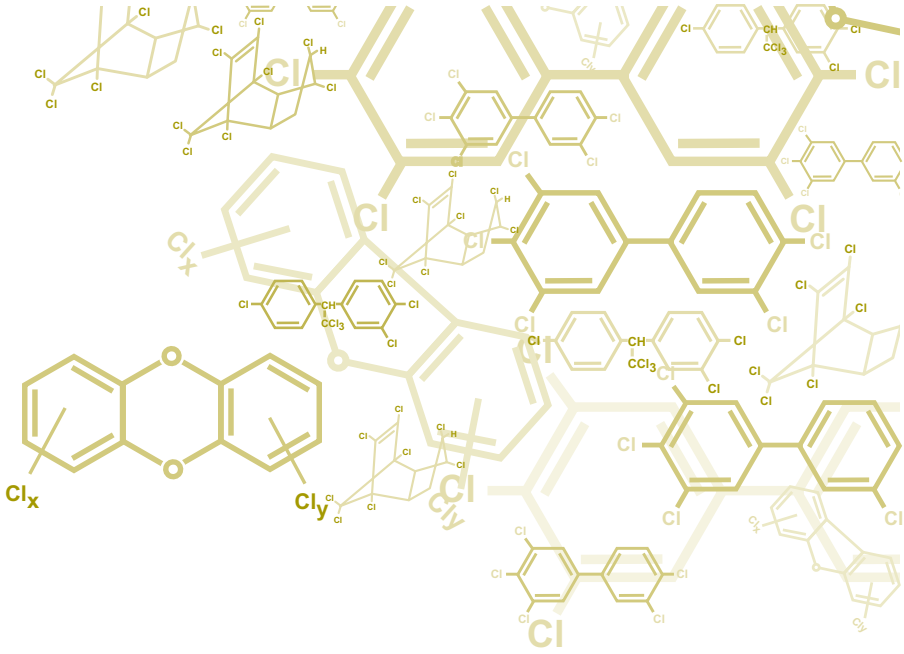

Ministry for the
Environment
Manatū Mō Te Taiao
REPORTING ON
Persistent
Organochlorines
IN New Zealand
Organochlorines Programme

Contents



Foreword

People around the world are concerned about organochlorine contaminants in the environment. Research has established that even the most remote regions of the world are affected by these persistent chemicals.

Organochlorines, as gases or attached to dust, are transported vast distances by air and ocean currents – they have even been found in polar regions. Organochlorines are stored in body fat and accumulate through the food chain. Even a low level of emission to the environment can contribute in the long term to significant risks to the health of animals, including birds, marine mammals and humans.

The contaminants of concern include dioxins (by-products of combustion and of some industrial processes), PCBs, and a number of chlorinated pesticides (for example, DDT and dieldrin). These chemicals have not been used in New Zealand for many years. But a number of industrial sites are contaminated, and dioxins continue to be released in small but significant quantities.

In view of the international concern, the Government decided that we needed better information on the New Zealand situation. The Ministry for the Environment was asked to establish an Organochlorines Programme to carry out research, assess the data, and consider management issues such as clean-up targets and emission control standards. As the contaminants are of high public concern, the Programme established networks for consultation and is keeping the public informed.

The fundamental research carried out under this programme has established for the first time the actual levels of these contaminants in the New Zealand environment – country-wide – in air, soil, rivers and estuaries. In addition, the dietary intakes of New Zealanders have been estimated through a study of organochlorine levels in food. The existing "body burdens" of the New Zealand population – the levels of organochlorines stored in fatty tissue – are also being assessed.

The publication of these New Zealand research reports marks an important contribution to international knowledge about these toxic chemicals. The comprehensive data contained in these reports is made all the more significant because of the scarcity of other data from the southern hemisphere.

The work has been peer reviewed internationally by experts and we are assured it is of the highest quality. We acknowledge the important contribution made by all those involved in the project within government and the private sector, from within New Zealand and abroad.

Finally, these reports lay a solid foundation in science for the development of policy. What message can we take from these results about the state our environment? Internationally, it appears that New Zealand could be categorised as being "moderately clean". While providing some comfort, this leaves no room for complacency. This research will assist the Government in preparing national environmental standards and guidelines for these contaminants to safeguard the health of New Zealanders and the quality of our environment.

Simon Upton
Minister for the Environment

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CHAPTER 1

Reporting on organochlorines in New Zealand

An overview

Organochlorine chemicals become environmental contaminants once released to air, land or water. On land, they can be washed into lakes and rivers as contaminated sediment. The contaminants may be taken up by aquatic organisms and enter the food chain. In due course, rivers also convey the contaminants into estuarine and coastal sediments where they can be taken up by shellfish and marine animals.

In addition, organochlorine contaminants may become air-borne and be widely dispersed through evaporation or attached to wind-blown dust. Contaminated dust particles may settle close by, whereas contaminated gases will be transported by air currents across oceans. But the properties of gases are such that a certain proportion will be deposited to the land or water beneath.

Because these chemicals do not readily break down, there is a continuing cycling process of these contaminants through the environment. Once taken up by organisms, these contaminants accumulate and concentrate through the food chain, causing an increase in toxic effects on biological functions. Animals at the top of the food chain are likely to suffer the worst adverse effects.

In this study a broad understanding has been obtained of the levels of organochlorine contaminants in the New Zealand environment. The information on the levels of organochlorines in air, soil, rivers and estuaries, and in food, provides an overview of the state of the New Zealand environment for these toxic contaminants.

The information in the following chapters shows that the levels of organochlorines in the air, soil and aquatic environments studied are generally low, and that New Zealanders have one of the lowest dietary exposures to these chemicals in the western world. These findings are consistent with New Zealand's limited industrial base and low population density. Higher than expected levels of dioxins were found in air associated with some population centres during the coldest winter months. But this finding is not reflected by higher levels of dioxins in soil. New Zealand's geography and wind patterns are likely to aid the dispersal of these contaminants off-shore.

The overall picture assembled is that the New Zealand environment is "moderately clean" relative to other countries that have comparable data.

Along with this assessment of background levels, it is important to realise that not all parts of our environment have been studied, and the picture is by no means complete. In addition, only preliminary information is available about areas where some of these contaminants exist at elevated levels, including contaminated industrial sites.

The New Zealand Organoclorines Programme

In 1995, the Ministry for the Environment commenced a national Organochlorines Programme. The programme has assessed the extent of contamination of the New Zealand environment by certain organochlorine contaminants. The organochlorines that are the focus of this programme are:

- Dioxins
- PCBs
- Organochlorine pesticides: aldrin, dieldrin, chlordane, DDT, HCB, heptachlor, lindane, and PCP.

The Organochlorines Programme will develop standards and guidelines for regulating industrial emissions of dioxins to air, land and water, cleaning up sites contaminated with organochlorines, and destroying waste stocks of organochlorine chemicals such as PCBs and persistent pesticides. These actions are also addressing international concerns about persistent organic pollutants (POPs). A global convention to protect the environment and human health from risks posed by POPs is being negotiated under the auspices of the United Nations Environment Programme (UNEP).

The Organochlorines Programme consists of three main parts: research, assessment, and a management strategy. The plan of how these and other components of the programme fit together is shown in Figure 1.1.

(i) Research

Surveys have measured the ambient levels of organochlorine contaminants in air, soil, rivers and estuaries as well as in eel, trout and shellfish. The present-day level of exposure of the New Zealand population has been estimated through a study of the levels of these contaminants in food and by calculating dietary intakes. The existing body burdens of the New Zealand population are also being assessed.

An understanding of these ambient levels is necessary before preparing technical standards and guidelines. Using this data, comparisons can be made between New Zealand's environment and that of other countries.

A dioxin emission inventory is being compiled to estimate an overall dioxin emission level, and to also gather information about the industrial processes and other sources thought likely to contribute to continuing emissions of dioxins in New Zealand.

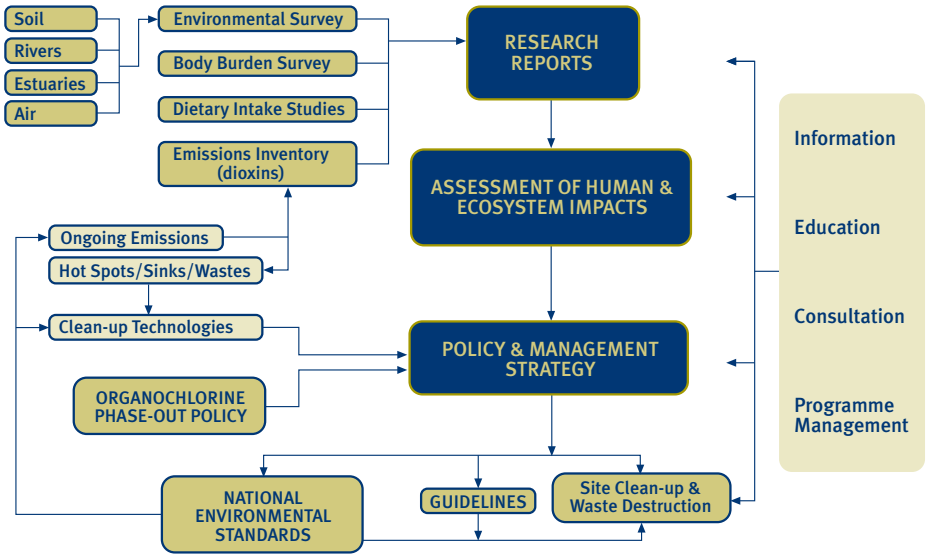
(ii) Assessment

This research has generated a large amount of important data. The data will be assessed by international and New Zealand experts to determine the nature and level (e.g. negligible, low, moderate or high) of any risk to the environment or human health. The final risk assessment reports will be completed in mid-1999.

(iii) Management strategy

The third and final phase of the programme is to develop a management strategy for any identified hazards and risks.

Figure 1.1 **Overview of the New Zealand Organochlorines Programme**



The outcomes expected from the Organochlorines Programme are:

- National environmental standards for dioxins and PCBs, and where necessary guidelines or standards for organochlorine pesticides;
- Identified clean-up technologies that can safely destroy organochlorine wastes as part of a management strategy for dioxins and other organochlorine contaminants and wastes in New Zealand;
- Informed public input to Government decisions on the management of organochlorines in the New Zealand environment;
- An application to the Environmental Risk Management Authority to permanently ban the use of specified organochlorine pesticides.

Where to from here?

The Organochlorines Programme set out to find answers to a number of questions. Reports are expected over the next year.

Questions	Expected report dates	Report type
1. What levels of dioxins, PCBs and organochlorine pesticides are present in the New Zealand environment and in food?	October 1998	Research
2. For these contaminants, how "clean" or "polluted" is New Zealand relative to other countries?	October 1998	Research
3. What levels of organochlorines do New Zealanders have in their bodies?	December 1998	Research
4. What are the reservoirs and current emission sources of dioxins in New Zealand?	December 1998	Research
5. Are organochlorines found in New Zealand at levels likely to pose a threat to the environmental or to human health?	March - May 1999	Assessment
6. What emission standards are applied through regulation in other countries to protect human health and the environment, and what standards should be adopted in New Zealand?	March - May 1999	Policy
7. Can contaminated soils and organochlorine wastes be treated safely, and what clean-up standards should apply?	May 1999	Management
8. What should be done to manage any risks associated with organochlorines in New Zealand?	June 1999	Management

Summary reports

This document contains summary information on research into the levels of organochlorine contaminants in the New Zealand environment and in the food eaten by New Zealanders (questions 1 and 2 above). Two further areas of research – an inventory of dioxin emissions, and a survey of organochlorine levels in the serum of the New Zealand population – are scheduled for completion in late 1998. The information from this research will be used by the Ministry for the Environment and the Ministry of Health to assess the risk to the environment and to human health.

Public consultation and the development of policy

There are a number of aspects about these particular organochlorine contaminants which warrant their careful appraisal in New Zealand.

- They are persistent in the environment and accumulate through the food chain; this means that even low levels in the environment may pose risks to humans and animals.
- People and animals are exposed to these contaminants mainly through the food chain.
- From studies of contaminated ecosystems in other countries, the health risks to animals include illnesses that affect fertility, reproduction, the immune system, growth and behaviour. The long-term health risks to people (from a low level of exposure over a lifetime), while uncertain, are not negligible.
- The international community, under the auspices of the UNEP, is now calling on all governments to seek ways to minimise the presence of these contaminants in the environment.

The development of national environmental standards for dioxin emissions and site clean-up requires a policy decision on a key question.

- **What is an acceptable level of exposure to dioxins?**

Because this decision potentially affects many New Zealanders, the Ministry for the Environment is arranging a number of opportunities for people to become involved in the development of policy on these issues.

(i) Public meetings will be held in the main centres throughout New Zealand to report directly on the findings of the Organochlorines Programme, and to take note of issues raised. These meetings are scheduled for October 1998 and February 1999.

(ii) Organochlorines Programme bulletins will continue to be issued to keep people informed of progress.

(iii) Draft policy documents will be distributed for public comment. Final policy decisions will be made by June 1999.

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Information on organochlorines in New Zealand

Dioxins

Dioxins are not produced intentionally, but are released to the environment from a variety of industrial and combustion processes, and from the past use of organochlorine chemicals contaminated with dioxins (as a manufactured by-product). Historical and present-day sources of dioxins in the environment are listed in Table 1.1.

