



Ministry for the
Environment
Manatū Mō Te Taiao

Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand

INTRODUCTION

August 1999

**Guidelines for Assessing and Managing Petroleum Hydrocarbon
Contaminated Sites In New Zealand**

ISBN 0 478 09064 1

Published by the Ministry for the Environment

PO Box 10362

Wellington

New Zealand

August 1999

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1 Preface

1.1 Sites in New Zealand contaminated with petroleum hydrocarbons

Attention to contaminated sites has increased over recent years, both internationally and in New Zealand. This is due to increased awareness among regulators, industry and the public of past practices which may have resulted in soil and water contamination.

Petroleum hydrocarbon facilities are potential sources of site contamination. These facilities range from refineries through to retail service stations.

Sites contaminated with petroleum hydrocarbons vary widely in complexity, physical and chemical characteristics, and the potential risk they may pose to human health and the environment.

These guidelines have been developed to provide both industry and regulatory authorities with advice on uniform and suitable methods for site investigation, contamination and risk assessment, modelling and site management. Such comprehensive guidance has not been readily available in New Zealand in the past, and this has led to varied approaches to contaminated and potentially contaminated sites management.

This document aims to address this shortfall and to establish consistency in approach by all parties as to the levels of site investigation and the way in which acceptance criteria are applied.

1.2 Guideline development

With the introduction of the Resource Management Act in 1991, the oil industry was faced with new regulators - the regional councils. With the prospect of widely variable requirements, the industry searched for a way to introduce a national solution.

The oil industry met with the Local Government Commission in 1993 to discuss what the priority issues were and what was the best mechanism for progressing the work. The outcome of this meeting was that five regional councils, Auckland, Waikato, Taranaki, Wellington and Canterbury; the Ministry for the Environment; and representatives from the four oil companies, Mobil, Shell, BP and Caltex, would work together to develop guidelines for:

- above-ground storage tank-farm containment systems
- analytical methods (for measuring levels of contamination)
- water quality
- existing underground tanks at service stations
- contaminated site management.

These latter guidelines, on contaminated sites management, were prepared by Montgomery Watson New Zealand (formerly Royds Consulting Limited) and Egis Consulting Australia (formerly CMPS&F), under the direction of the Oil Industry Environmental Working Group (OIEWG).

1.3 Purpose of the guidelines

The present guidelines have been designed to help both industry and regulatory authorities develop uniform and suitable methods of site investigation, contamination assessment, risk assessment, modelling and site management.

The guidelines focus on sites that have stored, handled, or distributed petroleum products. They aim to provide details of methods for investigating potentially contaminated sites, and for identifying whether or not remediation or controls of the site are necessary in order to protect human health and the environment. The guidelines are also intended to provide background information on petroleum products used in New Zealand, assist in understanding the characteristics of hydrocarbon contamination.

The guidelines are not intended for use at sites where releases of pure solvents (e.g. toluene, xylene) have occurred.

1.4 Approach taken to site assessment and management

The guidelines take a risk-based approach to the assessment and management of petroleum hydrocarbon contaminated sites. This risk-based approach is consistent with other guidelines developed in New Zealand, including the Ministry for the Environment's *Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand*, and the *Health and Environmental Guidelines for Selected Timber Treatment Chemicals* jointly published by the Ministry for the Environment

Risk assessment is the process of estimating the potential impact of a chemical or physical agent on an ecosystem or human population under a specific set of conditions. Risk assessment is a flexible tool that can be used at several stages in the assessment and management of contaminated sites. General details of the risk assessment process are discussed in more detail in Module 1.

A risk-based approach is flexible and allows decision-making to be appropriately tailored to site-specific conditions and hazards. This leads to more cost-effective solutions and allows the greatest effort to be targeted to where it will be most beneficial.

The guidelines follow the international trend towards integrating risk assessment practices with site assessment and management. To provide for economical use of both small and large facilities, a three-tiered approach has been adopted, similar to that used in the United States and involving increasingly sophisticated levels of data collection and analysis. Generic soil and groundwater acceptance criteria are developed to help determine whether site management is required (Tier 1 assessment) or whether a more detailed assessment involving the development of site-specific criteria (Tier 2 or 3) is advisable.

