.5 MW (capable of burning approximately 50 litres per hour to 2,500 litres per hour). The majority of the units appear to be at the smaller end of the scale.

There is very little difference between the used derived fuel oil and standard fuel oils/diesels in terms of physical properties such as viscosity and density, and for this reason many companies supply burners that can be used in this application. Three brands of burners that are marketed as being specifically for used oil are Kroll, Goldspot and Weishaupt.

3.4 LARGE USERS

There are a number of large users of used oil, these include Milburn Cement at Cape Foulwind, Tasman Pulp and Paper at their Kinleth Mill, and a number of asphalt plants (at least three with two more in the process of applying for consents), which combust the majority of the used oil in New Zealand. These processes all use atomising burners. The difference for these plants (apart from Tasman Pulp and Paper which is a standard boiler arrangement) is that the combustion gases have direct contact with either the asphalt or lime before being discharged to air. Because of the nature of these operations, the combustion equipment has some sort of control equipment that “cleans” the combustion gases prior to discharge. Depending on the nature of this control equipment, it has the potential to significantly reduce the concentrations of contaminants in the combustion gases. These processes, because of their size, are all covered by Resource Consents for discharges to air, many of which contain Conditions to ensure monitoring of discharges to air and which impose limits designed to minimise the potential effects on the environment.

3.5 HIGH TEMPERATURE VERSES LOW TEMPERATURE COMBUSTION

It is argued that “high temperature” is the most effective means of ensuring destruction of organic compounds in used oil. However, all combustion takes place at approximately the same temperature (between 1200 and 1400°C) and this is true whether occurring in a vaporising burner or an atomising burner.

What is referred to as a high temperature combustion process is not dependant on what the actual combustion process temperature is, but rather whether the process is one that maintains the post combustion gases at high temperature for a period of time after the combustion has occurred. This definition of high temperature combustion can equally be applied to all forms of burners as long as combustion gases post combustion are maintained at a high temperature.

The importance of this is that the extended period of time at elevated temperatures ensures almost total destruction of organic compounds in the fuel. However, it does not guarantee that the gases discharged to atmosphere will be free of organic compounds. De novo formation of organic compounds can occur post the combustion zone, and is most commonly effected by constituents in the gas stream and the speed with which the gases are cooled prior to discharge.

It is also important to note that the use of a high temperature process as defined above will not have any impact on the concentrations or quantity of metal contaminants discharged. This is governed by the pollution control measures used on the combustion gases prior to discharge.

4.1 INTRODUCTION

This Section of the report presents information on the following:

- used oil combustion emissions and calculations;
- the emission factors used in the modelling;
- the scenarios that were modelled; and,
- the results of the modelling.

These emission estimates are compared where possible with actual emission results for similar processes. The actual emission monitoring results for the Milburn Cement Cape Foulwind plant are also presented.

It should be noted that there has been no attempt in this report to estimate or assess dioxin emissions from used oil combustion. This has been considered in the recently published Dioxin Inventory (MfE 2000).

4.2 EMISSION FACTORS

There are no New Zealand emission factors available for used oil combustion. Therefore it has been necessary to look for other sources of information. This search revealed that although there are two sources (United States Environmental Protection Agency (US EPA) and Environment Australia) of emission information available for used oil combustion they are both based on information collected by the US EPA (US EPA 1995). As the US EPA is the source of the information it has been quoted as the source.

4.2.1 Appropriateness of Estimate Values

One of the concerns raised by MfE during the preparation of this report was the applicability of the US EPA data. Unfortunately the composition of the used oil used to establish the emission factors is not reported in the US EPA's Inventory, but it is assumed that it will be to the US EPA (US EPA CFR64) specification as presented in Table 4-1. A comparison between a typical US used oil (US EPA,1993) and the average New Zealand used oil concentration is also presented in Table 4-2. This indicates that for the elements that information is available for, the New Zealand used oils have lower concentrations of contaminants than the US used oils. The exception to this is sulphur where the New Zealand concentration is more than double the US average. It is also interesting to note that while the New Zealand arsenic concentration is lower than the US average, it is slightly higher than the US used oil specification. Therefore, Woodward-Clyde believes that it is appropriate to use the US EPA emission factors, although these will be conservative, and for example for both lead and chloride the emission estimates will provide over estimates of the actual emissions from the processes. The US EPA emission factors include the actual sulphur content in the fuel as one of the inputs, therefore the higher levels of sulphur present in the New Zealand used oil can be accounted for. The emission factors that are used for diesel and fuel oils are also taken from US EPA emission factors.

Table 4-1
United States Used Oil Specification

Compound	**US EPA (mg/kg)**
Arsenic	5 Max
Cadmium	2 Max
Chromium	10 Max
Lead	100 Max
Total Halogens[3]	4000 Max

Table 4-2
Comparison between US and New Zealand Used Oils
(all concentrations in mg/kg)

	Average US	**Average New Zealand**
Pb	1100	82
As	12	8
Al	45	16
Cd	1	0.8
Cr	6	2.6
Zn	800	249
Sulphur (%)	0.5	1.2
Cl	2200	390
Ash Content %	0.65	0.4

4.2.2 Emission Estimation Factors

The factors used in the combustion emission estimation calculations are contained in Table 4-3. In the estimation of emissions for trace metals that do not have emission factors (such as copper), it has been assumed that all of the metal present in the used oil will be discharged via the stack. This is likely to result in an over estimate of the potential metal emissions from the processes.

It is not possible to make the same assumption for the combustion products that do not have emissions factors, as these contaminants present in the oil, are likely to be destroyed in the combustion process, and new contaminants generated in the post combustion zone of the burners.

Based on the contaminant specified in the US EPA used oil specification, the contaminants identified in New Zealand by regional councils, and those identified as being of concern in Section 6 of this report, the potential effects of the following compounds has been assessed for each of the scenarios considered: arsenic, cadmium, chromium, lead, copper, napthalene, Total PAH, PM_{10}, NOx, SO_2, CO and VOC.

---

[3] The US EPA states that any oil containing more than 1000 ppm halogens is considered to be a hazardous waste and must be treated accordingly.

Table 4-3
Estimation Factors (kg/m^3)

	Used Oil		**Diesel**
	Vaporising	**Atomising**	
METALS			
Antimony	4.10x10^{-5}	5.40 x10^{-4}	0
Arsenic	3.00 x10^{-4}	7.20 x10^{-3}	6.5 x 10^{-8}
Berylium	0	2.20 x10^{-4}	5 x 10^{-8}
Cadmium	1.85 x10^{-5}	1.40 x10^{-3}	5 x 10^{-8}
Chromium	2.30 x10^{-2}	2.20 x10^{-2}	5 x 10^{-8}
Cobalt	6.80 x10^{-4}	6.20 x10^{-4}	0
Lead[4]	0.05	6	1.5 x 10^{-7}
Manganese	2.60 x10^{-4}	6.00 x10^{-3}	1 x 10^{-6}
Mercury			5 x 10^{-8}
Nickel	6.00 x10^{-3}	1.90 x10^{-2}	5 x 10^{-8}
Selenium	0	0	2.5 x 10^{-6}
PAHs			
Napthalene	1.60 x10^{-3}	1.10 x10^{-5}	1.36 x10^{-4}
Total PAH	6.50 x10^{-3}	3.60 x10^{-5}	1.43 x10^{-4}
COMBUSTION			
PM$_{10}$[5]	0	6.8	0.13
NOx	1.32	1.92	2.2
SO2[6]	12	12.8	17
CO	0.2	0.25	0.6
VOC	0.12	0.12	0.09

4.3 MODELLING SCENARIOS

There are two ways of assessing the potential environmental effects from a process, these are to directly measure effects or to model effects. In this study Woodward-Clyde has used modelling as this allows a more generic assessment to take place. Based on the information presented in earlier sections of this report and through consultation with MfE, it was decided that there were three types of equipment that should be assessed. These are:

1. Small vaporising burner, using 5 l/h of fuel oil.
2. Medium sized atomising burner (500 kW).
3. Asphalt plant using used oil as fuel (14 MW).

Each of these scenarios will be evaluated for a system burning diesel or light fuel oil as well as for the processed used oil.

Further justification for selecting these scenarios is given below, along with the modelling outputs.

---

[4] Concentration multiplied by the Lead concentration in the fuel

[5] Concentration multiplied by the ash content in %

[6] Concentration multiplied by sulphur content in %

4.3.1 Vaporising Burners

In this modelling scenario, the basic assumption has been made that the burner is installed in a workshop or garage and is being used for heating purposes. The unit is well maintained and has an appropriate stack. Other assumptions that have been made for modelling purposes are:

1. Fuel rate is 5 l/h.
2. The garage/workshop is using used oil collected on its own premises.
3. Emissions are discharged via a stack 3 m above the ground.
4. A number of residences are located within 20 m of the site.
5. There are no terrain effects.

These are reasonable assumption based on the typical installation of a Kroll vaporising burner. As discussed in Section 4.2, the US EPA emission factors have been used to estimate emissions from this process. The other parameters used in the modelling are given in Table 4-4.

Table 4-4
Vaporising Burner Modelling Factors

Parameter	Value
Velocity (m/s)	11.7
Discharge Temperature (°C)	400
Diameter (m)	0.15
Stack Height above ground (m)	3
Discharge Rate (g/s)	1

A summary of the emission rates for the pollutants for this scenario for both diesel and treated used oil are presented in Table 4-5. The full calculations are presented in Appendix B.

Table 4-5
Vaporising Burner Emission Rates

Compound	Used Oil (g/s)	Diesel (g/s)
Arsenic	3.3 x10^{-7}	7.3 x10^{-11}
Cadmium	2.1 x10^{-8}	5.5 x10^{-11}
Chromium	2.6 x10^{-5}	5.5 x10^{-11}
Copper	2.1 x 10^{-5}	1.1 x 10^{-10}
Lead	2.89 x10^{-9}	1.7 x10^{-10}
Napthalene	1.8 x10^{-6}	1.5 x10^{-7}
Total PAH	7.2 x10^{-6}	1.6 x10^{-7}
PM_{10}	1.4 x10^{-4}	1.4 x10^{-4}
NOx	1.5 x10^{-3}	2.4 x10^{-3}
SO_2	1.7 x10^{-2}	5.7 x10^{-3}
CO	2.2 x10^{-4}	6.7 x10^{-4}
VOC	1.3 x10^{-4}	1.0 x10^{-4}

These emission rates can be compared to some actual test results (AWN Consultants 1991) for a small used oil fired vaporising burner summarised in Table 4-6, and presented in full in Appendix C). These tests did not analysis for the full range of compounds that are being considered in this assessment, and did not provide any information on the original concentrations of contaminants in the used oil. The test result emission rates are similar to the estimated emission rates for most of the compounds. This indicates that there should be a high level of confidence in using the estimated emission rates to predict potential effects.

Table 4-6
Actual Emission Rates from Test on Kroll Heater

Compound	Used Oil (g/s)	Calculated Emission Rates (g/s)
Cadmium	<5 x 10^{-6}	2 x 10^{-8}
Lead	9 x 10^{-6}	2.8 x 10^{-9}
Zinc	9 x 10^{-6}	-
PM_{10}	6 x 10^{-4}	1.4 x 10^{-4}
NOx	4.5 x 10^{-3}	1.4 x 10^{-3}
SO_2	1.15 x 10^{-2}	1.7 x 10^{-2}
VOC	2 x 10^{-3}	1.3 x 10^{-4}

4.3.2 Atomising Burners

As discussed in Section 3, atomising burners are used in a wide range of boiler and water heater applications, with many being used to provide heat for horticultural applications. They are more likely to be located in industrial or rural areas.

For this modelling scenario, it has been assumed that the application is a horticultural site, with the burner being used to supply hot water for heating the greenhouse. The emissions are discharged via an appropriate stack, and because it is in a rural location, the nearest neighbours are not in close proximity. The main assumptions that have been made are:

1. 500 kW or 50 l/h fuel consumption.
2. Treated used oil is supplied for combustion.
3. Emissions are discharged through a stack 10 m above the ground.
4. Nearest residences are located 100 m away from the stack.
5. There are no terrain effects.

The other parameters used in the modelling are given in Table 4-7.

Table 4-7
Atomising Burner Modelling Factors

Parameter	Value
Velocity (m/s)	13
Discharge Temperature (°C)	200
Diameter (m)	0.15
Stack Height above ground (m)	10
Discharge Rate (g/s)	1

The emission rates of the pollutants are presented in

Table 4-8, with the calculation presented in Appendix B.

Table 4-8
Emission Rates for Atomising Burner

Compound	Used Oil g/s	Diesel (g/s)
Arsenic	9×10^{-5}	8.2×10^{-10}
Cadmium	1.8×10^{-5}	6.2×10^{-10}
Chromium	2.8×10^{-4}	6.2×10^{-10}
Copper	3.7×10^{-4}	1.3×10^{-10}
Lead	4×10^{-6}	1.9×10^{-9}
Napthalene	1×10^{-7}	1.7×10^{-6}
Total PAH	4.5×10^{-7}	1.8×10^{-6}
PM_{10}	3.4×10^{-2}	1.6×10^{-3}
NOx	2.4×10^{-2}	2.8×10^{-2}
SO_2	2×10^{-1}	6.4×10^{-2}
CO	3×10^{-3}	7.5×10^{-3}
VOC	1.5×10^{-3}	1×10^{-3}

4.3.3 Asphalt Manufacture

Asphalt manufacture is one application of the use of large atomising burners. The use of used oil for this type of application is also becoming more common, as it is a cheap source of fuel in a very competitive market. Also many plants are already operating using either diesel or light-fuel oil and it is relatively simple to convert from one type of fuel to another.

The scenario that is proposed involves an existing asphalt plant using 1,000 l/h of treated used oil. The emissions are discharged via a venturi scrubber through a stack 12 m above the ground, with the plant located in an industrial area, with the nearest neighbours 20 m away. No terrain effects have been considered.

The other parameters used in the modelling are given in Table 4-9.

Table 4-9
Asphalt Plant Modelling Factors

Parameter	Value
Velocity (m/s)	14
Discharge Temperature (°C)	60
Diameter (m)	0.95
Stack Height above ground (m)	12
Discharge Rate (g/s)	1

The emission rates are presented in Table 4-10. The calculations are presented in Appendix B. These emission rates are based on the emission being discharged directly to air. All of the asphalt plants in New Zealand that are currently operating on treated used oil are fitted with scrubbers. This will have an impact on the actual concentrations discharged to air. Table 4-11 below contains the results of some stack tests carried out by Woodward-Clyde (Woodward-Clyde 1999) on an asphalt plant burning used oil. The full report is presented in Appendix C. The results for particulate and copper are similar. The results for nitrogen dioxide and sulphur dioxide lower, and the result for lead higher

Table 4-10
Emission Rates for Asphalt Plant

Compound	Used Oil g/s	Diesel (g/s)
Arsenic	0.003	2.4×10^{-8}
Cadmium	0.0005	1.8×10^{-8}
Chromium	0.008	1.8×10^{-8}
Copper	0.011	5.4×10^{-8}
Lead	0.00011	5.4×10^{-8}
Napthalene	3.97×10^{-6}	4.9×10^{-5}
Total PAH	1.3×10^{-5}	5.2×10^{-5}
PM_{10}	1.0	0.05
NOx	0.7	0.8
SO_2	5.9	1.8
CO	0.09	0.22
VOC	0.04	0.033

Table 4-11
Actual Emissions from an Asphalt Plant

Contaminant	Mass Emission (g/s)
Particulate	1.3
SO_2	0.2
NO_2	0.03
Cu	0.004
Pb	0.006

4.4 ATMOSPHERIC DISPERSION MODELLING

The atmospheric dispersion modelling was carried out using the AUSPLUME dispersion model. This model is commonly use in New Zealand, and was developed for the Victorian Environmental Protection Authority.

One of the most important inputs to dispersion modelling is the meteorological data that is used in the assessment. This meteorological data tends to be very site specific and it is difficult to use the data from one location at another location. To overcome this problem and provide an assessment that is area specific, an artificial meteorological data set called Metsamp was used. This contains all of the worst case conditions that could potentially occur. However as this data set does not indicate frequency of weather conditions it can only be used to calculate results for short term averages such as 3 minute or 1 hour.

As the range of pollutant species that were assessed was large, a generic model was set up for each scenario with a 1 g/s pollutant discharge rate. . The modelling results are contained in Appendix D. The calculation of the off site concentrations for the different species, was then determined by multiplying the concentration at a particular location by the actual discharge concentration for that species. These calculations are presented in Appendix 4.