Table 1.1 **New Zealand sources of dioxins**

Historical sources

- Agrichemicals from the use of 2,4,5-T
- Timber treatment from the use of PCP
- Electricity industry from the use of PCBs
- Pulp and paper (chlorine bleach process)
- Combustion of fuels and incineration of wastes
- Motor vehicles (particularly from leaded fuels)

Current sources

- Waste incineration, including medical and hazardous waste
- Metallurgical industries, including metal smelting, refining and recycling
- Industrial and domestic coal and wood combustion
- Exhaust emissions from vehicles running on diesel and unleaded petrol
- Controlled burn-offs
- Uncontrolled and accidental fires
- Sewage wastes
- Ongoing releases from reservoirs, including sludge ponds and contaminated sites

A range of combustion processes, including the burning of chlorinated plastics and wastes, are ongoing sources of dioxins. Although forest fires have probably always been a minor source of dioxins, the environmental level of dioxins has increased markedly since the expansion of the chemical industry during the middle of the twentieth century and with the substantial increase in the use of fossil fuels and incineration processes.

Because they have the potential to cause cancer and have other toxic effects, the presence of low levels of dioxins in the environment has been a subject of concern for several decades.

Tighter government regulations, improved industrial processes and the use of modern pollution control equipment at industrial plants have resulted in lower dioxin emissions from known industrial sources in many countries. However, the complete elimination of dioxins from all sources is not achievable due to releases from uncontrolled and accidental fires.

PCBs (polychlorinated biphenyls)

PCBs were widely used in industry as electrical transformer fluids, heat transfer fluids, hydraulic fluids, solvent extenders, flame retardants and plasticisers, and in printing inks, paints, immersion oils and sealing liquids. The widespread use of PCBs, coupled with industrial accidents and improper disposal practices, has resulted in significant environmental contamination by these substances in many northern hemisphere countries.

The use of PCBs in New Zealand has been illegal since 1995. Most New Zealand stocks of PCBs have been shipped overseas and destroyed.

Organochlorine pesticides

Although few records were kept, the substantial use in New Zealand of organochlorine pesticides such as DDT, dieldrin and lindane, was most likely during the 1950s and 1960s. The main areas of use were agriculture, horticulture, timber treatment and public health (Table 1.2). Smaller amounts were also used in parks and by home gardeners. The use of these pesticides was progressively restricted by regulation so that by the mid 1970s use had largely ceased.

Table 1.2 **Summary of persistent organochlorine pesticide use in New Zealand**

PESTICIDE	APPLICATION
DDT	Used as a pasture insecticide to control grass grub and porina caterpillars. Frequently mixed with fertiliser or lime and applied to pasture, as well as lawns, market gardens and parks.
Lindane	Used in agriculture for the control of lice on cattle, ectoparasites (lice, keds and blowflies) in sheep, and grass grub in pasture. Also used for insect control on vegetables and in orchards. Household use: flyspray, flea control, and carpet moth.
Aldrin and dieldrin	Used in the control of ectoparasites in sheep. Aldrin was used to control horticultural pests such as wireworm, soldier fly and blackvine weevil, and in limited quantities to control household spiders. Dieldrin was used for controlling carrot rust fly, grass grub, crickets and armyworm. It was also used for timber treatment (mostly in plywood glues) and to mothproof carpets.
Chlordane	A broad spectrum agricultural insecticide, chlordane was also used in the timber industry as a treatment against termites and borer, and as an insecticide in glues used for the manufacture of plywood, finger jointed and laminated timber.
Hexachlorobenzene	Used experimentally between 1970 and 1972 as a seed dressing fungicide for cereal grain.
Heptachlor, endrin and toxaphene	Only small amounts of these pesticides were ever used in New Zealand. [Endrin and toxaphene were not included in the New Zealand survey.]
PCP	In the order of 5,000 tonnes of PCP is estimated to have been used in the New Zealand timber industry over a 35- to 40- year period as a treatment for freshly cut timber (mainly *Pinus radiata*). Its main use in the timber industry ceased in 1988. PCP was also used to a relatively minor extent by the pulp and paper industry, in mushroom culture, and in home gardens and on roofs to control moss and algae.

Chapter 2

Ambient levels of organochlorines in air

Background

In this chapter of the report, data is given on the levels of dioxins, PCBs, organochlorine pesticides and chlorophenols in New Zealand air.

Air sampling sites

This study measured organochlorine contaminant levels in air samples collected from ten sites around New Zealand. The sites were two reference sites (at Baring Head and Nelson Lakes), two rural sites (at Te Wera and Culverden), five urban sites (in Hamilton, Masterton, Greymouth, Christchurch and Auckland City), and an industrial site (at Auckland South). Most of the urban sites were in, or near, residential areas, while the Auckland City site was located on a major arterial road. A description of each site is given in Table 2.1.

Table 2.1 **Air sampling sites**

Site	Site description
Reference sites	
Baring Head	Baring Head is a well-established environmental monitoring station. The sampler was operated only during southerly winds, so the sample is representative of Southern Ocean maritime conditions.
Nelson Lakes	Located on the shore of Lake Rotoiti, Nelson Lakes National Park. The site is representative of a remote land environment.
Rural sites	
Te Wera, Taranaki	A typical hill country pastoral site in an agricultural region. The sampling site was located in a remote paddock on a private farm.
Culverden, Canterbury	A typical flat pastoral site in an agricultural region. The sampling site was located on a private farm.
Urban sites	
Hamilton East, Hamilton	A residential site in a major provincial centre subject to an even mix of vehicle, domestic and industrial emissions.
Masterton	Masterton is a typical provincial centre with moderate traffic, domestic and industrial emissions. The site was located on a major street within the vicinity of commercial and residential areas.
Greymouth	A provincial centre that is affected by significant emissions from coal and wood burning. The site was located in a railway yard adjacent to residential housing.
St Albans, Christchurch	The Christchurch urban area experiences significant air pollution problems during the winter months. This site was located in a residential suburb.
Newmarket, Auckland City	The sampler was located at the intersection of a major arterial road. Very high traffic volumes occur at the site and modest industrial activity. Poor air quality is experienced, mostly due to traffic emissions.
Industrial site	
Otahuhu, Auckland South	This site was located in a heavily industrialised area.

Samples were obtained using specialist equipment designed to trap any contaminants present in the air. Several air samples were collected from each site over a 12-month period, 1996-97. For all sites, each sample was collected continuously over approximately 20 days, except for Baring Head where samples were only collected during southerly winds.

Levels of organochlorines found

The average level of dioxins measured at each site is shown in Figure 2.1. Levels were very low at reference and rural sites, but were higher at urban and industrial sites. For individual samples, levels were between 0.77 - 7.48 fg I-TEQ m^{-3} of air at reference sites, 0.94 - 31.7 fg I-TEQ m^{-3} of air at rural sites, 6.15 - 262 fg I-TEQ m^{-3} of air at urban sites and 40.3 - 1170 fg I-TEQ m^{-3} of air at the industrial site. (For a definition of these units, see the Units section at the end of this document).

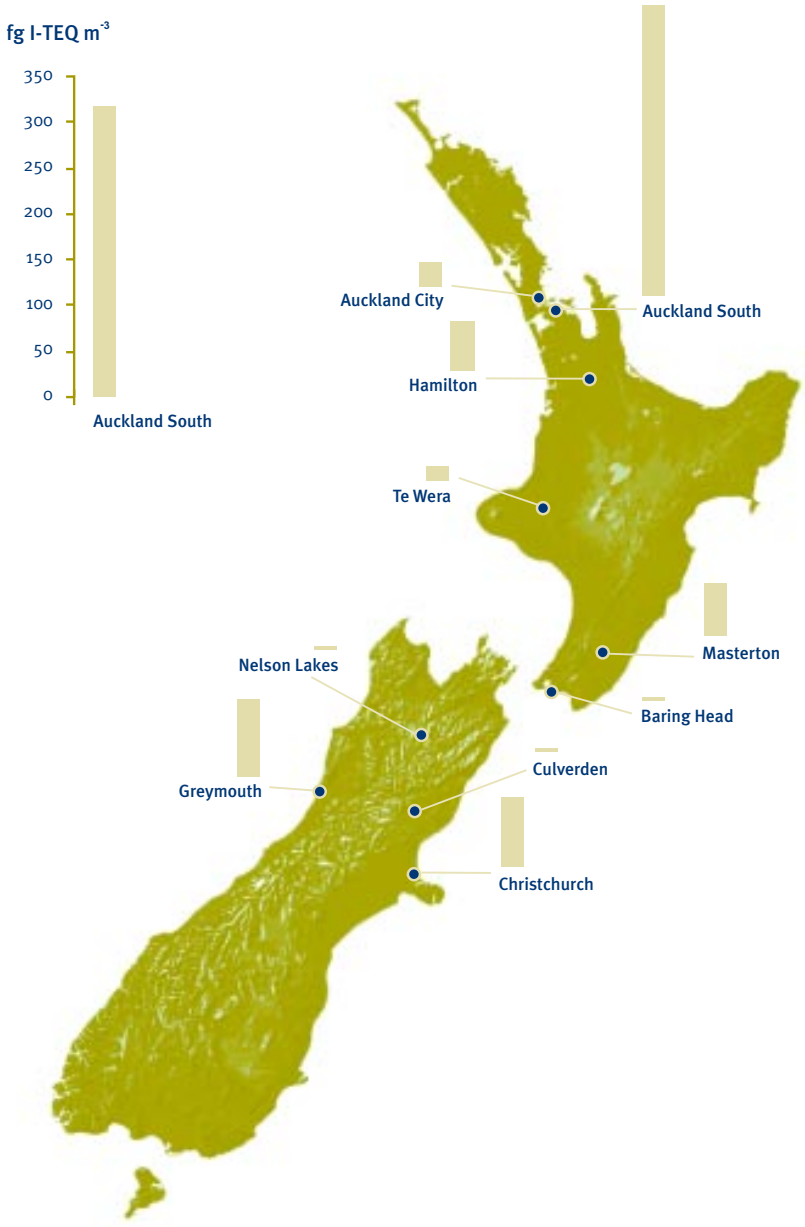

Figure 2.1 **Average levels of dioxins in air**

At a number of sites, the dioxin levels in air varied with the season. At Culverden, Hamilton, Masterton, Christchurch and Greymouth, the highest levels were measured in the colder winter months and the lowest levels in the warmer summer months. At these sites, the lower the night-time temperature the higher the dioxin level in the air. At two sites studied, the levels of dioxins were also strongly correlated to a chemical indicator of wood burning. These findings indicate that home heating is an important source of dioxins for some parts of New Zealand. In contrast, the Auckland City site showed very similar dioxin levels throughout the year. These are thought to come mainly from vehicle emissions.

The levels of dioxins found in New Zealand air were generally lower than those reported by similar surveys in other countries, and particularly for reference and rural sites, as illustrated in Figure 2.2. However, at New Zealand urban sites, the highest winter levels were similar to levels found in a number of European cities. The comparative data for dioxin levels in urban air in New Zealand and other countries are shown in Figure 2.3.

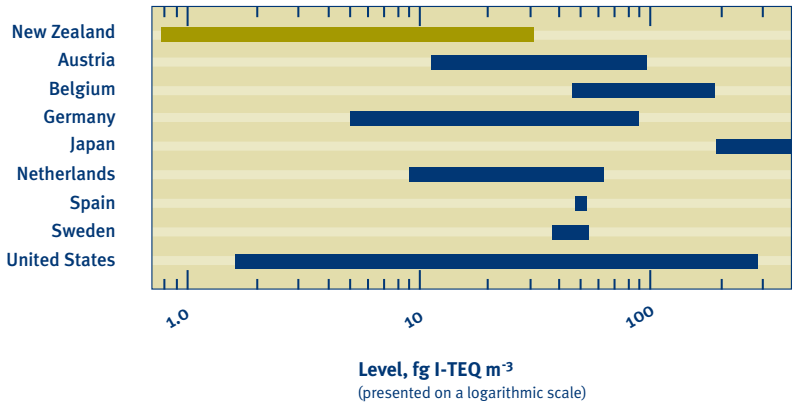

Figure 2.2 **International comparison of dioxin levels in reference and rural air**

This type of graph shows the range of contaminant levels found in this study and in similar studies in other countries.

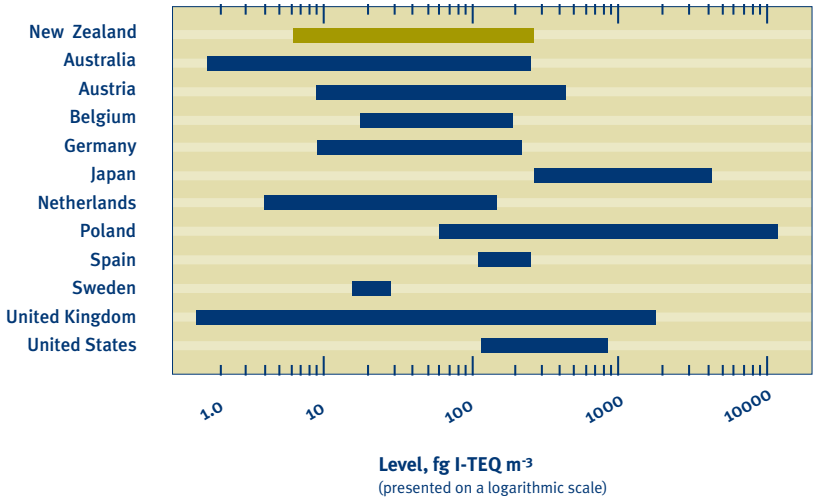

Figure 2.3 **International comparison of dioxin levels in urban air**

PCB levels were also very low at reference and rural sites, but were higher at urban and industrial sites. The average level measured at each site is shown in Figure 2.4.

