Ministry for the Environment
Manatū Mō Te Taiao

Environmental performance indicators

Technical paper No. 37 Toxic

Review of Environmental Performance Indicators for Toxic Contaminants in the environment – air, water and land.

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Signposts for sustainability

TABLE OF CONTENTS

APPENDICES

A. Review of Priority Toxic Contaminant Lists.

B. EPI Toxic Contaminant Programmes: Case Studies.

C Major sources of aquatic contaminants and environmental monitoring studies in New Zealand. (Source C Hickey, NIWA, 1998).

D. The U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Programme for Evaluating Contaminants in Tissues of Freshwater Biological Organisms.

LIST OF TABLES

EXECUTIVE SUMMARY

This report presents the scenarios for the development of Environmental Performance Indicators for toxic contaminants for inclusion in the Ministry for the Environment's overall Environmental Performance Indicator (EPI) Programme. An initial list of priority toxic contaminants was developed based upon a number of overseas examples as well as other relevant toxic contaminant and pollutant release inventories and registers in the USA and Canada. This framework was evaluated based upon the specific knowledge of the toxic contaminants either unique to or absent from the New Zealand environment.

In the development of the toxic contaminant indicators for the overall EPI programme, Stage 1 indicators were developed with a view to take full advantage of existing monitoring and data collection programmes, or for which data collection could be readily established. Stage 2 contaminants were those for which development or research would be needed before their inclusion in the programme could be considered. The extent of funding available for environmental indicators in New Zealand will dictate, in practical terms, the options for the selection of indicators that might form the core group of the toxic contaminant indicators. This has influenced the hierarchical approach taken in the overall selection and staging of the indicators.

A wide range of potential toxic contaminant indicators were identified. This was reviewed, and a list of 9 contaminants were identified which would be suitable to the New Zealand context. It was also noted that it would not be practical to implement such an extensive list of toxic contaminant indicators at the commencement of an EPI programme as it would likely result in significant delays in the implementation of the overall programme. The indicators chosen are mainly state indicators. While the importance of pressure and response indicators is acknowledged, the need to select indicators which will be integrated into an overall EPI programme and be required to comment, at least initially, on the state of the New Zealand environment on a regional and national level.

The toxic contaminant indicators chosen have been divided into two groups, Group 1 and Group 2. Group 1 are recommended to be implemented at the outset of the EPI programme and Group 2 to be established at some later date following a further review further prior to their inclusion in the overall EPI programme.

The recommended Group 1 indicators included: specific aspects of air quality, freshwater (eels / sentinel organisms), marine (sentinel organisms) and human (breast milk). Also recommended within this group the establishment of a toxic contaminants register or similar inventory, either as a subset of a larger chemical register or as a one dealing specifically with toxic contaminants.

1. INTRODUCTION

1.1 ENVIRONMENTAL PERFORMANCE INDICATORS

There is an ever-increasing public awareness in New Zealand of environmental issues. Frequent media coverage in relation to matters such as landfill operations, dredging activities, land contamination and even in relation to specific substances such as 1080 (sodium fluoroacetate) are a testament of New Zealander's concern about their environment. Even New Zealand's core agriculture-related sectors have fallen under the public's eye as is evident by concerns relating to the discharge of pesticides, agricultural wastes, and wool scouring, the discharges from which have been shown to have a high toxicity to some native species.

Understanding the condition of the New Zealand environment, being able to identify the causes of problems and then determining a solution to these problems is an essential undertaking fraught with difficulties. The inter-related nature of the environment and its components, along with the addition of the effects of human activities, means it is a complex system to understand and interpret. And so, simple questions regarding the health and state of air, water or ecosystems are very difficult to answer.

One means of providing this information is to develop understandable measures or indicators which either singly or in combination provide information on the quality of the environment. Indicators are used extensively by our society as measures of society's health. People accept indicators such as blood pressure monitoring as part of their daily lives. These measures can then serve as reference points for future measurements. Using these measures over time, decision makers or managers can determine the effectiveness of environmental management decisions and determine whether additional (or less) intervention is required. As environmental indicators are a decision making tool, it is essential that the indicators which are used are both relevant to the questions being asked and readily understandable.

Toxic contaminants are released to the environment by a wide range of activities, many of them an integral part of our everyday lives. This report describes indicators which can be used for the development of indicators of toxic contaminants for inclusion in the Ministry for the Environment's (MfE) Environmental Performance Indicator (EPI) Programme.

1.2 TOXIC CONTAMINANTS

Chemicals within the environment represent a range of contaminant types from the extremely toxic (e.g., 'sheep dip' - albendozol) to those with a comparatively low toxicity (e.g., ammonia in discharges from wastewater treatment plants, farms etc.,) which may differ greatly in their overall mass load to the environment. While some bioaccumulate strongly in organisms (e.g., organochlorines), others induce specific bio-chemical responses and yet others show effects largely by mortality on sensitive species. The varied nature of these toxic contaminants presents a challenge in detecting their presence and effects in the environment.

Toxic contaminants are commonly defined as those chemicals which give rise to some level of adverse biological effects to the living components of natural systems or humans, and can be liquid, gaseous or solid/particulate. The word ‘toxic’ in a strictly scientific sense, means the ability to cause mortality (i.e., death). However, it is now common practice to call any contaminant which produces an adverse biological effect ‘toxic’.

For the purposes of this document which focuses on the environment, the definition of toxic contamination has been limited to chemicals or contaminants which adversely effect biological or human systems.

Toxic contaminants are a now a major category of stress on the ‘natural’ environment largely as a consequence of human activity. It is important to understand that toxic contaminants are not necessarily static in the environment but can move through various states, phases or media and through various trophic levels in an ecosystem. If a contaminant is short-lived it may be broken down before its toxicity can be realised, or if a toxic contaminant is not mobile it is unlikely to be taken up by organisms. However, if the contaminant is stable and mobile it has a much greater chance of affecting organisms.

In certain cases, toxic contaminants that dissolve in fats may be retained for significant periods of time by organisms. Hence toxic contaminants will be subject to *bioaccumulation* i.e., an increase in concentration from the environment to the organism and biomagnification i.e., the tendency of contaminants to concentrate from one link in a food chain to the next.

In considering sustainable environmental management, it must be remembered that there are many beneficial aspects to the use of toxic chemicals particularly in the management of pests which destroy food harvests or carry disease. The use of toxic contaminants should accordingly be assessed in terms of a costs and benefits evaluation. For example, the use of DDT is banned in most developed countries on the basis that in those countries the environmental cost associated with its use greatly outweighs its benefits. However DDT is still used extensively in developing countries because it still the most effective means of malaria control. In this case, the human health benefit is considered to outweigh adverse environmental effects.

1.3 ROLE OF DECISION MAKERS

Regional and Territorial Authorities, alongside central government have an integral role in resource management as set out in the Resource Management Act 1991. Part of this process entails the selection and implementation of environmental performance indicators as a basis for decisions relating to sustainable management of resources. The information needs of the decision maker in this regard will drive the design of the overall toxic contaminant indicator programme. The information generated by the programme represents a distilled and concise indication of the state of the New Zealand environment.

Who is the decision maker? The decision maker is not represented by a single individual but rather represents a decision making process. Decisions concerning the state and therefore the overall management of the New Zealand environment requires distilled information as to the actual state of the environment. Decisions are made involving consultation and informed options and it is this process which required appropriate information such as that provided by indicators. An indicator is a tool which allows the decision maker to determine whether things are getting better or worse. For example, is the air quality with New Zealand's urban areas improving or getting worse?

The role of the decision making mechanism is to drive the design of the indicator programme in so far as the information which is generated allows for informed policy to be developed or to measure the success of existing environmental policy and laws.

1.4 THE PURPOSE AND STRUCTURE OF THIS REPORT

In this report and other documents such as report on the State of the New Zealand Environment and Proposals for Air, Freshwater, and Land (MfE, 1997a, b), MfE sets out its rationale for the development of a range of EPI scenarios for New Zealand. This report presents the scenarios for the development of Environmental Performance Indicators for toxic contaminants in the following manner:

- Section 2 provides an overview of MfE's indicators programme.
- Section 3 discusses the relevance of toxic contaminants in the development of an EPI programme, describes key concepts surrounding toxicity and the identification of priority contaminants overseas and in New Zealand.
- Section 4 presents background information relevant to the discussion of indicators for toxic contaminants. In particular, the fate of toxic contaminants in the environment.
- Section 5 presents and discusses aspects of a number of overseas indicator programmes. Information is also provided in relation to several international and local monitoring programmes that have relevance to indicators programmes.
- Section 6 summarises what is currently being done to monitor toxic contaminants in New Zealand.
- Section 7 identifies a preliminary list of potential indicators for toxic contaminants for New Zealand.
- Section 8 sets out options funding and implementation of toxic contaminant indicators in New Zealand.

2. EPI PROGRAMME

2.1 INTRODUCTION

Following the release of the October 1997 document entitled *Environmental Performance Indicators Discussion Document,* MfE convened a series of meetings throughout New Zealand to discuss issues raised within the document and to solicit a response from the public at large concerning the overall content. The public was encouraged to prepare submissions and comment on the material which was presented. An overall summary of the submissions received was prepared (Roxborough, 1997) and those matters of direct relevance to the establishment of toxic contaminant indicators (TCI) as part of an overall New Zealand EPI are outlined below.

2.2 OVERVIEW OF SUBMISSIONS

2.2.1 General

There was a general agreement amongst the submissions that a nationally consistent and common database for indicators of air, water and land was a positive undertaking for New Zealand. There was specific comment made that properly established and implemented TCIs would offer an opportunity to provide a widely useable, cost effective mechanism to measure the state of the New Zealand environment at large, and to a lesser degree the performance of legislation and regulatory bodies.

In balance, it was noted that an ecosystem focused programme dealing primarily with the life supporting capacity of the environment had the potential to limit information sharing (by other organisations) through the exclusion of human effects in the overall EPI programme. It was noted that there is an interdependence of ecosystem and environmental health, and social and economic well-being.

Broadly, the use of a Pressure-State-Response framework for the development of the EPI programme was supported.

2.2.2 Toxic Air Contaminants

Generally, comments were made in relation to the selection of appropriate air toxics as indicators. This was related both to the relevance of the indicator within a city or region and the scale of the monitoring or programme.

There was some discussion relating to the precise methodology of any air toxics monitoring programme as it related to capital cost of equipment and maintenance. It was noted that $PM_{2.5}$ should be considered as Stage I indicator based upon its emergence overseas as a critical air toxic. Further, there was discussion relating to the adoption of available real-time particulate monitoring technology. Hydrocarbons, VOC's, PAH's, dioxins, pesticides and metals were specifically discussed in terms of their appropriateness as Stage 1 air indicators. It was also recommended that indicators generally be linked to meteorological measurements.

There was support for vehicle emissions and visibility as Stage 2 indicators. Visibility was generally accepted as a major indicator but it was noted that more work was required to clearly establish a definition for this indicator.

In relation to the implementation of a monitoring network in New Zealand, it was recommended that sensitivity be applied in the level and type of monitoring for cities reflecting the specific nature of the conditions (i.e., smog issues within Christchurch). As a follow-on from this, it was recommended that baselines levels be established within the natural environment to allow for appropriate conclusions to be drawn from fluctuations.

2.2.3 Water

In the development of water-related toxic contaminated indicators for New Zealand, there was a view that the indicators chosen be internationally consistent to enable comparisons between other international programmes.

Groundwater, it was noted, is a significant drinking water source and this should be reflected in the development of groundwater TCIs. There was support for the division of freshwater indicators into two broad categories - those describing the life supporting capacity of aquatic ecosystems, and those which reflect human uses and values. It was recommended that the link between groundwater and surface water should be reflected by appropriate indicators. It was also noted that the inclusion of pressure indicators was important.

Comments of a specific nature included are summarised below

Table 2.1 Summary of Submissions relating to Water Toxic Contaminant Indicators for Water

• The monitoring of toxic contaminants was essential. TCIs for water should include dioxins, metals, hydrocarbons, pesticides, and geothermal indicators. • Support for the use of eel as Stage 2 river TCIs. • General agreement that TCIs be adopted for metals, organic solvents and toxic compounds.	• Support for the use of periphyton in rivers as TCIs. It was noted that interpretation of data could be problematic. Macroinvertebrate indicators (e.g., MCI's) were viewed as important. • Groundwater state indicators be developed which are consistent with drinking water.

2.2.4 Land

It was noted in relation to soil health that indicators would not be sufficiently sensitive to differentiate between land which is degrading, recovering from degradation and has already degraded. In response to this, it was recommended that further research be undertaken in this area.

It was noted that the use of soil biological properties as Stage II indicators are specifically relevant in the context of contaminated land as they are often directly affected (negatively and positively) by contaminants (pesticides, etc.). As a general comment, it was noted that special consideration is required in the understanding of proposed indicators and their meaning.

2.3 INFORMATION NEEDS AND MANAGEMENT

Although it was recognised that Councils undertake a wide range of monitoring, it was noted that there are cost issues which must be addressed regarding the use of Council collected information in a National EPI programme.

While it was noted that any collection and collation of existing data centrally would be beneficial, an effective information management system would also need to be developed - both quality control and quality assurance - for the collection, collation, management and interpretation of data. There was interest in a mechanism which would be put in place to support such a programme.

Comments were provided concerning a proposed clearing house system for information management. It was noted that the system would be better able to succeed if there was a 'buy-in' from the participating parties. This would be through the dissemination of standards throughout the widest range of potential users and providers, consultation at the system development stage and voluntary compliance mechanisms.

Given the need for data trackability and overall quality assurance, it was recommended to have a data reference capability. Of particular note was the recommendation that any system adopted could be enhanced by the recording of other peripheral sources of data to support additional indicators or uses which may develop over time.

3. TOXIC CONTAMINANTS

3.1 THE NEW ZEALAND SITUATION

The RMA (1991) definition of "contaminant" includes:

> *"any substance (including gases, liquids, solids, and micro-organisms) or energy (excluding noise) or heat, that either by itself or in combination with the same, similar, or other substances, energy or heat -*
>
> *(a) When discharged into water, changes or is likely to change the physical, chemical, or biological condition of water; or*
>
> *(b) When discharged onto land or into air, changes or is likely to change the physical, chemical, or biological condition of the land or air onto or into which it is discharged:".*

The New Zealand HSNO Regulations which will define a 'hazardous' contaminant for the purpose of the HSNO Act (1996) are currently being drafted. The HSNO Act defines a "hazardous substance" as:

> *"any substance with one or more of the following intrinsic properties:…- toxicity (both acute and chronic); - eco-toxicity;"*

In addition, the recently published guidelines on timber treatment chemicals do not define "toxic contaminant" (MfE/MoH 1997).

It has been proposed (MfE 1994) that the following criteria based on acute toxicity (adopted from OECD guidelines) be used to define a hazardous contaminant. The threshold for various contaminants with toxic properties is presented in Table 3.1. A contaminant is considered hazardous if it meets any one of the threshold levels.

3.2 TOXICITY

3.2.1 Introduction

Toxic contaminants are defined in a variety of ways with various qualitative and quantitative descriptions within a range of monitoring and assessment programmes.

While chemical measurements can be made to establish the concentration of contaminants present, adverse effect measurements on living organisms are required to establish thresholds for effect. The toxic potential of a chemical is governed by its concentration at the site of effect and the length of time the organisms are exposed. Appropriate risk assessment of chemicals relies on having data on both toxicity and likely exposure concentrations.

Quantitative or numerical definitions encompass dermal, inhalation, oral and aquatic exposure limits. Qualitative or narrative definitions are based upon toxicological and environmental fate characteristics.

TABLE 3.1: HSNO Regulations - Definition of hazardous contaminants.

Criteria	Threshold Level
Acute Toxicity (oral or dermal)	LD_{50} is less than 5000 mg contaminant / kg body weight of test animal.
Acute Toxicity (inhalation- gases and vapours [1])	LC_{50} is less than 50 mg contaminants / l air.
Acute Toxicity (inhalation- dusts and mists [2])	LC_{50} is less than 12.5 mg contaminants / l air.
Skin Irritation	The pH is less than 2 or greater than 11.5 or Draize Grade is greater than 1.5 for either erythema or oedema.
Eye Irritation	The pH is less than 2 or greater than 11.5 or Draize Grade is greater than 1 for either corneal opacity or iritis or Draize Grade greater than 2 for either conjunctival redness or chemosis.
Or results in the following effects	• **Sensitisation**: Any positive reaction on challenge. • **Mutagenicity**: Any positive reaction in vivo or in vitro assays. • **Reproductive / Developmental / Teratogenic Effects** (statistically significant biological effect [3]). • **Chronic Toxicity** (statistically significant biological effect [3]). • **Or any other statistically significant biological effect**.

1 Gases: is completely gaseous at 20 °C at a standard pressure of 101.3 kPa. Vapours: at 50 °C have a vapour pressure greater than 300 kPa

2 Dusts and mists: the test atmosphere contains greater than 90% particles with an aerodynamic diameter of less than 10 microns.

3 Statistically significant biological effect: a dose-response effect above a recognised background history for the test animals. Statistical significance is to $P < 0.05$.

Toxic contaminants have the ability to cause an adverse effect or negative response in organisms (including people) and it is this toxic response characteristic which serves as a criterion for the determination of whether a contaminant is toxic.

3.2.2 Factors Involved in Defining Toxicity

A toxic response may be in the form of an acute or chronic effect. There are a number of factors which are used to define toxicity and these are discussed in the following sections. It is important to recognise the exposure routes for air toxics fall into two broad categories - direct exposure (mainly through inhalation) and deposition (to skin, plants, water and soil). It is also important to recognise the time scale of effects. These can range from immediate (say breathing acid gas causing choking) to extremely long term (say a lifetime exposure to benzene or heavy metals reducing life expectancy).

Acute Toxicity

A toxic response may be in the form of an acute or chronic effect. Acute effects occur within a relatively short period of time, usually within days of exposure. Lethality is the end-point normally associated with acute toxicity where the benchmarks of toxicity are the LC_{50} (the concentration lethal to 50% of the test organisms) and LD_{50} (the lethal dose to 50% of the test organisms). Acute toxicity is usually determined in controlled laboratory animal exposure studies. The smaller the amount of the chemical which causes the toxic effect, the more 'toxic' the substance.

Acute toxicity can be further defined in terms of the route of exposure as follows:

- Oral and dermal toxicity.
- Respiratory toxicity.
- Aquatic toxicity.
- Phytotoxicity.

Chronic Toxicity

Chronic toxicity refers to long term effects (months or years) resulting from either a short exposure to a chemical which has long term health effects (e.g., cancer) or after a long period of exposure, typically continuous exposure to low levels of toxic chemicals. As part of the mandate of the World Health Organisations (WHO) - International Agency for Research on Cancer (IARC), carcinogenic data for a wide range of individual contaminants has been reviewed. WHO has assigned contaminants that have been evaluated into a series of carcinogenic classes (Table 3.2).

TABLE 3.2: IARC carcinogenic classes.

Classification by Group	Characteristics
Group 1	Carcinogenic to humans.
Group 2A	Probably carcinogenic to humans.
Group 2B	Possibly carcinogenic to humans.
Group 3	Not classifiable as to carcinogenicity to humans.
Group 4	Probably not carcinogenic to humans.

The IARC has categorised more than 600 contaminants. This classification system is followed by both the USEPA and Health and Welfare - Canada.

Mutagenicity is another factor which is considered in the assessment of contaminant toxicity. Mutagenic contaminants are those which are capable of causing damage to genetic material (i.e., DNA). As many mutagenic agents are considered potentially genotoxic, teratogenic and carcinogenic, the carcinogenic classifications typically provide suitable classification of this class of contaminants.

Endocrine Disrupting Chemicals are exogenous natural or anthropogenic agents that produce reversible or irreversible adverse effects by interfering with the synthesis, storage, release, secretion, transport, clearance, binding action, or elimination of endogenous hormones in the body.