4.4.1 Modelling Accuracy

Atmospheric dispersion modelling is not an exact science, and depends on a large number of variables. These include not only the values the user inputs, but also some of the base assumptions and extrapolations made by the designers of the models from the base experimentation that all of the models are based on. Therefore, actual concentrations can vary considerably from predicted concentrations. The commonly accepted perception is that a error factor of 2 should be considered. That is a very complicated subject and the error margin is not simply double or half the predicted value. In many cases, that error factor is misused, and should not be used to imply that the actual levels may be greater than those predicted. In fact one often finds that when predictions are rank-paired with observations, the agreement is excellent provided that the meteorological data is good, and the emission data etc has been properly characterised. However if one tries to time-pair the prediction with the observation, then the agreement is not very good at all and the error factor of two is probably not sufficient generous. Therefore the use of atmospheric dispersion modelling provides a good representation of what is measured in the real world.

4.4.2 Air Quality Guidelines

In terms of assessing the effects of combustion of used oil, it is necessary to have a set of criteria to evaluate against. This section presents the criteria that have been used in this assessment.

The guidelines have been divided into two sections. The first contains what are considered the conventional air pollutants. These are generally compounds associated with combustion processes. For this assessment the basis for the values used are the New Zealand Ambient Air Quality guidelines (AAQG) (MfE 1994). MfE are currently in the process of revising these guidelines, and therefore the proposed changes have been included for comparison purposes. The MfE AAQG should not be used as acceptance guidelines but rather as maximum acceptable guidelines. MfE (MfE 1997) have proposed a scale against which air emissions should be assessed (see Table 4-12 below). Based on this one third of the AAQG is considered acceptable.

Table 4-12
MfE Air Quality Categories

Category	Maximum measured value	Comment
Action	Exceeds the guideline	Completely unacceptable, by national and international standards
Alert	66 – 100% of the guideline	A warning level, which can lead to excedences if trends not curbed.
Acceptable	33 – 66% of the guideline	A broad category, where maximum values might be of concern in some sensitive locations but generally at a level which does not warrant dramatic action.
Good	10 – 33% of guideline	Peak measurements in this range are unlikely to impact on air quality
Excellent	< 10% of guideline	Of little concern, if maximum values are less than a tenth of the guideline, average values are likely to be much less.

There are a range of compounds primarily the metals that do not have New Zealand ambient air quality guideline values available. For these metals guidelines values have been derived from two sources. These are the Victorian Environmental Protection Authority (VEPA 1985 & 1988), referred to as the DGLC, and the New Zealand Workplace Exposure Standards (OSH 1992) referred to as the WES divided by 30.

All of the values used and their sources are shown in Table 4-13 below. It should be noted that the guideline number used for lead is not taken from the New Zealand AAQG. This is because the averaging time required in the guideline is 3 months. It is not possible to carry out a three month assessment using worse case scenario meteorological data, therefore a short term value derived from the WES has been used. This is also true for the particulate where a short term value has been used rather than the 24 average value in the New Zealand guidelines.

There is also no guideline number for VOCs therefore the guideline value for n-hexane has been used as the assessment criteria for VOC's.

There is also no guideline for total PAH. It is common practice to assess PAH emissions by considering that all of the emissions are present in the form of benzo(a) pyrene (BAP) for which there is an UK guideline value of 0.25 ng/m^3 as an annual average, and this is the proposed guideline in the revision of the MfE ambient air quality guidelines. This has not be done in this report for two reasons. Firstly, that there is no indication that there is any BAP present. Secondly it is not good practice to convert annual averages to shorter term averages such as 3 minute or one hour as would need to be the case here, due to the uncertainty of using the conversion equation for such large reductions.

Therefore as an appropriate guideline value exists for napthalene, which is estimated to be present in the largest quantity, it has been used as the primary assessment tool for PAH.

Table 4-13
Ambient Air Quality Criteria

Compound	Air Quality Criteria (µg/m^3)	Averaging Time	Source
Arsenic	1.7 *(0.33)*	3 Minute *(1 hour)*	WES/30 *(proposed AAQG)*
Cadmium	0.33	3 Minute	WES/30
Chromium	17 *(0.67)*	3 Minute *(1 hour)*	DGLC *(proposed AAQG)*
Copper	6.7	3 Minute	DGLC
Lead	3.3	3 Minute	WES/30
Napthalene	1.733	3 Minute	WES/30
Particulate	330	3 Minute	DGLC
NOx	100 *(67)*	1 hour *1 hour*	1/3AAQG *(proposed AAQG)*
SO_2	117	1 hour	1/3AAQG
CO	10,000	1 hour	1/3AAQG
VOC	6,000	3 Minute	DGLC

4.5 DISPERSION MODELLING RESULTS

This section of the report presents a summary of the dispersion modelling results for the different scenarios discussed above. The full modelling results are presented in Appendix E.

4.5.1 Vaporising Burner

Correct Operation

Table 4-14 presents the maximum off-site concentrations for burning treated used oil and diesel in a vaporising burner. Figure 4-1 shows the change in concentrations with distance for Lead from both used oil and diesel as an example for the other contaminants. Figure 4-2 presents the used oil only concentrations of chromium and copper. As can be seen from the results all of the predicted emissions are less than the guideline values.

Table 4-14
Maximum Off-site Concentrations for a 50 kW Vaporising Burner

Compound	Maximum Off-site Concentration		Guideline Values
	Used Oil	**Diesel**	
Arsenic (μg/m^3)	0.002	0.0000005	1.7 *(0.33)*[7]
Cadmium (μg/m^3)	0.00014	0.0000004	0.33
Chromium (μg/m^3)	0.17	0.0000008	17 *(0.67)*
Copper (μg/m^3)	0.14	0.0000008	6.7
Lead (μg/m^3)	0.00002	0.000001	3.3
Naphthalene (μg/m^3)	0.012	0.001	1,733
PM_{10} (μg/m^3)	0.25	0.3	330
NOx (μg/m^3)	5.5	4	100 *(67)*
SO_2 (μg/m^3)	58	9	117
CO (μg/m^3)	0.8	1	10,000
VOC (μg/m^3)	0.9	0.16	6,000

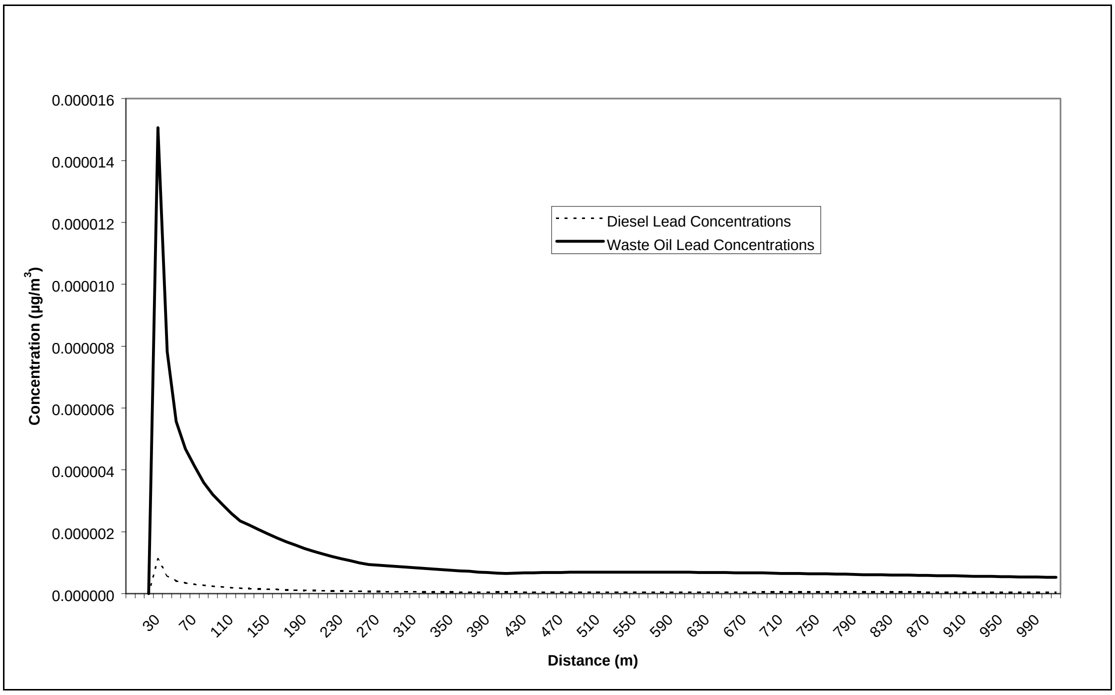


Figure 4-1
50 kW Vaporising Burner Lead Concentrations with Distance

---

[7] Values in brackets are taken from the MfE's proposed revision of the ambient air quality guidelines.

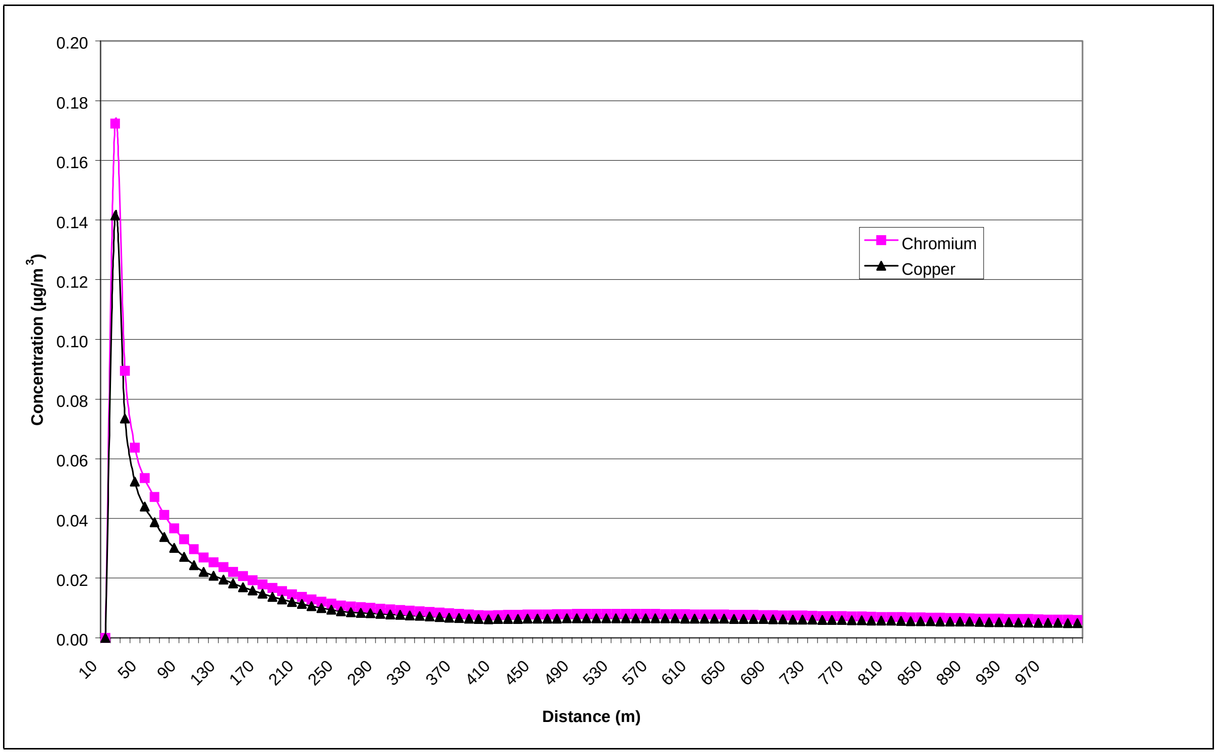


Figure 4-2
Concentrations of Chromium and Copper from 50 kW Vaporising Burner

Incorrect Operation

In the above section the results are presented for the situation where the equipment is operating ideally. There are many factors that can effect a process and may result in poor performance of a combustion unit and therefore increase its potential off-site environmental effects. One of the areas that is commonly incorrect is stack height. Correct stack height is important to ensure that the discharges to not get caught in the building downwash. The scenario used above was re-modelled with a stack height of 2 m instead of 3 m. The results of this modelling are presented in Table 4-15. These show significant increase in the maximum off-site concentrations when compared to correct stack height, with the maximum concentrations were generated in stable to moderately stable conditions with low mixing heights. This has also lead to the sulphur dioxide emissions exceeding the acceptable criteria.

Table 4-15
Maximum Off-site Concentrations for a 50 kW Vaporising Burner with 2 m stack

Compound	Maximum Off-site Concentration Used Oil	Guideline Values
Arsenic (µg/m^3)	0.005	1.7 *(0.33)*
Cadmium (µg/m^3)	0.0003	0.33
Chromium (µg/m^3)	0.39	17 *(0.67)*
Copper (µg/m^3)	0.32	6.7
Lead (µg/m^3)	0.00003	3.3
Naphthalene (µg/m^3)	0.027	1,733
PM_{10} (µg/m^3)	0.6	330
NOx (µg/m^3)	12	100 *(67)*
SO_2 (µg/m^3)	130	117
CO (µg/m^3)	1.9	10,000
VOC (µg/m^3)	1.1	6,000

4.5.2 Atomising Burner

Table 4-16 presents the maximum off-site concentrations (which occur in unstable conditions with low wind speeds) for burning treated used oil and diesel in a 500 kW atomising burner. Figure 4-3 shows the change in concentrations with distance for lead for both used oil and diesel as an example for the other contaminants. Figure 4-4 presents the chromium and copper concentrations for used oil combustion only. As can be seen in Table 4-16 for all parameters concentrations are significantly less than the guideline values. This indicates that it is unlikely that used oil combusted in atomising burners (based on the assumptions stated) will result in any off-site effects.

Table 4-16
Maximum Off-site Concentrations for a 500kW Atomising Burner

	Maximum Off-site Concentration		Guideline Value
Compound	Used Oil	Diesel	
Arsenic (µg/m^3)	0.03	0.0000003	1.7 *(0.33)*
Cadmium (µg/m^3)	0.006	0.0000002	0.33
Chromium (µg/m^3)	0.1	0.0000002	17 *(0.67)*
Copper (µg/m^3)	0.13	0.0000004	6.7
Lead (µg/m^3)	0.001	0.0000007	3.3
Naphthalene (µg/m^3)	0.00005	0.0006	1,733
PM_{10} (µg/m^3)	6.5	0.3	330
NOx (µg/m^3)	4.6	5.3	100 *(67)*
SO_2 (µg/m^3)	36	12	117
CO (µg/m^3)	0.6	1.4	10,000
VOC (µg/m^3)	0.3	0.2	6,000