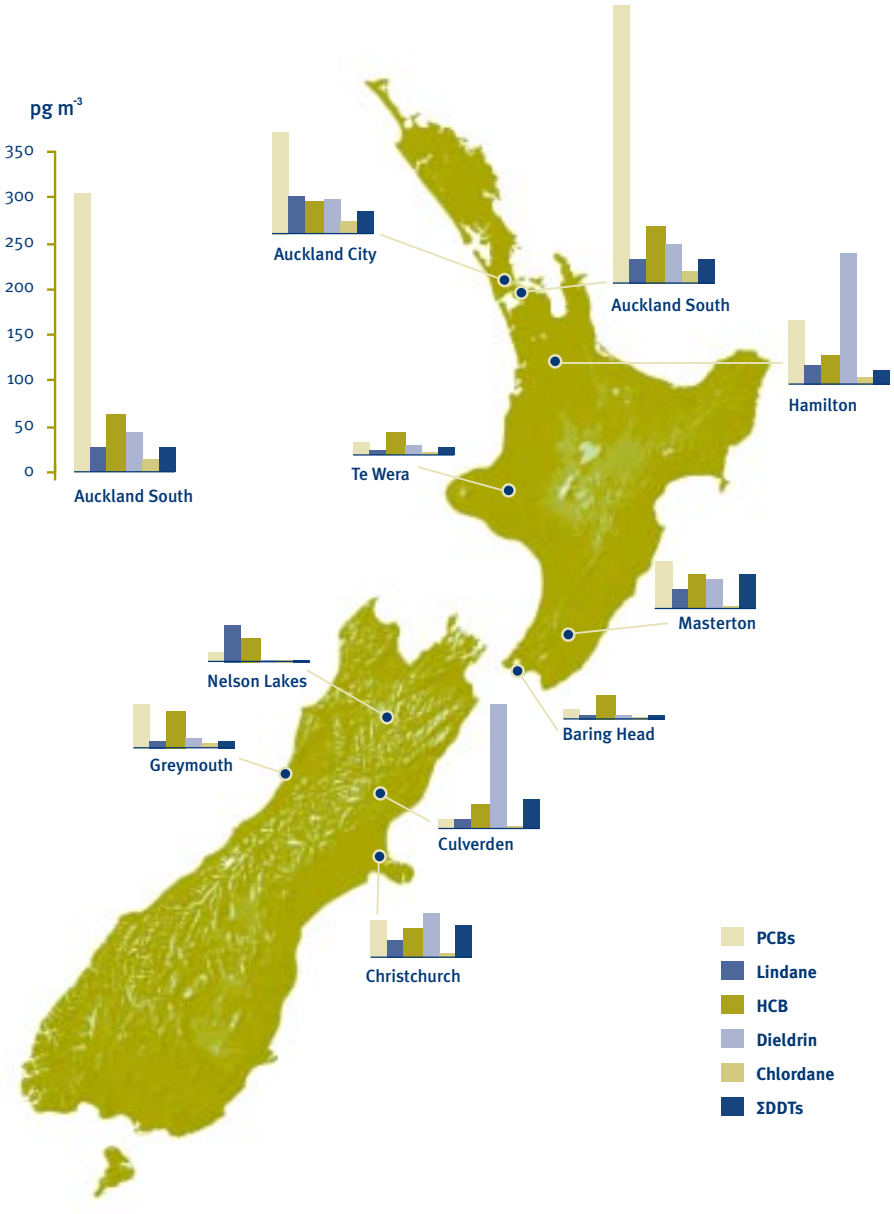

Figure 2.4 **Average levels of PCBs and organochlorine pesticides in air**

Levels of PCBs for individual samples were between 5.72 - 18.2 pg m^{-3} of air at reference sites, 4.99 - 30.0 pg m^{-3} of air at rural sites, 29.9 - 129 pg m^{-3} of air at urban sites and 210 - 471 pg m^{-3} of air at the industrial site. These levels are low when compared to levels reported for similar sites in other countries, as shown in Figure 2.5.

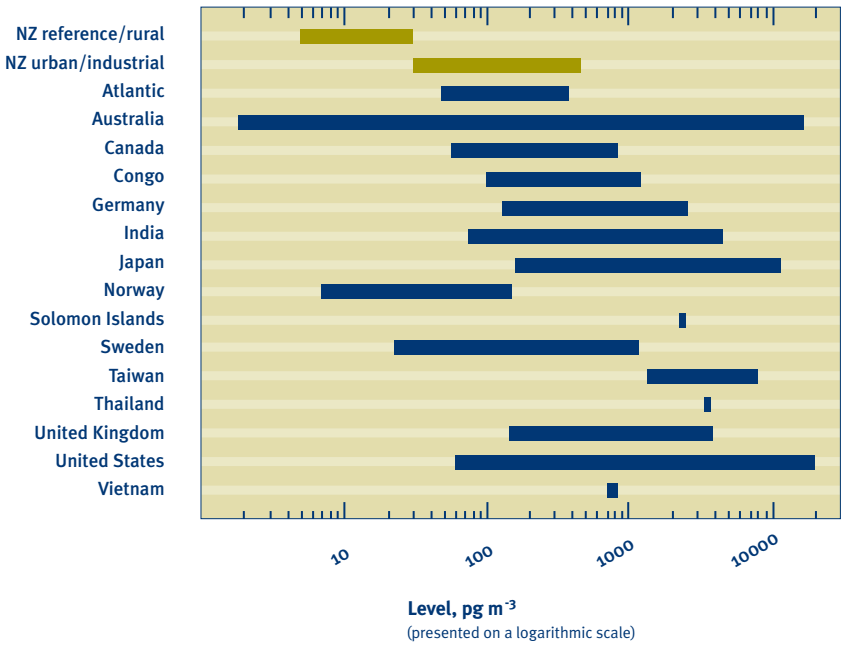

Figure 2.5 **International comparison of PCB levels in air**

At most of the New Zealand sites, the levels of PCBs in air were higher during the summer, with a strong relationship between the levels found at rural and urban sites and the average day-time air temperatures. PCBs are no longer used in New Zealand, and it is believed their presence in air results from evaporation from soils, and from contaminated materials at sites where they were once used. The processes of evaporation and atmospheric deposition mean PCBs recycle continuously through the environment. Industrial sources also contribute some PCBs to the atmosphere.

Organochlorine pesticides were detected at all sampling sites. The most abundant and frequently detected organochlorine pesticides were lindane, HCB, dieldrin and DDT. At least 50% of all air samples contained these contaminants in excess of 20 pg m^{-3}, as illustrated in Figure 2.4. Lindane was generally measured at lower levels than data reported in other countries, although levels of DDT and dieldrin were more comparable to air levels in other countries. It is thought that most lindane, dieldrin and DDT detected in New Zealand air is a result of the past use of these organochlorine pesticides.

The levels of HCB were generally very similar at all sites, and were also similar to levels reported in other countries, including levels measured in marine air. This indicates that HCB is likely to be uniformly distributed throughout the world and suggests that most of the HCB measured in New Zealand may not be of local origin.

Other organochlorine pesticides, including heptachlor and chlordane, were at lower levels, and generally not as frequently detected, whilst aldrin was found in less than 15% of the samples, and levels never exceeded 10 pg m^{-3} of air.

Trichlorophenols were found at all sites, with tetrachlorophenols and PCP being measured at most sites. Levels were low at reference and rural sites, but were higher at the urban and industrial sites, as shown in Figure 2.6.

Comparatively high levels of chlorophenols were measured at the Greymouth site. These results (which are not shown on Figure 2.6) are thought to be strongly influenced by a suspected local source at the site, and are not considered to be representative of Greymouth urban air.

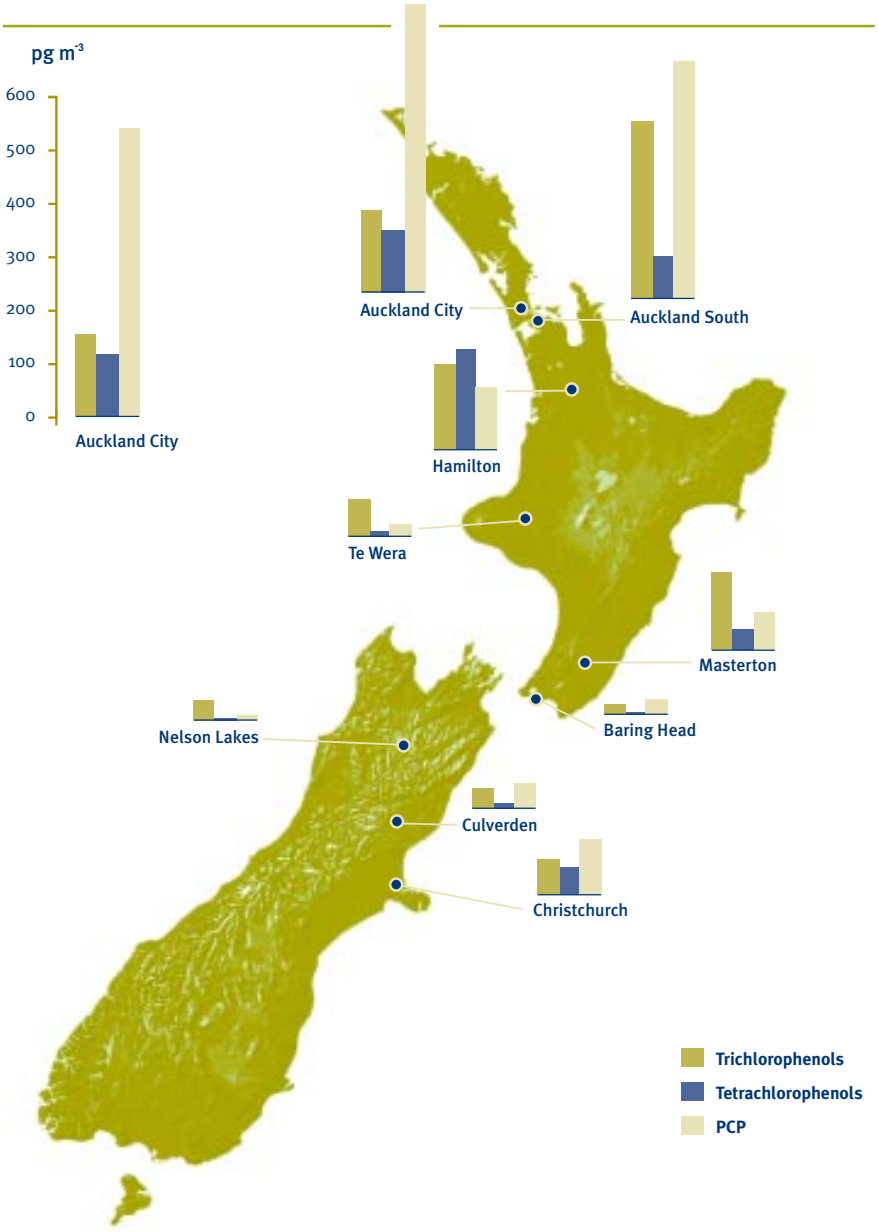

Figure 2.6 **Average levels of chlorophenols in air**

It is believed that most chlorophenols measured in air, especially the tetrachlorophenols and PCP, originate from the historic use of PCP as a timber preservative in New Zealand. Structures made from timber that had been treated with PCP, and sites where PCP was used, will act as reservoirs from which chlorophenols are slowly evaporating into the atmosphere. The levels of chlorophenols detected in air, however, are low.

Conclusion

Overall, the levels of organochlorine contaminants in New Zealand air are generally lower than levels reported in other countries, and in particular northern hemisphere countries. However, levels of dioxins in the New Zealand winter were comparable to air levels reported in Europe, although levels in summer were generally lower. Levels of some organochlorine pesticides were similar to data reported in other countries.

Chapter 3

Ambient levels of organochlorines in soil

Background

In this chapter, data is given on the levels of dioxins, PCBs, organochlorine pesticides and chlorophenols in New Zealand soils.

Soil sampling

Soil samples were collected from around New Zealand to cover the country's range of climates and landforms. The sites sampled comprised indigenous forests and grasslands, agricultural soils, and city parks and reserves in provincial and metropolitan centres. Indigenous forest and grassland soils were taken from National Parks and Department of Conservation land as shown in Table 3.1.

Table 3.1 **Soil samples collected from indigenous forests and grasslands**

	Indigenous forest	Indigenous grassland
North Island	Waipoua Forest	Ruahine Forest Park
	Pirongia Forest Park	Mount Egmont National Park
	Whirinaki Forest Park	Tararua Forest Park
	Rimutaka Forest Park	
South Island	Arthur's Pass National Park	Nelson Lakes National Park
	Paparoa National Park	Blue Mountains
	Catlins Forest Park	

Agricultural soils were sampled from hill country and flat land pastoral farms throughout the country. Urban soils were collected from parks and reserves in the provincial centres listed in Table 3.2, as well as from more than 50 parks and reserves throughout the metropolitan centres of Auckland and Christchurch.