Sites contaminated by petroleum hydrocarbons differ widely in terms of their physical and chemical characteristics and the risk they pose to human health and the environment. The tiered approach provides a decision-making process whereby the site assessment and need for remediation are related to the conditions and risks specific to each site. This allows focused and cost-effective solutions. In keeping with the approach adopted in other New Zealand guidelines, this document allows for the fact that the use of sites, and associated risk, will vary.

1.5 Other contaminated sites guidelines

Since the early 1990s a significant effort has been made to develop New Zealand-specific guidelines for the assessment and management of contaminated sites. To date, two other guidelines have been produced:

- *Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand* (available in PDF format from the Ministry web site <http://www.mfe.govt.nz/issues/contam.htm>)
- *Health and Environmental Guidelines for Selected Timber Treatment Chemicals* (available from the Ministry for the Environment).

There are also a number of international guidelines commonly used. These include the ANZECC, USEPA, Canadian and Dutch guidelines.

Where possible, it is important that guidelines developed specifically for New Zealand are used in preference to international guidelines, since the former are based on New Zealand conditions.

1.6 Intended audience

The guidelines have been developed for those people involved in assessing and managing sites contaminated by petroleum hydrocarbons, including site owners, consultants, regional councils, territorial authorities, and industry representatives.

This has been prepared as an introduction to the guidelines.

1.7 Status of the guidelines

These are guidelines only, prepared for the use of those involved in assessing and managing site contaminated by petroleum hydrocarbons in New Zealand. They have no statutory effect.

1.8 Other New Zealand guidelines for sites contaminated by petroleum hydrocarbons

The guidelines do not contain detailed information on sampling protocols and analytical methods. Another guideline has been prepared to cover this information:

“Sampling Protocols and Analytical Methods for Determining Petroleum Products in Soil and Water” (available from Ministry web site <http://www.mfe.govt.nz/issues/contam.htm>)

2 Structure of the guidelines

The guidelines comprise seven modules which provide a comprehensive guide on the assessment and management of sites contaminated by petroleum hydrocarbons. Where relevant, further supporting technical information for each module is provided in a series of appendices. The guidelines cover the following areas:

Module 1 Risk-based approach to site assessment and management

Module 1 presents an overview of the risk-based approach to assessing contaminated sites, including the use of a tiered approach to site assessment, a general review of risk assessment and the development of soil and groundwater acceptance criteria, and an integrated approach to site investigations, risk assessment and site management and remediation.

Module 2 Hydrocarbon contamination fundamentals

Module 2 provides a background and understanding of the physical and chemical factors important when assessing petroleum hydrocarbon contamination.

Module 3 Site assessment

Module 3 gives guidance on suitable methods of site investigation, including information on the design of a sampling programme, the suitability of various types of investigation equipment, sampling techniques, and quality assurance.

Module 4 Tier 1 soil acceptance criteria

Module 4 outlines the key principles in health and environmental risk assessment and the detailed procedures for developing soil acceptance criteria. The generic soil acceptance criteria derived in this section are summarised in “look-up tables” and form the basis of the Tier 1 assessment process.

Detailed procedures for deriving soil screening criteria are presented in this module, providing the basis for developing site-specific criteria used as part of a Tier 2 assessment.

Module 5 Tier 1 groundwater acceptance criteria

The health and environmental risk assessment principles outlined in Module 4 are applied to groundwater in order to derive generic groundwater acceptance criteria for use in Tier 1 assessments.

Module 6 Development of site-specific acceptance criteria

Procedures for developing Tier 2 and 3 site-specific acceptance criteria are outlined. Due to the highly site-specific nature of a Tier 3 assessment, it is not possible to provide detailed guidance, rather some of the key requirements and an indication of the necessary level of detail are presented.

Module 7 Site management

Module 7 contains an overview of the options readily available in New Zealand for addressing site contamination. These options range from control of the site to prevent exposure to site users or the surrounding environment, to treating the site soil, recovering product from the groundwater, and general water management.