A growing body of scientific research indicates that some chemicals and pesticides may interfere with the normal functioning of human and wildlife endocrine systems which control processes such as reproduction and development. These endocrine disruptors may therefore cause a variety of problems with development, behaviour and reproduction in a wide range of species.

Although some pesticides and industrial chemicals have undergone extensive toxicological testing, it is unclear whether this testing has been adequate to detect the potential for these chemicals and pesticides to be endocrine disruptors. There is widespread agreement that the development of screening and testing programs is appropriate if the identification and control of potential endocrine disruptors is to be achieved.

The USEPA's Office of Prevention, Pesticides and Toxic Substances (OPPTS) has established the Endocrine Disruptors Screening and Testing Advisory Committee (EDSTAC) to provide advice and counsel to the Agency on a strategy to screen and test chemicals and pesticides that may be the cause of endocrine disruption in humans, fish and wildlife.

Persistence is a characteristic of the toxic contaminant’s environmental behaviour rather than a direct characteristic of toxicity. Persistent chemicals are of concern because they have the potential to accumulate to high concentrations with extended use. Persistence is commonly defined by an environmental half-life which is the time it takes for half of the chemical’s original chemical mass to disappear from the environment. Definitions for persistence within the environment adopted by various agencies are set out below in Table 3.3.

The British Columbia - Ministry of the Environment (Canada) has defined toxic and persistent contaminants using the criteria set out in Table 3.4.

TABLE 3.3: Definitions of persistence.

Agency	Definitions for Persistence	Details of Definitions for Persistence
Great Lakes Water Quality Agreement (GLWQA)	Half-life in water	8 days
Ontario Ministry of the Environment (MOE)	Half-life in water, sediment, soil	50 days
German Federal Environment Agency	Air	10 days
Environment Protection Act (EPA) - Canada - Air Resources Branch (ARB) - Environment	Air	30 days

Canada		

TABLE 3.4: British Columbia Ministry for the Environment (Canada) - Toxic contaminant definitions.

Primary Toxic Criteria
• Oral dosage of 50 mg/kg results in LD_{50}. • Dermal dosage of 200 mg/kg results in LD_{50}. • Inhalation of 1500 mg/m^3 over 4 hours exposure results in LD_{50}. • Aquatic 96 hour LC_{50} >10 g/m^3 (organisms). • Human toxicity - IARC category 1 or 2A.
Supplementary Criteria
• Aquatic 14 day EC_{50} >100 g/m^3 (plant growth and biomass yield). • Contaminants listed as group C agent (cause reproductive toxicity). • Contaminants which exhibit non-carcinogenic chronic toxicity as determined by approved bioassay. • Carcinogenic potential in non-human biota a concern - contaminants classified as IARC group 2B.
Persistence
• $T_{1/2}$ >30 days in air. • $T_{1/2}$ >50 days in soil, sediment, water or other media. • BCF >100 in freshwater fish.

LD_{50}: Dosage level resulting in a 50% mortality level in a sample group.

Bioaccumulation is the ability of a contaminant to bioaccumulate (accumulate in an organism to higher concentrations than present in environmental media) and/or biomagnify (accumulate to higher concentrations at higher trophic levels). These properties are generally related to the chemical's affinity for fatty tissues and are therefore inversely related to its water solubility. This solubility is generally expressed as an n-octanol/water partition coefficient (K_{ow}) and the proposed threshold criteria for this value is 1000 (i.e., log K_{ow} >3) (MfE, 1994).

3.3 OVERSEAS DEFINITIONS OF TOXIC CONTAMINANTS

Two examples of international regulations governing toxic contaminants are the Clean Water Act and the Clean Air Act in the United States, implemented to control the introduction of contaminants to the American environment.

The USEPA Clean Water Act regulates the discharge of conventional pollutants and toxic contaminants. Section 307 of this Act requires the regulation of toxic pollutants. By 1977, the

Act specifically identified 129 toxic contaminants referred to as the ‘priority pollutant list’. Priority pollutant lists are discussed in greater detail in Section 3.3 below.

Section 112 of the USEPA Clean Air Act regulates toxic contaminants that are harmful to human health. Toxic contaminants are also regulated in the United States by additional legislation namely, the Toxic Substances Control Act (TSCA), the Resource and Conservation Recovery Act (RCRA), the Comprehensive Environmental Rehabilitation Compensation and Liability Act (CERCLA), the Superfund Amendments and Re-authorisation Act (SARA) Title III, and the Safe Drinking Water Act (SDWA), and the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA).

The OECD classification criteria for the aquatic environment is set out in Table 3.5. A similar type of classification system is likely to be adopted in New Zealand as part of New Zealand HSNO regulations.

TABLE 3.5: OECD aquatic acute toxicity criteria.

	Criteria		
Toxicity Test	**Very Toxic**	**Toxic**	**Harmful**
96h LC_{50} fish	$x \leq 1.0$ mg/l	$1.0 < x \leq 10$ mg/l	$10 < x \leq 100$ mg/l
or			
48h EC_{50} Daphnia	$x \leq 1.0$ mg/l	$1.0 < x \leq 10$ mg/l	$10 < x \leq 100$ mg/l
or			
72h EC_{50} algae	$x \leq 1.0$ mg/l	$1.0 < x \leq 10$ mg/l	$10 < x \leq 100$ mg/l
Bioaccumulation	$K_{ow} > 1000$ unless Biological Concentration Factor (BCF) is < 100		
Bio-degradation	BOD_5/COD ratio < 0.5		

x: concentration of the contaminant

Using the criteria in Table 3.5, the OECD classification system classifies any contaminant which meets one of the following criteria as “dangerous to the environment”:

Table 3.6 OECD Contaminant Criteria.

Classification	Description
Very Toxic	• acute aquatic toxicity only
Toxic	• aquatic acute toxicity plus bio-accumulating
Harmful	• aquatic acute toxicity plus bio-accumulating and not readily biodegradable

These criteria can also be applied to other media, particularly soil. However, additional factors such as mobility in soil, mineralisation and adsorption to soil particulate matter must also be considered.

3.4 PRIORITY LISTS

From the above discussion it is clear that many factors have to be considered when considering the risks of the wide range of chemical contaminants now present in the environment. The sheer number chemicals produced and released to the environment and our limited economic capacity to deal with these problems has led to the formulation of 'chemical priority lists' to provide a systematic means of dealing with environmental contamination.

Regulatory agencies have employed toxic contaminant definitions (Section 3.2) to develop 'toxic contaminant lists' for a variety of regulatory and legislative purposes. Most commonly, the lists are used as 'priority lists' which identify the chemicals of greatest concern for that given agency or country. While some priority lists are quite extensive (such as the 129 chemical USEPA priority pollutant list), others are quite short (such as the United Kingdoms "Red List" of 22 chemicals).

Successful prioritisation of toxic chemicals relies upon the availability of data on the toxicity and environmental behaviour of chemicals. In addition, there is limited information on the extent of the use of many chemicals in global commerce.

In a different approach, the OECD has developed a "High Production Volume" list of chemicals which lists 4,103 chemicals which are manufactured or used in quantities of over 1,000 tonnes per year by at least one member country. This assessment focuses initially on the possible dose of the chemical. From available toxicity persistence and accumulation data, the OECD has identified a sub-set of these chemicals for further investigation due to their potential to cause environmental or human toxicity.

A similar study has recently been released by the USEPA on the 2,863 organic chemicals produced or imported at or above 1 million pounds per year (USEPA, 1998). This report also extensively screened available information sources for basic data on the human and environmental toxicity and chemical properties (Screening Information Data Set, SIDS, OECD 1990) of these compounds This report concludes:

> *"43% of the US HPV chemicals (1,216 of 2,863) are identified as having no SIDS test data (i.e., no basic screening data) of any type available and only 7% of the chemicals (202 of 2,863) are reported as having data available for all of the SIDS data types. .... "*

To provide a means of effectively prioritising chemical priorities, the USEPA has recently released a "Waste Minimisation and Prioritisation Tool" (USEPA, 1997a). This system accesses a database containing persistence bioaccumulation and toxicity (PBT) data on 879 chemicals. To quantify chemical risks the PBT data is combined with production use or discharge data. However in the absence of production or use data, the program provides a relative level of concern for each chemical to produce a screening level assessment of potential chronic risks that chemicals may pose to human health and the environment.

Identifying the priority for toxic contaminants is a complex matter as it is completely dependent upon the objectives of the prioritisation. For this reason, lists of priority contaminants developed for the assessment of effects in terrestrial and marine ecosystems will differ between each other as well as between those created solely for the consideration of human toxicity. Overall, the development of any list for the purpose of assessing national environmental health must take into account a wide range of clearly defined factors. Key factors relevant to toxic contaminants in each of the core media of the environment are set out in Table 3.6.

TABLE 3.6: Key toxicity factors within media.

Air • Phytotoxicity • Dermal Toxicity • Respiratory Toxicity **Terrestrial Biology** • Phytotoxicity • Dermal Toxicity • Oral Toxicity • Bioaccumulation Factor	**Water** • Aquatic Toxicity • Oral Toxicity **Aquatic Biota** • Oral Toxicity • Bioaccumulation Factor **Human** • Oral Toxicity • Inhalation Toxicity

3.5 RELEASE INVENTORIES

Another approach to toxic contaminant monitoring is the establishment of release or emission inventory programmes or registers. These programmes require reporting to central government on the importation, use and discharge of specified chemicals to the environment.

The most extensive current programme is the USEPA Toxics Release Inventory (TRI) which lists over 650 chemicals whose use, transfer and disposal must be reported to the federal government. The TRI was established under Section 313 of the Emergency Planning and Community Right-to-Know Act 1988. The aim of the inventory is to assure that local communities have access to information on toxic contaminants in their local environment. To this end, data is readily accessible on the World-Wide Web at http://www.epa.gov/enviro/html/tris/tris-overview.html. Data can be accessed on a national, regional or local basis.

The Canadian National Pollutant Release Inventory (NPRI) list 176 chemicals that must be reported if used or released in quantities greater than 10 tonnes per year. To facilitate reporting, as with the USEPA TRI, data may be submitted on-line at a World-Wide Web site.

The Australian National Environmental Protection Council (NEPC) has produced a Draft National Environmental Protection Measure which includes designation of the chemicals to be reported in the National Pollutant Inventory. This list includes 95 high production/use chemicals and wastes as well as toxic contaminants.

Release inventory programmes are invaluable information collection systems for the monitoring of stresses on the environment. As such, they provide ideal databases for the development of pressure indicators. The accumulated data can also be used to assess national impacts of contaminants

The development of a similar pollutant inventory system has the potential to assist New Zealand authorities in the management of toxic contaminants in the environment. The MfE is currently conducting a scoping study to determine the possible need and options for the development of a release register or inventory (or the like) for New Zealand.

3.6 WHAT ARE NEW ZEALAND'S PRIORITY TOXIC CONTAMINANTS?

Identifying the specific prioritisation for toxic contaminants must take into account the toxicity to biological systems, effects on human health, persistence and accumulation, as discussed in previous sections. In addition, their prevalence and usage in New Zealand must be considered. A contaminant which has not been imported, produced or used in New Zealand would not likely be on a New Zealand priority pollutant list. The exception for this would be in the case of trans-boundary pollutant migration (e.g., Australian emissions) or global re-distribution of contaminants (e.g., PCBs). There are a number of chemical compounds (specifically manufactured pesticides) which have not been imported or used in New Zealand in large amounts (e.g., Toxaphene and Mirex). In contrast, Substance 1080 (sodium fluoroacetate) is widely used in New Zealand but is used in only limited amounts in other countries and so does not feature on many existing priority or emission lists used by overseas agencies.

In order to address New Zealand's priority toxic contaminants, a list cross-referencing toxic contaminants from overseas examples has been compiled. This has been overlaid with input from New Zealand researchers to ensure that toxic contaminants unique to, or absent from, New Zealand are considered. This list is presented in a series of tables organised by contaminant groups in Appendix A.

The broad contaminant groups are:

- Persistent Organic Pollutants (POPs).

- Metals.
- Polycyclic Aromatic Hydrocarbons (PAHs).
- Pesticides/Herbicides.
- Phthalates.
- Others (Asbestos, Substance 1080, Paper Industry Chemicals).
- Ammonia and Nitrate.

For comparative purposes, the New Zealand list has been compared to a variety of other chemical prioritisation systems as described previously. Most notable are the USEPA Priority Pollutants List released in 1989. The list is also compared with the relevant toxics and pollutants release inventory and register lists for the USA and Canada. These lists specify the chemicals for which releases to the environment must be reported to federal governments on an annual basis.

To give some estimate of possible use in New Zealand, chemicals have been marked for their presence on the 1997 OECD High Production Volume (HPV) list. These are chemicals that are manufactured or imported in quantities in excess of 1,000 tonnes in 1997 by at least one OECD member state. In addition some chemicals have been identified as warranting the gathering of further information (i.e., Screening Information Data Set (SIDS)) for more detailed risk analysis.

The rationale for a toxic contaminant’s inclusion on the list is set out below

3.6.1 Persistent Organic Pollutants (POPs)

While POPs are no longer imported into, or used in large volumes within New Zealand, they are of considerable concern internationally. A significant international treaty on the regulation of POPs is to be negotiated in 1998. Many of the POPs are also proven or are suspected of being endocrine disrupting chemicals. The international concern for POPs can be seen in focus in USEPA and OECD research and regulation. Further information on POPs is available from the United Nations Environment Programme (UNEP) on the World-Wide Web at (http://irptc.unep.ch/pops/).

Of particular note within New Zealand are recent human milk survey results in New Zealand which have shown POPs occur in the human environment (Hannah *et al*. 1994). Certain POPs have also been demonstrated to accumulate in New Zealand wildlife species such as Hectors dolphin (MfE 1997a).

Finally, while the use of POPs has been greatly decreased world-wide, there are still believed to be on-going sources. There are considerable stockpiles of POPs in New Zealand in variously secure repositories. The phenomenon of regional and global redistribution of these chemicals is not fully understood. Until more New Zealand trend data is available for these environmental contaminants it would seem prudent to continue to undertake research and investigations in this area.

3.6.2 Metals

The metals listed in Appendix A are those that commonly occur in the environment due to human activity. In particular copper, chromium and arsenic (arsenic is a metalloid but is included here for convenience of discussion) are included due to their prevalence in the timber treatment sector within New Zealand (MfE 1997a, c). Other metals arise from other processes and are applied to land in sewage sludge. Mercury is a significant contaminant in geothermal areas as a result of geothermal power generation. Metals in the New Zealand environment were reviewed extensively by Smith *et al.* (1990).

3.6.3 Polycyclic Aromatic Hydrocarbons (PAHs)

This group of chemicals has been identified by MfE as being a significant toxic contaminant within New Zealand (MfE 1997a, b, d). A subset of the PAHs are known carcinogens. The list included in Appendix A are the USEPA 16 priority PAHs. Scope exists for limiting this group for analytical purposes to a few specific and indicative PAH compounds. The toxicity, prevalence and on-going sources of PAHs warrant continued monitoring in terms of their prevalence in, and loadings to, the environment.

3.6.4 Pesticides/Herbicides

The usefulness of these compounds is rooted in their toxicity to specific organisms and as such, are used in the control of those organisms. Exposure of non-target species can cause environmental damage. Typically environmental damage caused by these compounds tends to be in acute toxicity events where the compounds are present at high concentrations for relatively short periods of time.

3.6.5 Phthalates

These ubiquitous chemicals are used predominantly as plasticisers. The ability of many of this group to act as endocrine disrupting chemicals has focused considerable attention on their effects in the environment and on human health. Due to their ubiquitous occurrence and the absence of quantifiable risk data which these chemicals pose to the environment and humans, these chemicals feature in many current priority lists (e.g., USEPA, OECD, NPRI - Canada).

3.6.6 Others

3.6.6.1 Asbestos

The human health implications of this contaminant has been, and remains to be, widely accepted. It is not generally considered to be of environmental concern

3.6.6.2 Substance 1080

This compound has had widespread use in New Zealand for the control of possum. Due to 1080's high public profile and extensive use throughout New Zealand, this chemical warrants its inclusion on any priority list.

3.6.6.3 Paper Industry Chemicals

These are of concern in only a few specific locations within New Zealand. The use of EDTA has recently increased considerably due to limitations in the use of chlorine and chlorine dioxide.

3.6.6.4 Ammonia and Nitrate

Ammonia and nitrate are two key contaminants produced by the agricultural sector, natural resource industries (such as meat works and dairy) and by wastewater treatment plants. The effects of elevated concentrations of ammonia and nitrate are widespread around New Zealand. Nitrate is of concern principally in relation to groundwater quality and drinking water quality (refer New Zealand Drinking Water Guidelines). Ammonia is capable of exerting toxicity in surface waters.

3.7 DEVELOPING A NEW ZEALAND PRIORITY LIST

3.7.1 Introduction

It is obvious from the material presented above that there are a large number of toxic contaminants that can be identified as requiring further information and potentially, assessment. Monitoring and assessment of all such toxic contaminants would be prohibitive due to the logistics of data acquisition, programme cost, and information management needs. It is necessary to prioritise chemicals to ensure that the monitoring of toxic contaminants in New Zealand is focused to provide information on those contaminants which potentially have the most significant effect on ecosystem or human health.

As noted earlier, other countries have developed priority pollutant lists and in many cases these lists are extensive. The USEPA priority pollutant list contains a total of 235 contaminants covering a wide range of toxic contaminants. Other countries and assessment programmes have reduced the number of toxic contaminants being monitored to provide a more manageable basis for regional, national, and international programmes. The Great Lakes Programme is briefly discussed below.

3.7.2 Great Lakes Program

In developing the Great Lakes Strategy, Environment Canada and the USEPA focused the strategy on those toxic contaminants that had been identified for "priority action" as a result of an assessment involving multiple screening criteria and processes. These were contaminants present in water, sediment or biota that were imparting a toxic effect, either singly or synergistically, on biota or humans. Two levels of contaminants were identified as set out in Table 3.6.

Level one contaminants were identified which would receive the greatest attention and would be the focus of management to eliminate them from discharges to the Great Lakes. The level two toxic contaminants were which were identified by the United States and Canada as having the potential to impact the environment of the Great Lakes through use or release. Reduction initiatives are encouraged for these contaminants. Consultation associated with the list occurs through the biennial State of The Lakes Ecosystem Conference (SOLEC).

TABLE 3.7: Great Lakes Level 1 and Level 2 toxic contaminants.

Level	Contaminant
ONE	• Aldrin/dieldrin • Benzo(a)pyrene • Chlordane • DDT(including DDD & DDE) • Hexachlorobenzene • Alkyl-lead • Mercury and compounds • Mirex • Octachlorostyrene • PCBs, PCDD (Dioxins) and PCDF (Furans) • Toxaphene
TWO	• Cadmium and cadmium compounds • 1,4-dichlorobenzene • 3,3'-dichlorobenzidine • Dinitropyrene • Endrin • Heptachlor and (heptachlor epoxide) • Hexachlorobutadiene and hexachlorocyclohexane • Pentachlorobenzene • Pentachlorophenol • Tetrachlorobenzene (1,2,3,4- and 1,2,4,5-) • Tributyl-tin • PAHs

3.7.3 Advancing a Priority List for New Zealand

To provide an initial evaluation of a priority list of toxic contaminants for New Zealand, a ranking of the contaminants in the primary list was undertaken through consultation with project members. Each contaminant was ranked from 1 (least significant) to 5 (very significant) as a toxic contaminant in each of the key media:

- Air
- Terrestrial Biota
- Freshwater
- Freshwater biota
- Marine water
- Marine Biota

Experts in the areas of air, terrestrial biota, freshwater, freshwater biota, marine water and marine biota conducted the preliminary assessment which was based upon the overall knowledge of each expert in their specific field of expertise and media knowledge for each constituent. Where the expert had no specific knowledge of a constituent or ranking, no ranking was completed.