Table 3.2 **Provincial centre sampling sites**

Provincial centre	Parks and reserves
Whangarei	Tarewa Park; Onerahi Domain; Beazley Park; Barge Park
Hamilton	Fairfield Park; Hayes Paddock; Lake Domain; Minogue Park
Napier	Botanical Gardens; Clive Square Memorial Park; Marine Parade Gardens; Kennedy Park Rose Garden
New Plymouth	Mt Moturoa Domain; Churchill Heights, Western Park; Marsland Hill; Brooklands Park
Masterton	Cameron and Soldiers Memorial Park; South Park; Douglas Park; Oxford Street Reserve
Timaru	Maori Park; Gleniti Park; West End Park; Alexandra Square
Greymouth	Karoro Domain; McLean Domain; Dixon Park; Greymouth Recreation Ground
Invercargill	Queens Park; Otakaro Park; Elizabeth Park; Russell Square

Sites were selected to be representative of the country as a whole. Soil sampling was undertaken from late February to early May 1996. The sampling involved taking a large number of soil cores over a wide area at each sampling site. The individual cores were then carefully mixed together to give a sample that accurately reflected the site.

Levels of organochlorines found

The levels of dioxins found are shown in Figures 3.1 and 3.2. Typically, these levels ranged between 0.17 - 1.99 ng I-TEQ kg^{-1} of dry soil (forest and grassland soils), 0.17 - 0.90 ng I-TEQ kg^{-1} (agricultural soils) and 0.52 - 6.67 ng I-TEQ kg^{-1} (urban soils). Most of the dioxins present in soil are likely to have come from atmospheric transportation and deposition.

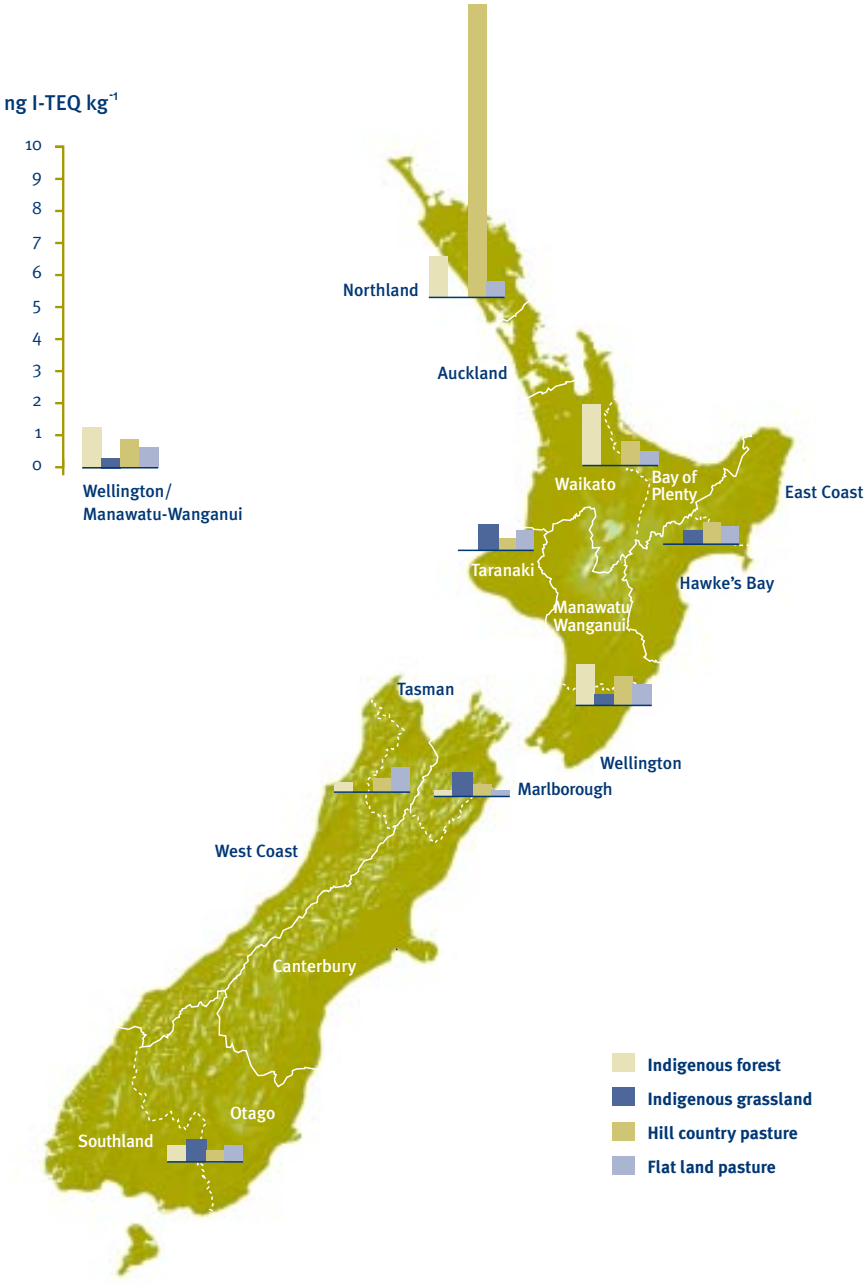

Figure 3.1 **Levels of dioxins in forest, grassland and agricultural soils**

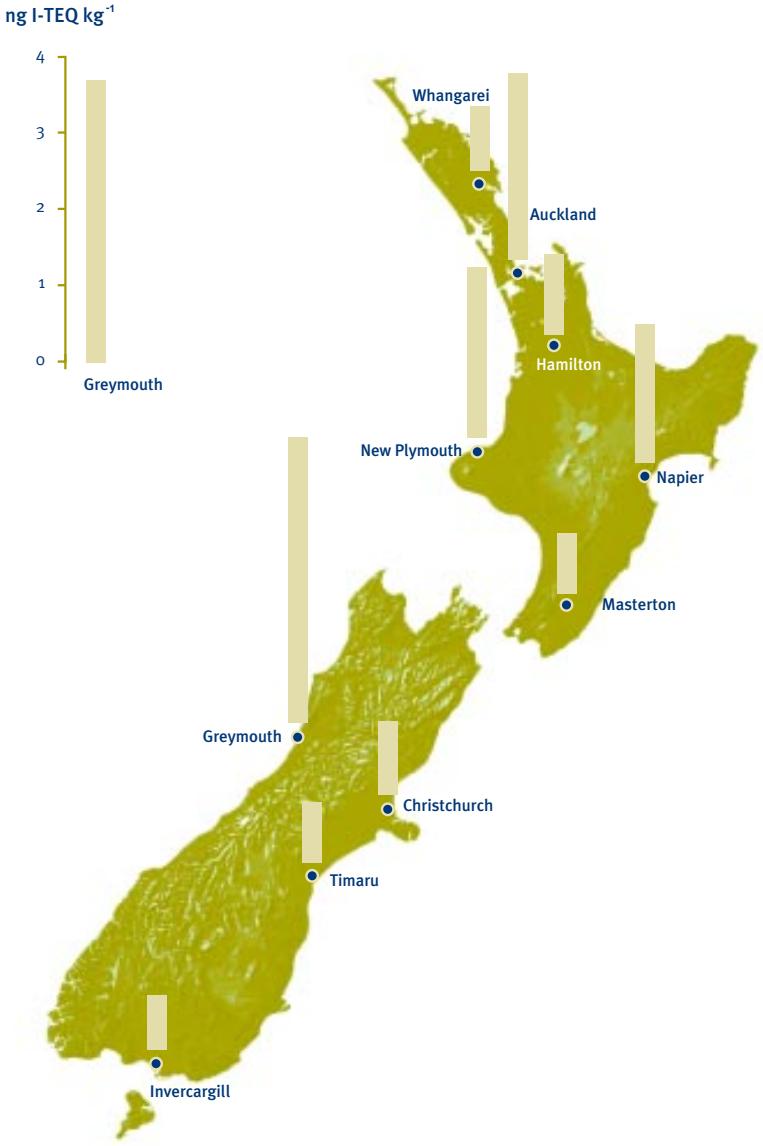

Figure 3.2 **Average levels of dioxins in urban soils**

Two sites contained dioxins that could be associated with the manufacture and use of the herbicide 2,4,5-T. These were a Northland hill country site, and a site adjacent to a chemical manufacturing plant in New Plymouth. The results for these two sites, the highest levels for all sites studied, are shown as hollow boxes in Figure 3.3 (agricultural soil and urban soil respectively).

The levels of dioxins found in forest, grassland, agricultural and urban New Zealand soils were lower than levels that have been reported in similar surveys in other countries. This is illustrated for agricultural and urban soils in Figure 3.3. In general, levels in New Zealand agricultural soils are about one-tenth of the levels found in agricultural soils in the countries listed. The low levels of dioxins present in New Zealand agricultural soils are why the levels of dioxins in meat and dairy products are also very low (see Chapter 6).

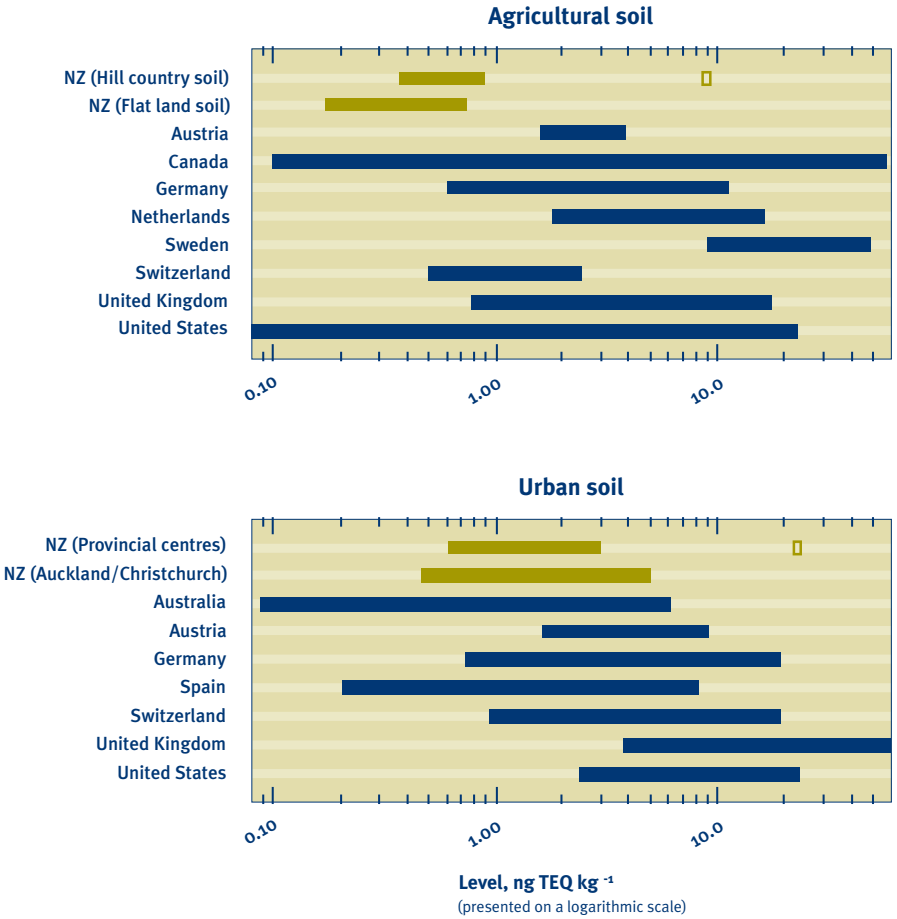

Figure 3.3 **International comparison of dioxin levels in soil**

The levels of dioxins found in New Zealand soils are considerably below international guidelines for land used for agricultural or residential purposes.

No PCBs were found in most forest, grassland or agricultural soils. As shown in Figure 3.4, some PCBs were found in urban soils, the highest level for an individual sample being 9.74 µg kg^{-1} of dry soil. Again, levels of PCBs are much lower than those found in other countries and well below guidelines published by the United States Environmental Protection Agency.

The levels of organochlorine pesticides in the soils studied were also low. In indigenous forest and grassland soils, only HCB, dieldrin and DDT were found. These organochlorine pesticides were also the most frequently detected in urban soils, with dieldrin and DDT being found in all samples.