3 Acknowledgements

The OIEWG expresses gratitude to the following people for their review of these guidelines. Their comments have significantly improved the quality and usefulness of this document.

- Ray Salter, Ministry for the Environment
- Stuart McLaren, Ministry of Health
- Jim Waters, Ministry of Health
- Dr Vivienne Smith, Canterbury Regional Council
- Robert Brodnax, Environment Waikato
- Dedric Smith, Environment Waikato
- Ramon Scoble, Auckland Regional Council
- Mark Goldsmith, Shell Research Ltd, United Kingdom (UK)
- Curtis Stanley, Shell Oil, United States (US)
- Norm Novick, Mobil Oil, US
- Mark Molander, Mobil Oil, US

The OIEWG also wishes to acknowledge the extensive detailed review by Dr Paul Johnson at Arizona State University in the US and Dr Colin Ferguson at Nottingham Trent University in the UK. Dr Paul Johnson has been involved with developing the Risk-Based Corrective Action (RBCA) guidelines in the US and is a recognised expert in fate and transport modelling. Dr Colin Ferguson has extensive experience in the areas of human health and ecological risk assessment including development of risk assessment models for the Department of Environment in the UK.

4 Acronyms and abbreviations

ANZECC	Australian and New Zealand Environment and Conservation Council
API	American Petroleum Institute
ASTM	American Society for Testing Materials
AT	Averaging Time
AVOC	Aromatic Volatile Organic Compounds
BAM	Behaviour Assessment Model
BTEX	Benzene, toluene, ethylbenzene, xylene
BW	Body Weight
CCME	Canadian Council of Ministers for the Environment
CDI	Chronic Daily Intake
CNS	Central Nervous System
DQOs	Data Quality Objectives
ED	Exposure Duration
EF	Exposure Frequency
HI	Hazard Index
HSA	Hollow Stem Auger
HQ	Hazard Quotient
IH	Inhalation Rate
LEC	Lowest Effect Concentration
LF	Leaching Factor
LNAPL	Light Non-Aqueous Phase Liquid
LOAEL	Lowest Observable Adverse Effect Level
MAHs	Monocyclic Aromatic Hydrocarbons
MAV	Maximum Acceptable Value
MDEP	Massachusetts Department of Environmental Protection
MfE	Ministry for the Environment
MoH	Ministry of Health
MRL	Maximum Residue Limit
MSDS	Material Safety Data Sheet
MTBE	Methyl tertiary butyl ether
NHMRC	National Health and Medical Research Council
NOAEC	No Observable Adverse Effect Concentration
NOAEL	No Observable Adverse Effect Level
NOEC	No Observable Effect Concentration
NOEL	No Observable Effect Level
NZDWS	Drinking Water Standards for New Zealand
OSH	Occupational Safety and Health
PAHs	Polycyclic Aromatic Hydrocarbons
PARCC	Precision, Accuracy, Representativeness, Completeness and Capability
PID	Photoionisation Detector
PUF	Plant Uptake Factor
PVC	Poly Vinyl Chloride
QC	Quality Control

RBCA	Risk Based Corrective Action
RfD	Reference Dose
RMA	Resource Management Act 1991
RME	Reasonable Maximum Exposure
RPD	Relative Percent Differences
SF	Slope Factor
TDS	Total Dissolved Solids
TEF	Toxic Equivalence Factor
TPH	Total Petroleum Hydrocarbons
TPHCWG	Total Petroleum Hydrocarbons Criteria Working Group
UK	United Kingdom
US	United States
USEPA	United States Environmental Protection Agency
VF	Volatilisation Factor
VOC	Volatile Organic Compound

5 Glossary

Acute

With reference to toxicity, having a sudden onset and lasting a short time (usually within 4-7 days for fish). Of exposure, severe enough to rapidly induce a response. Can be used to define either the exposure or the response to an exposure (effect). An acute effect could be a mild or sublethal.

Adsorption

Process by which a dissolved component becomes attached to the surface of a solid (such as soil particles).