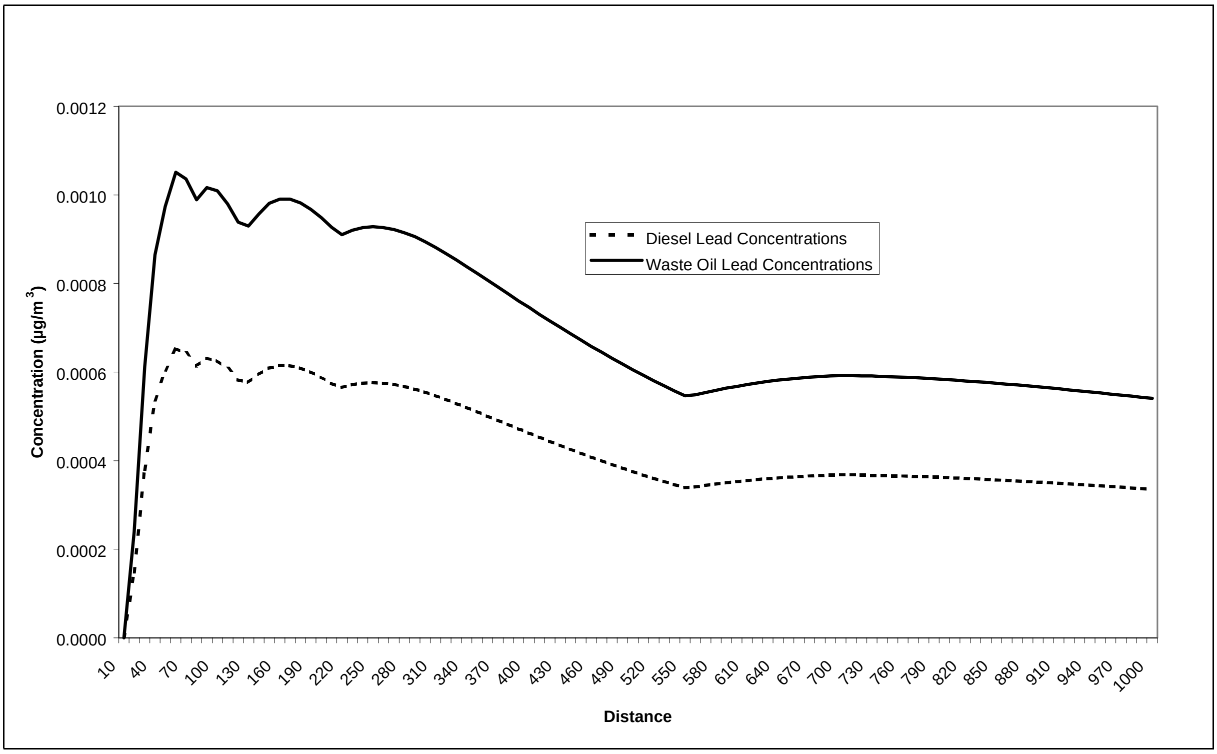


Figure 4-3
Lead Concentrations with Distance for a 500 kW Atomising Burner

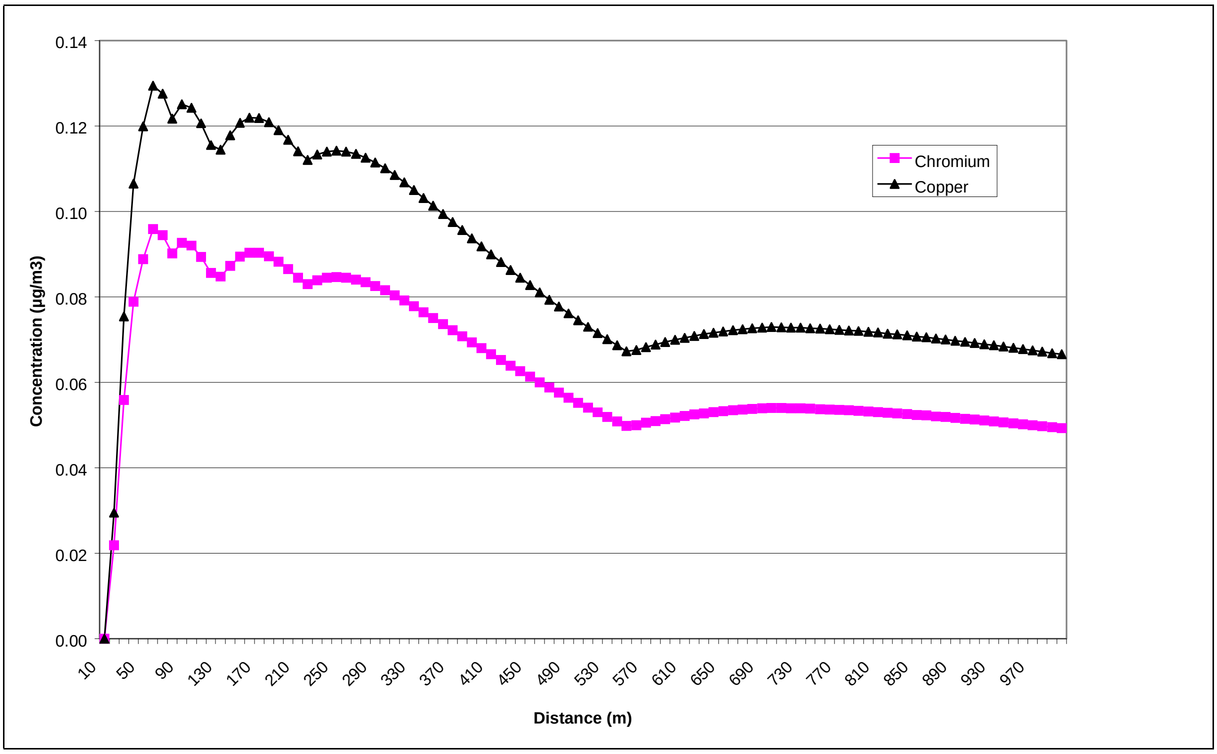


Figure 4-4
Chromium and Copper Concentrations with Distance for a 500 kW Atomising Burner

4.5.3 Asphalt Plant

Table 4-17 below presents the maximum off-site concentrations (which occur in neutral conditions with moderate wind speeds) for burning treated used oil and diesel in an asphalt plant burner. Figure 4-5 shows the change in concentrations with distance for lead for both used oil and diesel as an example for the other contaminants. Figure 4-6 presents the concentrations of chromium and copper for burning used oil. These results indicate that apart from sulphur dioxide all of the concentrations are significantly less than the guideline values. The fact that the sulphur dioxide is over the guideline is due to the inclusion in the emission concentration calculation of the sulphur concentrations for used oil from Ben's Oil Ltd (normally used in boiler installations) which distorted the average. This concentration was approximately twice as high as the next nearest sulphur concentration in the other samples. If the sulphur dioxide concentrations are recalculated using only sulphur concentrations from oils that are known to be used (or proposed to be used) in asphalt plants, the sulphur dioxide concentration drops to 83 µg/m^3, which is less than the acceptable guideline value.

Table 4-17
Maximum Predicted Offsite concentrations for an 14 MW Asphalt Plant

	Maximum Off-site Concentration		**Guideline Value**
Compound	**Used Oil**	**Diesel**	
Arsenic (µg/m^3)	0.12	0.000001	1.7 *(0.33)*
Cadmium (µg/m^3)	0.024	0.0000009	0.33
Chromium (µg/m^3)	0.38	0.0000009	17 *(0.67)*
Copper (µg/m^3)	0.51	0.000002	6.7
Lead (µg/m^3)	0.004	0.000003	3.3
Naphthalene (µg/m^3)	0.0002	0.002	1,733
PM_{10} (µg/m^3)	26	1.2	330
NOx (µg/m^3)	18	21	100 *(67)*
SO_2 (µg/m^3)	140	48	117
CO (µg/m^3)	2.4	5.7	10,000
VOC (µg/m^3)	1.1	0.9	6,000

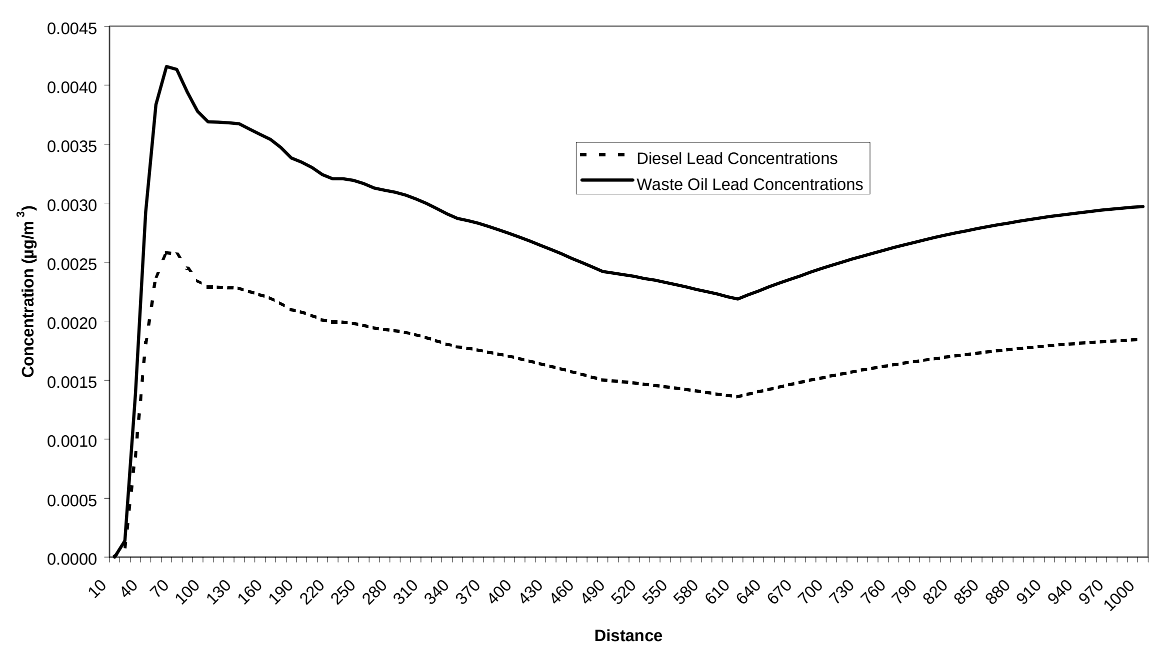


Figure 4-5
Lead Concentrations with Distance for a 14 MW Asphalt Plant

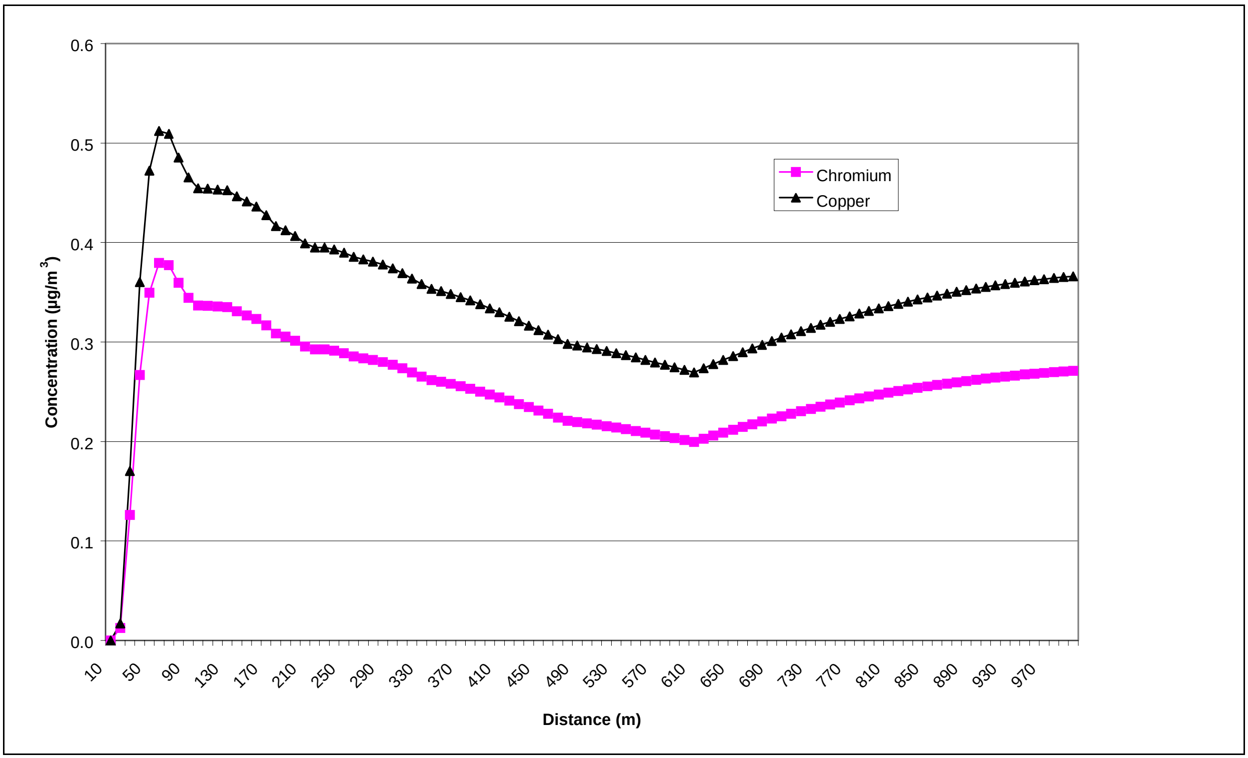


Figure 4-6
Chromium and Copper Concentrations with Distance for a 14 MW Asphalt Plant

4.6 RECOMMENDATION

Based on the results of the modelling presented in the preceding section, it is apparent that with some qualifications or limitations used oil can be combusted with minimal environmental effects. The qualifications are:

1. The equipment should be well maintained and operated in accordance with good practice. This includes the use of appropriate stack heights, and efflux velocities etc.
2. The used oil should be treated to minimum standards similar to the US EPA standard. In particular to ensure the concentrations of sulphur, copper and chromium are minimised.
3. Consideration should be given to limiting volumes of fuel usage/size of plant, otherwise additional pollution abatement equipment may be required. Note the modelling results are based on plant using used oil at certain rates.

4.7 EMISSIONS FROM MILBURN CEMENT

Milburn Cement are required to submit quarterly reports to the West Coast Regional Council, that present information on emissions from their process. Woodward-Clyde has been supplied with one set of tests (Milburn 1999) when the plant was operating on used oil. It should be noted that under their resource consent, Milburn Cement can only use used oil to supply 50% of the energy requirement for the kilns. Therefore the results measured are for a combination of used oil and coal and can only be used for comparison purposes. The emissions from the cement kilns pass through an electrostatic precipitator prior to discharge to remove fine particulate.

Table 4-18
Discharges from Milburn Cement Kiln 1

Compound	Stack Discharge Concentration (mg/m^3)	Stack Discharge Emission Rate (g/s)
Cadmium	0.0008	0.000008
Chloride	3.3	0.034
Chromium	0.075	0.0008
Copper	0.006	0.00006
Lead	0.018	0.00019
Particulate	48	0.5
NOx	1800	19
SO_2	1300	14

5.1 INTRODUCTION

The potential emissions from the use of used oil as a dust suppressant are associated with the concern that the oil may cause either contamination of the environment or health effects in people who come into contact with the dust.

Based on discussions with local authorities, MfE, and with some of the road oiling contractors, there are three main areas that road oiling is used in. These are:

- Dust suppression on roads around residences with relatively high seasonal use
- Dust suppression on roads used by commercial vehicles
- Dust suppression on private roads or low use roads close to horticultural crops

Dust modelling of emissions from the oiling of roads has been undertaken. Details of the background to this modelling, the scenarios chosen, and the techniques used to assess those emissions are presented in this section. The results from this modelling form the basis for the health risk assessment in section 7.

5.2 ROAD OILING SCENARIOS

The three roads that have been chosen to assess emissions are:

- A low use road;
- A medium use road; and
- A commercial road.

Each of these is discussed in more detail below. It is important to note that the results of this modelling can be used for any receiving environment landuse. Therefore no assumptions are presented as to the receiving environment along side the road.

5.2.1 Low Use Road

The low use road scenario is designed to replicate a common situation in the country areas, being a road with few vehicle movements, commonly this will be a no exit road which borders an orchard. The main assumptions that have been made are:

- 20 vehicle movements per day;
- Vehicles are cars or light vans; and
- Effectiveness of Road Oiling is 90% (Noyes 1983).

5.2.2 Medium Use Road

The medium use road scenario is designed to replicate roads that have a reasonable amount of traffic on them, but below the threshold that would result in the road being sealed. The road may have a high seasonal loading. The main assumptions that have been made are:

- 200 vehicle movements per day
- Vehicles are cars or light vans
- Effectiveness of Road Oiling is 90%

5.2.3 Commercial Road

This road scenario is designed to replicate the commercial roads used by logging firms. These are often unsealed and can run through areas of the countryside where lifestyle blocks exist or where people are farming. The main assumptions that have been made are:

- 50 vehicle movements per day;
- Vehicles are trucks; and
- Effectiveness of Road Oiling is 90%.

5.3 CALCULATION OF DUST EMISSIONS

The quantity of dust that is emitted from each of the roads above was determined using an emission equation published by the US EPA in AP 42 (US EPA 1999).

This equation is:

$$\boxed{\mathrm{E} = (281.9)\frac{k(s/12)^{a}(W/3)^{b}}{(M_{dry}/0.2)^{c}}\left[(365-p)/365\right]}$$

where

E annual size specific emission factor (g/Vehicle Kilometre Travelled)

s surface material silt content (%)

W Mean vehicle weight (tons)

Mdry Surface Moisture Content under dry uncontrolled conditions(%)

p number of days with at least 0.254 mm of precipitation

The coefficients a, b and c depend on the size fraction that is to be considered. The values are given in Table 5-1.

Table 5-1
Size Specific Co-efficients

Constant	$PM_{2.5}$	PM_{10}	TSP
k	0.38	2.6	10
a	0.8	0.8	0.8
b	0.4	0.4	0.5
c	0.3	0.3	0.4

In this assessment the total TSP values have been used. There are a number of variables in the equation that have to be chosen. Those used in this assessment are given in Table 5-2. The formula does not include any variable for dust suppression, the values calculated by the formula were multiplied by 0.1 (based on 90% dust suppression) to calculate the actual dust emission. The full results are presented in Appendix F, and summarised in Table 5-3 below.