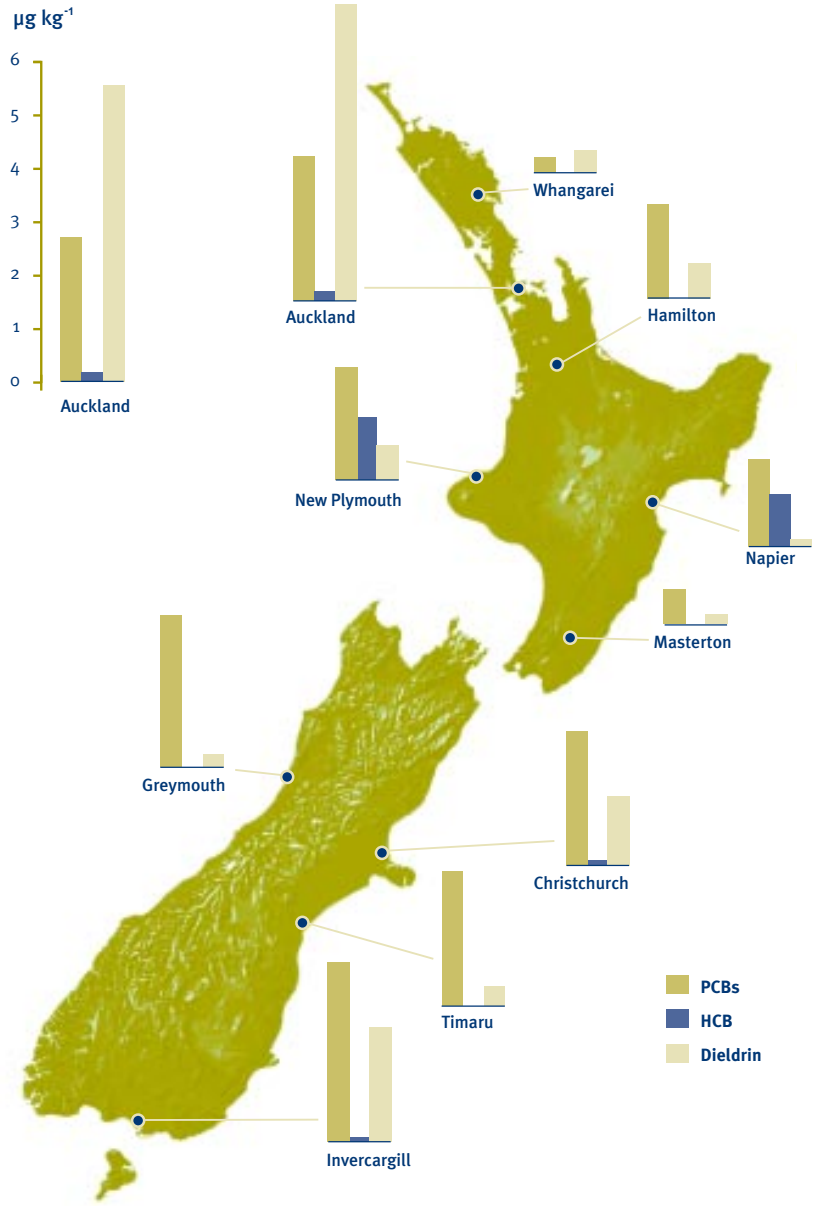

Figure 3.4 **Average levels of PCBs, HCB and dieldrin in urban soils**

The levels of HCB and dieldrin were generally similar, as illustrated for urban soils in Figure 3.4. However, the levels of DDT and its breakdown products were much more variable, as summarised in Table 3.3. These results indicate that historically, little use was made of DDT in the parks of most provincial centres, and in Auckland. In contrast, more use was made of DDT in Christchurch parks.

Table 3.3 **Levels of DDT and its breakdown products in urban soils**

Location	ΣDDTs, µg kg^{-1}
Whangarei	24.6
Auckland	25.4
Hamilton	1.50
Napier	23.0
New Plymouth	20.2
Masterton	69.4
Christchurch	431.
Timaru	7.77
Greymouth	32.8
Invercargill	244.

Other organochlorine pesticides found in urban soils included lindane and chlordane, but only in a limited number of samples, and at very low levels. It should be noted that agricultural soils were not analysed for organochlorine pesticides.

Chlorophenols were found in only a few samples. Three indigenous forest soils contained trichlorophenol, most likely as a result of atmospheric transportation and deposition. The Northland hill country soil contained trichlorophenol, and soils from Greymouth and Christchurch contained low levels of PCP at 2.1 µg kg^{-1} and 0.95 µg kg^{-1} of dry soil.

Conclusion

Overall, the background levels of dioxins, PCBs, organochlorine pesticides and chlorophenols in the New Zealand soils studied are generally very low, and are among the lowest levels measured anywhere in the world.

Chapter 4

Ambient levels of organochlorines in rivers

Background

In this chapter, data is given on the levels of dioxins, PCBs, organochlorine pesticides and chlorophenols in New Zealand rivers.

River sampling

River water was collected from thirteen rivers at sixteen sampling sites. These were selected as broadly representative of the country as a whole. Eel were captured from all thirteen rivers and trout from nine of the thirteen rivers. River sampling was undertaken from January to March 1996, with some additional sampling of trout in late 1996.

Three rivers were selected as "reference" or "clean" rivers with no wastes having been discharged to them at, or above, the sampling sites. The other rivers were selected because they received a variety of waste discharges, or because the river ran through an agricultural area. A list of the rivers studied and a summary of the discharges known to occur near or upstream from the sampling sites are given in Table 4.1.

Table 4.1 **River sampling sites**

River	Sampling site	Discharges to the river
Waipa	Whatawhata	Stormwater and sewage from Te Awamutu; dairy industry; freezing works; timber processing; mining/quarrying; agricultural runoff.
Rangitaiki	Te Teko	Stormwater and sewage from Murupara; agricultural runoff.
Waingongoro	State Highway 45	Stormwater and sewage from Eltham; freezing works; timber processing; mining/quarrying; agricultural runoff.
Wanganui	Te Maire	Stormwater and sewage from Taumarunui.
Manawatu	Opiki Bridge	Stormwater and sewage from Palmerston North; dairy industry; freezing works; agricultural runoff; biochemical processing plant.
Mohaka	Raupunga	No point source discharges. Reference site.
Tukituki	Tamumu Bridge	Stormwater and sewage from Waipukurau, Waipawa and Takapau; landfill leachate; timber processing; agricultural runoff.
Ruamahanga	State Highway 2	Agricultural runoff.
Ruamahanga	Waihenga	Stormwater and sewage from Masterton, Carterton and Greytown; timber processing; mining/quarrying; agricultural runoff.
Haast	Roaring Billy	No point source discharges. Reference site.
Waimakariri	Old Highway Bridge	Freezing works.
Halswell	McCartneys Bridge	Agricultural runoff.
Taieri	Sutton Stream	Stormwater and sewage from Middlemarch; agricultural runoff.
Taieri	Allanton	Stormwater and sewage from Mosgiel; agricultural runoff.
Mataura	Parawa	No point source discharges. Reference site.
Mataura	Seaward Downs	Stormwater and sewage from Gore; dairy industry; freezing works; paper mill; agricultural runoff.

Levels of organochlorines in river water

No organochlorine contaminants were measured in any river water from any site despite the sensitive analytical methods used. These methods are able to measure these contaminants in river water at the pg L^{-1} level for dioxins, and at the ng L^{-1} level for PCBs, organochlorine pesticides and chlorophenols.

Even allowing for the possibility that these compounds were present below the limits of detection (i.e. at levels which the analytical methods could not detect), the levels would still be lower than levels found in waterways in other countries. For the organochlorine pesticides, the levels would also be lower than existing aquatic guideline values. This is illustrated for dieldrin in Figure 4.1. The Australian and New Zealand Environment and Conservation Council (ANZECC) guideline value for the protection of aquatic life is shown as a dashed line.

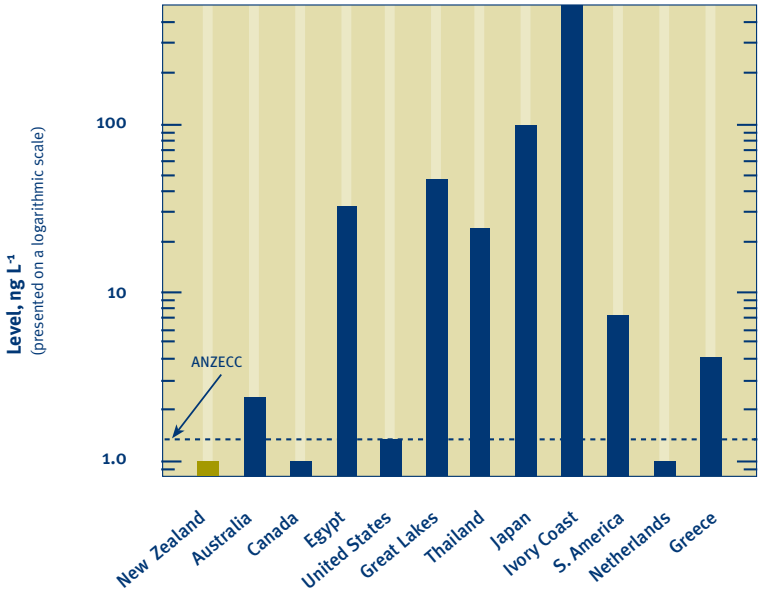

Figure 4.1 **Maximum dieldrin levels in water from New Zealand and other countries**

Levels of organochlorines in eel and trout

Levels of some organochlorines were measured in eel and trout living in these rivers, including those rivers that were selected as reference sites. These results indicate that, although not detectable in water, these contaminants, where present, accumulate through the food chain of eel and trout.

Dioxins were measured in less than half of the fish samples collected. The levels were very low at all sampling sites, and lower than levels found in fish in other countries. The levels measured were between 0.16 - 0.39 ng I-TEQ kg^{-1} for eel and 0.016 - 0.20 ng I-TEQ kg^{-1} for trout.

All but one of the fish samples contained trace levels of PCBs. As shown in Figure 4.2, the highest levels measured were 18.5 µg kg^{-1} for eel and 8.80 µg kg^{-1} for trout. These levels are well below human health criteria for the consumption of fish that contain PCB residues.

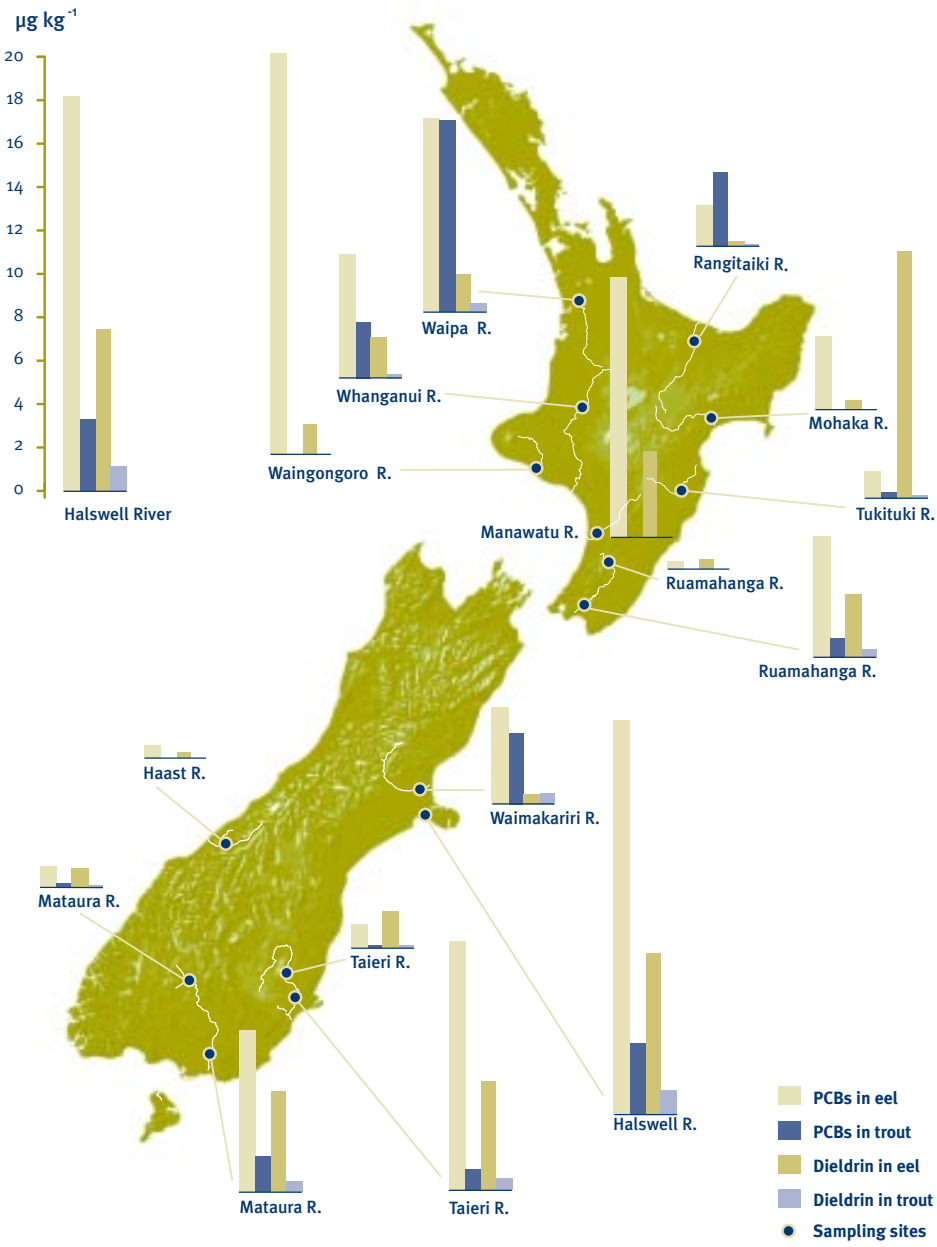

Figure 4.2 **Levels of PCBs and dieldrin in eel and trout**

The levels are also much lower than levels reported in Europe and North America. Figure 4.3 shows a comparison of the New Zealand data with PCB levels that have been found in fish from a number of countries.