Advection

Pressure driven (convective) mechanism for vapour transport, resulting from bulk movement of media e.g. soil - gas.

Aerobic

Living only in the presence of free oxygen.

Aesthetic

Relating to appearance, taste and smell, such as to be pleasing to human (and non-human) sensors.

Aliphatic compounds

An organic compounds in which the carbon atoms exist as either straight or branched chains. Examples include pentane, hexane, and octane.

Alkane

Hydrocarbon of paraffin group with saturated bonds.

Alkene

Hydrocarbon of olefin group, with one unsaturated bond.

Alluvial

Pertaining to or composed of alluvium or deposited by a stream or running water.

Alluvium

A general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semi-sorted sediment in the bed of the stream or on its floodplain or delta, or as a cone or fan at the base of a mountain slope.

Anaerobic

Living only in the absence of free oxygen.

Analytical

Employing the use of algebra and calculus methods to solve an equation, such that the solution is single-valued and continuous in the range of interest.

Anion

A negatively charged ion that migrates to an anode, as in electrolysis.

Anisotropic

Having some physical property that varies with direction.

Aplastic anaemia

A type of bone marrow disorder due to reduction of haematopoietic marrow cells.

Aquiclude

A saturated, but poorly permeable bed, formation or group of formations that does not yield water freely to a well or spring. However, an aquiclude may transmit appreciable water to or from adjacent aquifers.

Aquifer

Layer of rock or soil able to hold or transmit water.

Aromatic compounds

Contain carbon molecular ring structures and include compounds such as benzene, toluene, ethylbenzene, and xylene (BTEX). These compounds are somewhat soluble, volatile and mobile in the subsurface environment and are useful indicators of contaminant migration.

Bailer

A cylindrical device with a check valve on the bottom and a hook for a cord on the top. It is used to recover liquid from a well.

Bedrock

A general term for the rock, usually solid, that underlies soil or other unconsolidated material.

Bentonite

A colloidal clay, largely made up of the mineral sodium montmorillonite, a hydrated aluminium silicate.

Biodegradation

Process by which organic compounds are degraded by micro-organisms into less harmful substances.

BTEX

Abbreviation for benzene, toluene, ethylbenzene and xylenes. These compounds are somewhat soluble, volatile and mobile in the subsurface environment and are useful indicators of contaminant migration.

Capillary fringe

The zone at the bottom of the vadose zone where groundwater is drawn upward by capillary force.

Carcinogen

Cancer-causing agent.

Cation

An ion having a positive charge and, in electrolytes, characteristically moving toward a negative electrode.

CDI

Chronic Daily Intake - estimate of daily exposure to a contaminant averaged over a chronic period, typically one year or a 70-year lifetime.

Chromatogram

Graph produced during a gas chromatogram analysis and showing the constituents that are present and their relative concentration.

Chronic

Exposure/effects over a long period of time. The USEPA considers a chronic exposure to be associated with an exposure period between seven years and a lifetime.

Conductivity (m/day)

The capacity of a geologic material's ability to transmit water.

Cone of depression

A depression in the groundwater table or potentiometric surface that has the shape of a inverted cone and develops around a well from which water is being withdrawn. It defines the area of influence of a well.

Confined aquifer

A formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined groundwater is generally subject to pressure greater than atmospheric.

Consolidated bedrock

Sedimentary rocks that have been hardened by natural cementation (i.e. shale, limestone, sandstone).

Corrective action

Site management or remediation designed to "correct" an environmental impact.

Cytotoxicity

Damaging to living cells and tissue.

Destructive

Used to describe a treatment technology that transforms contaminants into non-hazardous components such as water and carbon dioxide.

Diffusion

Migration of contaminants by natural movement of particles, resulting in migration from areas of higher concentration to areas of lower concentration without bulk movement of the media (e.g. soil - gas or groundwater).

Dispersion

The spreading and mixing of chemical constituents in groundwater caused by diffusion and mixing due to microscopic variations in velocities within and between pores.

Drawdown

The distance between the static water level and the surface of the cone of depression.