The ranking identified a primary series of key toxic contaminants for which contributors considered there was sufficient knowledge to promote their inclusion in monitoring programmes and environmental assessments. A second series of constituents was identified for which there were intermediate rankings recorded, and a third ranking which included those constituents of either low ranking or for which there was little specific knowledge. It is emphasised that any hierarchical list such as this should be viewed as dynamic and that it will change as more environmental or toxicological information becomes available on any given contaminant.

The toxic contaminants identified from the Category 1 list are shown in Table 3.8.

TABLE 3.8: Preliminary category one toxic contaminants in New Zealand.

Preliminary Category One Toxic Contaminants	Examples
Metals	• Arsenic, cadmium • Copper • Chromium • Lead • Mercury • Zinc.
Polyaromatic Hydrocarbons	• PAHs (16 two to five ring PAHs)
Polychlorinated Biphenyls	• Specific priority congeners
Organochlorine Pesticides	• DDT • Dieldrin • Chlordane
Volatile Aromatic Hydrocarbons	• Benzene • Ethylbenzene • Toluene • Xylene
Volatile Chlorinated Aromatics	• Chlorobenzene
Chlorophenols	• Pentachlorophenol
Oxygenated Compounds	• 2,3,7,8-Dioxin and -Furan congeners
Miscellaneous Compounds	• Cyanide • Nitrate • Ammonia

4. TOXIC CONTAMINANTS, MEDIA AND MONITORING

4.1 INTRODUCTION

As discussed in Section 3, toxic contaminants have a wide variety of chemical and physical properties which influences their effects on and fate in the environment. These differing properties result in different chemicals or classes of chemicals accumulating in different parts, or ‘compartments’, of the environment. The extent to which this behaviour has been investigated in the past and can be predicted for the future greatly aids in monitoring, as programmes can focus on key areas or environmental compartments to evaluate environmental trends in contamination.

In terms of the monitoring of toxic contaminants, the air and water are of particular significance as they represent the two major environmental “mobile phases”. The bulk transport of contaminants within and between regions must occur via these media. The significance of air and water transport of contaminants on an intra-hemispheric basis has been compared by Iwata *et al.* (1993). While the effect of damming rivers on the transport of contaminants has been demonstrated by Giesy *et al.* (1994a). In contrast soils and aquatic sediments act as the major ‘store houses’ or reservoirs of a range of contaminants. For example, New Zealand soils still contain significant levels of DDT group compounds which are slowly being released to the environment.

Classically, toxic contaminant indicators involve the measurement of the contaminant in the media (e.g., air, water, soil etc.,) or organisms within the media (e.g., invertebrates, fish, mammal, birth etc.,). The data obtained provides a measure of the state of that environmental compartment or component. Other indicators can be developed that address pressure on the environment (e.g., various components of a TRI). These classical state indicators form the backbone of most environmental monitoring in New Zealand at present (refer Section 6).

The monitoring of the state of the environment is clearly the most direct method of addressing current contamination levels. However, these measures do have some disadvantages in a management framework. Firstly, they do not allow the prediction of future impacts in that a current chemical concentration cannot be used to estimate future levels if continuing inputs are occurring to the system. Secondly, state monitors are relatively slow to react particularly for chemicals that remain in the environment for a long time. This means that in a management framework alterations in state monitors do not provide a rapid enough indication of societies response to environmental contamination. Therefore state indicators do not indicate pressure on the environment and they are generally too slow to indicate response mechanisms?.

4.2 AIR

4.2.1 Background

Most of the environmental toxic contaminants in the environment can occur in gaseous or particulate form in the air. For much of the time, and in most places, the concentrations of these contaminants are well below levels which would cause any significant risk to the environment or to humans. However there are circumstances when concentrations can be higher and present significant risks.

Many of the risks associated with exposure to toxic chemicals are not well understood, and the range of potential contaminants is very wide and growing. This is an important general point about toxic contamination which must be recognised. The state of knowledge is such that risk levels are continually being developed and revised, and new contaminants are frequently added to the list.

Furthermore, there is substantial uncertainty about the risks, and by no means consensus. Dioxin is a good example - there are some who hold that there should be no dioxin in the environment whatsoever, as a single molecule can cause a cell mutation. However there are others who argue that zero risk is unattainable, and there is a maximum dioxin level which does not significantly add to the overall level of risk due to combined environmental factors.

4.2.2 Sources of Toxic Contaminants to Air in New Zealand

The sources of toxic contaminants to air in New Zealand fall into four broad categories, each of which may require a different type of indicator.

4.2.2.1 Point sources

These are typically specific industrial sources, many of which are regulated by a resource consent issued under the Resource Management Act (1991) and subject to specific monitoring. Where a significant discharge is recognised, it will usually be subject to monitoring. However there are circumstances where monitoring will not be adequate, and these include cases where the discharge is not known, and cases where a number of smaller industries can produce a significant cumulative effect. Emissions potentially include almost every toxic contaminant.

4.2.2.2 Mobile sources

Vehicles (e.g., cars, trucks, ships, aircraft) are recognised internationally as the major contributor to air contamination, including toxic contaminants. Emissions of toxic contaminants include volatile hydrocarbons (toluene, benzene, 1, 3 butadiene, and others), combustion products (PAH's, etc.), fuels additives (heavy metals, MTBF, and others) and ancillary emissions (metals and rubber from tyre wear). The measurement of any of these components of vehicle emissions would provide a suitable indicator for toxic contamination from this source. The proposed stage one indicators for air monitoring in New Zealand are CO, PM_{10}, NO_2, O_3, and SO_2. Measurement of any of the above toxic contaminant parameters could be easily integrated with sampling for the proposed stage one indicators.

4.2.2.3 Pesticide and Herbicide Spraying

The use of pesticides and herbicides in agriculture and horticulture poses a significant environmental and health threat principally due to the requirement that the chemicals used be toxic. The inappropriate use of such chemicals or inability to control their spread from the point of application represent the most significant sources of risk.

The sources include horticultural spraying, both fixed and aerial, forestry spraying, roadside spraying and even private garden spraying. Typical contaminants include insecticides (e.g., diazinon, malathion, chlorpyriphos, mevinphos), herbicides (e.g., 2,4-D, 2,4,5-T, triazines, triazoles, dipyridilium), fungicides (e.g., ethylenethiourea, mancozeb, dicarboximides) and miscellaneous metals (e.g., tin, mercury, copper, arsenic). A more comprehensive list is contained in the Standards New Zealand document NZS 8409 Agrichemical User's Code of Practice.

4.2.2.4 Natural

'Natural' sources of air toxics are not usually included (e.g., they are specifically omitted from the USEPA lists of toxic sources). However it may be relevant to include these in the New Zealand case because of the high level of geothermal activity in many parts of the country. Active geothermal sources can emit high levels of mercury, arsenic, boron and other metals (Timperley *et al.*, 1997). Due to human use of many of these geothermal resources it can often be difficult to distinguish the 'natural' from the anthropogenic component of the emissions.

4.2.3 Types of Monitoring

Monitoring of toxic emissions to air in New Zealand has focused on the use of concentration or state monitoring (see section 6). These existing monitoring programmes have amassed a significant database of information that will be invaluable in the development of environmental performance indicators

4.2.3.1 Biomonitoring

Due to the relatively rapid movement of air masses it can be difficult to effectively monitor the concentrations of toxic contaminants in air to gain an effective picture of contaminant levels.

For this reason recent interest has focused on the use of biomonitoring to provide a long term (months - years) integrative picture of the presence of toxic contaminants in air.

The use of vegetation as passive monitors of air contamination has been investigated by several groups. This work focused on the ability of waxy pine needles to absorb organic contaminants from air. One attractive feature of this method is that the years 'new' needles are easily identified and so only those needles recently exposed can be selected for analysis.

As with other biomonitoring procedures this method is attractive in that it provides integration over time rather than requiring expensive operation and maintenance of ambient air sampling equipment. It also has the potential disadvantage of being biased by local sources, and cannot provide any information on the nature of short term peaks, on synergistic effects, and potentially suffers for confounding effects due to differing absorption rates due to undetermined factors.

Research has been carried out on air pollution bio-indicators by Landcare Research for a number of years. Preliminary results have indicated that some lichens have specific value as bio-indicators of general air pollution as well as to industrial areas.

A range of plants have been used in biomonitoring studies. Lichens and bryophytes have been extensively used. The use of bryophytes, lichens, gymnosperms and other plants for monitoring metals, organic pollutants, gaseous pollutants, radionuclides has been reviewed in detail by MARC (1985, 1986). In New Zealand lichens, bryophytes and other plants have been used in relation to the assessment of potential air toxics arising in particular from large point sources such as industry and power stations.

4.2.3.2 Biomarkers

In addition to the specific measurement of air-borne toxic contaminants, there is also a linkage between air-borne toxic contaminants and acute and chronic health effects in humans. The key area of interest here is the use of biomarkers to predict chronic adverse health effects - in particular asthma, lung cancer and cardiovascular problems - of particular concern with regard to urban air pollution and health is the adsorption of PAHs to respirable particulates which are metabolised by cytochrome P_{450} dependent mixed function oxygenase in tissues.

In addition to in-vivo assessment of physiological response to toxic contaminants, test systems are being evaluated which can be utilised to determine the relative toxicity of extracts of particulate atmosphere pollutants. These extracts can be applied to whole animal and in-vitro models to assess the toxicity of complex mixtures. This provides a linkage between toxic contaminants and epidemiological studies (Adonis *et al.* 1997). In-vitro and whole animal models are being set up in New Zealand for routine measures such as induction of cytochrome P_{450} and immunotoxicological parameters.

4.3 LAND

4.3.1 Soil

The land environment is susceptible to the accumulation of toxic contaminants. Deposition of contaminants on particles settling from the air and in rain water act as on ongoing source of many contaminants. In addition many toxic chemicals are applied to the land during normal agricultural practices. The passage of water through soils has the capacity to leach chemicals deeper into the soil and in some cases into ground water. This passage of contaminants through soil is countered by the tendency of contaminants to adhere to soil particles and so remain stationary. The balance between these leaching and absorption phenomena determine the rate of passage of a chemical through the soil.

Soil contains many species and large numbers of bacteria which are essential to the health and function of the soil. Some of these bacteria are also able to breakdown some contaminants and therefore reduce levels of soil contamination.

The presence of toxic contaminants in soils can lead to transfer of these chemicals into vegetation and animals. As many of these products are human food items there exists the possibility of exposure of humans as well as wildlife. In addition the diet of many mammals and birds can contain 2-10% soil on a dry weight basis (Beyer *et al*. 1994).

4.3.1.1 Soil Contamination

The key causes of soil contamination in New Zealand fall into four groups:

- Agricultural use of pesticides and fertilisers.
- Roadside deposition of contaminants originating from motor vehicles.
- Atmospheric deposition of contaminants from short range (e.g., spraydrift) or long range atmospheric transport.
- Local contamination caused by specific industrial activity.

Agricultural use of pesticides and fertilisers, has resulted in the contamination of farmland with DDT and other organochlorine pesticides. In addition the use of phosphate based fertilisers has resulted in elevated cadmium concentrations in areas.

The influence of **roadside deposition**, arising from vehicle emissions has been studied in New Zealand by Ward *et al.* (1977a, b), Fergusson *et al.* (1980), Collins (1984) and Kennedy *et al.* (1988). Use of lead in petrol in New Zealand resulted in lead concentrations adjacent to roads which declined exponentially with distance away from the road.

Contamination by industry is, a site or catchment specific activity. The most well known examples of site specific contamination in New Zealand are associated with the timber treatment industry (MfE 1997c). A number of other industries are known to have historically resulted in soil contamination. These included gasworks (MfE 1997d) and battery smelters and factories (Ward *et al.* 1975, Chee 1982, Graham 1993). Specific emissions from other industries such as metal smelters and paper mills are generally monitored only in the media to which the industry emits (i.e., air or water).

Contamination associated with homes in urban areas in New Zealand is a less appreciated source of general contamination of New Zealand soils. Lead in garden soils has been examined in a number of studies because of concerns arising from the removal of lead based paints from houses (Jordan & Hogan 1975, Kjellstrom *et al.* 1978, Kennedy *et al.* 1988). Contamination also arises from the disposal of rubbish and coal ash and backyard incinerator ash in gardens.

4.3.1.2 Summary

Any examination of soil quality whether it be in remote, rural or urban areas needs to take into account specific factors such as soil organic matter content and soil particle size as both factors influence the accumulation and retention of contaminants. Soil sampling requires precise sampling and analysis techniques (depth, soil fraction tested, extraction techniques) to enable direct comparison between studies.

4.3.2 Vegetation

The effects of contaminants on vegetation are well known. This is particularly the case in relation to global and regional examples such as the effects of sulphur dioxide and acid rain in North America and northern Europe.

Plant indicator species which are sensitive to a particular contaminant have been used to detect elevated concentrations of contaminants through observations of the extent of injury to the plant (e.g., leaf necrosis etc., or damage at the cellular level).

On a global basis there have been a vast array of biomonitoring studies to assess the extent of accumulation of contaminants such as radio-nuclides, atmospheric deposition of metals and organic compounds from urban and industrial sources.

4.3.3 Terrestrial Biota

Terrestrial biota are commonly monitored as part of contaminated sites monitoring, investigation and remediation to determine levels of exposure to soil contamination (Talmage & Walton, 1991).

Work on earthworm biomarkers in New Zealand is reported in Eason *et al*. (1997). As an example of biomarkers in earthworms Neutral-red retention by coelemocyte lysosomes has been shown to be a suitable biomarker for organophosphate and polyaromatic hydrocarbon contamination in soils. Biomarkers are considered to be more sensitive indicators of exposure

than factors such as growth and survival and combine both the features of chemical measurement and toxicology. As such this biomarker, for example, provides an indication of sub-lethal effects arising from soil contamination.
Bird eggs have proved to be a useful tissue for monitoring of toxic contaminants. The major advantage of using eggs is the relative ease of collecting samples. The Canadian EPI programme includes the monitoring of DDE and PCBs in the eggs of cormorants (see Section 5.2) to monitor persistent organic contaminants in the Canadian freshwater and marine ecosystems. In the New Zealand context this form of investigation is currently being used by the Department of Conservation and ESR to determine levels of toxic contaminants in New Zealand albatross. This data is readily comparable with data recently published for the North Pacific Ocean (Jones et al. 1996a) and plans are currently being developed to organise a global monitoring programme using albatross eggs (J.P. Giesy, Michigan State University, Personal communication).

In New Zealand, work on the use of terrestrial biota as indicators has focused on particular environmental species and issues (e.g., Eason & Rumpf, 1995). For example:

Earthworms	• Ubiquitous, saprophagous (being developed internationally with a simple biomarker test).
Springtails	• Key species involved in soil processes, saphrophagous
Lacewings	• Important in agricultural land, predator
Mallard Duck	• Mobile herbivore
Starling	• Mobile omnivore common in farm land
Skylark	• Mobile insectivorous/granivorous bird
Mice	• Granivorous animal

A range of studies have been carried on the value of terrestrial biota as indicator species.

4.4 FRESHWATER

4.4.1 Introduction

Freshwaters in New Zealand support a diverse range of biological resources and provide for human activities and requirements such as swimming, fishing, drinking water and commercial, recreational, cultural activities and commercial fisheries.

Rivers and streams are important resources in New Zealand. In urban areas waterways are subject to stormwater run-off and the pressures associated with people living along their margins. In agricultural areas rivers are subject to the extraction of water for agricultural uses and also receive runoff from agricultural lands which may contain pesticide and fertiliser residues

Lakes provide reservoirs for hydro-electric power generation agricultural uses and recreational resources. The lakes throughout New Zealand vary dramatically in their physical and chemical characteristics, flushing characteristics and inputs of man-made contaminants.

4.4.2 Water

Concentrations of organic chemical contaminants are generally low in water due to adsorption of contaminants onto sediments, this is particularly the case for the highly lipophilic organic contaminants. In addition discharges to water in New Zealand tend to be at relatively low loading levels therefore water soluble contaminants are generally considerably diluted in receiving waters.

A table which summarises the sources of contaminants to the aquatic environment in New Zealand is presented in Table 5.3 as part of the discussions in Section 5.5.1 relating to monitoring programmes in New Zealand.

4.4.3 Sediments

An equilibrium exists between sediments and water with the concentration of man-made organic compounds in sediment depending upon their half life and their n-octanol/water partitioning coefficient (as a measure of affinity for organic matter). As such sediments act as the ultimate repository for many contaminants and also provide an ongoing reservoir from which contaminants can re-enter the food chain. This is particularly the case for estuarine sediments where the rapid changes in physical and chemical properties due to the transition form fresh to salt water result in the flocculation and precipitation of organic matter concentrating contaminants in these sediments.

Sediments are an important link between benthic health and food-chain transfer of contaminants. Many organisms at lower trophic levels eat by passing large quantities of sediment through their bodies and in the process extract and concentrate contaminants from sediments . In addition resuspension of sediments by floods or storms can result in transport of particle bound contaminants into the wider environment. While the slow natural burial of contaminated sediments does occur such mixing events and 'bioturbation' by living organisms contribute significantly to the ongoing presence of contaminants in the ecosystem.

4.4.4 Freshwater Biota

New Zealand's river and lakes support both significant recreational and commercial fisheries. Therefore the quality of our river systems impacts directly on the economic state of the nation. In addition our rivers support a number of small endangered fish species whose protection is an environmental priority.

4.4.4.1 Biomonitoring

There have been a number of biomonitoring studies in New Zealand involving the use of freshwater organisms. These have included the accumulation of contaminants in eels and the effects of those contaminants on the organisms (Jones, *et al* 1995; Jones, 1996b). Successful utilisation of freshwater organisms in bio-monitoring programmes requires a knowledge of the organism involved in relation to the contaminant(s) being monitored. Considerable work has also occurred in relation to trout and other invertebrates such as mussels (refer Sections 6 and 7).

4.4.4.2 Macroinvertebrate Indices

Macroinvertebrate indices provide information on the overall health of aquatic ecosystems. Although not directly related to toxic contaminants indicator selection and monitoring, they represent generic ecological monitoring which can be linked to any environmental indicator programme. For instance, stream invertebrate monitoring is widely undertaken in New Zealand with the Macroinvertebrate Community Index (MCI) and the Quantitative Macroinvertebrate Community Index (QMCI), an index developed for organic pollution biomonitoring (Stark 1993) Recent studies of invertebrates undertaken by NIWA sampled at 9 sites in 3 Coromandel streams with heavy metal contamination have showed that the QMCI could not distinguish between reference and polluted stream sites, suggesting the this index was not suitable for heavy metal impact detection. Rather, abundance, species richness and numbers of EPT taxa were best the indicators of effects. These findings suggest that while QMCI may be very valuable in the New Zealand EPI programme as an indicator of aquatic community integrity there is a need to develop similar indicators that are relevant to toxic contaminants

4.4.4.3 Biomarkers

A number of different biomarkers have been utilised in freshwater organisms. Biomarkers may be specific to different groups of chemicals (e.g., acetyl cholinesterates for organophosphates; cytochrome P4501A for dioxin like compounds vitellogenin in fish or fish hepatocytes for endocrine disruptors) or non-specific as in the case of scope for growth or Fish Health Profile analyses. The latter can be utilised for monitoring changes in general water quality.

4.5 ESTUARIES AND COASTAL WATERS

4.5.1 Introduction

As with freshwater, most contaminants are present in low concentrations in open ocean and coastal waters. This arises because of the affinity of most contaminants for particulate matter and the uptake of contaminants by plankton.