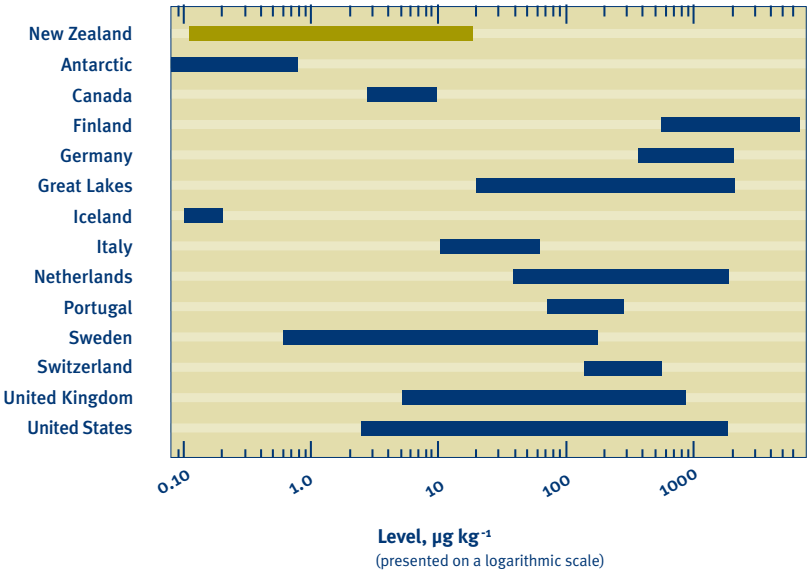

Figure 4.3 **International comparison of PCB levels in fish**

The most common organochlorine pesticides found were dieldrin and DDT, which were present in all fish samples. Levels of dieldrin measured in eel and trout are shown in Figure 4.2 and levels of DDT and its breakdown products measured in eel and trout are shown in Figure 4.4. HCB was the next most common organochlorine pesticide found, but on average at a level approximately one-tenth the level of dieldrin.

Although the levels of these organochlorine pesticides were generally higher in eel than in trout, they were always well below overseas pesticide residue limits for the human consumption of fish.

Of the other organochlorine pesticides, chlordane was less frequently detected and was measured at lower levels, whilst aldrin and heptachlor were not detected in any fish captured from any river.

No trichlorophenols or tetrachlorophenols were detected in any of the fish captured. PCP was measured in eel from the Ruamahanga River and the Taieri River, and in trout from the Mataura River. In all cases, the levels were close to the limit of detection of the analytical method.

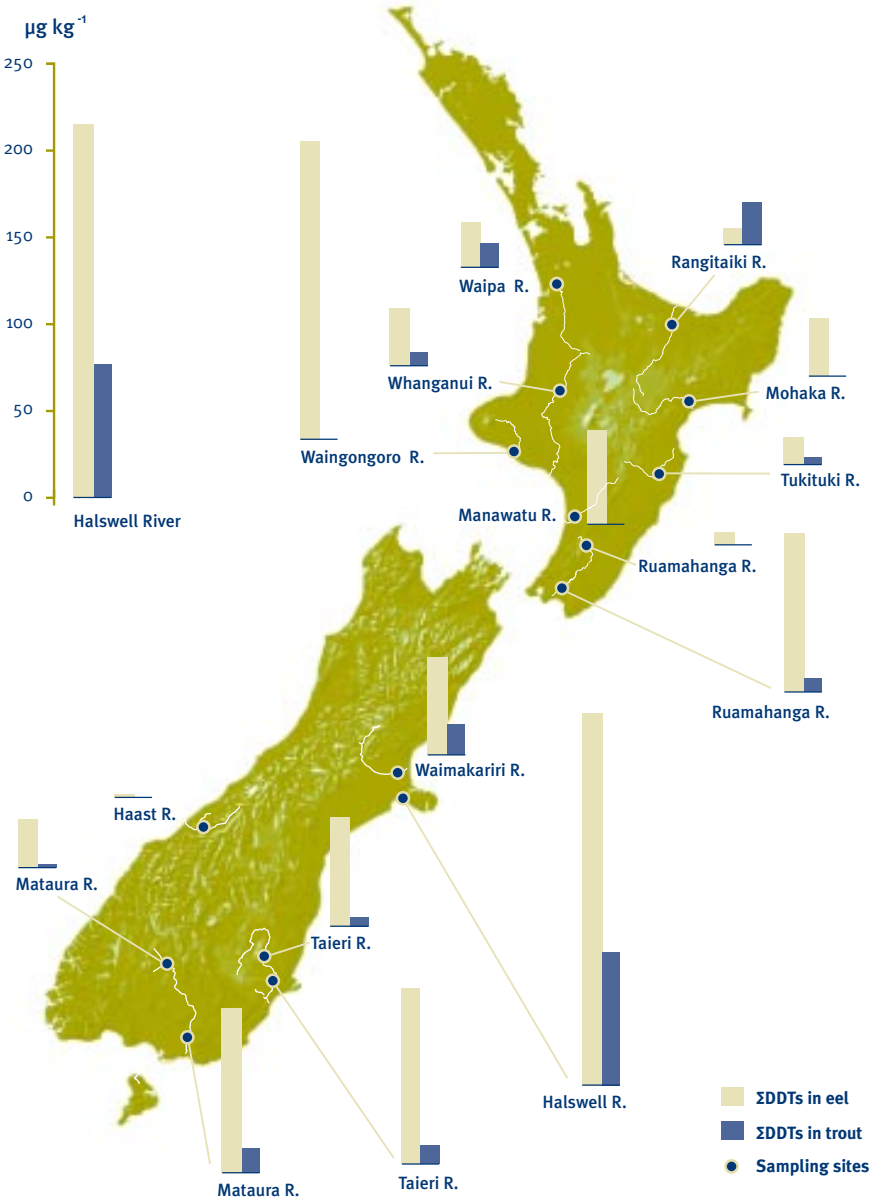

Figure 4.4 **Levels of DDT and its breakdown products in eel and trout**

Conclusion

Overall, this survey has demonstrated that the New Zealand rivers sampled are relatively free of contamination by dioxins, PCBs, organochlorine pesticides and chlorophenols. The presence of only trace levels of these contaminants in fish which live in these rivers indicates a generally low level of contamination of the New Zealand environment.

CHAPTER 5

Ambient levels of organochlorines in estuaries

Background

In this chapter data is given on the levels of dioxins, PCBs, organochlorine pesticides and chlorophenols in New Zealand estuaries.

Estuary sampling

Sediment and shellfish (cockles and oysters) were collected from twelve estuaries and analysed for organochlorine contaminants. Apart from specific information about the level of organochlorines in these estuaries, measuring the contaminant levels in shellfish is especially important, because shellfish are often a step in the food chain for people and wildlife.

To be representative of the country, estuaries were selected from remote areas, agricultural areas, and urbanised catchments. A list of the estuaries studied and a summary of the discharges and industries within each catchment are given in Table 5.1.

Table 5.1 **Estuary sampling sites**

REGION	ESTUARY	DISCHARGES AND INDUSTRIES WITHIN CATCHMENT
Northland	Parengarenga Harbour	No point source discharges.
	Whangarei Harbour	Stormwater and sewage from Whangarei and Portland industrial area; cement and fertiliser manufacture; oil refineries; general port activities.
Auckland	Manukau Harbour	Sewage and stormwater from Auckland; industrial wastes; agricultural runoff.
	Hellyers Creek, Waitemata Harbour	Urban stormwater.
Waikato	Kawhia Harbour	No point source discharges; agricultural runoff.
Bay of Plenty	Tauranga Harbour	Stormwater (and in the past, sewage) from Tauranga and stormwater from Mt Maunganui; timber processing; fertiliser manufacture; agricultural runoff.
Marlborough	Wairau Estuary	Agricultural runoff.
Tasman	Whanganui Inlet	Kahurangi National Park. No point source discharges.
	Moutere Inlet	Stormwater from Motueka; fish processing factory; sawdust dumps; agricultural runoff.
Canterbury	Avon-Heathcote Estuary	Stormwater and sewage from Christchurch.
Otago	Otago Harbour	Stormwater and sewage from Dunedin; fertiliser manufacturer; agricultural runoff.
Southland	New River Estuary	Stormwater and sewage from Invercargill; agricultural runoff.

Typically, two samples of sediment and shellfish were collected and analysed from each estuary. Sampling was carried out during May and June 1996 (except for Otago Harbour and New River Estuary, which were sampled in November 1996). Each sediment sample involved taking a large number of cores over a wide area at each sampling site. The individual cores were then carefully mixed together to give a sample that accurately reflected the site. Similarly, each shellfish sample consisted of a large number of shellfish that were gathered from the sampling site.

Levels of organochlorines found

Organochlorines were measured at low levels in all estuaries, in the sediment and/or shellfish, as illustrated in Table 5.2.

Table 5.2 **Organochlorine contaminants found in estuaries**

	Dioxins	PCBs	Lindane	HCB	Dieldrin	Heptachlor	Chlordane	ΣDDTs	PCP
Parengarenga Harbour	●		☆						
Whangarei Harbour	✪	✪	●	●	✪			✪	
Manukau Harbour	✪	✪	✪	✪	✪		☆	✪	☆
Hellyers Creek	✪	✪	✪	✪	✪	●	✪	✪	●
Kawhia Harbour	✪	☆			☆			✪	
Tauranga Harbour	✪	✪	☆	●	✪			✪	
Wairau Estuary	☆		☆		☆			✪	●
Whanganui Inlet	☆		☆		☆			✪	
Moutere Inlet	✪				✪			✪	
Avon-Heathcote Estuary	✪	✪		☆	✪		☆	✪	☆
Otago Harbour	●	☆		☆	☆		☆	☆	
New River Estuary	✪	☆	☆	☆	✪		☆	✪	

☆ *Found in shellfish only;*

● *Found in sediment only;*

✪ *Found in both shellfish and sediment.*

The levels of dioxins found in sediment were between 13.2 - 700 ng I-TEQ kg^{-1} of sediment organic carbon, and in shellfish, between 1.77- 28.9 ng I-TEQ kg^{-1} of shellfish fat. The average level of dioxins found in shellfish from each estuary is shown in Figure 5.1. These results are consistent with other studies of sediment and shellfish sampled from Banks Peninsula and the Bay of Plenty.

Generally the levels of dioxins found in New Zealand sediment are lower than levels reported in the northern hemisphere. This is illustrated in Figure 5.2. The levels found in shellfish were also lower than levels reported in other countries, and are below the Canadian guideline limit for human consumption. However, in some estuaries the levels exceeded the (much stricter) Canadian limit for the protection of shellfish-eating wildlife.