Table 5-2
Variables used in Dust Emission Calculations

	Value
Average Car Weight (tonnes)	2
Average Truck Weight (tonnes)	35
Surface Silt Content (%)	12
Surface Moisture Content (%)	0.2
Annual Rain Days	120[8]

Table 5-3
Road Dust Emissions per Kilometre

	Unsuppressed Emission (g/s)	**Suppressed Emission (g/s)**
Low Use Road	0.38	0.038
Medium Use Road	3.75	0.38
Commercial Use Road	3.64	0.36

Most of the variables used in this calculation will not be significantly different throughout the country. What does vary significantly is the quantity of rain days. Table 5-4 has been included to provide an indication of the sensitivity of the dust emission calculation to rain. The calculations have been made relative to the average number of rain days of 120 days used in this assessment. This indicates that an area that experienced for example 80 rain days a year would experience a 16% increase in the dust emissions than those presented in Table 5-3, and an area that experienced 160 rain days a year would expect a 18% decrease in the dust emissions presented in Table 5-3.

Table 5-4
Percentage Change in Dust Emissions with Rain Days

Number of Rain Days	**% Change in Dust Emissions**
80	16
100	8
120	0
140	-11
160	-18

5.4 ROAD DUST MODELLING

The emission rates for the suppressed dust in Table 5-3 were then fed into the Fugitive Dust Model (FDM) developed by the US EPA, to determine the dispersion of dust from the road. As the health effect assessment requires annual data, it was necessary to use a full years meteorological data rather than the METSAMP data used in the combustion emission modelling. One of the difficulties with doing this is the site specific nature of meteorological data. This will effect a number of parameters including the wind direction.

In this assessment three different meteorological data sets were considered (Auckland, Christchurch and Invercargill). After assessing the results for one scenario, the Auckland

---

[8] Average New Zealand Value, Personnel Communication with NIWA

meteorological data set was selected as providing the worst case emissions. Figure 5-1 presents the results of this comparison.

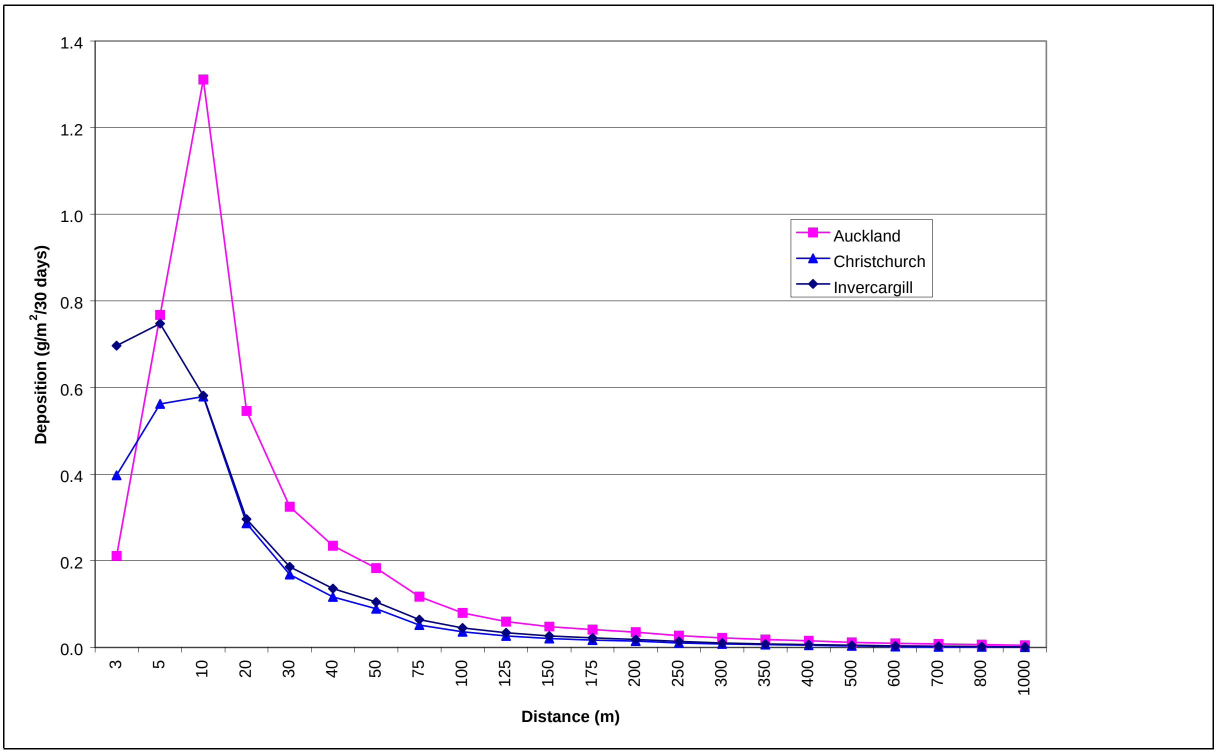


Figure 5-1
Comparison of Deposition Results for Different Meteorological Data Sets

The modelling produced two sets of data, deposition rates and ambient concentrations. Figure 5-2 presents the dust concentration information and Figure 5-3 presents the deposition information.

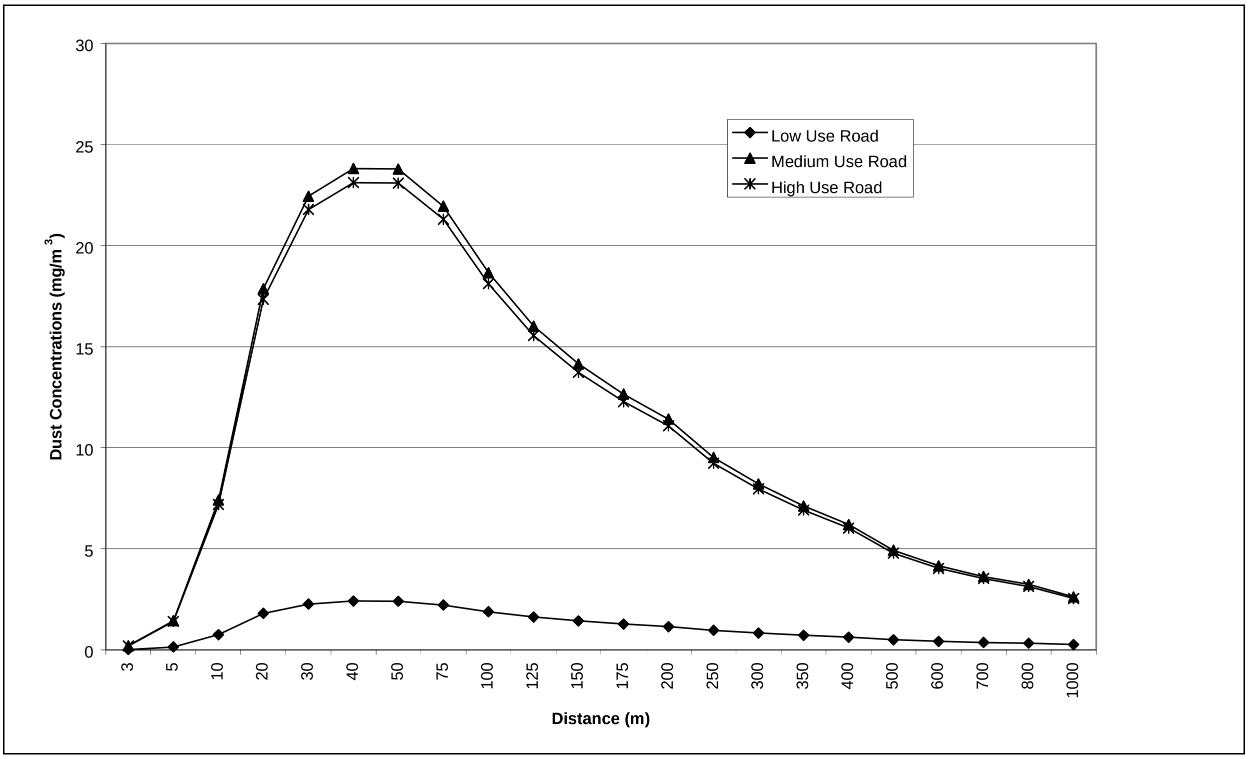


Figure 5-2
Total Dust Concentrations from Roads (Annual Average)

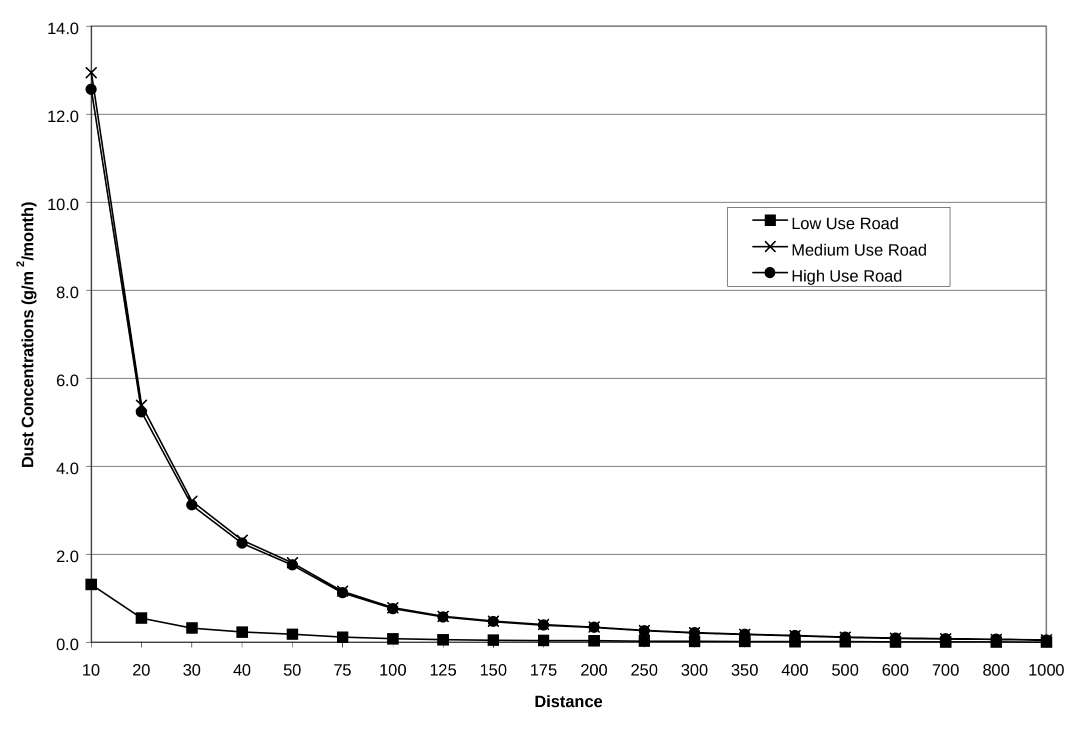


Figure 5-3
Dust Deposition

5.5 EMISSIONS FROM UNSUPPRESSED ROADS

For comparison purposes the potential effects from the dust for the unsuppressed emissions has also been assessed. The results of this modelling for ambient concentrations and dust deposition are presented in Figures 5-4 and 5-5 respectively. As can be seen the emissions from the medium use road and the commercial road are above the PM_{10} guideline value and all three of the roads are above the dust deposition nuisance value.

This demonstrates the need for some form of dust suppression on these types of roads to ensure that both health and nuisance effects from dust are mitigated.

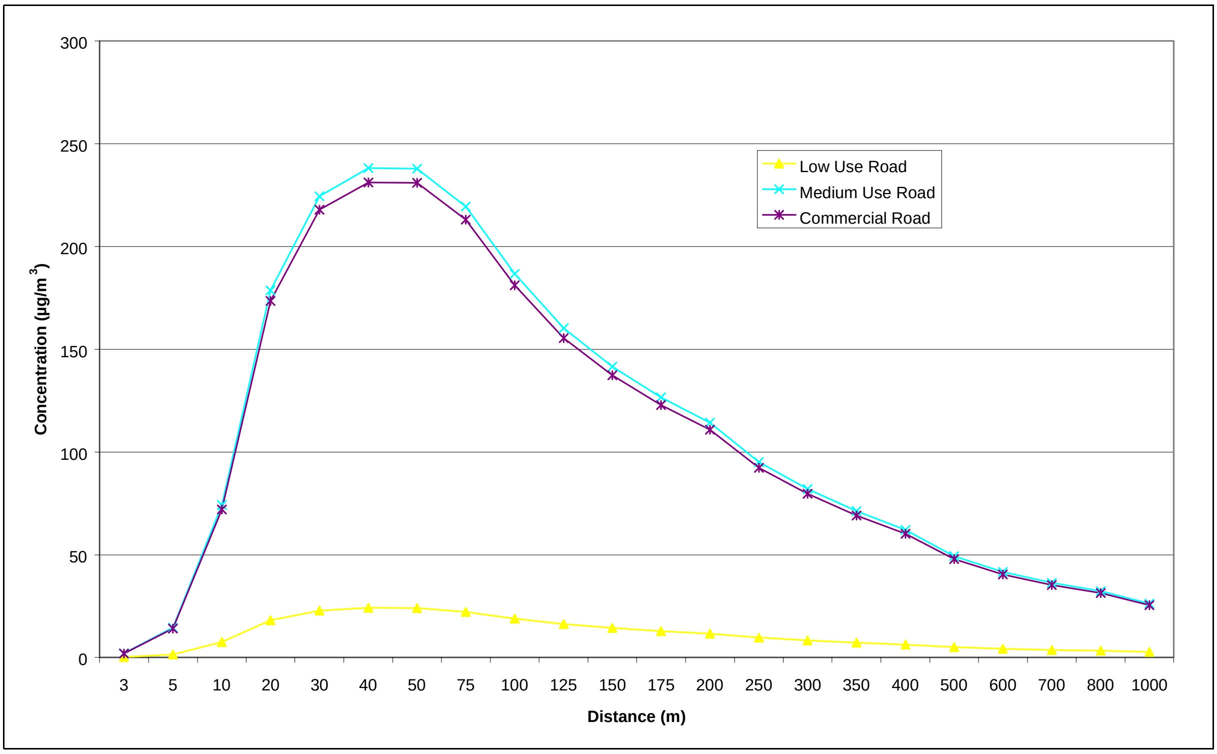


Figure 5-4
Dust Concentrations for Unsuppressed Roads

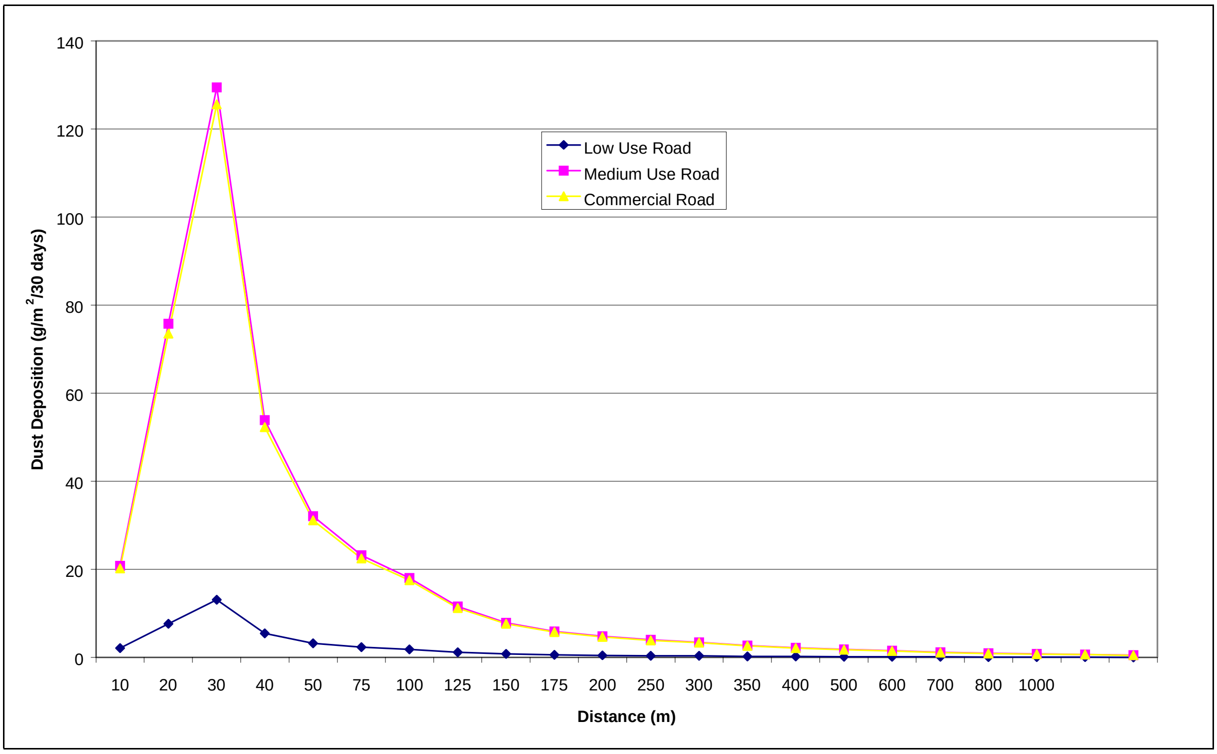


Figure 5-5
Dust Deposition for Unsuppressed Roads

5.6 MODELLING CONCLUSIONS

It is possible to compare the actual dust emissions to ambient air quality guidelines. The two most appropriate guidelines to compare with are the MfE guideline for PM_{10} of 40 µg/m^3 (as an annual average) and commonly accepted dust deposition nuisance value of 4 g /m^2/30 days. The modelling results presented in Figure 5-2 for dust concentrations and Figure 5-3 for dust deposition are both less than the guidelines and therefore unlikely to result in any dust effects. These results can be compared with those from the unsuppressed roads in Figures 5-4 and 5-5. This comparison indicates that based on particulate health guidelines there are real benefits in using some form of dust suppression. The health effects of contaminants potentially associated with the dust are presented in Section 7.