Estuaries and coastal waters in New Zealand support a diverse range of biological resources and provide for human activities and requirements such as swimming and other forms of recreation, fishing, and commercial, recreational, cultural and commercial uses of fisheries and shell fisheries resources.

4.5.2 Water

There has been relatively little direct monitoring of contaminants in New Zealand coastal waters. Smith (1986) reviewed available information on metals in New Zealand coastal waters. As noted earlier, concentrations of contaminants are typically low in water. As such relatively specialised sampling and measurement techniques need to be used to accurately identify the concentrations of metals and organic compounds in marine waters. Studies investigating and monitoring of metals in New Zealand coastal waters have been undertaken by Dickson & Hunter 1981; Hunter 1983; and POAL (1990).

4.5.3 Sediments

As with freshwater sediments, coastal sediments act as sinks for many contaminants. The presence of elevated concentrations of contaminants in sediments may result in changes in the abundance and diversity of benthic invertebrates inhabiting sediment, through acute toxicity resulting in death or through chronic effects such as impairment to reproductive systems. These effects may have implications to the integrity of ecological systems or to the viability of commercial species in those areas.

There has been a significant amount of monitoring of sediment quality within the New the Zealand coastal environment. Table 4.1 provides a summary of publications relating to sediment contamination in New Zealand estuarine and coastal sediments. (Smith 1986, Stoffers *et al.* 1986, Glasby *et al.* 1988, Kennedy 1993, Williamson *et al* 1996; Burggraaf *et al.* 1994 etc.,). In general this work has focused on locations adjacent to urban areas, ports and marinas. Techniques for monitoring in coastal sediments in New Zealand has been reviewed by ARC (1989).

Monitoring sediments for contaminants in the coastal zone provides direct information about the flux/transport of contaminants from land based sources to the marine environment. It also provides information about the potential effects on organisms inhabiting the sediment.

TABLE 4.1: Summary of Studies measuring metals and organic compounds in New Zealand coastal sediments.

Contaminant	Reference
Metals	• Stoffers *et al*. (1986) Glasby *et al*. (1988) • Kennedy (1993) • Williamson *et al*. (1996)

	• POAL (1990), etc.
Organochlorine Compounds, PAHs, etc.	• POAL (1990), etc. • Burggraaf *et al*. (1994) • Simpson, *et al*. (1995) • Fox, *et al*. (1988) • Holland, *et al*. (1993)
Dioxins, PCBs	• Jones *et al*. (1996a, b)

4.5.4 Biological Resources

Due to their biological 'richness' estuarine and coastal waters act as valuable feeding breeding and nursery areas for many fish species. In addition the richness of these environments makes them valuable habitat for migratory birds and they provide significant recreational and commercial shell fisheries to humans.

Key biological resources within the coastal environment are plankton, benthic invertebrates (including commercial shellfish), fish, sea-birds and mammals. In New Zealand, fish-eating sea-birds and marine mammals are some of the key top predators in marine ecosystems.

Monitoring of the direct bioaccumulation of contaminants in marine organisms in New Zealand has been carried out across a range of marine ecosystems. Examples of such studies are summarised in Table 4.2.

Careful selection of the target tissues for analysis, and a sampling strategy based on knowledge of uptake, depuration, and metabolic transformation rates in the chosen species are required for reliable monitoring. The retention times (e.g. half-lives) of contaminants in fish can vary greatly. PAHs, for example, are taken up and lost rapidly compared with some organochlorines. Since fish are mobile species, able to move from polluted to unpolluted areas relatively quickly, these factors are important background information for monitoring programme design. Monitoring objectives therefore need to be carefully defined, and a sampling strategy based upon the physico-chemical behaviour of key contaminants and the biology of the target fish species.

TABLE 4.2: Summary of Studies measuring metals and organic compounds in New Zealand marine organisms.

Organism	Contaminant	Reference
Molluscs	• Metals • Metals, organochlorines	• Kennedy (1986) • Purchase & Fergusson (1986) • ARC (1992). • POAL (1996), etc.
Amphipods	• Metals	• Rainbow *et al*. (1993)
Crustaceae	• Organochlorines	• Day (1996)
Barnacles	• Metals	• Zauke *et al*. (1992)
Fish	• Organochlorines, dioxins, PCBs	• Day (1996) • Holland (1993)
Birds	• Dioxins, PCBs, organochlorine pesticides	• Jones (1998a)
Mammals	• Dioxins, PCBs, organochlorines, PCBs	• Jones *et al*. (1998b, c) • Day (1996) • Jones, *et al*. (1996c)

Marine mammals have many desirable characteristics for the monitoring of contaminated environments. These species are long lived and have a high lipid content facilitating the accumulation of high concentrations of lipophilic contaminants. Many species cover large ranges thus integrating levels of contamination over wide spatial and temporal ranges.

4.6 GROUNDWATER

Close (1992, 1993a, 1993b) has examined and reported on pesticide contamination of groundwater in New Zealand. Close (1993b) examined pesticides in 82 wells from six areas around New Zealand. A total of seven pesticides were detected in a total of six wells. An exceedence of USEPA drinking water guidelines for atrazine was found in one well. The percentage of wells with detectable pesticides (11%) was compared with other overseas surveys even though the various studies had differing objectives and sampling strategies by Close (1993b). The comparison indicated that the incidence of pesticide detection was lower than in a range of studies in the United States.

4.7 HUMAN COMPARTMENT

The easiest and most extensively used sampling method for assessing contamination of the human population, particularly for organic contaminants, is the analysis of breast milk. While this method has previously focused on organic contaminants some recent studies have also focused contamination with heavy metals. Milk is a particularly suitable medium for analysis of a range of contaminants as it is 'designed' to transfer a wide range of necessary nutrients to the growing infant. The occurrence of a range of chemicals in human milk has been recently reviewed (Somogyi & Beck 1993). Other approaches to the contamination of the human environment include analysis of blood serum (Patterson, *et al.* 1988) and hair. Some studies have also used the analysis of tissue samples from human cadavers (Graham, *et al*. 1986, Beck, *et al*. 1990, Ryan 1986) however ethical considerations make these studies difficult.

The greatest advantage with the breast milk survey method is the relative ease with which samples can be obtained. In addition there have been several World Health Organisation (WHO) sponsored global surveys of the contamination of breast milk. These reports provide a valuable basis for comparison of New Zealand to the rest of the world and, given continued effort, will provide an indicator of trends in contamination of the human environment.

The breast milk surveys conducted by the Ministry of Health revealed that samples from New Zealand mothers had similar contaminant concentrations to those collected in other western countries (Bates *et al*. 1990). The levels of PCBs dioxins and most organochlorine pesticides were in the low end of the range for overseas studies. One exception was DDE, a metabolite of DDT, which in the high end of the range for overseas studies.

5. TOXIC CONTAMINANT INDICATOR PROGRAMMES AND CASE STUDIES

5.1 INTRODUCTION

There are numerous examples of international, national and regional programmes which, regardless of the specific rational for their original implementation, provide a vast resource in terms of accessible information. In many cases, availability and presentation of this information to the public and decision makers is enhanced by its presentation on the World-Wide Web.

This section overviews a number of programmes and case studies that relate to toxic contaminants in various compartments of the environment. Detailed descriptions of these case studies are presented in Appendix B. These examples although not necessarily developed specifically as indicator programmes, provide information which can be easily extracted and used to develop specific indicators and programmes. Similarly, there are a number of efforts underway in New Zealand which provide information on the health of the New Zealand environment and are highlighted as a key component in the development of toxic contaminant indicators.

5.2 INTERNATIONAL AND NATIONAL PROGRAMMES

5.2.1 The International Joint Commission on the Great Lakes (International Indicator Programme)[1]

Background

Industrialisation in the Great Lakes region together with a slow water turnover has led to the accumulation of high levels of a wide range of toxic contaminants within the Great Lakes ecosystem. The International Joint Commission (IJC) was established by the United States and Canada to administer the use and preservation of the Great Lakes.

Adverse effects of chemical contamination in the Great Lakes ecosystem were first noted in the 1960s and early 1970s with the depletion of lake trout (*Salvelinus namaycush*) and the virtual elimination of fish-eating water birds. Contaminants of particular concern in the Great Lakes ecosystem are PCBs, dioxins and a range of pesticides and other organic compounds that are spread throughout the lakes. Heavy metals are also of concern in some locations.

Extensive monitoring and research has been carried out on the Great Lakes ecosystem, especially on the concentrations of contaminants in the tissues of wildlife. Wildlife tissue banks have been established for the identification of long-term trends in contamination (Turle, *et al.* 1991) (Waller *et al.* 1995) and data has shown an apparent levelling-off in the decline in contaminant concentrations (Stow 1995).

[1] Also see Appendix B.

The IJC identified in 1996 a range of indicators to evaluate the progress of the Great Lakes Water Quality Agreement (signed in 1972). The selection process placed an emphasis on integrative indicators of ecosystem integrity with very few chosen which were directly related to water quality. The indicators selected included the following:

Table 5.1: Integrative indicators of ecosystem integrity identified by the IJC (1996).

- Beach closings due to persistent toxic contaminants in relation to swimming.
- Reductions in loadings and concentrations of chemicals, and expenditures for public waste water treatment in relation to aesthetics and perception.
- Contaminant levels in tissues in relation to wildlife health.
- Number of closures due to persistent toxics in relation to commercial and subsistence fishing.

Canada introduced two environmental indicators of the contamination of aquatic food chains with organic contaminants. These both use double-crested Cormorant eggs which have a nation-wide distribution This is particularly important in allowing comparison between regions. The specific toxic contaminant indicators chosen are:

1. DDE and PCBs concentration in double-crested Cormorant eggs.
2. Dioxins and furan concentrations in double-crested Cormorant eggs .

The Cormorant is near the top of the aquatic food chain which means it acts as an integrator and concentrator of contaminants over relatively wide areas. These indicators are of considerable relevance to the Great Lakes as the organic contaminants monitored are currently the major cause for concern in this ecosystem. The United States has not yet established federal indicators pertaining to the Great Lakes.

5.2.2 International Mussel Watch Programme (International Monitoring Programme)[2]

5.2.2.1 United States Implementation of the Mussel Watch Programme

A mussel watch programme established by the USEPA in 1970 led to the National Oceanic and Atmospheric Administration (NOAA) initiating the National Status and Trends (NS&T) - Mussel Watch Programme in 1986. This programme samples and analyses bivalve samples from 200 coastal sites on a biennial basis (Lauenstein, 1995). As well as immediate sample analysis, sub-samples of tissue are archived for possible future analysis. This procedure is a critical component of this monitoring programme as it allows for retrospective analysis of any "new" environmental hazards and also allows for the re-analysis of previous samples in light of recent advances in technology (Lauenstein, 1995).

[2] Also see Appendix B.

The NS&T programme also monitors sediment concentrations of contaminants at some of the same sites (see Section 5.2.3), and includes *The Benthic Surveillance Programme* which monitors chemical concentration in fish tissues and biological responses of the fish to that contamination.

The NS&T program has a total of 240 sites throughout each of the states with a coastline. The Mussel Watch Programme measures a range of chemical contaminants in both mussel and oyster tissues, including 16 metals, 24 PAHs, 6 DDT group compounds (DDT and breakdown products), 11 chlorinated pesticides, 18 PCBs and organotin compounds such as TBT.

5.2.2.2 International Implementation

The International Mussel Watch Programme involves the Inter-Governmental Oceanographic Commission (IOC) of UNESCO, UNEP and NOAA. The initial phase of this programme was launched in Latin America and the second phase is currently being formulated for the Asia/Pacific region.

5.2.3 Arctic Monitoring and Assessment Programme (AMAP) (International Monitoring Programme)[3]

The Arctic Environmental Strategy has included monitoring of toxic contaminants in the Arctic since 1991. The contaminants programme is managed by a range of governmental and environmental agencies in Canada, Denmark/Greenland, Finland, Iceland, Norway, Sweden, Russia, and the United States. The programme includes the monitoring of a number of organochlorine compounds, heavy metals, radionuclides and hydrocarbons in wildlife species and in native community breast milk.

This programme has raised a number of issues relating to the carrying out of monitoring programmes that endeavour to assess the effects of contaminants on people and wildlife. As with all such programmes, the key issue revolves around establishing cause and effect. This is especially difficult when effects are at either chronic or lower levels. Data generated by the AMAP and other Arctic studies have been central to the development of our understanding of the long range atmospheric transport of contaminants. Information and reports on this programme are available at http://www.grida.no/amap/.

5.2.4 National Status and Trends Program: Sediment (Monitoring Programme)[4]

The National Oceanic and Atmospheric Administration (NOAA) - National Status and Trends (NS&T) Program has monitored coastal sediment contamination since the mid-1980s

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[3] Also see Appendix B.
[4] Also see Appendix B.

and provides a picture of coastal sediment contamination on a regional and national basis. The data has linked contaminant concentrations to adverse effects in a number of specific locations. This work is specifically focused on toxic contaminants in the coastal environment, in particular harbours and estuaries (O'Connor, 1990).
The NS&T Program measures the concentration of a number of metals (cadmium, chromium, copper, lead, mercury, silver and zinc) and organic compounds (DDT, chlordane, PCBs and PAHs) in sediments. This data provides information on the spatial distribution of these key contaminants. There are however, considerable difficulties in using this data for the assessment of temporal trends.

5.2.5 Freshwater USGS NWQAP Programme (Monitoring Programme)

Beginning in 1986, the United States Geological Survey (USGS) have been developing a National Water Quality Assessment (NAWQA) Program to evaluate contaminants in tissues of biological organisms. The goals for the full-scale programme are to provide a description of current water quality conditions, an indication of long term trends, and an identification and description of explanation of the major factors that affect observed water-quality conditions and trends. Specific components of the programme include:

- Tissue analysis of biological organisms to measure the occurrence of toxic or potentially toxic compounds, including trace elements and organic compounds.
- Biological monitoring to determine the occurrence and distribution of waters contaminated by faecal material.
- Ecological surveys to assess the relations between the physical and the chemical characteristics of streams
- Ecological surveys to assess the relations between the functional or structural aspects of the biological community.

A further objective of the program is to define and quantify biological processes that affect the physical and chemical aspects of water quality.

The USGS programme provides a comprehensive review of the monitoring being undertaken in the United States and provides guidance on the selection of biomonitoring organisms and is of particular value in the development of a New Zealand toxic contaminant indicators (TCIs) as part of an EPI. Information on the NAWQA programme, including study design and results, are available at http://www/rvares.er.usgs.gov/nawqa/nawqa_home.html on the World-Wide Web.

5.2.6 USEPA Environmental Indicators (National Indicator Programme)

The USEPA has developed an indicators programme that is focused on providing information in relation to a series of specific objectives that relate to the provision of clean water for human and ecosystem health. To date, the focus of the programmes has not been on the direct measurement of toxic contaminants in waters although this is changing with the introduction of key contaminants, especially toxic metals, into a number of indicator programmes. The measurement of toxic contaminants in shellfish (as integrators) is undertaken for six contaminants - copper, mercury, lead, PAHs, DDT and PCBs. Point sources of toxic contaminants are monitored through the USEPA Permit Compliance System (PCS).

Contaminated sediments are used to indicate potential risk to ecological and human health by focusing on the risk to benthic organisms (such as shellfish) exposed to the sediments, and the risk to human consumers of those benthic organisms. Sites are classified into 3 Tiers where Tier 1 represents a site where associated adverse effects are probable; Tier 2 represents a site where associated adverse effects are possible but expected infrequently, and Tier 3 represents a site where there is no indication of adverse effects. Data is collected as part of the National Sediment Inventory (NSI), and contains some 230 different chemicals or chemical groups including mercury and PAHs.

5.3 REGIONAL INDICATOR PROGRAMMES

5.3.1 Introduction

A number of individual states in the United States and provinces in Canada have their own indicator programmes which can be geographically considered regional programmes. In addition, there are a number of ecosystem specific indicator programmes in the United States and Canada. Other details surrounding these case studies are presented in Appendix B.

5.3.2 State of Minnesota

The Minnesota Department of Natural Resources operates an EPI programme to assess the condition of the State's environment. This programme identified that much of the State's environmental information was inconsistent and incomplete, not enabling overall statements to be made about the Minnesota environment. Minnesota established an Environmental Indicators Initiative which was an inter-agency effort sponsored by the Environmental Quality Board and funded by the legislative Commission on Minnesota resources. A task force was established in 1993 to guide the initiative. The aim of the initiative is the set up of an integrated set of indicators that are scientifically valid and robust and are of significance to the public and decision-makers. The initiative will review and catalogue existing monitoring data and then develop a set of indicators to assess the state of the environment through and evaluation of health and overall trends.

A number of reports are in preparation including environmental indicators fact sheets to assist in the use and interpretation of specific indicators. The Minnesota EPI can be found on the World-Wide Web at http://www.dnr.state.mn.us/eii.html

5.3.3 State of North Carolina

The State of North Carolina, initiated the concept of an EPI programme for the state in 1988. In 1992, the State Center for Health and Environmental Statistics within the Department of Environment, Health, and Natural Resources (DEHNR) began developing the indicators programme and has been running since 1993. The initial programme was limited to air, water and waste with a strong indicator emphasis on use and impairment of use.

Contaminants such as carbon monoxide are monitored as part of North Carolina's ambient air quality monitoring network. Data is entered into the USEPA Aerometric Information Retrieval System and assessed for exceedence of air quality standards and air quality trends. The DEHNR also monitors radioactivity as there are a number of nuclear power plants, research reactors and fabrication plants in the State.

In relation to drinking water, maximum contaminant levels (MCLs) are set under the Federal Safe Drinking Water Act in the US. Contaminants such as trihalomethane and lead are key toxic contaminants monitored and compared to the MCLs in the Drinking Water Act.

5.3.4 California Environmental Protection Agency

The California Environmental Protection Agency (CalEPA) (http://www.fsu.edu/~cpm/segip/states/CA/intro.html), has an indicators programme that encompasses the areas within its regulatory scope.

In relation to water, the State Water Resources Control Board, collects information in a number of areas. For most where data is collected on a random basis (e.g., fish and mussel tissue contaminants), the data are not suitable for trend analysis. The primary source of data appropriate for use as an indicator is the data on rate of occurrence and remediation of leaking underground storage tanks.

California has maintained a toxic release inventory database since the federal Toxic Release Inventory (TRI) programme was started in 1987. The data base allows trends in a wide range of air quality emissions (including toxic contaminants) to be tracked.

5.3.5 Chesapeake Bay Programme

As part of the Chesapeake Bay Programme, an EPI programme is used to evaluate the progress of the Chesapeake Bay restoration effort and to pass make available to the public and other interested parties the information obtained in the programme. Toxics are identified as an area of focus in addition to nutrients and living resources. The EPI programme tracks a number of toxic contaminant-related indicators, such as the pesticide collection, disposal and container recycling programmes, trends in rainfall metal concentrations, and bald eagle population counts.

The Chesapeake Bay Programme can be found on the World-Wide Web at http://www.chesapeakebay.net/bayprogram/measure/ and the EPI Programme at http://www.chesapeakebay.net/bayprogram/measure/indicatr/indover.html.

5.4 THE NEW ZEALAND SITUATION

5.4.1 Introduction

Within New Zealand, there are numerous toxic contaminant monitoring programmes which are either currently underway or have been completed and are a source of valuable information about the New Zealand environment. A number of specific regional and national monitoring initiatives are highlighted in this section as key components in the development of TCIs in the New Zealand environment.

Most of the data on contaminants and measurements of their effects on resident biota in New Zealand comes from a wide variety of studies undertaken by various university, research and management organisations. Hickey (1995) reviewed toxicity testing and other contaminant-related studies in New Zealand. Information from this review is presented in Table 5.2 along with additional the information available from various publications in relation to major contaminant sources and environmental monitoring studies.