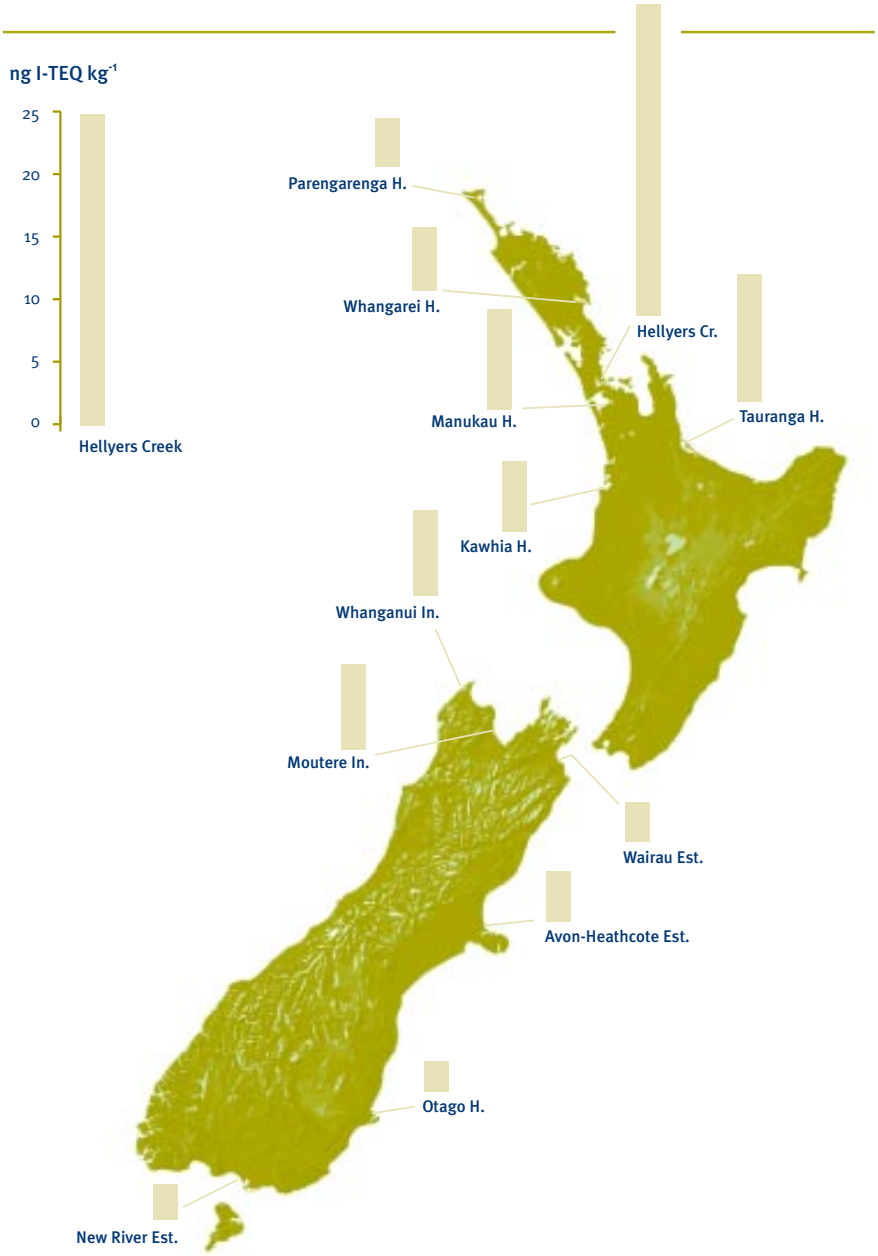

Figure 5.1 **Average levels of dioxins in shellfish**

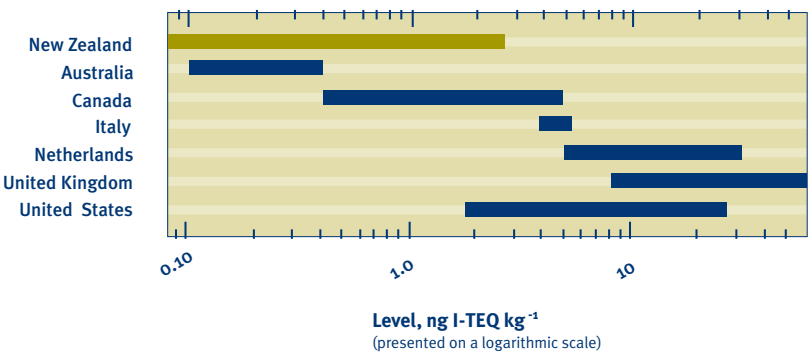

Figure 5.2 **International comparison of dioxin levels in sediment**

PCBs were measured at low levels in 35% of sediment samples collected, ranging from 9.72 - 926 µg kg^{-1} of sediment organic carbon. The average level determined for each estuary is shown in Figure 5.3. These levels are generally at the lower end of the ranges reported for estuarine sediment in other countries, and are below the United States, Canadian and Netherlands sediment quality criteria.

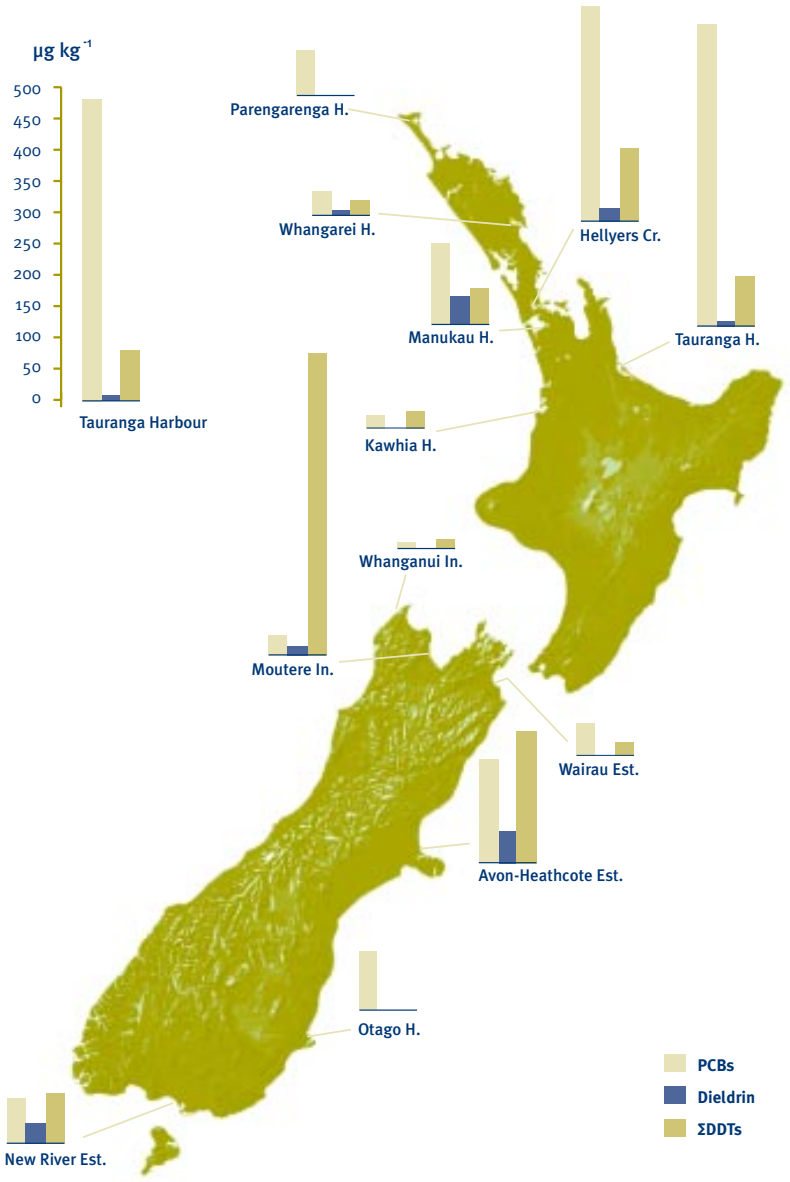

Figure 5.3 **Average levels of PCBs, dieldrin and ΣDDTs in sediment**

PCB contaminants were more frequently measured in shellfish, with levels in individual samples between 13.3 - 1430 µg kg^{-1} of shellfish fat. Average levels shown in Figure 5.4 are considerably lower than levels found in shellfish in other countries, with the exception of shellfish from Hellyers Creek. In this estuary, the level of PCBs was approaching the levels measured in urbanised estuaries in other countries.

A number of organochlorine pesticides were found in both sediment and shellfish, the most common being dieldrin and DDT. The average levels of dieldrin and ΣDDTs measured in sediment from each estuary are shown in Figure 5.3, and in shellfish in Figure 5.4.

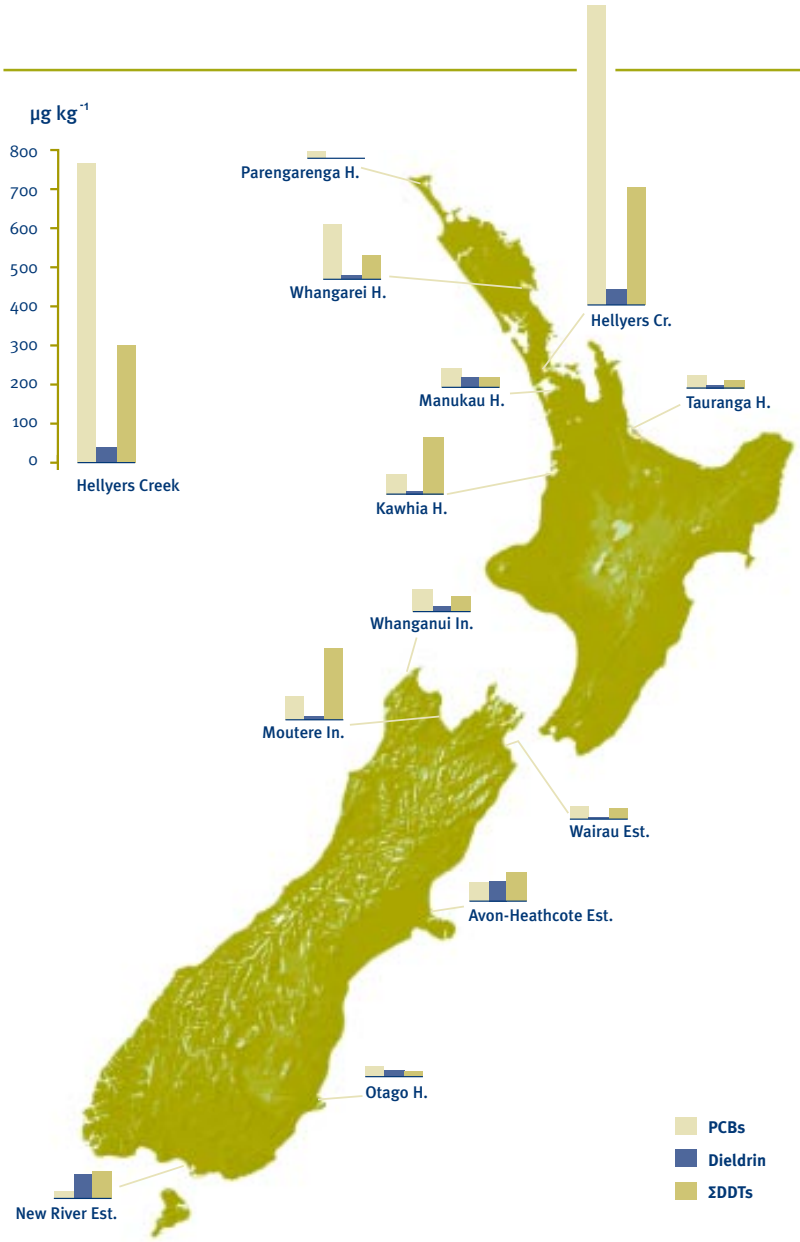

Figure 5.4 **Average levels of PCBs, dieldrin and ΣDDTs in shellfish**

Although the levels of organochlorine pesticides found were low by international standards, levels of DDT from Moutere Inlet exceeded the Canadian and Netherlands sediment quality guidelines for the protection of wildlife. However, the levels for all organochlorine pesticides were well below overseas regulatory limits for the human consumption of shellfish.

No trichlorophenols or tetrachlorophenols were measured in any sample. PCP was measured in sediment from Hellyers Creek and Wairau Estuary, and in shellfish from Manukau Harbour and Avon-Heathcote Estuary. In all cases the levels were close to the limit of detection of the analytical method, and were well below the Netherlands sediment quality guideline for PCP.

Conclusion

Overall, the levels of organochlorine contaminants in New Zealand estuaries, both in sediment and shellfish, are very low. Of the twelve estuaries studied, only two were found to contain organochlorines at levels approaching those commonly found in urbanised estuaries overseas.

CHAPTER 6

Exposure to dioxins and PCBs from food

Background

Overseas research has shown that most human exposure to organochlorines such as dioxins and PCBs is through food. Since dioxins and PCBs are found mainly in fat, people are exposed to these contaminants primarily through eating food containing animal fat.

To find out the dietary intake of dioxins and PCBs for New Zealanders, a dietary survey has been undertaken. In this chapter, data is reported on the levels of dioxins and PCBs in various foods, along with an estimation of a person's exposure based upon how much of these foods are typically eaten. Only dioxins and PCBs were investigated in this study and not the organochlorine pesticides. This is because pesticide residues in retail foods are measured by the Ministry of Health as part of the dietary surveys it undertakes, and residues in meat are also monitored by the Ministry of Agriculture and Forestry.

Food sampling and preparation

The foods studied were those that are commonly eaten in New Zealand, are available nationally, and have been shown to be a source of exposure to dioxins and PCBs in other countries. They included meats, poultry, fish and dairy products, as shown in Table 6.1. Staple foods such as cereals and potatoes were also analysed. However, because organochlorines are not usually found in foods which do not contain fat, less emphasis was placed on analysing a wide range of fruit and vegetables.

Table 6.1 **Foods analysed for dioxins and PCBs**

Meat	Beef, lamb, mutton, pork, liver and processed meat products (including meat pies and sausages).
Dairy	Milk, butter, cheese, ice cream and yoghurt.
Poultry	Chicken meat and eggs.
Fish	New Zealand fish and shellfish, and overseas tinned fish.
Cereals	Bread, breakfast cereals, spaghetti, biscuits and cake.
Other foods	Potatoes, vegetable oils and snack foods, including potato crisps and chocolate.

All foods were bought at supermarkets and other retail outlets in Auckland, Christchurch, Dunedin, Napier and Wellington. The samples of each food were prepared and cooked as most New Zealanders would do in making any meal.

Levels of dioxins and PCBs found

In some foods, no dioxins were found, and only low levels were found in all other foods. Levels of PCBs were also very low and present in most foods. The lowest and highest levels of dioxins and PCBs found for each type of food are summarised in Figure 6.1 and Figure 6.2. These results are reported as the amount of dioxins or PCBs present in the fat portion of the food.

With the exception of fish, no foods contained any dioxins or PCBs that were above 1 ng TEQ kg^{-1} of fat, and for many foods, levels were markedly below this. The levels measured were well below levels found for similar foods in other countries, particularly in Europe and North America. The low levels of dioxins and PCBs found in New Zealand meats and dairy products are consistent with the low levels of these contaminants in agricultural soils (see Chapter 3).