5.7 CALCULATION OF OIL EMISSIONS

Based on the dust emissions calculated in Section 5.3 (c.f. Table5-3), a road oiling rate of 2 l/m^2 (which was specified in the MfE brief based on common practice) and the used oil composition it is possible to calculate the quantity of the various contaminants that are present on the dust. This analysis is presented in Section 6.

5.8 CALCULATION OF VOLATILE EMISSIONS

One of the concerns that had been raised is that there may be emissions of volatiles from the road during the oiling process. This has not been assessed, as any emissions will occur over a very short period of time (probably within hours). This is therefore potentially an OSH issue for people involved in the oiling process and outside the scope of this report.

6.1 INTRODUCTION

This section presents the findings of the impact of the contaminants in the used oil applied to roads for dust suppression purposes on soil, water and sediment quality. The results are subsequently used to estimate the accumulated concentrations of the contaminants in the food chain via cows milk, root crops and fruit trees. The final step of the study is a human health risk assessment based on exposure to food, inhalation and dermal absorption and this is presented in Section 7.

The risk assessment approach is consistent with the Australia and New Zealand Environment and Conservation Council (ANZECC, 1992) Guidelines for the Assessment and Management of Contaminated Sites. As defined by the ANZECC (1992) Guidelines, the risk assessment process attempts to estimate the magnitude of an adverse effect if it were to occur in a receiving population due to the presence of contaminants in the environment.

There are many different exposure pathways by which the contaminants in used oil on road could enter both the environment and the food chain. A summary of the assessed pathways is provided in Figure 6-1 and this is discussed further in Section 6.4.

6.2 GENERAL ASSUMPTIONS

The environmental impact assessment is based upon a number of general assumptions which are explained below. The human health risk assessment also involves a number of assumptions. In the case of the human health risk assessment, the assumptions used to generate the input data are typically based on the estimates made for the environmental impact assessment, hence the human health risk assessment process might appear to be limited by the environmental assumptions. However, to ensure that the risk assessment is as representative of the real situation as possible, real data was used if available and the assumptions and estimates made are typically conservative (or include a factor of safety). The net result is most likely to be an over-estimation of the human health risk. Where further assumptions were required for the separate calculations, these are explained in the following sections.

6.2.1 Locations

Three areas in New Zealand in which road oiling practices are known to occur where used for the purposes of this assessment. The areas were Wanaka, Taranaki and Hawkes Bay. The three regions have different land uses and different weather patterns and therefore contribute different scenarios or exposure pathways to the study. For example, in Taranaki, the used oil is applied to a farm race and cows maybe able to access the grass verge along the edge of the race. Consequently, the uptake of contaminants by grass and excretion into milk was assessed as a possible exposure pathway.

In Hawkes Bay, oiled roads may lie adjacent to stone or pip fruit crops and consequently the deposition of dust on apples was assessed. The Wanaka area roads typically lie close to freshwater receiving environments and the contaminant concentrations reaching this environment were considered.

6.2.2 Oils

The concentrations of contaminants in the used oil assessed for this study were based on the analytical results of a single sample. The levels in the oil were presented in Table 2-3**.** The contaminant levels detected in this oil were the highest of all the data available for this study.

6.2.3 Road and Traffic

The environmental assessment begins with an unsealed road that is 6m wide. The road is assumed to have a slight camber (2%) so that runoff drains equally to either side of the road. The concentrations of deposited dust and stormwater runoff were calculated on a per square metre basis, hence the actual length of the road was not required. To calculate the concentration of each contaminant in the road dust, the dust layer on the road was assumed to be 2mm thick and comprised of particulates.

The volume of traffic over the road was assumed to be based on one of three scenarios, low density (20 car movements per day), medium density (200 car movements per day) or high density (50 truck movements per day) (as discussed in Section 5). The dust deposition modelled found that the medium density traffic volume (200 cars per day) actually generated the higher dust deposition rate. Thus, the assessment of dust deposition in the environment was based on the medium density traffic volume only. It was assumed that if the medium density traffic deposition rate resulted in an acceptable human health risk and environmental impact then the remaining traffic scenarios would also be acceptable.

6.2.4 Dust Deposition

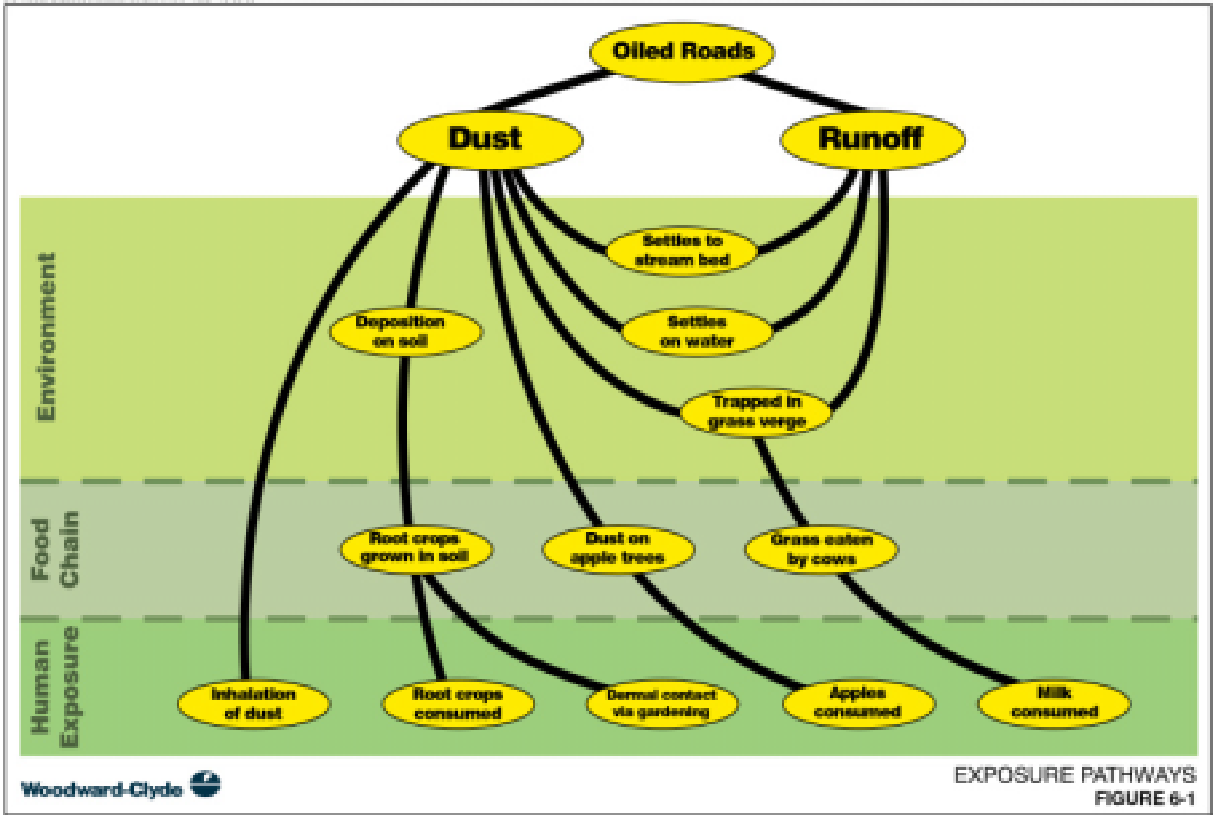
The assessment of deposition rates found that the maximum volume of dust was deposited on soil 10m from the centre of the road (i.e. 7m from the edge of the road). Thus the assessment assumed that each environmental receptor (water, soil, crops, etc) was only 7m from the edge of the road. In reality, many of the receptors would be greater than 7m from the road, but this deposition rate was used to ensure that a consistently conservative approach was employed.

6.2.5 Used Oil Application

For the purposes of this assessment it was assumed that each unsealed road is oiled once per annum (during summer only) at a rate of less than or equal to 2L of oil per square metre of road surface. This application rate is conservative when compared to the maximum application rate of 1.54m^2 reported to be currently used (Canterbury Regional Council, 1999).

It was also assumed that the application of road oil does not occur within 5m of a watercourse. This is consistent with District Plan provisions, for example, Canterbury Regional Council specify the following separation with respect to road oiling.

> *a) “there should be at least 5 metres of flat, level grassed area between the road and:*
>
> - *surface waters (streams, drains, water races, etc.);*
> - *springs;*
> - *well heads;*
> - *dry water channels’ or*
>
> *b) a greater distance on slopes.”*



EXPOSURE PATHWAYS
FIGURE 6-1

6.2.6 Accumulation

Accumulation of the contaminants in the environment was undertaken in two ways. The initial calculation for each receiving environment or receptor was based on an annual load of the contaminant reaching the environment. The volume of dust and the contaminant concentration on the dust was assumed to remain unchanged over the period of one year i.e. the deposition rate was consistent throughout the year. The contaminant concentration on the dust also remained constant throughout the year.

For example, the concentration of lead in soil as a result of dust deposition was assessed over a period of one year where the concentration of lead on the dust was assumed to be the same at the start of the year and at the end of the 12 month period. In addition, the deposited dust (and lead) was assumed to remain in the soil rather than be leached or washed away. This provided an annual load or concentration in the environment.

The second assessment involved the further assumption that the annual concentration of lead in the soil had been accumulated over a 70 year period, i.e. 70 annual loads of lead had entered the soil as a result of long-term road oiling. Further, the lead in the soil accumulated over this time was conserved at a rate of 100% i.e. there was no further loss to the environment via leaching or plant uptake etc. This provided a starting point for assessing the potential impact of soils historically contaminated by road oiling.

The deposition of “clean” or uncontaminated dust particles was excluded from the assessment as this would further dilute the contaminant load in the environment.

6.2.7 Guidelines

A number of guideline documents are used in this report for the purposes of comparison with the estimated environmental concentrations. These guidelines include:

Water

- ANZECC guidelines for the protection of aquatic biota in fresh and marine waters (1992). These are the generally accepted and commonly used criteria for the protection of aquatic biota.
- Draft ANZECC Guidelines (1999). The draft guidelines are currently being modified as a result of public submissions in 1999 and have not been adopted for use in New Zealand at the time of writing this report. The values for water quality are used for the purposes of comparison.

Sediment

- National Oceanic and Atmospheric Administration (NOAA) values reported by Long et al. (1995) have been used to assess the impact of sediment contaminant levels on biota in the adjacent watercourse. The values typically apply to marine or estuarine environments but have been used in this study for a freshwater environment given the lack of New Zealand criteria.
- Draft ANZECC guidelines (1999). The values for sediments in this document are interim values only and are generally based on the NOAA values.

Soil

- ANZECC contaminated sites guideline (1992). The background soil concentration range presented in this document was used to assess the concentrations in the soil as a result of dust and runoff loadings.
- Gaswork site guidelines (1997). The generic soil acceptance criteria for agricultural and horticultural use were used for the organic compounds not represented in the ANZECC 1992 document.

6.3 CONTAMINANTS

The contaminants species assessed include two heavy metals (copper and lead) and a number of organic compounds. Each species was either detected in the used oil analysed for this study or was present at a level of less than the detection limit (LOD). For compounds with concentrations of less than the limit of detection, the assessed concentration was assumed to be equal to the LOD. The organic compounds detected were polycyclic aromatic hydrocarbons (PAHs). These compounds typically consist of two or more aromatic ring structures and are known to be relatively persistent in the environment. The concentrations of the species are given below in Table 6-1.

Table 6-1
Concentrations of Contaminants in Oil and Road Dust

	Concentration in Oil (mg/kg)	Total Annual Mass (mg)	Concentration in Dust (mg/kg)
Lead	71	127.8	45.6
Copper	105	189	67.5
Naphthalene	125	225	80.4
Pyrene	70.7	127.3	45.45
Benzo(a)pyrene	2.301	4.142	1.6
PAH	204	365.4	130.5

6.3.1 Lead

Lead was assessed in this study as this metal was identified in the scope of work provided by MfE. In addition, the concentration of lead in the used oil was elevated relative to most other heavy metals.

6.3.2 Copper

Copper, while not specifically identified by MfE in the scope of work, was present in the oil at an elevated level, and so was included in the assessment.

6.3.3 Naphthalene

The concentration of naphthalene in the used oil sample was almost an order of magnitude greater than the concentrations of the other organic compounds. Two naphthalene species were detected (naphthalene and 2-methyl-naphthalene) and this study uses the combined total concentration of these species when assessing the environmental and human health exposure levels for naphthalene.

6.3.4 Pyrene

Pyrene was detected in the used oil at a concentration of 13 mg/kg. For the purposes of the environmental assessment and the human health risk assessment, the concentration of pyrene was based on the sum of the concentrations of the other non-carcinogenic PAH's found in the oil. Thus the total pyrene concentration in the oil was 70.7 mg/kg.

6.3.5 Benzo-a-pyrene

Benzo(a)pyrene was not detected in the used oil, similarly, the concentrations of a number of other carcinogenic PAHs were also found to be below the LOD. To use the carcinogenic PAHs in this assessment, the concentration of each compound was assumed to be equal to the limit of detection. The human health risk assessment required an estimated total concentration of carcinogenic PAHs, thus the benzo(a)pyrene concentration used for the assessment (both human health risk and environmental) was based on toxic equivalency factors and represents the concentrations of the other carcinogenic PAHs (benzo(b)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, bidenzo(a,h)anthracene and benzo(g,h,i)perylene).

6.3.6 Total PAH's

The total PAH concentration was also assessed, primarily for the purposes of comparing the environmentally accumulated levels with guideline values. The concentration of total PAH's was derived from the sum of all PAH's found in the used oil, including naphthalene. This assessment was also included as the low (less that detection limit) concentrations of the more carcinogenic compounds and the lack of individual guideline values for these species limited the efficacy of the assessment for the individual PAH compounds.

6.3.7 Other Contaminants

Although a number of other metals were detected in the used oil these species were not assessed for the purposes of this study. In particular, despite the concentration zinc in the oil, the application of oil to roads was unlikely to result in zinc concentrations above any guideline values. In addition, zinc is ubiquitous in the environment and relatively less toxic than lead or copper.

Chromium was also detected in the oil but only at a very low concentration and hence was not assessed.

Table 6-1 also shows the total annual mass of each assessed contaminant and the resulting concentration in the dust on the road.

A spread sheet with the details of these calculations is provided in Appendix G. The total mass of contaminants was based upon 2L of oil per square metre, on oil density of 0.9kg/L and a 2mm layer of dust per square metre.

6.4 EXPOSURE PATHWAYS

A summary of the assessed exposure pathways was provided in Figure 6-1. The pathways were divided into three levels: environmental, food chain and human health. This section provides the details on the environmental and food chain pathways, while the human health risk assessment is given in Section 7.