Ecological

Relating to organisms and their environmental surroundings. Concerned with population of species rather than individual organisms.

Epidemiology

Study of the frequency, distribution and causes of disease, injury and other health-related events in human population.

ERF

Mathematical ERROR function.

ERFC

Mathematical function: Complimentary ERROR function.

Exposure pathway

Route for migration of contaminant from the contamination source to the receptor. Includes release mechanism, transport media, exposure point and exposure route (e.g. ingestion).

Ex situ

Used to describe a treatment technology that transforms contaminants into non-hazardous components such as water and carbon dioxide.

Filter pack

Sand or gravel that is smooth, uniform, clean, well-rounded, and siliceous. It is placed in the annulus of the well between the borehole wall and the well screen to prevent formation material from entering the screen.

First order decay

Biodegradation rate assuming a first-order exponential decay curve (i.e. $C = C_0 e^{-kt}$).

Flux

Rate of transport, defined as mass per unit area per unit time.

Genotoxicity

Damaging to DNA and therefore capable of causing mutations or cancer.

Granuloma

Small nodule with white blood cells.

Groundwater table

The surface between the zone of saturation and the zone of aeration; the surface of an unconfined aquifer.

Haematological

Pertaining to blood.

Haematopoietic

Blood forming.

Half-life

Measure of time required for a source to biodegrade to half its initial concentration (assuming first-order decay).

Hepatotoxicity

The occurrence of adverse effects on the liver following exposure to chemicals.

Heterogeneous

Non-uniform in structure or composition throughout.

Homogeneous

Uniform in structure or composition throughout.

Hydraulic conductivity (m/day)

The rate of flow of water in cubic metres per day through a cross section of one square metre under a unit hydraulic gradient, at the prevailing temperature.

Hydraulic gradient

The rate of change in total head per unit of distance of flow in a given direction.

Hydraulic head

Energy contained in a water mass, produced by elevation, pressure or velocity.

Immunotoxicity

The occurrence of adverse effects on the immune system following exposure to chemicals.

Infiltration

Water migrating vertically from the surface into the soil column in response to a head difference.

In situ

Used to describe a treatment technology that is implemented in the subsurface of ex-situ.

Ion

An element or compound that has gained or lost an electron, so that it is no longer neutral electrically, but carries a charge.

Isotropic

Said of a medium whose properties are the same in all directions.

Laminar flow

Flow in which the stream lines remain distinct and in which the flow direction at every point remains unchanged with time. It is characteristic of the movement of groundwater.

Lymphocytopenia

Reduction in the number of white blood cells (specifically lymphocytes) in the blood.

Lymphoid

Pertaining to lymphatic system.

Mass balance

Equation based on the laws of conservation of mass:

Accumulation = incoming mass - leaving mass + generated mass - destroyed mass.

Morphological

Pertaining to the forms and structure of organisms, or of a particular organ.

Narcosis

A non-specific and reversible depression of the central nervous system characterised by a lower level of consciousness.

Nephrotoxicity

The occurrence of adverse effects on the kidneys following exposure to chemicals.

Neurotoxicity

The occurrence of adverse effects on the nervous system following exposure to chemicals.

Numerical

Method or process of computing a solution using iterative calculation techniques.

Palatability

Pleasantness to taste.

Partition coefficient

Coefficient which describes the ratio of contaminant concentrations in two different phases. Examples include:

K_{oc} - Organic Carbon Partition Coefficient.

K_{ow} - Octanol Water Partition Coefficient.

Partitioning equilibrium

Set of relationships between solid, water and vapour phases in the soil matrix, which determines the distribution of a chemical between the individual phases.

Perched water

Unconfined groundwater separated from an underlying main body of groundwater by an unsaturated zone.

Permeability

The property or capacity of a porous rock, sediment or soil for transmitting a fluid; it is a measure of the relative ease of fluid flow under unequal pressure.

pH

A measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increased alkalinity and decreasing with increased acidity.

Phototoxicity

Toxicity of a substance in the presence of light.

Point of exposure

Reference location on a site at which exposure to a contaminant is assumed to occur.