Other potential sources of this type of information are Regional and District Councils, port companies and consultancy organisation reports dealing with environmental impact studies and discharge monitoring programmes. The potential limitation of these sources for use in an EPI programme is their lack of external cataloguing at libraries etc. as well as their diverse data acquisition methods. Some specific examples of Regional Council studies are reviewed in Section 6.2.1 and for specific case studies in Section 6.2.3.

In the case of consultancy reports and the like, while this information would be valuable, it is typically collected to address a specific issue thereby making it difficult to harmonise with data acquisition quality control and assurance methods within a structured EPI programme. Further, issues are likely to arise with respect to the ability to use such data collected for purposes other that for which it was collected.

5.4.2 Water

Most of the national water quality monitoring programmes in New Zealand have addressed conventional water quality constituents (e.g., nutrients, suspended solids) and physical habitat changes as either specific studies (e.g., ‘100 Rivers’ Study), on-going river (e.g., (Smith & McBride 1990)) or lake programmes. Only MfE’s Organochlorines Programme (see Section 6.3.3) has addressed a contaminant, or in this case group of contaminants, issue on a national basis.

TABLE 5.2: Major aquatic contaminant sources and environmental monitoring studies in New Zealand[5].

Industry	Contaminants
Agriculture (dairy, tannery, piggery, horticulture)	ammonia, hydrogen sulphide, Cd, pesticides
Mining	heavy metals, suspended solids
Forestry (pulp and paper, timber treatment forestry operations)	resin acids, chlorinated organics, dioxins. Cu, Cr, As, PCP, chlordane
Geothermal	Hg, As, B
Stormwaters	heavy metals, PAH, suspended solids
Harbour Dredging	heavy metals, organics
Municipal Wastes	ammonia, hydrogen sulphide, pesticides
Municipal Wastes	various
Estuarine Sediments	various
Marine Biota	various
Marine Waters	various
Freshwater Sediments	various
Freshwater Biota	various
Freshwaters	various
Groundwater	various
Estuarine Birds	various
Source Reviews	various

See Appendix C for complete reference list.

5.4.3 Shellfish Quality

While a Mussel Watch Programme of the scale described in Section 5.2.2 has not been established in New Zealand, there are studies involving the use of fresh water mussels for biomonitoring of contaminants (e.g., Waikato River monitoring of geothermal (Hickey *et al.* 1995) and organochlorines (Hickey *et al.* 1997) contaminants). As well, there are a number of programmes initiated by the Auckland Regional Council which use oysters and mussels for contaminant biomonitoring (refer ARC 1992). Specific examples of other studies are reviewed as case studies in Section 6.2.3.

5.4.4 Food Quality

There have been a number of well known surveys to evaluate long term trends or the national distribution of contaminants in New Zealand foodstuffs. While these studies are aimed directly at estimating human exposure to contaminants, by virtue of their national scale they also provide valuable information on the contamination of the environment.

[5] Full reference citations presented in Appendix C.

MfE also carried out an extensive analysis of the New Zealand diet as a part of the Organochlorines Programme. The data from this study is scheduled for release in the second half of 1998.

5.4.4.1 Total Diet Surveys

The 1997/98 New Zealand Total Diet Survey (NZTDS) is the fifth such study of its kind in New Zealand. Its primary focus is to assess the pesticide and contaminant element intakes from foods consumed by the average New Zealander. As such, foods are analysed on the basis of amount consumed. The previous four surveys have been carried out jointly by the Ministry of Health (formerly the Department of Health) and ESR (formerly DSIR Chemistry Division).

The first survey was carried out in 1974 and involved analysis of a relatively small number of food group composites. The 1982 survey was similar, but the energy content of the diet was recalculated to give intake estimates for other age/sex groups. The 1987/88 survey saw a change in survey design to an analysis of a large number of individual foods. This increased the flexibility of the survey and allowed calculation of estimated dietary intakes for a wider range of age/sex groups (ESR/MoH, 1994). The 1990/91 survey adopted a similar approach for food selection (Vannoort *et al.*, 1995a, b; Hannah *et al.*, 1995; Pickston & Vannoort, 1995), and this is to be used as the basis for the 1997/98 survey.

Recent NZTDSs considered a wide range of nutrient elements (thirteen nutrient elements in 1987/88, and eleven nutrient elements plus one vitamin in 1990/91) in addition to pesticides and contaminant elements. The 1997/98 NZTDS is focused more on contaminants in food, with only two nutrient elements of special interest (selenium and iodine) being considered. The range of pesticides screened for has increased consistently with each NZTDS. The survey is conducted in accordance with the recommendations of the FAO/WHO Joint Expert Committee on Pesticide Residues and in agreement with the objectives of the Joint FAO/WHO Global Environmental Monitoring Systems (GEMS; FAO/UNEP/WHO, 1985). The objectives of the 1997/98 NZTDS are numerous. These are:

• To assess the health implications of the chemical quality of the New Zealand food supply (based on the NZTDS food list, which represents at least 70% of the most consumed food items) for selected pesticide residues, contaminant elements and trace elements. • To estimate the potential dietary intakes of selected pesticide residues, contaminant elements and trace elements by interpreting data from the NZTDS in terms of simulated 'typical' diets of a number of New Zealand population groups. The project will: 1. Assess the chemical status of the New Zealand food supply. 2. Indicate any potential intake concerns. 3. Demonstrate trends in dietary exposure.	• To contribute data to WHO GEMS/Food programme, so that accurate international comparisons can be made of New Zealand dietary exposure to contaminants. • To provide, where appropriate, data on the contaminant and nutrient content of food, suitable for incorporation into the New Zealand Food Composition Database for use by interested parties. • To make data on the contaminant and nutrient content of food available to stakeholders in a timely manner during the course of the NZTDS.

5.4.4.2 Foods

Foods to be analysed have been divided into two categories. The first are National Foods (66) which are not expected to exhibit any regional variability and include processed foods such as biscuits, breakfast cereals and beverages, which are uniformly available New Zealand wide. National Foods will be sampled in a single location (Palmerston North) on two occasions. The second are Regional Foods (48) which may be expected to demonstrate variation in pesticide, contaminant and nutrient level depending on the location in which the food was produced. Regional foods include meat, fruit and vegetables. Regional foods will be sampled in each of four locations (Auckland, Napier, Christchurch and Dunedin) on two occasions.

5.4.4.3 Mercury in Fish

A number of overseas counties who import fish from New Zealand have strict limits on the allowable concentrations of mercury in fish and fish products. The concentration of mercury is measured in fish being exported to ensure that it complies with these regulations. As noted earlier in Section 4, the concentration of mercury varies by size and age in a number of fish species. As such, the data may not provide an accurate measure of the mercury available to domestic consumers of fish products (Kjellstrom et al. 1990; Kjellstrom et al. 1986; Mitchell et al. 1982).

The export surveys of mercury in fish do however provide data on the concentrations of mercury in a range of fish species caught around the New Zealand coastline but does not provide information on the effects of localised contamination of the environment by mercury.

5.4.4.4 Contaminants in Meat

The Ministry of Agriculture and Forestry - Regulatory Authority undertakes residual chemical monitoring of meat and urine randomly selected at export slaughterhouses, domestic abattoirs, deer slaughtering premises, and on-farm. While the majority of testing is related to the detection of disease and veterinary products, analysis is also undertaken for pesticides and other environmental contaminants. A summary of the environmental contaminants included in the MAF contaminants surveillance programme are described below in Table 5.3.

Table 5.3 Environmental Contaminants included in the MAF Contaminants Surveillance Programme.

Environmental Contaminants	
• DDT & metabolites	• Heptachlor
• HCH (a and b)	• Heptachlor epoxide
• Lindane	• PCBs
• HCB	• Oxy-chlordane
• Aldrin	• Endosulfan sulphate
• Dieldrin	

The results of the 1 October 1996 - 30 September 1997 and 1 October 1996 - 31 December 1997 meat production periods illustrate the nature of information produced for a limited number of toxic contaminants. In these periods, 4,589 and 705 animals respectively were randomly sampled at export slaughterhouses, domestic abattoirs, deer slaughtering premises, and on-farm to assess their chemical residue status. A range of 86 different compounds were analysed in total.

For the 1 October 1996 - 30 September 1997 period, of the 300 pigs sampled for mercury residue analysis, 8 (2.67%) were reported with residues in kidney tissue above the Mean Residue Level (MRL) of 0.03 mg/kg. Residues of DDE were identified in one lamb (0.13% of total sampled) at a concentration greater that the MRL of 5.0 mg/kg. Trace levels of heptachlor epoxide were also found in one lamb (0.13%) and one pig (0.13%). The New Zealand MRL for this compound is 0.001 mg/kg.

During the first quarter of the 1996-97 meat production year (1 October 1996 - 31 December 1997), a total of 7,387 analytical tests were performed. Kidney samples from 84 pigs were tested for mercury and no residues above the MRL of 0.03 mg/kg were identified. Organochlorine compounds were screened for in the fat of 230 animals. Residues of DDE above the New Zealand MRL of 5.0 mg/kg were found in one lamb (0.44%).

The analysis results are for animals sourced from across New Zealand throughout all regions. The overall number of toxic substances which are analysed for as part of this surveillance is limited but the relevance of a database such as this obvious in the context of TCIs.

5.4.4.5 Vertebrate Pesticides Database

The Department of Conservation and Landcare are collaborating in the development of a National database on vertebrate pesticides (e.g., Substance 1080) in wildlife. This database already contains extensive information of pesticide residues in birds and other wildlife for the period 1990 to 1998.

5.4.5 Air

A review of air quality data (continuous, 24 hour, 7 day a week sampling) collected in Auckland and Christchurch by the New Zealand Health Department was prepared by Graham (1993). Data examined covered the period from 1964 to 1988. The review highlighted the effects of the phase out of lead in petrol which began in July 1986. Declining concentrations were apparent by September of that year and by 1987 the reductions were marked (refer also Taylor (1993) for further discussion on this subject). Concentrations of lead in air have reduced to such an extent since 1987 that it is no longer regarded as an environmental threat in air. Lead is also discussed in Section 5.4.6.2.

5.4.6 Humans

5.4.6.1 Breast Milk surveys

Breast milk surveys have been previously undertaken in New Zealand (Bates, *et al.* 1990) and the Ministry of Health is currently planning another survey for sampling in 1998. These surveys have focused on residue of organic contaminants particularly the difference in DDT residues between urban and rural populations. Surveys were conducted using standard protocols outlined by WHO.

5.4.6.2 Blood surveys

The Biochemistry Department of Princes Margaret Hospital in Christchurch has undertaken an analysis of blood lead levels of New Zealanders on an extensive basis since 1974. Walmsley *et al.,* (1993) reported on the trends in blood lead levels in Christchurch over the period up to 1988. The long term surveillance data showed downward trends in red cell lead concentrations in both males and females. Reductions in lead levels in petrol which occurred immediately prior to the review by Walmsley *et al.* (1993) were not yet reflected in red cell blood lead levels.

6. PREFERRED INDICATORS

6.1 INDICATORS

The stress caused by toxic contaminants on ecosystems are best indicated by the direct effects those stresses have on the biological components of those ecosystems. As an essential step, the presence of contaminants should be determined by chemical analyses. However, the analysis does not provide any information about effects on individual organisms or populations or ecosystems.

Upgraded environmental information and the prediction and prevention of ecosystem health degradation requires the establishment of key indicators and standards which can measure improvements or deterioration in the environment over time. As such, environmental indicators provide environmental monitoring and input to the development of national policies for the sustainable management of air, land and waterways.

Population monitoring provides evidence of pressures of possible changes within ecosystems, but rarely gives indications of their causes. A combination of chemical analysis, biomarker (physiological changes in response to a toxicant in an individual) and population monitoring allows links to be made between cause and effect and recognises that there are differences in the availability of toxic contaminants from different media, and potential synergistic effects from mixtures of contaminants.

6.2 SELECTING INDICATORS

Indicators are classified as Pressure, State or Response Indicators. The indicators are categorised within the Pressure-State-Response system. Activities exert pressures on the environment (e.g., the discharge to the environment of a toxic contaminant). The pressures change the state of the environment (i.e., the concentration of the toxic contaminant in a particular compartment of the environment). The response to the change in the state is society's response to the state of the environment. In addition, indicators are identified as Stage 1 or Stage 2 indicators.

Stage 1 indicators are those indicators that can be readily developed from existing monitoring programmes or data collection or indicators for which data collection could be established.

Stage 2 toxic contaminant indicators are indicators for which development or research would be needed before their inclusion as part of the overall EPI.

The extent of funding available for environmental indicators in New Zealand will dictate, in practical terms, the options for the selection of indicators that might form the core group of the toxic contaminant indicators (TCIs). These options are:

- Use currently available toxic contaminant monitoring progressive data and 'modify' those current programmes to provide the required EPI information.
- After identifying 'useable' Stage 1 indicators, identify additional key indicators and add these to the TCIs.

- Develop long term/range integrative indicators that can be analysed relatively infrequently.

There are a range of monitoring activities across a range of media that have the potential to form the basis for regional or national TCIs. The level of monitoring being carried out in relation to toxic contaminants differs in the different media and also at the level or type of monitoring or data collection being carried out. There are a number of specific monitoring activities that can or should allow the inclusion of toxic contaminants into a regional/national indicators programme.

6.3 CHARACTERISTICS OF INDICATORS

It is important in the selection of any specific indicator as part of an assessment programme that the suitability of the indicator for inclusion in the programme be assessed. The suitability can be assessed by pre-determining a set of selection criteria against which the potential performance indicator is assessed and evaluated. Indicators suggested in the following sections have been selected on a priority basis taking account of their suitability and practicability to contribute to overall EPI goals.

In simple terms, indicators should be:

- Measurable with available technology.
- Measurable at a reasonable cost.
- Scientifically defensible.
- Easy to interpret and understand.

In relation to scientific validity, a series of criteria that should be considered include:

- What is the quality of the data obtained?
- Is the indicator sensitive to pressure?
- Is the indicator anticipatory (e.g., early warning system)?
- Is the indicator timely (i.e., is the time from collection of sample to action short enough?)?
- What are the costs and resources required to obtain the data?
- Is the indicator necessary to characterise/assess an outcome or progress?
- Is the indicator or outcome readily understandable by the public?

These are noted as a series of acceptable criteria for the New Zealand programme, and are adopted here.

6.4 POTENTIAL INDICATORS

6.4.1 Introduction

In the following sections, potential TCIs for a New Zealand EPI are described. The potential indicators in each media compartment are described and the potential use of each indicator is identified and a commentary on including that indicator into a national indicators programme is provided.

The preferred indicators below focus on Stage I indicators and most are state indicators. The use of Stage 2 indicators such as biomarker and organism health impacts in relation to environmental monitoring is identified in the following section. There are, however, currently still difficulties in linking 'health effects' to contaminant exposures. For example, the exposure of fish to pulp and paper mill effluents results in the induction of specific cytochrome P450 enzymes. However, the exact nature of the chemical(s) causing the induction is unknown as are the long term effects on individual fish and fish populations.

6.4.2 Air

Air indicators can be developed at two levels.

- Indicators (measures) of air toxics that provide information on likely human health.
- Indicators (measures) of air toxics that provide information about ecosystem health (This includes animals, plants, and deposition to land and water surfaces).

There are a number of air quality monitoring programmes that collect data on toxic contaminants in the air around New Zealand. Air quality can be benchmarked against international air quality standards and those set in Regional Air plans where Councils have adopted standards or guidelines that involve toxic contaminants. However it is important to note that as this is a very new and difficult topic, there are few of these at present.

Biological indicators (of air toxics) are discussed further in Section 7.4.3 below. Potential air indicators that could be used within New Zealand include:

Indicator	Type	Comment
Toxic Release Inventory emissions to air (of identified toxic contaminants)	**Pressure**	Assessment of all potential toxic emissions to air by area and by time within New Zealand. This would form the primary quantified pressure indicator, which for some toxic substances with some focused research, could also become the primary state indicator.
Measurement of air quality (e.g., lead) at selected sites. (Measurement of priority toxic compounds in air - see below)	**Pressure**	Comparison to risk assessment criteria (where known). Comparison of quality against international and New Zealand air quality guidelines (% exceedence by time and by location principle indicator).
Surveys of animal and vegetation damage (diseases, burn-out, unusual effects)	**Response**	Similarly data on any instances of out-of-the-ordinary diseases or burnt vegetation effects can be compiled. This is a poor surrogate indicator, since not every part of the country can be surveyed regularly, but is an appropriate response measure.
Surveys of health impacts (asthma, spray drift effects, skin rashes, etc.,)	**Response**	Since for many potentially toxic contaminants measurements are impossible to obtain, a surrogate response indicator is some trend in the known (or suspected) effects. The Ministry of Health has recognised this and is attempting to formulate programmes for national data collection.

The list given below is the currently assessed priority list for toxic contaminants that might be present in New Zealand's air. The list is not comprehensive and will need continual review (at least annually) and is based completely on some rather subjective current factors - such as what has been measured overseas, what has appeared in the New Zealand media, what has had previous effects, and what is achievable. Monitoring would continue to be largely carried out by Government (Ministry of Health, Ministry for the Environment) and Regional Councils. Key toxic contaminants that should be included in the air programme would be:

6.4.2.1 First Tier

- Volatile hydrocarbons (mainly benzene, toluene, 1,3 butadiene and other compounds found in fuels).
- Heavy metals (mainly mercury, arsenic, and other metals found in transport fuels.)
- PAHs (mainly from transport emissions).
- Organochlorines (mainly dioxins and compounds used in timber treatment).

- Pesticides (mainly the components in spray drift, as identified in the NZ Standards reference document).

6.4.2.2 Second Tier

- Specific compounds found in use in NZ. It is difficult to fully identify these at present. These will be an outcome of the development of a national toxic contaminant register (TCR) or the like.

It is recommended in the first instance that evaluation of trends and changes in data would be carried out on an annual basis.

The potential for stage two indictors of toxic contaminants in air is emphasised. Considerable advances are being made in relation to the use of biomarkers of contaminant exposure in humans. There are also developed linkages between acute effects in animals in-vitro test systems as predictors of chronic adverse health effects in humans.

Note that a very important feature of this recommendation is the need for a detailed, regularly-updated TCR. Without this is it impossible to determine just what is being released into the environment, and thus, what are the measurement priorities. Also, because of the cost and complexity, it will be difficult to measure all the potential toxic contaminants in the air or other parts of the environment. The TCR will provide a key indicator (perhaps the only one) of the release of toxics into the environment. As such, this is viewed as a key component of the EPI programme.

Overall it is recommended that air quality TCIs be set up utilising the following:

- A TCR or the like be used as a first stage basis for EPI programme.

- Measurement at existing monitoring sites for specific toxic substances.

It is not difficult to establish a preliminary TCR using existing or readily available information (e.g., Council records, import statistics, major industry surveys, etc.). Once an initial register is set up, it can be refined annually.

6.4.3 Land

6.4.3.1 Soil Quality

The ability of soils to accumulate toxic substances is well known. In New Zealand this has been seen in contaminated sites (refer MfE/MoH 1997c) and in the accumulation of contaminants adjacent to roads, in pastures and generally through urban areas. Soil contamination is very site specific. As such it is extremely difficult to measure soil contamination on a national basis in an impartial manner. Monitoring programmes can be established to monitor long term trends in soil quality arising from aerial deposition. This is not considered to be warranted in New Zealand.

There are a number of potential pressure indicators that provide information on what toxic substances are entering the terrestrial environment as a whole. These include:

Indicator	Type	Comment
Inventory of the application of sewage sludge and effluent to land.	**Pressure**	Estimates of the land area used for the application of sewage sludge will provide an estimate of contaminant loadings to land from this source. Data on the expected levels of toxic contaminants in the sludge/effluent would provide a more robust indicator of pressure as alterations in contaminant levels may be expected with different treatment systems.
Inventory of fertilisers applied to land.	**Pressure**	Some fertilisers are known to contain elevated levels of heavy metals.
Inventory of pesticide/herbicide us by agriculture sector.	**Pressure**	Estimates of type and amount applied and area applied to land.