Two main exposure pathways were identified for the purposes of this assessment i.e. the mobilisation of dust by wind and traffic and the loss of particulates via rainfall and storm events.

6.4.1 Dust Deposition

Contaminant dust from the oiled road surface has the potential to impact on soil quality and may settle in a watercourse, impacting on both surface water quality and the sediment on the stream bed.

The dust also has the potential to settle on pip or stone fruits such as apples (the potential for rain to wash the dust off was excluded).

Once in the soil, the contaminants may be taken up by root crops and grazing cows, and the subsequent milk produced by lactating cows is also a potential exposure pathway.

Gardening in the dust contaminated soil may result in dermal absorption of the contaminants and this is assessed in the human health risk assessment.

6.4.2 Runoff from Road

Runoff laden with dust as a result of a storm event could enter the grass verge adjacent to the road. If the volume of water as a result of rainfall was sufficient to carry the contaminated particulates to a nearby watercourse, then road runoff could also impact on the quality of both the water and the sediment.

6.4.3 Pathways not Assessed

A number of scenarios or exposure pathways were excluded from this assessment. These include:

- Infiltration of runoff to the subsurface soil in the grass verge. This is unlikely to result in any of the contaminants percolating to subsurface soil layers or into groundwater as the contaminants are typically bound to the particulates rather than existing in the dissolved phase. Thus the impact on deeper subsurface soil layers and groundwater were not assessed for this study.
- Irrigation of crops with stream water. The stream assessed for this study was assumed to be shallow with a low flow and velocity. It was therefore expected that an alternative source of irrigation water would be used as the stream was expected to have limited flow during the summer months.
- The use of the stream for drinking water supply or swimming/contact recreation. The proximity of the unsealed road to the watercourse would limit the use for potable water supply and the low volume of water in the assessed stream would reduced the likelihood of contact recreation.
- The consumption of dusty grass by cows. This was excluded given the frequency of rainfall, which would wash the dust and associated contaminants into the soil.

6.5 ENVIRONMENTAL ACCUMULATION

6.5.1 Mass of Water and Particulates Mobilised in Runoff

To assess the volume or mass of particulates that could potentially become entrained in stormwater runoff from the road, the Universal Soil Loss Equation (USLE) was used. (Goldman et al., 1986). This equation includes factors such as erosion potential, slope length and steepness, and vegetative cover and rainfall. A spreadsheet showing the calculation is given in Appendix G. The equation estimates the particulate yield in tonnes/hectare/year using A=R.K.LS.C.P, where:

R, the rainfall erosion index, is a measure of the erosive force of the rain and the intensity of rainfall in a normal year. The equation used to calculate R uses a 1 in 2 year return frequency storm event with a 6 hour duration. To estimate the 2 year 6 hour rainfall for the equation, the rainfall figures for Wanaka, Taranaki and Hawkes Bay (27, 54 and 39mm respectively) were averaged to give 40mm. R is therefore equal to 47.09 J/ha.

K is the soil erodibility and represents the ability of the surface to resist the erosive energy of rain. When calculating K the soil structure and texture are taken into account. For the purposes of this study the soil on the road was assumed to consist of 0% organic matter, 40% clay, 45% silt and 15% sand. The value of K was corrected by a factor of +0.1 to account for the lack of organic matter. K was equal to 0.462.

LS represents the length and slope of the surface contributing the runoff. The road used in this study was assumed to have a slight camber (2%). The length of road was 3m, i.e. the distance from the centre line to the road verge. LS is therefore equal to 0.10.

C is the vegetated cover factor and has a value of 1 when the soil is bare and unprotected. This figure reduces to 0.01 when the soil is protected with undisturbed nature vegetation. A value of 1.0 was used in this assessment.

P represents the roughness of the surface. A value of 1.0 represents undisturbed pasture while a value of 1.3 is used for compacted and smooth soil. A value of 1:2 was used in this assessment and is representative of a track.

The resulting mass of particulate was equal to 2.61 t/ha/yr. Given that the contributing catchment was assumed to be a strip 1m wide and 3m long ($3m^2$) the estimated particulate loss was 0.783kg/m/yr. Each 1m wide strip of the road was assumed to contribute the same mass of sediment.

To estimate the volume of water generated by a 1 in 2 year storm of 6 hours duration, the Rationale formula (Williamson, 1993) was used, where the volume of water (Q) is equal to the area (A) x rainfall intensity (i) x a correction factor (c) that accounts for the degree of impermeability of the road surface. The catchment area used was 1m wide and 3m long ($3m^2$), the average rainfall over the three regions was 40mm and a correction factor of 0.5 was applied to represent the unsealed road surface.

The volume of water generated was therefore equal to $0.15m^3$. In addition, for the purposes of this assessment it was assumed that a single storm event contributed the entire particulate and water load to the grass verge.

Grass verge calculations

To estimate the volume of particulates and water retained or trapped in the grass verge, the verge was assumed to be 1m wide and 5m long. The 5m length was based on the Canterbury Regional Council District Plan which prohibits oiling of roads within 5m of a water course. It was also assumed that the 5m buffer between the road and the watercourse was vegetated by grass, weeds or small shrubs. The verge would then act as a retention device, trapping both runoff and the mobilised particulates, for the purposes of this study. The verge was assumed to retain 75% of the water and particulates in the runoff. The remaining 25% was assumed to enter the watercourse. In reality, the roads are generally only oiled during summer when the subsurface soil in the verge is more likely to be dry, thus greater infiltration of the runoff is likely. Consequently the volume of water is (and therefore particulates) entering the water course is likely to have been over estimated.

Table 6-2 shows the calculated mass of soil and concentration of each contaminant for both annual and 70 years of accumulation in the soil. To calculate the annual contaminant load due to the storm event it was assumed that the runoff was mixed through the top 10cm of soil in the grass verge. A 10cm mixing depth was considered appropriate for this study given that it was assumed that cows are able to graze the verge and contribute to the mixing.

The 70 year historically accumulated concentration of contaminants in the soil was based on the assumption that each annual load was retained in the soil and that 70 successive storm events each contributed the same annual load to the verge.

These concentrations were then combined with the concentrations of contaminants on the soil as a result of dust deposition (Section 6.5.2) and used to estimate the exposure of cows and milk to the oil contaminants.

Table 6-2
Contaminant Concentrations from Runoff in Grass Verge after Storm.

Contaminants	**Annual Concentration in Grass Verge (mg/kg)**	**70 Year Concentration in Grass Verge (mg/kg)**
Lead	0.038	2.53
Copper	0.0566	3.74
Naphthalene	0.674	4.46
Pyrene	0.0052	0.341
Benzo(a)pyrene	0.001	0.082
PAH	0.109	7.24

Runoff to Watercourse

The remaining 25% of the contaminants in the stormwater runoff were assumed to pass over the 5m long strip of grass verge and enter a single square metre area of the adjacent stream. The width of the stream was not determined for this assessment but rather the water in a square metre cell was assumed to receive the runoff. The stream was assumed to be 30cm deep and the water was not flowing. Thus the runoff mixed with $0.3m^3$ of water in the stream. The mass of particulates and volume of water in the runoff entering the stream are given below in Table 6-3.

To calculate the concentration of contaminants in the water, the volume of water in the stream was combined with the runoff volume. 100% of the contaminant load in the runoff was assumed to remain suspended in the stream water.

The sediment concentration in the stream was estimated assuming that the 100% of the runoff particulates settled to the stream bed and mixed with a 2cm layer of sediment already on the stream. To estimate the accumulation of contaminants in the sediment layer after 70 years, 70 annual runoff particulate loads were assumed to be retained in the stream bed. A 70 year loading of suspended contaminants in the water column was not undertaken given that mixing of the water column was likely within the stream.

Before the concentrations of contaminants in the water, soil and sediment can be compared with guideline values, the concentration of contaminants as a result of dust deposition need to be assessed.

Table 6-3
Contaminant Concentrations from Runoff in Sediment and Water Column of Stream after Storm.

Contaminants	Annual Concentration in Water (mg/m^3)	Annual Concentration in Sediment (mg/kg)	70 Year Concentration in Sediment (mg/kg)
Lead	28.36	0.32	15.0
Copper	41.9	0.47	22.18
Naphthalene	49.1	0.56	26.4
Pyrene	38.2	0.04	2.02
Benzo(a)pyrene	0.92	0.01	0.49
PAH	81.1	0.91	42.88

6.5.2 Dust Deposition to Soil, Water and Sediment

The calculated deposition rate of dust is included in Appendix G. The concentration of each contaminant on the dust was calculated and is included in Appendix G. To estimate the contaminant concentration in soil as a result of deposition, the mass of each contaminant was mixed with either:

- a 10cm layer of soil (1m x 1m);
- a 2cm layer of sediment (1m x 1m), or
- assumed to remain suspended in the water column (0.3m x 1m x 1m).

The resulting concentrations for an annual deposition of dust are given in Table 6-4.

The concentrations of contaminants in the sediment and water column as a result of deposited dust after one year are slightly less that those from the stormwater runoff. However, the concentrations of contaminants in soil from dust deposition are higher than those sourced from the road runoff. This difference is due to a number of factors, including the different surface area of soil available for mixing the dust (1m^2) compared to that used for the runoff (5m^2). The runoff particulates are water borne and are therefore able to travel over a greater length of soil than the dust (which is deposited in a single square metre).

The total concentration of each contaminant in water, sediment and soil (grass verge) is given in Table 6-5. The relevant guideline values for each species are also given in Table 6-5. Data for the total accumulated concentration after 70 years is also included for sediment and soil.

Table 6-4
Contaminant Concentrations from Runoff in Sediment and Water Column of Stream after Storm.

Contaminants	Annual Concentration in Grass Verge (mg/kg)	70 Year Concentration in Grass Verge (mg/kg)	Annual Concentration in Water (mg/m^3)	Annual Concentration in Sediment (mg/kg)	70 Year Concentration in Sediment (mg/kg)
Lead	0.0513	3.33	23.96	0.255	12.9
Copper	0.0758	4.93	35.4	0.377	19.1
Naphthalene	0.09	5.87	42.2	0.449	22.7
Pyrene	0.0511	3.32	23.9	0.254	12.8
Benzo(a)pyrene	0.002	0.11	0.78	0.008	0.417
PAH	0.147	9.53	68.5	0.73	36.9

Table 6-5
Total concentrations of contaminants after annual and 70 year accumulation of both dust and runoff.

Contaminant	Lead	Copper	Naphthalene	Pyrene	Benzo(a)pyrene	PAH
Soil Concentrations (mg/kg)						
Annual	0.0893	0.1324	0.1574	0.0563	0.003	0.256
70 year accumulation	5.86	8.67	*10.33*	3.661	0.190	16.77
ANZECC Guideline (1992)	<2 – 200	1 - 190	-	-	-	0.95 – 5
Gasworks Guideline (1997)	-	-	2	150	0.2	80
Sediment Concentration (mg/kg)						
Annual	0.571	0.847	1.009	0.294	0.0183	1.64
70 Year Accumulation	27.9	41.28	*49.1*	*14.82*	0.907	*79.78*
NOAA Values (1995)	46.7 – 218	34 - 270	0.16 – 2.1	0.665 – 2.6	0.43 – 1.6	1.7 – 9.6
Draft ANZECC (1999)	50 – 220	65 - 270	0.16 – 2.1	0.665 – 2.6	0.43 – 1.6	1.7 – 9.6
Water Concentration (mg/m^3)						
Annual	*52.32*	*77.3*	*92.1*	*62.1*	*1.70*	*149.6*
ANZECC (1992)	1 – 5	2 - 5	-	-	-	3
Draft ANZECC (1999)	1.2	0.33	0.3	-	0.3	-

Note: Numbers given in *italics* exceed guideline values.

6.5.3 Comparison with Guidelines

Water Quality

A comparison of the estimated water borne contaminant concentrations as a result of annual dust deposition and runoff to the stream with the ANZECC guidelines (1992 and 1999) shows that both sets of guideline values are exceeded if the annual load is deposited in the stream at once. However, the expected flow of the stream and additional inputs from rain are expected to mix and further dilute the contaminant load. The estimated concentrations are also based on the conservative assumption that all particulates remain suspended in the water column. In reality, the heavy particulates would settle to the sediment layer on the stream bed, reducing the concentration in the water column. Thus the practice of oiling roads with used oil to reduce dust volumes is expected to have an adverse effect on the quality of water in a stream lying between 5m and 7m from the road (5m and 7m are the length of the grass verge and the distance from the road with the highest deposition rate, respectively). The adverse effect is not quantified here but is expected to be minimised by on-going mixing in the stream.

To further minimise the effect of deposition and runoff on water quality, the minimum distance between the oiled road and watercourse could be increased to greater than or equal to 10m.

Sediment Quality

The total annual contaminant concentrations in the sediment as a result of the dust deposition and particulate laden runoff are all below the lower guideline values given in both the draft ANZECC (1999) and NOAA (1995) guidelines, with the exception of naphthalene. In addition, the annual loads from each individual source, once settle to the sediment layer, are below the lower guideline levels. The total concentration of naphthalene in the sediment from both sources exceeds the lower guideline value (or ER-L) but does not exceed the upper level (or ER-M).

After 70 years of historic accumulation, the metal concentrations are still below the lower guideline values. However, the concentrations of the organic compounds all exceed the upper guideline values, with the exception of benzo(a)pyrene.

The 70 year accumulation does not allow for further mixing, erosion, flooding, dilution with clean sediment or degradation of the organic species. Thus the assessment over-estimates the expected 70 year concentrations. Despite this, the concentrations of most organic species significantly exceed the relevant guideline values. Consequently, over a period of 70 years, accumulation of organic compounds in the sediment layer is expected to adversely effect benthic biota, although the effect has not been quantified for the purposes of this study.

To reduce the contaminant concentrations in the sediment layer of an adjacent stream, it is recommended that road oiling not be undertaken within 10m of a watercourse. This increased distance will reduce the deposition rate of dust to the stream and provide a wide verge to filter any particulates entrained in stormwater runoff.

Soil Quality

The concentrations of contaminants in the soil as a result of both dust deposition and runoff accumulation were presented in Table 6-5. The ANZECC guidelines (1992) for the assessment and management of contaminated sites provide a concentration range typical of background contaminant levels. Comparison of the estimated total concentrations with the guidelines show that all metal and organic concentrations in the soil after accumulation for one year are within the background range. Note: the organic species naphthalene, pyrene and benzo(a)pyrene do not have individual guideline values in the 1992 document.

The 70 year historic accumulation concentrations for the metals are also within the ANZECC background range, while the total PAH concentration exceeds the background maximum value of 5 mg/kg by approximately three times.

The guidelines for assessing and managing contaminated gasworks sites (MfE, 1997) provide a summary of the generic soil acceptance criteria for agricultural and horticultural use and include values for the organic compounds assessed in this study but not listed in the ANZECC document, as well as a number for total PAHs. The concentration of pyrene after 70 years of accumulation in soil is well below the gasworks criterion of 150 mg/kg, as is the total PAH concentration (16.77 mg/kg compared with 80 mg/kg in the guidelines). The concentration of benzo(a)pyrene is slightly less than the guideline criterion of 0.2 mg/kg while the concentration of naphthalene in the soil exceeds the gasworks value.

While the annual soil concentrations due to dust deposition and runoff are well below the guideline values for the assessed contaminants, the 70 year historically accumulated levels exceed guideline values for naphthalene. When comparing the estimated concentrations with these guideline values it should be noted that the accumulation in soil over time has been conservative with no loss or degradation of contaminants.

The concentration of contaminants accumulated in the soil would not be significantly altered by extending the distance between the road and an adjacent watercourse.

6.6 FOOD CHAIN ACCUMULATION

The three main food chain receptors assessed were root crops grown containing deposited dust, dust settling on apples while growing on trees and grass uptake of contaminants from soil, the subsequent consumption of grass by cows and the excretion into milk.

6.6.1 Root Crops

To calculate the uptake of contaminants from soil by root crops, bioconcentration factors were used. The assessment of root vegetable uptake was based on the concentration of contaminants in the soil as a result of dust deposition. It was assumed that vegetable gardens were typically greater than 10m from the road centre and were therefore not exposed to the particulates from road runoff. Despite the expected distance of the gardens from the road, it was assumed that the peak dust deposition rate was still applicable, which means the concentrations of each contaminant in the soil were over-estimated.