Pore water

Water phase in the soil matrix.

Porosity

The percentage of the bulk volume of a rock or soil that is occupied by interstices, whether isolated or connected. Ratio of air, water or other fluid-filled volumes to total volume.

ppm

Parts per million (10,000 ppm = 1%)

Probabilistic risk assessment

Risk levels are based on exposure factors defined by probabilistic distributions, rather than single values, to ultimately produce risk levels in terms of a probability distribution curve.

Pseudo steady-state

Assumption of equilibrium in physico-chemical properties such as phase partitioning (steady state), used in conjunction with a non-equilibrium/steady-state mechanism (e.g. depleting source).

Pumping test

A test that is conducted to determine aquifer or well characteristics.

Radius of influence

The radial distance from the centre of a well bore to the point where there is no lowering of the water table or potentiometric surface (the edge of its cone of depression).

Receptor

An organism, plant or physical structure that receives, may receive or has received environmental exposure to a chemical.

Recharge

The addition of water to the zone of saturation; also, the amount of water added.

Reference dose

An estimate of daily exposure to the human population, including sensitive subgroups, that is likely to be without appreciable risk of adverse effects during a lifetime.

Residual saturation

Percentage of the void space of a soil which contains a fluid that cannot be mobilised by gravity forces.

Risk

The probability of an adverse outcome in a person, a species, a group, or an ecosystem that is exposed to a hazardous agent. Risk depends on both the level of toxicity of hazardous agent, and the level of exposure.

Run-off

Precipitation that flows along ground surfaces. Can migrate to stormwater drains, streams, etc.

Sensitive aquifer

An aquifer that has the potential to be contaminated by a leak or spill of petroleum hydrocarbons and which is subject to use or potential use.

Separate phase hydrocarbons

Liquid phase hydrocarbons in soil or above groundwater, where water is not a constituent. Separate phase is usually formed when water phase reaches maximum solubility limit.

Slope factor (SF)

The slope of the dose-response curve in the low-dose region, used to relate the probability of contracting cancer as a result of exposure to that chemical.

Site classification

Classification assigned to a site which characterises the site in terms of the level of threat to receptors, and the timeframe for response.

Soil-gas

Vapour phase in the soil matrix.

Subchronic

Between chronic and subacute. The USEPA considers a sub-chronic exposure associated with an exposure period between two weeks and seven years.

Surfactants

Chemicals that are used to reduce the resistance to flow of certain fluids.

Surrogate

Substitute compound.

TEF

Toxic Equivalent Factor The TEF for a specific compound may be defined as the ratio of the carcinogenic potency of the compound to that of a reference carcinogenic compound.

Teratogenicity

Pertaining to the ability to induce a congenital abnormality in embryos and foetuses resulting in birth defects.

Total dissolved solids, TDS

A term that expresses the quantity of dissolved material in a sample of water, either the residue on evaporation, dried at 356°F (180°C), or, for many waters that contain more than 1,000 mg/l, the sum of the chemical constituents.

Transmissivity (m²/day)

The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

Transmissivity values are given in cubic metres per day through a vertical section of an aquifer one metre wide and extending the full saturated height of an aquifer under a hydraulic gradient of one.

Unconfined aquifer

An aquifer where the water table is exposed to the atmosphere through openings in the overlying materials.

Unconsolidated materials

Loose earth materials that result from erosion of bedrock.

Vadose zone

The zone containing water under pressure less than that of the atmosphere, including soil water, intermediate vadose water and capillary water. This zone is limited above by the land surface and below by the surface of the zone of saturation, that is, the water table. Also known as unsaturated zone.

Viscosity

The extent to which a fluid resists a tendency to flow.

Volatilisation

Process by which a substance changes its state from solid or liquid to a vapour.

Water table

The surface between the vadose zone and the groundwater; that surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.

Weathering

The in-situ physical disintegration and chemical decomposition of rock materials at or near the Earth's surface.

Well screen

A filtering device used to keep sediment from entering a water well.

Well yield

The volume of water discharged from a well in cubic metres per day.

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