Overall, a series of pressure TCIs are recommended as part of the overall EPI. These measures, coupled with the TCR, would provide pressure indicators about the movement of toxic substances to land and the biological components of that system.

6.4.3.2 Vegetation

The key limitation to the development of national vegetation indicators of environmental quality is the need to identify widespread plant species and the need to be able to interpret the identified response seen in the plant. As discussed, there have been a number of environmental monitoring programmes that have used plants. These have occurred in North America and Europe/Scandinavia principally in response to acid rain and other air issues.

In general, plants are relatively poor indicators of toxic contaminants. This is due to the tight regulation of the passage of such contaminants across the root barrier. Exceptions to this would be the passive uptake of organics into leaf cuticle and the active uptake of some heavy metals by some plant species.

Potential vegetation indicators that could be used within New Zealand include:

Indicator	Type	Comment
Assessment of *Pinus radiata* needle health at selected sites around New Zealand.	**State**	Use of needles as overall integrator and indicator of air quality. This would require a specific knowledge of the link between overall air quality and toxic contaminants within air.
Assessment of particular crustose lichen distribution and health at selected sites.	**State**	Use of lichens (abundance and diversity) as an indicator of overall air health at specific sites. This would require a specific knowledge of the link between overall air quality and toxic contaminants in air.
Measurement of selected toxic contaminants in plant tissue (e.g., herbage) as an indicator of uptake.	**State**	Toxic contaminant concentration an absolute measure of airborne deposition of toxic contaminant and uptake from soil.
Measurement of toxic contaminants in vegetables as part of on going diet surveys.	**State**	Toxic contaminants reflect deposition and movement of contaminants into food chains including humans.

Although plant species that could be utilised include widespread forest species; native or introduced plants or agricultural crops (e.g., grain), there appears to have been insufficient work in New Zealand to date to identify a sufficiently robust terrestrial plant indicator of overall environmental or air quality.

As such, vegetation is seen as a generic indicator of overall air quality rather than toxic substances in particular. Uptake by plants from soil is a very site specific factor and as such is highly unlikely to provide suitable information for a national EPI programme. No specific indicator is recommended however, information on toxic contaminants in some vegetables and fruits in New Zealand could be obtained from the National Diet Survey.

6.4.3.3 Animals

Animals have the potential to provide an integrated or specific response to environmental quality - typically soil quality). Although, New Zealand has naturally no endemic terrestrial mammals, there are (as described in Section 4) a range of introduced bird (e.g., sparrow, pigeon) and mammal species (e.g., mice, hedgehogs) that could be used as indicators of exposure to toxic contaminants. There are also a range of native bird species (e.g., gull species) and other organisms (e.g., earthworms) that have potential as well.

The use of birds has a particular advantage in that eggs can be collected without sacrificing adult birds. Another species with considerable utility as an indicator species would be the harrier hawk. This species is a high level predator and so feeds over an extended area providing good integration. In addition the availability of accidentally killed (automobile) specimens would provide a good source of specimens for analysis.

The key limitation to the development of national animal indicators of environmental quality is the need to identify widespread animal or bird species and the need to be able to interpret the identified response seen in the organism. There have been a number of monitoring programmes utilising organisms as noted above but few appear to have been incorporated into indicator programmes.

Overall, there appears to have been insufficient work in New Zealand to date to identify a sufficiently robust terrestrial organism or organisms to provide information as an indicator of overall environmental quality. However, as indicated above, there are several options that have potential as state indicators. These include bird eggs and the collection of dead harrier hawks.

In these cases and in the potential case of other bird species such as gulls and sparrows as an indicator of environmental quality in the New Zealand environment, further evaluation will be required to assess their viability. The use of biochemical markers in animals is recommended as a Stage 2 indicator to be dealt with at a later date.

Potential animal indicators that could be used within New Zealand include:

Indicator	Type	Comment
Measurement of selected toxic contaminants in bird species as an overall indicator of environmental health. Eggs would be the preferred tissue for measurement.	**State**	Use of birds (e.g., gulls) is a relatively site specific monitoring tool. Different species can be selected to selectively monitor different environmental compartments
Analysis of toxic contaminants in harrier hawk carcasses	**State**	This species is widely distributed and road killed individuals are generally not difficult to obtain.
Measurement of selected toxic contaminants in mammal species as a general indicator of environmental health.	**State**	Use of mammals such as mice and hedgehogs is a highly site specific monitoring tool. Terrestrial animals including both vertebrate and invertebrate species can be effective sentinel species for toxic contaminants through the sampling of wild animals in the field and measurement of body burden (chemical analysis); assessment of effects; using caged animals and carrying out laboratory testing.
Assessment of meat quality from grazing animals in New Zealand. Sheep and cows are the key animals due to their widespread distribution in New Zealand.	**State**	Two options for monitoring. The first is as part of MAF meat quality surveys. The second is by specific sampling of tissue from designated properties. The former can represent random and or biased sampling. The second method of sampling allows systematic and repetitive sampling to be carried out over time. The latter allows specific trend assessment to be carried out.
Measurement of biochemical markers in selected species.	**State**	Measurement of effects of complex mixture when the total range of chemicals present is unclear. Recommended as a Stage II indicator.
Measurement of selected toxic contaminants in earthworms as an indicator of soil health.	**State**	Use of earthworms is a highly site specific monitoring tool.

6.4.4 Freshwater

6.4.4.1 Water

Toxic substances are typically transient in freshwaters. Many substances have very short residence times within water. As a result, monitoring of freshwaters often reflects short term events within catchments feeding the water body. This needs to be reflected in the use of water as an indicator. However, the National Water Quality Monitoring Programme has shown the capability of well designed and managed water quality monitoring programmes.

Examples of potential water quality performance indicators in the freshwater environment include:

Indicator	Type	Comment
Compilation of all Regional Council water quality toxics monitoring data. If no specific toxics monitoring is being carried out, then a limited number of specific sites could be established in degraded waterways in major urban waterways. This would allow a benchmark programme for improvement to be established.	**State**	Comparison against regional or national toxics guidelines provides an indicator of exceedence of guidelines in relation to ecosystem health; recreational use; and in relation to use by stock and other agricultural uses. If a benchmark programme is established then trends over time would be the main purpose of the programme.
Measured quality of wastewater treatment plant discharges to the freshwater and marine environments.	**State**	Testing of a selected range of wastewater treatment plant discharges to the freshwater and marine environments in New Zealand is carried out.
Inventory of toxic waste discharges to freshwater	**State / Pressure**	TCR data provides the best pressure indicators. Such indicators will depend on the implementation of a New Zealand TCR programme

There are a number of water quality monitoring programmes that collect data on toxic contaminants in freshwater around New Zealand. Water quality can be benchmarked against international criteria and guidelines for toxic contaminants and those set in Regional Plans where Councils have adopted standards or guidelines that involve toxic contaminants. There is however, only a limited amount of toxic contaminant monitoring currently underway.

The existing monitoring programmes carried out by Regional-District Councils and or NIWA should be examined to identify a series of representative sites that include a balanced range of sites throughout New Zealand. In this case the National Water Quality Monitoring Programme may not contain sufficient sites to provide information relating to sites with possible stress from the presence of toxic contaminants. This would provide an existing series of sites that contaminants are being monitored for. It is likely however that some additional toxic contaminants may need to be incorporated into the existing programmes. This may require a limited amount of additional monitoring to be carried out by Councils within their existing programmes. The use of the National Water Quality Monitoring Programme would require the addition of new constituents to the monitoring programme and testing. Monitoring would continue to be carried out by Councils (to consistent methodology) and the data provided to a centralised data base. Key toxic contaminants that should be included in the freshwater quality indicators programme would include ammonia nitrogen, selected metals, selected organic compounds such as PAHs.

It is recommended in any freshwater programme that the evaluation of trends and changes in data would initially be carried out on a two yearly basis.

Given the very limited amount of toxic substance monitoring in the existing Regional Council monitoring programmes (refer Section 5.4), it is unlikely that toxic substances measurement in water could be utilised immediately as an indicator. Ammonia nitrogen is the only common toxic substance included in Council monitoring programmes and the National Water Quality Monitoring Programme.

It is also recommended, however, that loads and quality of municipal wastewater treatment plant discharges be used as an indicator of pressure on the freshwater (and also the marine) environment. Many sewage treatment plants have resource consents that require flows and loads of key constituents to be determined. A small proportion have toxic substance monitoring programmes.

6.4.4.2 Sediment

As discussed in Section 4, freshwater sediments provide integrated data on the presence of toxic contaminants in aquatic environments. The accumulated toxic contaminants in sediment reflect catchment or site specific activities. Sampling location and the collection of systematic data is typically the key to the collection of useable information. As described in Section 4, sediment sampling is carried out in several large United States environmental monitoring programmes. In the larger of New Zealand rivers, monitoring sediment quality could provide useful information about overall environmental quality. It should be noted however, that few of New Zealand's urban centres are located inland. The majority are located on the coast or on major harbours and estuaries. Potential sediment indicators that could be used within New Zealand include:

Indicator	Type	Comment
Compilation of all Regional Council sediment quality toxics monitoring data. If no specific toxics monitoring is being carried out, then a limited number of specific sites could be established in degraded waterways in major urban waterways. This would allow a benchmark programme for improvement to be established.	**State**	Comparison against international recognised sediment quality guidelines would provide an indicator of exceedence of guidelines in relation to ecosystem health. If a benchmark programme is established then trends over time would be the main purpose of the programme.

Overall it is considered that given the sensitivity of carrying out repetitive measurements of contaminants in sediments that a nation-wide sediment quality indicators programme is not warranted.

The existing monitoring programmes carried out by Regional-District Councils and or NIWA should be examined to ascertain whether a small series of representative sites can be identified to provide indicator of regional trends as a reflection of overall catchment inputs to specific rivers located in urban areas. Key toxic contaminants to be included in any freshwater sediment programme are: selected metals, selected organic compounds such as PAHs and organochlorines. It is recommended in the first instance that evaluation of trends and changes in data would be carried out on a two yearly basis if such a programme were developed.

6.4.4.3 Freshwater Organisms

Freshwater organisms can provide integrated data on the presence of specific toxic contaminants in aquatic environments. The meaningful use of freshwater organisms does however require species specific knowledge of uptake and bioaccumulation. Similar understanding of biochemical ecotoxic response measures is also required. A wide range of indicator species can be used for contaminant biomonitoring in tissues, which would be suitable for bioaccumulative organic contaminants and heavy metals. Taxa used for tissue bioassessment in United States freshwater monitoring programme are summarised in Table 6.1 following.

TABLE 6.1: National target taxa list for tissue bioassessment in the water-quality assessment program[6].

Group	Taxon
Molluscs	• *Corbicula fluminea* (Asiatic clam)
Insect Larvae	• Trichoptera (Caddisflies) • *Hydropsyche* sp. • *Brachycentrus* sp. • *Limnephilus* sp. • Chironomidae (Midges) • *Chirononomus* sp. • Plecoptera (Stoneflies) • Peridae • Perlodidae • Pteronarcyidae
Fish	• Carp *(Cyprinus carpio)* • White sucker (*Catostomus commersoni)* • Longnose sucker *(Catostomus catostomus)* • Largescale sucker (*Catostomus macrocheilus*) • Channel catfish (*Icatalurus punctatus)* • Largemouth bass *(Micropterus salmoides)* • Brook trout *(Salvelinus fontinalis)* • Brown trout (*Salmo truta)* • Bluegill (*Lepomis macrochirus*
Vascular Plants	• Pond-weed *(Potimogeton* sp.) • Hydrilla (Hydrilla verticillata)

[6] See also Appendix D, The U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program for Evaluating Contaminants in Tissues of Freshwater Biological Organisms (Crawford & Luoma, 1994).

- **Invertebrates**

Potential freshwater indicator species for New Zealand would include molluscs (freshwater mussel), invertebrates (various), freshwater crayfish, fish (eels, bullies, trout) and vascular plants (i.e., oxygen weed, Potomogeton). Of all the freshwater invertebrates in New Zealand, freshwater mussels have been specifically identified as being a potential indicator in relation to the presence of toxic contaminants in New Zealand. It is likely that mussels have potential as a regional indicator especially in the central North island of New Zealand and the Waikato River.

The ability to use existing monitoring programmes in a number of regions needs to be assessed. The need to supplement this work to obtain sufficient data to assess quality using such an indicator needs to be determined. There are however, a number of potential performance indicators that involve invertebrates.

These include:

Indicator	Type	Comment
Measurement of specific toxic contaminants in specific invertebrate species as measure of toxic contaminant distribution in New Zealand freshwater systems.	**State**	Any species specific invertebrate monitoring programme would require understanding of uptake and effects of uptake on that species. Likely to be of limited use. No such monitoring appears to have occurred in New Zealand.
Measurement of toxic contaminants using sentinel organisms (e.g., freshwater mussels).	**State**	Applicability for certain toxic contaminants has been shown in certain parts of New Zealand.
Measurement of biochemical markers in selected species.	**State**	Measurement assumes knowledge of toxic contaminant presence and response in species. Recommended as Stage II indicator.

- **Fish**

In New Zealand, salmonids (trout species) and eels represent likely indicator species in relation to toxic contaminants. Eels represent a long lived hardy species of freshwater fish that may be a suitable indicator species. They are widely distributed, long lived, relatively sedentary and are of considerable cultural and commercial significance. Their ability to accumulate environmental contaminants has been demonstrated and they also appear to be amenable to caging which permits good control over actual exposure. Salmonid species have been included in a number of overseas indicator programmes.

Potential fish indicators that could be used within New Zealand include:

Indicator	Type	Comment
Measurement of specific toxic contaminants in specific fish species as measure of toxic contaminant distribution in New Zealand freshwater systems.	**State**	Any species specific fish monitoring programme would require understanding of uptake and effects of uptake on that species. Purpose would be trend analysis Trout are likely to be key species.
Measurement of biochemical markers in selected species.	**State**	Measurement assumes knowledge of toxic contaminant presence and response in species. Recommended as a Stage II indicator.
Assessment of condition and other features such as tumours.	**State**	Provides an indication of overall exposure to toxic contaminants.

Some assessment will be required to determine specific programme details surrounding the use of existing monitoring programmes in a number of regions, as well as the need to supplement this work to obtain other data.

Closure of fisheries due to the presence of toxic substances occur overseas. However, in New Zealand there are no current closures of the fishery nor are there likely to be any. As such, the frequency of closure of the fishery due to contamination is not viewed as an appropriate indicator for New Zealand. Further, the assessment of fish condition is problematic as such conditions are potentially a response to a wide variety of environmental situations. The presence of tumours etc., would be primarily indicative of highly impacted systems only.

Overall, eels or trout are likely to be useful Stage 1 indicators of the presence of toxic substances in the freshwater environment. No systematic national monitoring occurs at present and as such a programme would need to be co-ordinated. Measurement of biochemical markers is identified as a stage 2 indicator.

6.4.5 Marine Environment

6.4.5.1 Water

The concentrations of toxic contaminants in the water-column are likely to be highly variable, and in most places extremely low. Monitoring data would be difficult to interpret and its associated “noise” would mean it is likely to be of little use for detecting temporal trends. For these reasons, monitoring methods which “integrate” and “accumulate” contaminant signals from the water column are preferred. Contaminant levels in sediments and biota are therefore preferable indicators for the marine environment.

An alternative, increasingly used method for measuring dissolved contaminant levels in the water column is the “Semi-Permeable Membrane Device” (SPMD). Hydrophobic contaminants are concentrated from the surrounding water by diffusion into a lipid-filled membrane tube. Deployments of several weeks are possible, enabling time-integrated measures of contaminant levels to be made. Contaminant concentrations in the water column can be estimated if contaminant uptake and equilibration times are known. SPMDs offer many of the advantages of biological monitors (e.g., shellfish) without the disadvantage of biological variability inherent in biomonitoring approaches. Their prime disadvantages are membrane fouling during deployment and their relatively recent development, which means they are less well established than shellfish monitoring. Trials of SPMDs have recently been carried out in New Zealand, although results are not yet available. This method is well worth pursuing to complement biomonitoring techniques. It is equally applicable to the freshwater environment, and has even been used for air monitoring overseas.

Potential marine water indicators that could be used within New Zealand include:

Indicator	Type	Comment
Compilation of all Regional Council water quality toxics monitoring data. If no specific toxics monitoring is being carried out, then a limited number of specific sites could be established adjacent to major urban areas. This would allow a benchmark programme for improvement to be established.	**State**	Comparison against regional or national toxics guidelines for aquatic toxicity provides an indicator of exceedence of guidelines in relation to ecosystem health. If a benchmark programme is established then trends over time would be the main purpose of the programme. Comparison against regional or national toxics guidelines for recreational quality provides an indicator of exceedence of guidelines in relation to recreational use.
Quality and measured quality of wastewater treatment plant discharges to the marine environment.	**Pressure**	Testing of a selected range of wastewater treatment plant discharges to the marine environment in New Zealand is carried out.
Inventory of toxic contaminants discharged to the marine environment	**Pressure**	Dependent of the establishment of a New Zealand toxic contaminant inventory.

There is currently little toxic substance monitoring in marine waters. No specific indicator is recommended using marine waters in New Zealand. The possibility of increasing monitoring effort in New Zealand in this area should be assessed and its technical value confirmed.

6.4.5.2 Sediment

Coastal sediments are the ultimate recipients of hydrophobic contaminants. The accumulation of contaminants in estuarine sediments is well documented in New Zealand. Sediments are heterogeneous materials and subject to three-dimensional mixing and redistribution via processes such as bioturbation, wave-action, and current-induced erosion. They are therefore complex media to sample and a sediment monitoring programme would need to take into account of these features. They offer a practical approach for monitoring trends in contaminant exports from land over time, and for spatial characterisation of contaminant levels (e.g., relating to catchment uses). The potential for biological impacts can be inferred by comparing contaminant levels with overseas Sediment Quality Guidelines.

Potential marine sediment indicators that could be used within New Zealand include:

Indicator	Type	Comment
Compilation of all Regional Council sediment quality toxics monitoring data. If no specific toxics monitoring is being carried out, then a limited number of specific sites could be established in areas known to be degraded (e.g., adjacent to major urban centres) This would allow a benchmark programme for improvement to be established.	**State**	Comparison against international recognised sediment quality guidelines would provide an indicator of exceedence of guidelines in relation to ecosystem health. If a benchmark programme is established then trends over time would be the main purpose of the programme.

6.4.5.3 Marine Organisms

- **Invertebrates**

Marine invertebrates, in particular bivalves (e.g., mussels, oysters), are among the most suitable biological indicators for toxic contaminants. They accumulate most organic contaminants and metals from the water column, sediments, and food sources by filter-feeding and/or particle ingestion. They offer advantages of many species being sessile, relatively resistant to pollution, transplantable, and (depending on sampling strategy) contaminant levels in their tissue generally reflect changes in water column/sediment/food contaminant levels. These advantages have lead to their adoption world-wide for pollution monitoring (e.g., Mussel Watch programmes).

The Auckland Regional Council has run such a programme for 11 years in the Manukau Harbour, using naturally resident Pacific oysters (*Crassostrea gigas*) to measure spatial and temporal trends in organic and heavy metal contaminants. Potential marine invertebrate indicators that could be used within New Zealand include:

Indicator	Type	Comment
Measurement of specific toxic contaminants in specific marine invertebrate species as measure of toxic contaminant distribution and temporal trends in New Zealand benthic marine systems	**State**	Any species specific invertebrate monitoring programme would requires an understanding of contaminant uptake and depuration in order that contaminant burdens be correctly interpreted. and effects of uptake on that species. Likely to be of limited use. Limited monitoring appears to have occurred in New Zealand.
Use of transplanted sentinel organisms (e.g., mussels and oysters)	**State**	Monitoring has been carried out in various locations in New Zealand. Has capability potential to be reproducible and part of Regional Council monitoring programmes. Interpretation requires knowledge of contaminant uptake & depuration characteristics of sentinel organisms.
Measurement of biochemical markers in selected species.	**State**	Measurement assumes knowledge of toxic contaminant presence and response in species. Recommended as a Stage II indicator.