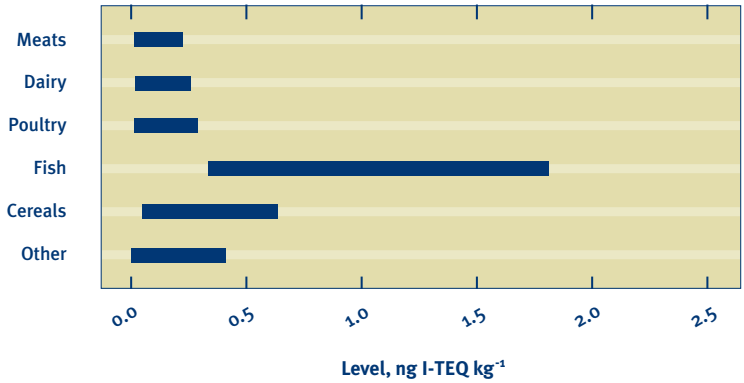

Figure 6.1 **Ranges of dioxins in retail foods in New Zealand**

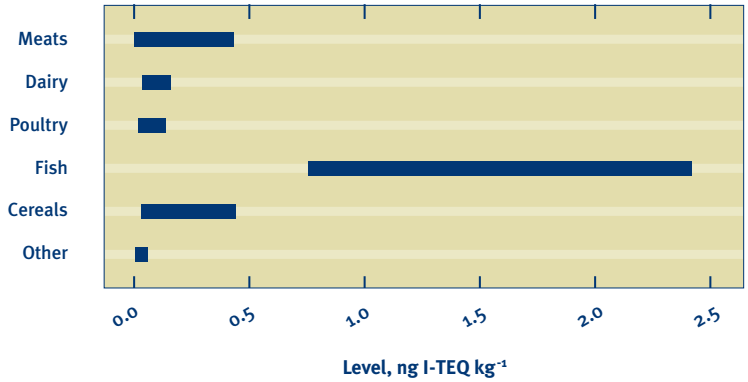

Figure 6.2 **Ranges of PCBs in retail foods in New Zealand**

The levels reported for fish are elevated due to the inclusion of imported tinned fish. The imported fish had markedly higher levels of dioxins and PCBs than the New Zealand fish. For example, levels of dioxins in New Zealand fish and shellfish ranged from 0.33 - 0.71 ng I-TEQ kg^{-1} of fat, whereas dioxin levels in imported fish were between 1.67 - 1.82 ng I-TEQ kg^{-1} of fat. Although the contaminants measured in tinned fish do not originate within New Zealand, it is important to include them in this study because New Zealanders are still exposed to them through their diet.

Levels of dietary exposure to dioxins and PCBs

It is possible to estimate a person's daily intake of dioxins and PCBs from these results. To do this, the amount of food a person eats each day (on average) is multiplied by the contaminant levels of dioxins and PCBs that have been measured in the food.

This type of dietary intake estimation has been done using the average amounts of food eaten by two dietary groups – an 80 kg adult male on a typical diet and a 70 kg adolescent male on a high energy diet. Males were chosen for this estimation because they generally eat more food than females. This means that they are more likely to represent a 'worst case' exposure to organochlorines through the diet.

The results show that an adult male on a typical diet is exposed to 14.5 pg I-TEQ of dioxins a day and 12.2 pg TEQ of PCBs a day. Similarly, an adolescent male on a high energy diet is exposed to 30.6 pg I-TEQ of dioxins a day and 22.7 pg TEQ of PCBs a day. The relative contributions of each type of food to the total daily intake of dioxins and PCBs are shown for the typical adult male diet in Figure 6.3 and the high energy adolescent male diet in Figure 6.4.

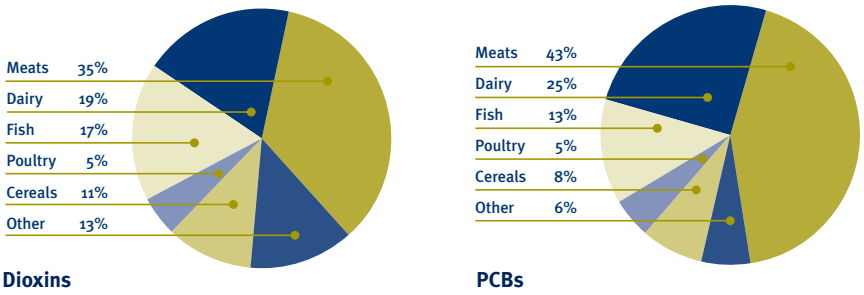

Figure 6.3 **Contribution of foods to the daily intake of dioxins and PCBs for a typical adult male diet**

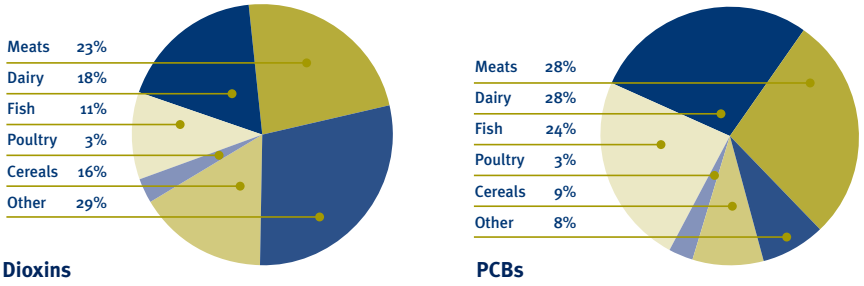

Figure 6.4 **Contribution of foods to the daily intake of dioxins and PCBs for a high energy adolescent male diet**

Another way to express these exposures is as an intake of organochlorine contaminants for each kilogram of a person's body weight (bw). The advantage of this approach is that it allows a person's dietary intake to be compared directly with dietary standards for dioxins and PCBs set by other countries.

For an adult male, these estimates show that the daily intake of dioxins through the diet is 0.18 pg I-TEQ/kg bw/day and of PCBs is 0.15 pg TEQ/kg bw/day. For an adolescent male, the daily intake of dioxins is 0.44 pg I-TEQ/kg bw/day and of PCBs is 0.32 pg TEQ/kg bw/day.

As shown in Figure 6.5, these levels of exposure are below the exposures measured in other countries, and the World Health Organisation (WHO) tolerable daily intake range for dioxins and PCBs of 1-4 pg TEQ/kg bw/day. The levels of exposure are also below dietary intake standards set by other countries.

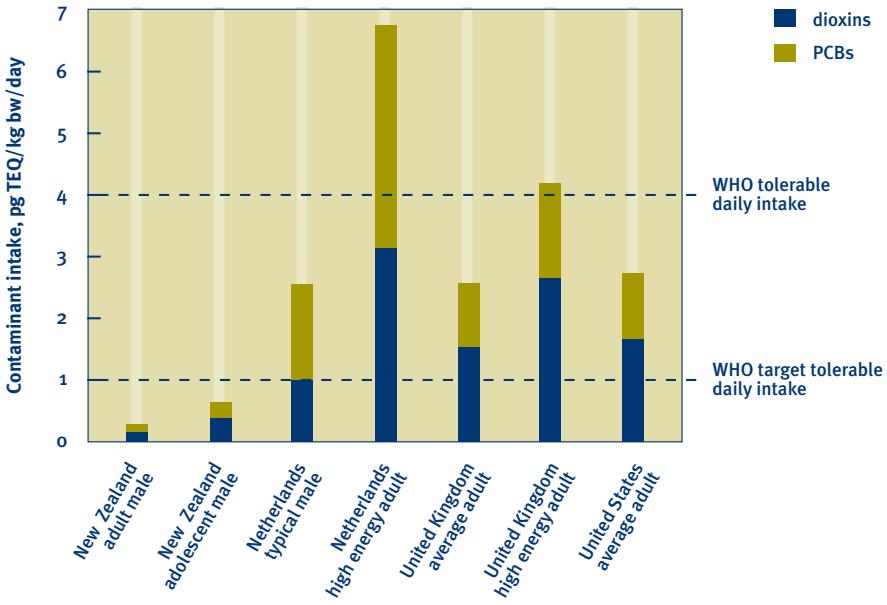

Figure 6.5 **International comparison of dioxin and PCB dietary intakes**

Conclusion

Different dietary habits make a direct comparison with results from studies undertaken in other countries difficult. However, the dietary intakes of dioxins and PCBs by New Zealand males are consistently lower than those of other countries where comparable studies have been undertaken. The dietary intakes are also below internationally accepted dietary intake standards for dioxins and PCBs.

Abbreviations and glossary

Aldrin	An organochlorine pesticide.
Analysis	To determine the presence and to measure the levels of a contaminant in a sample.
Analytical method	A procedure used for the analysis of a sample.
Atmospheric deposition	The transfer of a contaminant from air to another medium such as soil or water.
Atmospheric transportation	The movement of a contaminant on air currents from one place to another.
Ambient	The background level of a contaminant. The level expected for most areas of New Zealand.
Body burden	The amount of a contaminant stored in a person's body.
Chlordane	An organochlorine pesticide.
Chlorophenols	A family of chlorinated phenolic compounds that includes the trichlorophenols, tetrachlorophenols and PCP.
Contaminant	A chemical substance that is found in a place where it should not be. This does not necessarily mean that it is harmful, but depending on what it is, and the amount present, it may be.
Core	A portion of soil (or sediment) that when combined with other cores makes up a sample for analysis.
DDT	Dichlorodiphenyltrichloroethane. An organochlorine pesticide.
ΣDDTs	The sum of DDT residues. This comprises DDT and its breakdown products.
Daily intake	The amount of a contaminant taken in by a person each day.
Dieldrin	An organochlorine pesticide.
Dietary intake	The intake of a contaminant from a person's diet.
Dioxins	A family of closely related chemicals that includes the polychlorinated dibenzo-p-dioxins and the polychlorinated dibenzofurans.
Dioxins emission inventory	A list of sources that release dioxins to the environment.
Food chain	Plants and animals that are linked together in a feeding relationship.
Guidelines	Assessment and management recommendations. They may include recommended safety limits for contaminants in air, soil, water and sediment.

γ-HCH	Gamma hexachlorocyclohexane. An organochlorine pesticide, commonly known as lindane.
Hazard	The capacity to cause harm to people or the environment.
HCB	Hexachlorobenzene. An organochlorine pesticide.
Heptachlor	An organochlorine pesticide.
Level	The amount of a contaminant that is present in a given quantity of a sample. Also known as a concentration.
Limit of detection	The lowest level at which a chemical can be measured in a sample by the analytical method used.
Lindane	The common name for γ-HCH. An organochlorine pesticide.
Logarithmic scale	A non-linear mathematical scale used to aid the presentation of graphical information.
National environmental standard	A technical standard under the Resource Management Act 1991. A national environmental standard for dioxins and PCBs would set a safety limit for these contaminants in air, soil, water and sediment to protect human health and the environment.
Organochlorine	A chemical that contains carbon and chlorine atoms.
Organochlorine pesticides	A family of chlorinated chemicals used for killing insects and other pests. This family includes aldrin, chlordane, DDT, dieldrin, HCB, heptachlor, lindane, and PCP.
PCBs	A family of chemicals known as the polychlorinated biphenyls.
PCP	Pentachlorophenol. An organochlorine pesticide that belongs to the family of chlorophenol chemicals.
POPs	Persistent organic pollutants. Chemicals that take a long time to break down, can be transported long distances in the atmosphere, and accumulate and concentrate through the food chain.
Reference site	A site where the lowest level of a contaminant is expected to be found. Data from a reference site can be compared with data from a site where discharges may or do occur, allowing an estimate of any impacts to be made.
Reservoir	A site where a quantity of contaminated material occurs. The reservoir may pose an actual or potential hazard depending on whether the contaminant is being released from the site.
Risk	An estimate of the likelihood of harm resulting from exposure to a hazard.
Sample	Material (including air, soil, water, sediment, fish and food) that is analysed to measure the level of a contaminant present.
Sampling site	A place where a sample is collected.
Serum	One component of a person's blood. That component which separates from coagulated blood.

2,4,5-T	2,4,5-Trichlorophenoxyacetic acid. A herbicide used for the control of gorse, blackberry etc.
TEQ or I-TEQ	Toxic equivalents or international toxic equivalents. Used to report levels of dioxins and PCBs.
Tolerable daily intake	An estimate of the intake of a contaminant which can occur every day over a whole lifetime without appreciable health risks.
Toxic	A substance capable of causing harm (e.g. poisonous) to humans, animals or other living things.
UNEP	United Nations Environment Programme.
WHO	World Health Organisation.

Units

µg kg^{-1}	micrograms per kilogram. Equivalent to 1 x 10^{-9} of a kilogram. Also known as parts-per-billion (ppb). To give some idea of the scale that this unit measures, one µg kg^{-1} or one ppb approximates to one second in 32 years.
ng kg^{-1}	nanograms per kilogram. Equivalent to 1 x 10^{-12} of a kilogram. Also known as parts-per-trillion (ppt). To give some idea of the scale that this unit measures, one ng kg^{-1} or one ppt approximates to one second in 32 thousand years.
ng L^{-1}	nanograms per litre. Equivalent to 1 x 10^{-12} of a litre.
pg L^{-1}	picograms per litre. Equivalent to 1 x 10^{-15} of a litre. Also known as parts-per-quadrillion (ppq). To give some idea of the scale that this unit measures, one pg L^{-1} or one ppq approximates to one second in 32 million years.
pg m^{-3}	picograms per cubic metre of air. Equivalent to 1 x 10^{-15} of a cubic metre.
fg m^{-3}	femtograms per cubic metre of air. Equivalent to 1 x 10^{-18} of a cubic metre.

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REPORTING ON

Persistent *Organochlorines* IN New Zealand

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