The annual mass of each contaminant was mixed with the top 10cm of soil as this was representative of the soil mixing as a result of typical gardening activities. The uptake by crops after exposure to the soils with 70 years of historically accumulated contaminants was also assessed.

The bioconcentration factors (BCF) for root crops were taken from a number of sources.

Metals

The BCF values for lead and copper were taken from the Shell Oil (New Zealand) HESP Reference Manual (1994).

Organic Compounds

The BCF values for the organic species in the used oil were taken from the Ministry for the Environment (MfE) guidelines for assessing and managing petroleum hydrocarbon contaminated sites in New Zealand (1999). The value used for PAH was taken as an average of the values given in the guidelines.

The uptake of metals from soil by root crops is limited by the number of competing chemical and physical processes available for binding and immobilising metals in soil. Such mechanisms include adsorption, precipitation and complexation to organic matter, all of which reduce the free metal concentration in the soil solution. Lead in particular is relatively insoluble and is not taken up by the edible portion of the plant (NRC, 1996) and this is reflected in the low BCF value for lead. Copper is typically more bioavailable than lead and is translocated to the vegetative parts of the plant or crop. However the phytotoxicity of copper to plants is such that plant growth is so severely stunted by potentially harmful concentrations of copper, that consumption of contaminated crops by animal or humans is prevented by the inability to harvest the plants (NRC, 1996).

The uptake of organic compounds in soil by root crops and other plants is also limited by the chemical immobilisation of the compounds in soil. PAHs have typically low water solubility and in soil are usually bound to the soil matrix. The transfer of PAHs from contaminated soil to root crops was found to be minimal, while transfer to the above ground portion of the plant was essentially zero (NRC, 1996).

Table 6-6 presents the bioconcentration factor used in the assessment and the accumulated concentrations in root crops.

Table 6-6
Total concentrations of contaminants after annual and 70 year accumulation of both dust and runoff.

Contaminant	Bioconcentration Factor	Concentration with annual load (mg/kg)	Concentration with 70 year load (mg/kg)
Lead	0.001	5.13 x 10^{-5}	0.003
Copper	0.1	7.58 x 10^{-3}	0.493
Naphthalene	0.0673	6.06 x 10^{-3}	0.394
Pyrene	0.0221	1.13 x 10^{-3}	0.073
Benzo(a)pyrene	0.0179	3.58 x 10^{-5}	0.002
PAH	0.0358	5.26 x 10^{-3}	0.341

These concentrations were then used in the human health risk assessment to determine the ingested contaminant levels and the associated risk (Section 7**).**

6.6.2 Pip and Stone Fruit

To assess the potential contaminant load collected via dust deposition on horticultural crops a number of assumptions were made:

- That apples were representative of pip and stone fruit.
- That the apple trees were approximately 7m from the edge of the road and therefore receive the peak depositional dust volume.
- That apples were exposed on the trees for six months of the year.

- That the apples during those six months, were fully grown, that is, approximately 8cm in diameter.
- That during this six month period, no dust was washed from the apples by rainfall.
- That 75% of the surface of the apple was exposed to, and accumulated, dust.

The above assumptions were designed to be conservative in terms of dust accumulation. The potential washing of the apples by rainfall was excluded from the calculation, as was the growth rate of the apples on the trees. While this information, if included in the assessment, may have reduced the number of conservative assumptions, the ensuing calculation would become considerably more complicated.

The results of the calculations are given below in Table 6-7 and detailed calculations are provided in the spreadsheets in Appendix H.

Table 6-7
Estimated mass of contaminants on each apple.

Contaminant	Mass in apple (mg)
Lead	0.0539
Copper	0.0797
Naphthalene	0.0949
Pyrene	0.0536
Benzo(a)pyrene	0.0017
PAH	0.1541

These results were then used for the human health risk assessment in Section 7.

6.6.3 Uptake by Grass and Excretion into Cows Milk

The uptake of contaminants from soil by grass, consumption by cows and the excretion into cows milk was assessed for the organic components of the used oil only. The organic contaminants have typically low water solubility and are predominantly partitioned into the fat and milk of a cow. The metals were not assessed as part of the study. Copper uptake by grass is limited by the phytotoxicity of copper and lead is virtually insoluble, thus essentially zero translocation to the leaf or above ground portion occurs.

The contaminant concentrations in the soil were take to be the total of the runoff and dust deposited scenarios. This would represent the situation where cattle were able to graze the grass verge of the oiled road. The concentrations of the organic species were assessed in cow's milk after consumption of grass that had grown in an annual load of contaminants and after consumption of grass that had grown in 70 years of accumulated contaminants from runoff and dust.

The uptake organic contaminants by the above ground portion of grass is very limited and for PAHs essentially zero (NRC, 1996). However, to take a conservative approach, the BCF values used in the uptake of contaminants by root crops were applied to the uptake by grass. It was also assumed that the translocation of the organic fraction from the root to the leaf/stem was 0.2 time the BCF for root crops (MfE and MoH, 1997). PAHs were not assessed in the human health risk assessment as data for the other organic species (naphthalene, pyrene and benzo(a)pyrene) were used to represent the carcinogenic and non-carcinogenic compounds.

For the purposes of this assessment cows were assumed to eat only grass and consume approximately 15 kg of dry matter each day. On average soil generally comprises no more than 6% of the total dry matter intake of most grazing stock. Variability of conditions in the field could further reduce the soil intake (Wild and Jones, 1992). Consequently soil consumption was excluded from this assessment.

Table 6-8 shows the estimated concentrations of contaminants in the grass and the annual mass of contaminants consumed by a cow. Once consumed the organic species are partitioned preferentially into the fat and milk or excreted as waste. The excretion into milk was calculated using McLachlans model (1994) where the carryover into milk = 1/(1.283 + (2.875 x 10^{-8} x K_{ow}). The K_{ow} values were taken from the USEPA (2000) and the MfE guidelines for petroleum hydrocarbon contaminated sites (1999). To calculate the K_{ow} for the groups of compounds, the values for the individual compounds were weighted according to the percentage weight present in the used oil. The detailed calculations are provided in the spreadsheets in Appendix H.

Table 6-8
Concentrations of contaminants in grass and daily mass consumed by cow.

Contaminants	Grass Concentration (mg/kg)	Mass consumed by Cow (mg/day)
Naphthalene	0.0105	0.158
Benzo(a)pyrene	5.4E-5	8.1E-4
Pyrene	0.00124	0.0186
PAH	0.256	3.84

To calculate the mass of the organic species excreted into milk on a daily basis, the intake was then multiplied by the carry-over factor. To calculate the concentration in milk produced on a daily basis it was assumed that each cow typically produced 10L of milk each day. Production values from the Northland Dairy Company showed that cows peak at approximately 20-21L/day and are generally least productive at 14-15L/day. To be conservative and cover an annual period, a volume of 10L/day was used in this assessment. The resulting concentration of the organic contaminants in the milk after both annual and 70 year historic contaminant loads of dust and runoff in soil are shown in Table 6-9.

Table 6-9
Concentrations of contaminants in Milk

Contaminants	Concentration from annual contaminant soil load (mg/L/day)	Concentration from 70 year contaminant soil load (mg/L/day)
Naphthalene	2.47E-3	0.162
Benzo(a)pyrene	1.22E-5	7.71E-4
Pyrene	2.89E-4	0.0188
PAH	2.14E-3	0.14

These values were then used for the human health risk assessment in Section 7.

7.1 INTRODUCTION

A health risk assessment is the process of estimating the potential impact of a chemical or a physical agent on a specified human population under a specific set of conditions.

The aim of health risk assessment is to estimate an individual's chemical intake and compare it to a level of intake deemed acceptable. In New Zealand, an acceptable cancer risk level of 1 in 100,000 per lifetime (one additional case of cancer per 100,000 people per lifetime) has been adopted by the Ministry of Health. In assessing possible adverse effects on human health, consideration is given to a range of carcinogenic and non-carcinogenic effects.

There are four basic steps in a human health risk assessment:

Hazard Identification	The objective of this step is to select the chemicals of concern for the risk assessment.
Exposure Assessment	The objective of this step is to estimate the type and magnitude of exposures to the chemicals of potential concern. This is done by identifying the pathways by which a chemical can move from a source and the potential organisms, known as receptors, which may then be exposed.
Toxicity Assessment	This involves assessing the possible adverse effects that may be associated with exposure to the identified chemicals of concern.
Risk Characterisation	The risk to human health is assessed by comparing estimated chemical intakes with toxicity values for various exposure pathways.

7.2 HAZARD IDENTIFICATION

The basis for selecting lead, copper, naphthalene, pyrene and benzo(a)pyrene as the contaminants of concern in used oil was discussed in Section 6.3.

7.3 EXPOSURE ASSESSMENT

7.3.1 Exposure Pathways

Five significant exposure pathways were identified for human receptors, as discussed in Section 6.4. These are:

- Ingestion of crops grown in soil impacted by deposition of contaminated dust.
- Dermal (skin) contact with soil, which is impacted by deposition of contaminated dust, during vegetable gardening.
- Ingestion of milk from cows that have been grazed on grass impacted by deposition of contaminated dust and contaminated surface runoff.
- Ingestion of dust coated apples in an orchard located adjacent to an oiled road.
- Inhalation of contaminated dust while travelling along or living close to an oiled road.

Note that the health risk assessment assessed both adults and children in the context of a agricultural/horticultural land use, which is assumed to be the most appropriate land use scenario for areas where road oiling occurs.

It was assumed that all potential human exposures are cumulative (i.e. the relevant exposures noted above were not assessed separately, but were summed to assess a total potential exposure). For example, a person (both adult and child) was assumed to eat crops grown in soil impacted from contaminated dust deposition, drink unpasturised milk from cows who had eaten grass grown in soil impacted by contaminated surface runoff and deposited dust, eaten apples impacted by deposition of contaminated dust, and inhaled contaminated dust whist travelling along an oiled road.

7.3.2 Exposure Concentration Estimation

Concentrations of the contaminants in the soil, crops, cows milk and apples to which human receptors may be exposed, were calculated in Section 6.

7.3.3 Exposure Estimation

To quantify the amount of exposure experienced by the receptors, non-threshold carcinogenic and threshold daily intakes were estimated for each exposure pathway using the following relationship:

$$\textit{Daily Chemical Intake (mg/kg/day)} = \textit{Chemical Conc. (in soil, milk, crops etc)} \times \textit{Intake Factor}$$

7.3.4 Exposure Factors

A summary of the exposure factors for both adult and child receptors is provided below. These factors are consistent with those adopted in the revised *Health and Environmental Guidelines for Selected Timber Treatment Chemicals*.

The Intake Factor is normalised for time and body weight and is generally calculated as:

$$\textit{Intake} = \frac{\textit{Concentration} \times \textit{Contract rate} \times \textit{Exposure frequency} \times \textit{Exposure duration}}{\textit{Body weight} \times \textit{Averaging time}}$$

An intake factor is a pathway-specific and receptor-specific value that converts the concentration of chemicals into a daily intake, expressed as milligrams of contaminant per kilogram of body weight per day. Assumptions made in quantifying the intake were based on those used in relevant New Zealand guideline documents (MfE and MoH, 1997), which use currently accepted ANZECC and USEPA default factors. These intake factors have been based on an estimate of the “reasonable maximum exposure” (RME) that may be expected. This is an exposure scenario that is “protective and reasonable”, i.e. not an absolute worst case but a reasonable maximum.

A discussion on the derivation of the intake factors for each of the exposure pathways is provided below. Detailed references are presented in the Exposure Parameters spreadsheets contained in Appendix I.

Global Exposure Parameters

(These exposure parameters are common to all receptors and exposure pathways).

The following common exposure parameters are assumed:

- Two age groups are considered:
    - Adults
    - Children (1 to 6 years old)
- Exposure Duration (ED):
    - A child is assumed to be exposed from when it is a toddler up until six years of age. (i.e. ED = 6 years)
    - An adults exposure is assumed to correspond from toddler to thirty years of age. (i.e. ED = 30 years).

  These exposure duration's are based on the reasonable maximum time spent on the one site in a rural context based on USEPA, 1989.
- Exposure frequency (EF) = 350 days/year (USEPA, 1989).
- Averaging time (AT):

  = (ED × 365) days for non-carcinogens by convention, and

  = (70 years × 365) days for carcinogens, representing a lifetime exposure, by convention (USEPA, 1989).

Exposure to Contaminants in Dust

Exposure to contaminants by inhaling dust released from the road surface was assessed based on a child inhaling at a rate of 3.8 m^3/day and an adult inhaling at a rate of 20 m^3/day. The dust concentration was calculated using a particulate emission factor derived from air emission modelling discussed in previous sections. This factor was applied to the contaminant concentrations present in the road dust to derive a contaminant concentration in dust.

As a conservative assumption, it was assumed that this concentration was inhaled by the receptors (in fact there would be considerable dilution over distance).

Exposure to Contaminants in Produce

Intake of produce was assessed assuming intake rates of 130 and 450 g/day for children and adults, respectively. This intake is assumed to be the total fruit and vegetable intake. In accordance with New Zealand guidelines (MfE, 1997), it was assumed that only vegetables may be impacted by contaminants in soil as a result of deposited dust, and that these comprise 60% of the total intake. It was further assumed that all vegetables consumed were sourced from land impacted by contaminated dust deposition and mixing to a depth of 10cm.

Exposure to Contaminants in Dairy Products

Intake was assessed based on data provided by the New Zealand Dairy Board, that 340 million litres of milk are currently supplied to the New Zealand domestic market annually. Based on a population of 3.7 million, this equates to an average milk consumption of around 90 L/year, or 0.25 L/day. This assumption was applied to both children and adults. It was further assumed that all of the milk consumed by the residents was sourced from stock grazed on land subject to both dust deposition and runoff.

Exposure to contaminants in Apples

To assess the concentration of each contaminant on the apples, a number of further assumptions were made:

- That the apples were consumed at a rate of three each day for 90 days (three months) and,
- That the concentration of each contaminant was estimated over the total volume of the apple.

These assumptions cover the situation where adults and children routinely consume apples directly from a fruit tree without washing the dust off first.

To calculate the ingestion rate, the mass of each contaminant was divided by the volume of the apple to give the contaminant concentration "in" the apple. It was also assumed that 100% of the apple was consumed each time to ensure exposure to 100% of the contaminant load. Over the three month period 270 apples would be ingested. This equates to 0.74 apples each day over a 12 month period and an ingestion rate of 0.179 kg of apple each day.

The concentrations of contaminants in each apple are given in Table 7.1 below.

Table 7-1
Concentrations of contaminants in each apple

Contaminant	Concentration in Apple (mg/kg)
Lead	0.222
Copper	0.329
Naphthalene	0.391
Pyrene	0.221
Benzo(a)pyrene	0.007
PAH	0.635

Dermal Exposure to Contaminants in Soil

To assess the dermal absorption of contaminants from soil when gardening, the soil contaminant levels were taken from Table 6-4 for the deposition of dust. Th assessment assumed that contaminants from runoff would not be present in a typical vegetable garden as such garden were expected to be greater than 7m from the edge of the oiled road.

7.4 TOXICITY ASSESSMENT

The level of exposure associated with the onset of adverse human health effects is characterised using dose-response factors, which are developed from published toxicological data. Dose-response factors are used to characterise the relationship between the level of exposure and the likelihood of adverse effects. Chemicals may be generally divided into two groups: carcinogens and non-carcinogens, and therefore there are two types of dose response factors, or toxicity values:

1. **Carcinogens (non-threshold):** Chemicals that exhibit no threshold in the dose-response relationship, i.e. any amount of exposure to the chemical carries with it a degree of risk. The dose-response factors for carcinogenic chemicals are referred to as slope factors. The World Health Organisation (WHO) only assigns slope factors to genotoxic carcinogens

(genotoxic carcinogens are those that are considered to interact directly with genes). The US EPA assigns slope factors to all carcinogens (genotoxic and non-genotoxic). Benzo(a)pyrene was used to represent the carcinogenic compounds in this assessment.

2. **Non-Carcinogens:** Chemicals that exhibit a threshold dose-response relationship, i.e. there is a level of exposure below which there is no (or no appreciable) risk. These chemicals are, using WHO definitions, carcinogens that operate through a non-genotoxic mechanism. Pyrene, naphthalene and the metals were used to represent this class of compound.

   The potency factors for these chemicals are referred to as reference doses (RfD) or tolerable daily intake (TDI). The term RfD tends to be used primarily by the US EPA; the term TDI is used primarily by WHO. The units of measurement for both the RfD and TDI are milligrams of chemical per kilogram of body weight per day.