It is envisaged that, as overseas, such monitoring would best be done using similar deployment and analysis methods as those used in the global ‘mussel watch’ programme. Contaminant levels are generally lower in New Zealand than in many overseas settings and therefore, methods need to reflect this difference (i.e., more sensitive analytical methods). More refined trend detection than is used in some overseas programmes is needed, as the scale of New Zealand’s geography and range of issues is generally smaller. International collaboration will provide data quality comparable to the rest of the world. Absolute concentration comparisons will depends very much on the sentinel animal used, where and how it is deployed and sampled etc.

- **Fish**

Fish have been used in the monitoring of toxic contaminants in the estuarine and marine environments, particularly overseas (e.g., NOAA Benthic Surveillance Programme). Monitoring has included both toxic contaminant bio-accumulation and the monitoring of effects via the examination of fish health and histopathology (e.g., lesions, tumours, etc.,). Gross pathological disorders reported in overseas programmes reflect the sampling of extremely contaminated environments of a severity not found in New Zealand. Effects in New Zealand fish are more likely to be subtle disorders, which may be more difficult to measure and link with environmental contaminants. The marine/estuarine fish most likely to be useful for contaminant monitoring in New Zealand are flatfish (e.g., flounder), which live in intimate contact with the sediment and feed on sediment-dwelling prey. They are therefore susceptible to contaminant exposure, especially in near shore estuarine locations. Potential marine fish indicators that could be used within New Zealand include:

Indicator	Type	Comment
Measurement of specific toxic contaminants in specific marine fish species as measure of toxic contaminant distribution and trends in New Zealand marine systems.	**State**	Any species specific fish monitoring programme would require understanding of uptake and effects of uptake on that species. Understanding of the habitat preferences and movement of fish required to interpret data. Purpose would be trend analysis and spatial comparisons. Flounder and snapper (not sure about snapper - less likely to be exposed to contaminants than flatfish) are likely to be key species.
Measurement of biochemical markers in selected species.	**State**	Measurement assumes knowledge of toxic contaminant presence and response in species. Recommended as a Stage II indicator.
Assessment of condition and other features such as tumours.	**State**	Provides an indication of overall exposure to toxic contaminants (refer to comments above regarding freshwater fish).

In New Zealand, flounder and snapper are the two most well studied fish species in terms of bioaccumulation. Flounder are especially important as they have also been used in a number of overseas monitoring programmes. They are also of cultural, commercial, and recreational importance.

It is recommended that flounder be used in any estuarine monitoring programme. Although fish do not appear to be used by Councils on a regular basis in monitoring programmes, a small programme of sample collection and analysis for organochlorines and other selected organic compounds can be readily developed. Research on the effects of chemical contaminants on flounder is currently being carried out in a collaborative project by NIWA and ESR.

- **Mammals**

Although no environmental indicators as such have been developed using marine mammals several long term monitoring programmes are in place from which useful indicators can may be extracted. In the international context the work of Tanabe's group at Ehime University stands out as a significant contribution to the understanding of the global contamination of marine mammals, and therefore the marine environment, with chemical contaminants (Tanabe, 1994). In particular this group has focused on long term trends in chemical contamination in the Southern Ocean and in the North Pacific.

Trend information is now available for organochlorine contaminants in marine mammals over approximately a twenty year span. This data demonstrates a slow but significant decrease in contamination in some marine mammals in the North Pacific. The potential animal indicators that could be used within New Zealand include:

Indicator	Type	Comment
Measurement of specific toxic contaminants in specific marine mammals as measure of toxic contaminant distribution and temporal trends around New Zealand.	**State**	Any species specific monitoring programme would require understanding of uptake and effects of uptake on that species. Purpose would be trend analysis Dolphin and whale strandings are likely to be the key species.
Measurement of biochemical markers in selected species.	**State**	Measurement assumes knowledge of toxic contaminant presence and response in species. Recommended as a Stage II indicator.

A considerable amount of information is available on the concentrations of organic contaminants in New Zealand marine mammals back to the late 1980s (Buckland *et al.* 1990; Jones *et al.* In Press). This data would represent a valuable baseline for future monitoring.

6.4.6 Groundwater

Sampling and analysis are keys to ensuring the quality and robustness of indicators of groundwater quality that are being used to show change in relation to specific objectives and goals. New Zealand carries out extensive groundwater monitoring organised on a regional basis. This existing monitoring system has the potential to be used to develop a regional/national monitoring system.

Possible indicators of groundwater quality include:

Indicator	Type	Comment
Measurement of specific toxic contaminants in groundwater as a measure of toxic contaminant distribution in groundwater around New Zealand. Data to be compiled from Regional Council data or from very specific sampling programme.	**State**	Exceedence of New Zealand Drinking Water Guidelines would provide measure of performance.

The existing monitoring programmes carried out by Regional-District Councils should be examined to identify a series of representative sites throughout New Zealand. The use of the existing programme would provide an existing series of sites that contaminants are being monitored for. It is likely however that some additional toxic contaminants may need to be incorporated into the existing programmes. This may require a limited amount of additional monitoring to be carried out by Councils within their existing programmes. Monitoring would continue to be carried out by Councils (to consistent methodology) and the data provided to a centralised data base. Key toxic contaminants that could be included in the groundwater quality indicators programme would include ammoniacal nitrogen, selected metals, selected organic compounds such as PAHs.

It is recommended in the first instance that evaluation of trends and changes in data would be carried out on a two yearly basis.

6.4.7 Human Exposure

One of the key goals of environmental management is to protect human health. To assess our performance in protecting humans from exposure to toxic chemicals it is necessary to monitor levels of these contaminants in the human population. Obtaining samples of the human population can be difficult and costly therefore the most benefit needs to be derived from these studies.

Historical and current studies have focused on the use of blood, breast milk and dietary surveys to estimate this exposure. Continuation of these studies is recommended but an integrated assessment of which chemicals should be monitored to obtain maximum benefit from the surveys is suggested.

The current breast milk and diet studies are being carried out with an approximate five year cycle time. This is considered adequate given the rate of change in chemical concentrations observed in these studies and in overseas programmes.

Recommended human exposure indicators include:

Indicator	Type	Comment
Measurement of contamination in breast milk.	**State**	Breast milk surveys are on-going. Data is internationally comparable.
Measurement of specific toxic contaminants in diet in relation to intake of contaminants.	**State**	Diet surveys are ongoing. Substantial data base exists for comparative assessment. Date would provide information on dietary intake.
Measurement of specific toxic contaminants in drinking water supplies in relation to intake of contaminants.	**State**	Data to be compiled form routine regional monitoring. Data would provide information on dietary intake.

6.4.8 Media Summary

A number of specific media orientated performance indicators have been identified that should be considered as part of a New Zealand toxic contaminants assessment programme.

A summary of selected media and media compartment indicators is presented in Table 6.2. The suggested ranking of priorities for the implementation of these indicators is also presented.

There are a number of indicators which are either in the initial investigation and research stages or are being used overseas but have not been used or adapted for New Zealand. It would be advantageous during discussions regarding specific nature of any EPI programme to view the programme as dynamic. A staged approach allows for new tools to be considered or used which are being developed as part of international research as well as, through various research programmes within New Zealand.

There are a number of TCIs that could be utilised as part of a New Zealand EPI. In the following section, the indicators are discussed further in relation to two key matters:

- Firstly, should the indicator be included in a core of a set of indicators initially used in New Zealand.

- Secondly, given that there is an extensive list of contaminants that have been identified within the New Zealand environment and that comprise the list of priority contaminants within New Zealand, can key toxic contaminant indicators be identified that provide data on their own in relation to the overall presence of toxic contaminants in the environment (or in a particular environmental compartment)?

TABLE 6.2: A summary of selected media and media compartment indicators, and priorities for implementation.

Media	Stage I		Primary Implementation	Secondary Implementation
	P-S-R	Indicator		
Overall Environmental Pressure		• TRI or similar register	4	
Air	**Pressure / State**	• Specific air monitoring		4
Terrestrial Vegetation	**State**	• Vegetable part of National Diet Survey	4	
Animals	**State**	• Bird eggs - tissue burden (MAF monitoring) • Harrier Hawk / Skylark carcasses -tissue burden • Meat - tissue burden (MAF monitors)	 4	4 4
Land	**Pressure**	• Sewage sludge use • Fertiliser use • Pesticide/Herbicide use	4	 4 4
Fresh-water	**Pressure**	• Specific site water quality assessment • Wastewater loads and quality	 4	4
Fresh-water Organisms	**State**	• Eel, trout - tissue burden • Mussels - tissue burden		4 4
Fresh-water/Marine Sediment	**Pressure**	• Specific site sediment quality assessment		4
Seawater	**Pressure**	• Wastewater loads and quality	4	
Marine Organisms	**State**	• Mussel - tissue burden • Flounder - tissue burden		4 4
Groundwater	**State**	• Ground water quality	4	
Human Compartment	**State**	• Diet survey • Drinking water survey • Breast Milk Survey	4 4 4	

6.5 PREFERRED INDICATORS FOR THE TOXIC CONTAMINANTS INDICATOR PROGRAMME

6.5.1 Introduction

This report has reviewed and identified a wide range of potential indicators that could be incorporated into the New Zealand EPI programme. A number of the toxic contaminant indicators discussed have been used in overseas indicator programmes. However, as has become clear through the review process, there are as yet few examples of overseas EPI programmes which have been able to provide direct information into management decision making. Rather, the information provided must be viewed within the specific context for which it has been collected in order to facilitate the management of toxic contaminants in the environment. As these programmes develop, evidence will accumulate as to the trends (negative or positive) of toxic contaminants in particular environmental compartments.

The establishment of EPI programmes, and more particularly indicator programmes involving or including toxic contaminant indicators, is a significant undertaking both in terms of the logistics involved and the potential expense. To facilitate this process, the list of potential indicators has been reviewed further. The list provided in Table 6.2 should be regarded as an ideal list which could be expanded over time. However, it would not be practical to implement such an extensive list of toxic contaminant indicators at the commencement of any EPI and any attempt to do so may result in significant delays in the implementation of any EPI.

When the toxic contaminant indicators are initiated, it will be important that the programme is balanced in that it should provide a whole picture as far as possible of the different compartments of the New Zealand environment. That is, it encompasses the terrestrial, aquatic, air and human environment. This will provide managers with a complete picture in relation to the state of the New Zealand environment at both the regional and national level. This has been taken into account in refining the list of indicators.

Specific sites and timing of sampling for the toxic contaminants indicators are not provided here. It is envisaged that the toxic contaminants indicators sampling will be integrated into the entire EPI sampling/analysis programme and that the final selection of toxic substances would be confirmed along with the methods involved by an appropriate review committee. Comment is provided on further refinement of the list of contaminants, where possible.

While the advantages of response and pressure indicators are acknowledged the above constraint has resulted in the initial choice of mainly state indicators. Furthermore, the desire for an immediate and cost effective implementation of selected indictors has resulted in the choice of mainly measures of chemical concentrations rather than measures of chemical effect. The advantage of biological measures of chemical effect are recognised and it is strongly recommended that the next effort within the EPI programme be towards the implementation of indicators based upon measures of biological effects.

6.5.2 Preferred Indicators

Set out below is a commentary on the refined list of preferred indicators.

6.5.2.1 Air Indicators

Indicator 1. Measurement of toxic contaminants in urban air.

Air quality in urban environment is a significant issue in parts of New Zealand and involves both human and environmental health. Air quality issues encompass a range of contaminants and these were described in Section 6.4.2. A first tier list of toxic contaminants was identified that included hydrocarbons, organochlorines and metals. It is considered that an air indicator should include three groups of compounds initially:

- volatile hydrocarbons (e.g., benzene, 1,3-butadiene, toluene, formaldehyde, ethene, propene, n-butene, trichloroethylene, dioxins).
- PAHs (e.g., benzo(a) pyrene, total).
- metals (e.g. mercury, cadmium, lead, zinc, chromium, arsenic).

For each of these categories, measurement methods often employed are able to provide data on a range of compounds without much more expense than on a single one. As these chemical groups contain numerous individual chemicals, the specific indicator compounds should be confirmed but the compounds selected should reflect the key sources contributing contaminants to the atmosphere and should reflect key issues in New Zealand. Data from a New Zealand toxic contaminants register (TCR) or the like, would assist in this decision.

Monitoring will need to be carried out on a regular basis at sites located in key urban areas. Sites should be linked to key long term monitoring sites already established where ever possible as part of other regional monitoring programmes. Integration with existing programmes will need to be reviewed in more details prior to the initiation of an indicator These programmes would provide data on other key airborne contaminants and meteorological conditions relevant to the interpretation of collected data. The location and sampling frequency will need to be confirmed.

6.5.2.2 Terrestrial Indicators

A range of potential indicators were identified that could be utilised to identify the presence of toxic contaminants in the terrestrial environment. At this stage two indicators have been identified.

Indicator 2. Meat contaminant surveys.

Monitoring of contaminants in meat is carried out by the Ministry of Agriculture and Fisheries on an on-going basis as a requirement for export quality assessment. As such, this programme is already established and therefore presents an opportunity in the indicators programme to have an indicator that provides data on the flow of contaminants from the agricultural environment to animals. Given the importance of agriculture in New Zealand, it is considered that the indicator has the potential to provide valuable information on the state of part of the New Zealand environment.

To utilise the Ministry's meat monitoring programme, a review will be necessary of the range of contaminants examined in the programme and how data collected in the programme could be utilised. Based upon the review, the use of the data may need to be limited. However, because of its scale it provides valuable data on the general quality of a component of the terrestrial environment. It should be noted that a single contaminant indicator has not been identified. The use of the 'meat' indicators would utilise any available data. The programme would however be limited to the contaminants that provided sufficient data to allow temporal comparisons. The data obtained would include POPs, other pesticides and some metals (in particular mercury) with emphasis on the organic compounds.

Prior to any use of such an indicator, discussions will need to be held with the Ministry in relation to access to data and the analytical programme. Data management within the programme to develop output in relation to environmental quality will need to be examined.

It is recognised that this potential indicator only provides information in relation to agricultural animals and agricultural land. This is seen as a deficiency and effort will need to be made within the EPI programme to identify state indicators and more particularly effects indicators that focus on wildlife as the natural terrestrial environment is a key component of the New Zealand environment.

Indicator 3. Groundwater quality.

Groundwater quality has been identified as a preferred indicator as groundwater is an important resource in New Zealand and reflects the overall nature of activities in the terrestrial environment. As identified in Section 6.2, there is substantial monitoring of groundwater quality in New Zealand which can be utilised to establish an indicator with minimal expenditure.

As such, groundwater quality represents an environmental quality indicator that can be established relatively easily and provide information on a key compartment of the New Zealand environment. However, prior to its inclusion in any EPI programme, further work will be required to:

- Review the monitoring carried out by Regional Councils further.
- Review what contaminants are being measured.
- Identify where monitoring is being carried out (e.g., aquifer, location). At this stage no specific list is provided. However the list of key indicator

contaminants will depend upon the purpose of any groundwater indicator. Key contaminants are likely to include ammonia (agriculture, landfills), nitrate (drinking water), copper (timber treatment) and hydrocarbons (fuel).

- Confirm whether an indicator can be established based upon existing resources and information collection.

Further comment is provided on both of these indicators later in this section.

6.5.2.3 Aquatic Environments

Freshwater Indicators

The review of freshwater indictors identified several possible indicators. At this stage it was considered that the use of freshwater quality and sediment quality in relation to toxic contaminants would not provide sufficient robust data to augment a national EPI. Although no specific water quality monitoring has been proposed, it should be emphasised that ammonia which is an important aquatic toxic substance in New Zealand is already included in the EPIP and the National Water Quality Monitoring Network. As organisms that live in freshwater can provide an integrated picture of the presence of toxic contaminants, the preferred indicator utilises a freshwater organism. The organisms recommended for use are:

Indicator 4a. Freshwater eels.
Indicator 4b. Sentinel biomonitoring species (mussels and or eels).

Eels are found throughout New Zealand, are of cultural significance as a food source and are considered to be environmentally tolerant. Further, of all of the fish species found in New Zealand they are the most well understood in terms of bioaccumulation.

A second indicator option involves the use of sentinel freshwater organisms that can be transplanted to provide an indication of the presence of toxic contaminants. The New Zealand freshwater mussel which has already received considerable use as a sentinel species in the Waikato and Bay of Plenty (e.g., Waikato and Tarawera Rivers) and is recommended as a species for use. Eels have also been caged and utilised as sentinel organisms in these locations. Finally, eels have also been utilised within the current organochlorines programme.

A wide range of contaminants were identified in the preliminary priority pollutant list earlier in this review.

Insufficient work appears to be carried out systematically enough by Regional Councils to develop an indicator around existing monitoring. How existing Council work can be fitted into any proposed programme or vice versa, needs to be determined. The final identification of what contaminants should be monitored will require confirmation of the key contaminant issues. However an initial list would comprise:

- Mercury as the key metal.
- Benzo(a) pyrene as a key PAH.
- DDE and PCBs as key POPs.

The specific contaminants included will depend on the nature of the analytical work carried. For example all 16 USEPA priority PAHs may be determined at the same time. The development of a TCR and identification of specific issues will assist in developing this list. Protocols and monitoring strategies will need to be established for Indicator 4.

Following the implementation of the freshwater state indicator organism or organisms that the development of effects indicators be developed for the freshwater environment. Effects based monitoring such as biomarkers will fit well with indicator 4.
Macroinvertebrate monitoring will be a key indicator in any freshwater indicator programme. Macroinvertebrate monitoring is well established and understood in New Zealand and currently represents the most effective monitoring tool for state of freshwater environments in New Zealand. Although macroinvertebrate monitoring per-se has limited ability to identify cause and effect (i.e., in relation to toxic substances), the use of macroinvertebrates should be linked into any toxic contaminant monitoring programme.

Marine Indicators

As with freshwaters, the review identified a series of possible indicators. Two indicators were identified for the marine environment. These are:

Indicator 5. Sentinel species (mussels).
Indicator 6. Estuarine sediments.

Because of the variability in estuarine and marine invertebrate distribution and availability it is considered that the use of a sentinel invertebrate species such as mussels is the most appropriate indicator of water borne contaminants in the coastal environment. Mussels are already utilised around New Zealand as sentinel organisms. The use of mussels would provide a programme that would parallel the International Mussel Watch Programme.

It is also recommended that further evaluation be carried out following the initiation of the New Zealand EPI programme regarding the use of marine mammal (e.g., dolphin species or fur seal) contaminant data to provide a measure of the state of the overall inshore coastal environment in New Zealand.

In relation to the key indicator toxic contaminants that should be measured in Indicator 5, a number of key contaminants can be identified. These are:

- Lead and mercury as the key metals (the inclusion of other metals needs to be clarified due to control of bioaccumulation by organisms).
- Benzo(a) pyrene as the key PAH.
- DDE and PCBs as key POPs.

The inclusion of other contaminants should be reviewed. As sediments are the most significant repository of toxic contaminants in the estuarine and marine environment, monitoring of sediment quality at carefully selected locations is recommended to provide further information on the quality of the inshore environment.

A number of specific issues arise in the use of sediments as an indicator in relation to toxic contaminants. These are:

- Sediment quality will be highly variable in relation to contaminant sources.
- Sediment quality will be highly variable in relation to sediment properties.