7.4.1 Risk Characterisation

Risk characterisation is the final step of the quantitative risk assessment process. To characterise the potential risks, the extent of exposure is compared with the toxicity data to determine whether a risk exists, based on target risk levels. The calculations used in the risk characterisation were undertaken using Woodward-Clyde (NZ) Ltd's in-house spreadsheet model, RiskE, contained in Appendix I.

ANZECC Approach:

The potential for adverse health effects by exposure to non-carcinogenic chemicals has been evaluated by comparing, for each of the chemicals of concern, the estimated daily chemical intake with their respective toxicity values (TDI). The resulting ratio is referred to (by the USEPA) as the hazard quotient and is derived as follows:

$$\text{Hazard Quotient (HQ)} = \frac{\text{Daily Chemical Intake (mg/kg/day)}}{\text{Tolerable Daily Intake (mg/kg/day)}}$$

$$\text{ie. } 1 = \frac{C \times \text{Intake Factor}}{TDI}$$

If the hazard quotient exceeds one, i.e. the daily intake exceeds the TDI, adverse health effects may occur, and an unacceptable risk would be concluded. The hazard quotient may be calculated for each pathway, and summed to give the overall risk by all pathways.

USEPA Approach:

The risk due to exposure to carcinogenic contaminants is calculated using the following equation:

$$\text{Risk} = \text{Daily Chemical Intake (mg/kg/day)} \times \text{Slope Factor (mg/kg/day)}^{-1}$$

$$\text{ie. } Risk = C \times IF \times SF$$

New Zealand guideline documents (and acceptance criteria) have adopted an incremental lifetime risk of cancer of 1 in 100,000 per substance (10^{-5}).

In this study, carcinogenic contaminants exhibiting genotoxicity (e.g. benzo(a)pyrene) were assessed using a non-threshold dose response model (i.e. USEPA approach) and all other contaminants were assessed using a threshold dose response model (i.e. ANZECC approach).

7.4.2 Summary

The risk to human health (both child and adult receptors) was assessed in RiskE using both the 1 year and 70 year contaminant concentrations calculated in Section 6.0. A summary of the nonthreshold carcinogenic and threshold non-carcinogenic risks posed to both a child resident and adult resident are respectively provided in Tables 7.2 and 7.3 below.

Table 7-2
Risk Summary – Child Resident

Pathway	**Nonthreshold Carcinogenic Risks RME**		**Threshold Risks-Chronic Hazard Index RME**	
	1 year contaminant concentrations	70 year contaminant concentrations	1 year contaminant concentrations	70 year contaminant concentrations
Ingestion of chemicals in homegrown crops	1.12×10^{-7}	6.14×10^{-6}	7.89×10^{-3}	0.514
Ingestion of homegrown dairy products (milk)	1.22×10^{-7}	7.71×10^{-6}	1.00×10^{-2}	0.657
Dermal contact with chemicals in soil	2.65×10^{-10}	1.50×10^{-8}	9.37×10^{-6}	5.51×10^{-4}
Inhalation of particulates outside residence	2.48×10^{-13}	2.48×10^{-13}	2.23×10^{-9}	2.23×10^{-9}
Ingestion of fruit (apples)	5.15×10^{-5}	5.15×10^{-5}	1.92	1.92
TOTAL	**5.17×10^{-5}**	**6.53×10^{-5}**	**1.94**	**3.10**
Limit of Acceptable Risk	1×10^{-5}		1.00	

Table 7-3
Risk Summary – Adult Resident

Pathway	**Nonthreshold Carcinogenic Risks RME**		**Threshold Risks-Chronic Hazard Index RME**	
	1 year contaminant concentrations	70 year contaminant concentrations	1 year contaminant concentrations	70 year contaminant concentrations
Ingestion of chemicals in homegrown crops	4.14×10^{-7}	2.28×10^{-5}	5.85×10^{-3}	0.381
Ingestion of homegrown dairy products (milk)	1.31×10^{-7}	8.26×10^{-6}	2.15×10^{-3}	0.141
Dermal contact with chemicals in soil	3.02×10^{-8}	1.91×10^{-6}	1.41×10^{-4}	9.24×10^{-3}
Inhalation of particulates outside residence	6.88×10^{-12}	6.88×10^{-12}	1.03×10^{-8}	1.03×10^{-8}
Ingestion of fruit (apples)	5.51×10^{-5}	5.51×10^{-5}	0.412	0.412
TOTAL	**5.57×10^{-5}**	**8.81×10^{-5}**	**0.420**	**0.943**
Limit of Acceptable Risk	1×10^{-5}		1.00	

The sum of the nonthreshold carcinogenic risks from individual exposure pathways, using 1 year contaminant concentrations, is 5.17×10^{-5} and 5.57×10^{-5}, for a child and adult respectively. These respective risks increase to 6.53×10^{-5} and 8.81×10^{-5} when using 70 year historic contaminant concentrations. In both cases, the risk to human health is considered unacceptable given that the risk is greater than the acceptable level risk of 1×10^{-5} used in New Zealand guideline documents.

The sum of threshold noncarcinogenic risks (Chronic Hazard Index) from individual exposure pathways, using 1 year contaminant concentrations, is 1.94 and 0.420, for a child and adult respectively. These respective risks increase to 3.10 and 0.943 when using 70 year contaminant concentrations. The hazard to a child receptor, as a result of exposure to the individual pathways, is unacceptable given that the hazard index is greater than 1. The hazard to adults is less than 1 and is therefore acceptable.

7.4.3 Discussion of Results

For each scenario it is the exposure to dust on apples that is primarily responsible for the risk associated with the carcinogenic compounds and this applies to both children and adults. When the risk calculated for apple consumption is excluded from the calculation, the total carcinogenic risk for both children and adults from the annual contaminant load is 2.34×10^{-7} and 5.57×10^{-7} respectively, i.e. is acceptable. Exposure to 70 years of historic accumulation increases the child and adult risk to 1.38×10^{-5} and 3.29×10^{-5} respectively and remains unacceptable.

The risks associated with the non-carcinogenic compounds were also unacceptable for the child receptor both after annual contaminant load exposure and after 70 years historic accumulation. Removing the contribution to the risk from exposure to apples reduced the non-carcinogenic risk after 70 years contaminant accumulation to 1.189 and after one year of accumulation to 0.01. Thus the one year accumulation exposure would be acceptable while the 70 year accumulation scenario would not.

The sensitivity of the carcinogenic risk associated with apple consumption was tested by reducing the daily consumption rate from three apples per day for three months to two apples per day for three months. Although this reduced the value of the risk, the risk was still unacceptable.

The conservative assumptions associated with the deposition rate and retention of dust on the apples could be varied or modified to take rainfall and partial washing of the apples into account. While this analysis has not been undertaken for the purposes of this assessment, it would be expected to significantly reduce the potential exposure to the dust borne contaminants via apple consumption.

The risks associated with the carcinogenic compounds in dairy products (milk) were similar to those for exposure to the homegrown produce for both children and adults. The exposure to an annual contaminant load via with milk or root crops resulted in an acceptable risk for both children and adults. The risk became unacceptable for adults after exposure to crops grown in historically contaminated soil (for 70 years), while the risk to children remained acceptable. However, when the risks for milk and crop consumption are combined, both the adult and child receptors would be exposed to an unacceptable risk based on 70 years of historic contamination.

The influence of the contaminants sourced from runoff on the risk factors associated with the carcinogenic compounds in the soil – grass – cows – milk pathway was checked for the 70 year accumulation assessment for adults and children. While the risks for this exposure pathway in isolation were acceptable, when combined with other pathways the total risk was unacceptable. Removing the runoff loading and instead using the dust deposition data only reduced the risk factors by approximately half, leaving the risk of the combined pathways still unacceptable. Preventing cows from gaining access to the grass verge would reduce the risk associated with milk consumption but not sufficiently when combined with the other pathways to result in an acceptable risk.

A sensitivity analysis to determine how many years of contaminant accumulation would be required to shift the carcinogenic risk from acceptable (1 year) to unacceptable (70 years at present) has not been undertaken. From discussion with authorities that currently oil unsealed roads, it is understood that the practice has been on-going for greater than 30 years.

The carcinogenic compound risk factors calculated in this study were based on a less than detection limit concentration of benzo(a)pyrene and other carcinogenic compounds. It was assumed that these compounds were therefore present at a concentration equal to the limit of detection. This assumption may have been too conservative given the results and sensitivity of the estimated risk values to these compounds could be further assessed by lowering the limit of detection of the analytical technique and using a more representative concentration of benzo(a)pyrene in the assessment.

7.4.4 Discussion of Uncertainty

The risk assessment incorporates a large number of assumptions. In some cases, information required to perform calculations has not been available, and hence has been estimated based on: a) our experience, and (b) information for related substances, organisms, or plants.

In any natural population, individuals respond differently to different stimuli, and even members of the same species can, for example, accumulate contaminants to different degrees, which may be influenced by factors such as age, size or diet. The same applies to humans, no two individuals will react in the same way to a given stimulus, and it is for this reason that the risk assessment is conservative, and attempts to predict risks or hazards for the most sensitive individuals.

Whilst it is recognised that some of the exposure pathways may have been underestimated due to the lack of reliable information in the scientific literature, we believe that the conservative assumptions used to derive concentrations, extents of contamination, and times of exposure, should more than compensate for any such uncertainties.

Based on the used oil combustion assessment presented in this report Woodward-Clyde makes the following recommendations.

That the combustion of used oil be permitted subject to the following conditions:

- Oil conforms to US EPA requirements or similar including an appropriate guideline value for sulphur.
- Combustion equipment is properly installed and operated and meets the Regional Air Plan requirements for the region in which it is installed
- Consideration should be given to limiting fuel usage or the size of plant that used oil can be combusted in without the need for mitigation measures. Above this size appropriate mitigation measures such as scrubbers may be required to achieve acceptable environmental outcomes.

Based on the assessment of the environmental effects and human health risk assessment the following are recommended:

- Used oil should continue to be applied at a rate of less than 2 l/m^2;
- The oil should not be applied within 10m of a watercourse to protect both the water and sediment quality.
- Cows should not be permitted to graze grass within 10m of an oiled road. This would reduce the impact of runoff associated contaminants trapped in the grass verge on cows milk.
- Apples and other pip and stone fruit should be washed before consumption.
- To minimise runoff of free oil product the used oil should be applied:
    - to a dry road
    - when 2-3 days of fine weather is forecasted.
- The water content in the oil should be minimised as far as practicable. If the oil is to remain in the tanker for a number of hours prior to discharge to the road, the separated water should be bled off prior to the oil being spread on the road surface.
- Benzo(a)pyrene is the main contributor to the unacceptable risk for the combined exposure pathways. If possible the benzo(a)pyrene concentration should be measured in the oil and the oil only applied to the road if the concentration is less than a specified value. A sensitivity analysis could be undertaken to determine this value.

To achieve these ends it may be necessary for MfE to formulate a guideline or standard similar to that promulgated by the US EPA.

ANZECC (1992a) Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites. Australian and New Zealand Environment and Conservation Council and the National Health and Medical Research Council, January 1992.

ANZECC (1992b) Australian Water Quality Guidelines for Fresh and Marine Waters. Australian and New Zealand Environment and Conservation Council, November 1992.

ANZECC (1999) Draft Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, July 1999.

AWN Consultants PTY Ltd (1991) Monitoring of Emissions to Air from a Waste Oil Fired Heater. February 1991.

Canterbury Regional Council (1999) Used Oil in Canterbury: Production, Recovery and Environmental Impacts. Report R99/2, ISBN 1-86937-360-X, June 1999.

Goldman, S.J, Jackson, C. and Abarsztynsky, T. (1986) Erosion and Sediment Control Handbook, Chapter 5, Universal Soil Loss Equation.

Long, E.R., MacDonald, D.D., Smith, S.L and Calder, F.D. (1995) Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management*, **19(2)**, 81-97.

McLachlan, M.S. (1994). Model of the Fate of Hydrocarbon Contaminants in Cows. *Environmental Science and Technology* **28**, 2407-2414.

Milburn New Zealand Limited (1999) Quarter 3 Report. November 1999.

Ministry for the Environment (1994), Ambient Air Quality Guidelines. Wellington 1994.

Ministry for the Environment (1997) Environmental Performance Indicators. October 1997, Wellington.

Ministry for the Environment (1997), Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand. August 1997.

Ministry for the Environment (1999a) Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand. June 1999, Wellington.

Ministry for the Environment and Ministry of Health (1997) Health and Environmental Guidelines for Selected Timber Treatment Chemicals. June 1997.

Ministry for the Environment (2000) New Zealand Inventory of dioxin emissions to air, land and water, and reservoir sources. March 2000, Wellington.

Ministry for the Environment (1999), Preliminary Assessment of National Environmental Standards for Used Oil. By Worley Consultants, July 1999.

Ministry of Health (1995) Drinking Water Standards for New Zealand 1995. Compiled by National Drinking Water Standards Review Expert Working Group, Ministry of Health, 1995.

Ministry of Labour (1992) Workplace Exposure Standards. Wellington 1992.

National Research Council (1996) Use of Reclaimed Water and Sludge in Food Crop Production. Committee on the Use of Treated Municipal Wastewater Effluent and Sludge in the Production of Crops For Human Consumption, Water Science and Technology Board, Commission on Geosciences, Environment, and Resources, National Research Council, 1996, National Academy of Sciences, Washington, U.S.A.

Noyes Data Corporation (1983) Fugitive Dust Control Technology.

Shell HESP Model, HESP User Guide, Version 2.10a - The concepts Of HESP: reference manual – human exposure to soil pollutants. September 1994, by W. Veerkamp, SIPM HSE/3.

United States Environmental Protection Agency (1995) Compilation of Emission Factors, AP42, Fifth Edition 1995.

United States Environmental Protection Agency (1995) Compilation of Emission Factors AP42, Fifth Edition, 1995.

United States Environmental Protection Agency (1993), Background Document for AP-42 Section 1.11 Waste Oil Combustion. April 1993.

USEPA (1989) Exposure Factors Handbook. EPA/600/8-89/043.

United States Environmental Protection Agency (1999), Compilation of Emission Factors Section xxx 1999.

United States Environmental Protection Agency (2000) Region IX: Preliminary Remediation Goals (PRGs) Tables: Physical Chemical Values, as at March 2000.

United States Environmental Protection Agency CFR64 Part 279 Standards for the Management of Used Oil.

Victorian Environmental Protection Authority (1985 & 1988) State Environmental Protection Policy (The Air Environment), 1985 & 1988.

Wild, S.R. and Jones, K.C. (1992) Organic chemicals entering agricultural soils in sewage sludges: screening for their potential to transfer to crop plants and livestock, *The Science of the Total Environment*, **119**, 85-119.

Williamson, R. Bruce (1993) Urban Runoff Data Book: a manual for preliminary evaluation of stormwater impacts. 2nd edition, Water Quality Centre Publication 20, Water Quality Centre, Ecosystems Division, NIWAR, 1993.

Works Environmental Management (1993) Monitoring of the Environmental Effects of Spraying Waste Oil on Roads. Prepared for Western Bay of Plenty District Council, July 1993, Wellington.

Appendix A
Used Oil Composition Information

Appendix A
Waste Oil Composition Information

Appendix C
Emission Test Information for Used Oil Burning Equipment

Appendix C
Emission Test Information for Used Oil Burning Equipment

Appendix D
Used Oil Combustion Atmospheric Dispersion Modelling

Appendix D
Atmospheric Dispersion Modelling

Appendix E
Calculation of Off-Site Concentrations

Appendix E
Calculation of Off-Site Concentrations

Appendix F
Dust Emission Modelling

Appendix G
Environmental Data

Appendix G
Environmental Data

Appendix I
Risk Assessment Data

FINAL REPORT

ASSESSMENT OF THE EFFECTS OF COMBUSTION OF USED OIL, AND HEALTH EFFECTS ASSOCIATED WITH THE USE OF USED OIL AS A DUST SUPPRESSANT

Prepared for

Ministry for the Environment
Wellington

7 February 2001

Rev.	Status	Prepared by	Reviewed by	Authorised by	Date
A	Draft	A Curtis			20/3/00
B	Revised Draft	C Bebelman	A Feeney	A Curtis	15/5/00
C	Final Report				

Appendix B
Calculation of Emissions Rates From Used Oil Combustion

Appendix H
Food Chain Data

Appendix H
Food Chain Data