To reduce effort, at risk or key sites should be included in the programme. An extensive list of contaminants can be included; however there are only a small suite of contaminants that are typically present in estuarine - marine sediments in New Zealand. The following toxic contaminant indicators have been selected:

- As, Cu, Cr, Cd, Pb, Hg, Zn, Ni.
- DDT as the key POP.
- Benzo(a) pyrene as the key PAH.
- Ammonia (because of its role in sediment toxicity).

Seven metals have been identified at this stage each of which important contaminants in relation to the quality of the New Zealand environment: As, Cu, Cr in relation to the timber treatment industry; Cu, Pb, Zn in relation to transport; Cu, Cr, Ni in relation to tanning and metal industries; Cd and Hg as they are important environmental contaminants. In order for a reduced list of these contaminants to be developed, a review of specific sources, locations and extent of contamination in New Zealand would need to be undertaken.

Protocols (in particular for sediments) and monitoring strategies will need to be established for Indicators 5 and 6.

6.5.2.4 Human Exposure

The evaluation of the human environment identified two key indicators both of which are already utilised in New Zealand to assess the state of human health. These are:

Indicator 7. Diet survey for metals and POPs, pesticide residues and PAHs.
Indicator 8. Human milk for POPs, metals and pesticide residues.

Human diet and breast milk surveys are carried out about every 5 years in New Zealand. As noted earlier in the review this work is on-going and provides data that allows temporal comparisons and also comparisons with similar overseas data.

It should be pointed out that diet surveys do not provide a specific picture of the state of the New Zealand environment as not all of the foods examined are grown in New Zealand. However as with the MAF meat quality monitoring, the data provides valuable information on the contaminant levels in an important component of the New Zealand environment. Further review of the use of diet survey information is recommended at some stage.

Although the diet survey incorporates a range of metals, the TCIs should initially be focused on As, Cd, Pb and Hg due to their greater toxicological importance.

6.5.2.5 Pressure

The last 'group' of indicators are pressure indicators. That is:

Indicator 9. Establishment of a toxic contaminants register for New Zealand.

The establishment of a New Zealand release register has been given considerable emphasis in this review as it would provide the principal information to provide long term direction to the toxic contaminant indicators within the EPI programme. MfE has already carried out scoping work in relation to inventories. It is recommended that initially protocols for the collection of data should be established for:

- Measurement of metals, PAHs and POPs in sewage.
- Measurement of metals, PAHs and POPs in sewage sludge applied to land.

These two components of the register would provide information on waste load movement within the terrestrial and aquatic environments from urban centres throughout New Zealand and would represent the simplest components of a this type of programme to establish. As such, it is considered more important that this component of the EPIP covers a wider range of contaminants within the groups identified above. Following an initial period of data collection, it is envisaged that any list could become more focused and reduced.

Given the importance of agriculture in New Zealand, it is also recommended that a pesticides inventory (importation etc.,) be established, by the appropriate agency, as one of the first components of a TCR.

Protocols and monitoring strategies will need to be established for any data collection carried out for Indicator 9. It is acknowledged that there is significant administrative work required to establish and implement a register or part of it. As such, specific components have been recommended in order to identify a priority list for the initial establishment of such a register.

6.5.3 Short List

In Section 6.5.2, a total of 9 TCIs were identified. Within this list a number of indicators were identified that required significant review prior to implementation. As such, the indicators are further divided into two groups.

Group 1

- Air Quality
- Freshwater (eels / sentinel organisms)
- Marine (sentinel organisms)
- Human (breast milk)
- Toxic contaminants register or the like

It is considered that a total of five TCIs provide a core set of indicators which can be used to implement or include toxic contaminants with the overall New Zealand Environmental Performance Indicator Programme.

Group 2

- Land (meat quality)
- Land (groundwater quality)
- Marine (sediments)
- Human (diet survey)

Group 2 TCIs should be reviewed further prior to their inclusion in the overall EPI programme. Other possible preferred indicators identified in Section 6 should also be reviewed over time.

7. EPI MONITORING PROCESS

7.1 INTRODUCTION

The process of indicator monitoring at a national level within New Zealand necessitates co-operation between central government and those groups currently involved and potentially involved in monitoring. It would be neither cost effective or practical to establish a centralised ‘authority’ to perform indicator monitoring. This having been said, central government needs to recognise the national strategic relevance of indicators as a measure of the state of the New Zealand environment and ensure that an appropriate level of funding is available to meet the needs of any ultimately developed indicator programme. Similarly, those agencies currently involved in monitoring need to recognise the advantages of the indicators programme to regional environmental management programmes (e.g., state of the environment reporting by Regional Councils) and become involved in the indicators programme.

It may be that the programme developed does not entail a complex monitoring programme, relying rather on a simple approach but even so, there will be some additional cost to central government. Resources will need to be committed for the overall management of information - data collection, collation, interpretation and dissemination. In addition, there may be some cost implications in the ‘obtaining’ data the collection of which has been funded by other sources.

In the following sections, a range of strategies for the implementation of environmental indicators programmes for toxic contaminants are described. It must be remembered that the toxics indicators programme is and must be an integrated component of the larger environmental indicators programme.

7.2 MONITORING STRATEGY

7.2.1 Possible Strategies

There are a number of strategies that can be adopted for TCIs as part of an EPI which differ in scale between those programmes utilising only a limited range of currently available data and information, and those programmes entailing a broad range of Central government initiated monitoring programmes. In the previous section, the potential options for toxic contaminant indicators were discussed. As noted, there a range of possible indicators that could be used to record and track environmental well-being within New Zealand in relation to toxic contaminants.

Centralised

Central government accepts the strategic national value of indicators and allocates funding for the acquisition of necessary data and the central information processing. This may include the acquiring data from other monitoring agencies such as Regional Councils as well as the initiation of programmes to obtain data not currently being collected. The time and location for collecting this data may be under central government control while existing monitoring programmes continue to be under the control of other monitoring agencies. To ensure indicator programme continuity, it would be beneficial for the acquisition of necessary data to remain a central government role to ensure programme continuity should Council monitoring schemes alter.

Not surprisingly, the use of centralised resourcing is the most resource intensive option available for TCIs however, it provides central government with the greatest chance of maintaining a cohesive indicators programme. It is central to the use of performance indicators, that monitoring data be consistent over extended periods of time i.e., at least decades.

Existing Data Collation/Management

In any scenario involving the utilisation of existing data collection sources, a central body using limited resource will 'acquire' data from any existing and sources. The role of the central body would be primarily one of data collection, collation and interpretation. The lack of control over data acquisition would mean that there could be no guarantee of the continuity of indicator data collection. Comparability of data between locations and over time would rely on the good will of those doing the monitoring, presumably Regional Councils and Territorial Authorities.

This option offers the least chance of both a rationalised and consistent programme over time. With no guidance on monitoring methods or data handling there may be problems with comparing data across regions and over time. To some extent this may be alleviated by co-ordination between monitoring agencies but the 'burden' of such co-ordination may be cost effective only between adjacent regions, not on a national scale.

Co-operative

The co-operative strategy will involve making the best possible utilisation of existing programmes utilising already collected information. The programme would offer flexibility, allowing for data from newly initiated programmes to be included. The need for additional programmes would be strategic based upon an identified lack of specific information. Any indicator programme of this nature would be designed with the view to limit the need for new programmes implementation until the use of existing information was investigated thoroughly.

This option is considered to offer the greatest flexibility which is viewed as an integral component to a successful indicators programme. However, there needs to be a clear recognition and understanding of the contributions made by all parties.

This option will allow the best utilisation of existing data and will offer the best opportunity to develop the indicators programme in a coherent fashion over time as environmental management issues and priorities will change in New Zealand. An environmental indicator programme must recognise these changes and alter accordingly in a carefully managed fashion.

In this scenario, central government is seen as performing a co-ordinating and directing role in the indicators programme as well as a data collection/dissemination role. Direction setting would be done in consultation with end-users and could involve the use of an 'expert group' or co-ordinating committee. The use of a co-ordinating committee would provide ample opportunity for the needs and management requirements of monitoring agencies to be included in the indicators programme.

Existing Data Collation and Management

In this scenario, a central body using limited resource will acquire data from any existing and/or available source. The role of the central body would be primarily one of data collection and collation. The lack of control over data acquisition would mean that there could be no guarantee of the consistency of data collection or the continuity of indicator collection. Comparability of data between locations and over time would rely on the good will of those doing the monitoring, presumably Regional Councils and territorial authorities.

Integration

The final nature of the final toxic contaminants indicators programme will be dependent upon the structure of the rest of the EPI programme. For example:

- Aquatic/water quality monitoring as part of fresh water indicators programme may include general water quality monitoring (including ammoniacal nitrogen) and macroinvertebrate monitoring to assess overall aquatic health. Sites selected for toxic contaminants monitoring would be a sub-set of the sites used for more widespread assessment.

- Air monitoring may include indicators of general air quality such as particulate monitoring. Sites selected for toxic contaminants monitoring would be a sub-set of the sites used for more widespread assessment.

As such the development of any toxic contaminant indicators programme will need to be developed in conjunction with other programmes. Integration will reduce the overall effort required by agencies carrying out the monitoring.

Overall, there are a number of strategies that can be adopted for the implementation of TCIs as part of an overall EPI. These range from entirely centralised collection of new data through to the collation of existing monitoring programme data. Given that New Zealand has a regionalised environmental management system (in terms of permitting, monitoring etc.,) it is considered sensible to use the existing regional authority capability as the core source of information for the toxics contaminant indicators programme. In section 6 of this document, the current monitoring carried out by Councils and other parties was described. There are a number of areas where comprehensive monitoring is currently being carried out throughout New Zealand. Good examples include groundwater quality. In the following section, the importance of QA/QC and effective data management is described as a key need to ensure that such national programmes are as effective as possible.

7.2.2 Who Should Monitor?

The strategic national value and use of indicators most clearly benefits central government however it is acknowledged that most monitoring data is currently collected by regional/territorial authorities.

The key use of the information to regional/territorial authorities lies in regional state of the environment reporting (e.g., some Councils produce annual state of the environment reports) and most are able to use information from indicators programmes producing data in their region to identify environmental changes that may or may not support Regional Policy statement policies and objectives.

These authorities typically have limited budgets and must design monitoring programmes that meet their immediate resource management requirements

Some portions of the proposed toxic contaminant indicators programme are clearly the responsibility of central government, for example the development of a national toxics contaminants register (TCR) or the like.

This report favours a co-operative approach to monitoring as such the responsibility for monitoring and sampling designs and QA/QC would rest between central and local government.

7.2.3 Frequency

It is not a requirement of an indicators monitoring programme that all indicators be measured at the same time. It many cases it is also not necessary to carry out monitoring to a strict timetable.

The frequency of monitoring will vary greatly according to the contaminant of interest and the data currently collected. For example, there is little reason to monitor organochlorines on an annual basis as the persistent nature of these compounds means that significant alterations in environmental concentrations are unlikely to occur within a 5 - 10 year time frame. In contrast monitoring of PAHs in air may be desirable on an annual basis. Alterations in management practices (e.g., mandating efficient wood burners) may have a significant impact on such indicators within a one year time frame.

It is important that the objective of including any particular indicator within the indicators programme be assessed carefully to ensure that its inclusion is practically and technically defensible. For example the monitoring of some organic compounds in marine bivalves may be of little use as a long term indicator of their presence in the marine environment if traditional single point in time sampling is used as their half life is very short and the monitoring may only reflect transient trends rather than long-term ones (refer Section 4).
Similarly it would seem obvious to monitor pressure indicators in the form of a TCR on an annual basis as this would fit well with current structures for business reporting.

It is recommended that final decisions on the monitoring frequency could be made by an indicators co-ordinating committee.

7.2.4 Where to monitor?

The integrative monitors outlined focus on obtaining a national picture of levels of toxic contaminants. This is particularly the case for the diet and breast milk surveys and for the organochlorines programme. To obtain this national picture sampling effort has to be relatively widely dispersed over the whole country.

Locations for monitoring will be very dependent upon the objectives established for the inclusion of particular indicators within the programme. For example it is likely that a number of possible indicators (e.g., groundwater quality, drinking water quality) will involve widespread sampling locations and some will involve focused and localised sampling (e.g., use of freshwater and marine mussels biomonitors; urban air quality monitoring).

For each possible indicator it will be necessary to review existing national sampling effort and locations and based upon that review identify whether the existing sampling distribution is sufficient to meet the objectives established for that indicator. This is generally not a problem for integrative measures as concentrations are relatively consistent between adjacent regions.

7.2.5 DATA MANAGEMENT

7.2.6 Introduction

Large amounts of data are collected in indicators programmes. In discussing information management it has to be remembered that the toxics indicator programme is a component of a wider environmental performance indicator system.

There many large indicator programmes particularly in North America that have grappled with data management to develop effective data management systems. Systems such as those provided by the Canadian Government and the Status and Trends Programme in the United States are examples.

The means of processing data will depend on the process determined for the entire indicators programme.

7.2.7 Quality Management

For environmental programmes, quality management consists of all activities conducted to ensure that data acquired provides a valid representation of actual conditions.
Quality assurance (QA), quality control (QC) and standard operating procedures (SOP) are separate components of a monitoring programme. Together they minimise and quantify the errors that are introduced from the sampling through to the reporting stages, and allow the tracking of errors that might occur. The purpose of quality management is to produce data of a known quality.

Quality management will be one of the most important features of the indicators programme. Key areas of quality management of the Indicators programme are:

- Sampling/monitoring procedures.
- Testing laboratory QA and certification of data.
- Reporting of data.
- Data management.
- Short-term and long-term statistical interpretation of data.

As far as possible, sampling/monitoring protocols should be standardised although this could be difficult to achieve due to the large number of groups that are likely to be involved with these activities. Standard testing laboratory QA procedures are covered by laboratory certification and do not vary greatly from one laboratory to another. Standard protocols for data reporting and data management will require development. It is not uncommon for the statistical interpretation of data to be contentious, especially in relation to the analysis of long-term data. It is, however, such data interpretation that affords the 'big-picture' information regarding patterns and trends which is at the heart of the Environmental Indicators Programme. Accurate long-term statistical analysis of environmental data is heavily reliant on quality sampling, testing, data reporting and data management.

7.2.8 Interpretation

It will be necessary to develop methodologies for the assessment of trends in data over time. Such assessment procedures are relatively well developed and the national water quality monitoring programmes have provided a considerable amount of information in relation to such assessment and associated methodology. A similar exercise will be needed prior to the implementation of all indicator programme components that involve the collection and interpretation of data to ensure that statistically the programme (individual indicator) objectives can be met. The means of processing data will depend on the process determined for the rest of the EPI programme. The preferred model seems to be the “Data clearing house”. In this model a central agency will have access to data held by various providers. Access will be tightly controlled to maintain the intellectual property of the supplier.

7.3 COMMUNICATION AND REPORTING

Communication

Extensive communication and reporting is a cornerstone of any successful indicators programme. In particular there is a need to involve the public at large in this process. It is therefore foreseen that several pathways of dissemination will be required.

Three types of information need to be available and/or disseminated. These are firstly the raw data obtained from the indicators programme; secondly reports summarising data at points in time and trends over time (e.g., every two or five years) and thirdly summarised information required for public consumption and information.

The extensive use of the World-Wide Web will be a key pathway for dissemination as outlined in the “Clearing House” network (MfE 1997) proposal. It should however be recognised that ‘net users’ still represent a somewhat biased audience although the breadth of the audience is increasing steadily. So, while the World-Wide Web will be a key dissemination tool others may also be required. Possible methods could include:

- In the case of toxic contaminants sold to the public, such as pesticides herbicides solvents and fuels information could be provided at point of sale.

- Inclusion of brief summary information on a regional basis with annual rating information.

- Distribution of “Bulletins” such as those prepared for the organochlorines programme.

In the public context, it is interesting to note that the Toxics Release Inventory List (United States) was enacted under the “Emergency Planning and ***Community Right to Know***“ Act. This stresses that local communities have a right to know what is being discharged to their environment. As such in the New Zealand context it may be desirable to request that industry include discharge information in their normal annual reports.

The selected TCIs will need to need to address key aspects of data management and dissemination including:

- Standardised data forms for providers of data to forward data electronically to the centralised data system.

- A data system that allows the inclusion of commentary and other data (site information etc.) that provides users with further information that might assist in identifying its suitability in other situations (collectively referred to as meta-data).

- An interfaceable (able to be queried) data system that allows appropriate access to data.
- Security for data systems.

- Compatibility of terminology used in the indicators programme and data system.

Reporting

A methodology (guidelines) will need to be established for the toxic contaminants indicator programme to identify how data collected in the programme will be interpreted and reported. It is likely however that guidelines for interpretation and reporting will be developed for the greater EPI programme as the approach used will have commonality with other indicator programmes.

As noted in the previous section there will be a need to produce status reports on the overall EPI programme and or sections of that programme. These reports will need to be communicated to regional authorities, the public and other interested parties. They should also be available through the Internet.

7.4 TRAINING

Following the development and dissemination of necessary guidance documentation to assist in the development of consistent methodology for the toxic contaminant indicators programme, it is likely that some form of training programme will need to be developed.

The training programme will ensure that:

- Data collectors understand the purpose of indicator information collection.

- Sample collection techniques are being implemented appropriately.

- Analytical methods are being used appropriately.

- Reporting of data is accurate and correct.

Training programmes will need to be tailored to specific indicators (e.g., air, biomonitoring, groundwater). Typically such training would be implemented by a training team established by the agency responsible for the co-ordination of the EPI programme. Funding would need to be sourced from the agency responsible for the EPI programme.

7.5 COST IMPLICATIONS

A range of activities have been identified for which capital (establishment costs) and operational costs would need to be met. The key cost centres that would need to be funded in relation to any potential toxic contaminants indicators programmes. A number of these identified cost areas may be incorporated within general EPI programme funding.

The recommended approach that has been discussed in the previous sections is one of what can be considered a balance of cost/effort with the highest potential for beneficial output in relation to the overall EPI programme. A hierarchical or developing approach to the toxic contaminant indicators programme has also been suggested which will allow the programme to be developed as information from this and other indicators programmes allows the programme to mature in terms of its content and robustness.

The key identified cost centres are:

- As part of the overall EPI, the establishment of a TCIs committee or management group (possible inter-agency, sub-committee of another EPI programme committee).
- The development of the toxics release inventory.
- The confirmation of specific indicators as TCIs.
- The identification of the monitoring location, frequency and sampling/analytical methodology for that indicator.
- The confirmation of statistical and interpretational approach.
- The identification and implementation of guidance documentation for participating organisations and interest groups.
- The development of an inter-agency training group to facilitate compatible information gathering throughout New Zealand.
- The development of a centralised data collection and storage data-base. Associated with this would be the establishment of electronic communication systems, Internet sites etc.
- The development of a standardised periodic assessment and reporting system (including peer review).
- The development of a mechanism for dissemination of TCI information within the overall EPI.

The TCIs must be seen in relation to the rest of the EPI programme. The integration of the various indicator options will have a wide range of financial implications. This will be particularly so where the collection of TCI samples and EPI can be co-ordinated thereby reducing costs. The major cost of the TCIs as part of the EPI will however remain as the cost of the analyses themselves. Opportunities to reduce these costs do exist with large sample sizes and innovative new technologies. Where access to currently gathered data is expected then some form of cost sharing may be required.

8. FURTHER WORK/RECOMMENDATIONS

The principal recommendation arising from the assessment of TCIs is the high priority that should be given to investigate the establishment of a toxic contaminant register or the like for New Zealand. Such an inventory will be indispensable in developing pressure indicators for toxic contaminants.

As was noted in submissions to the EPI draft document current proposal for EPIs and for these toxic contaminant indicators are heavily focused on state indicators. Systems and methods for the development of pressure and response indicators require further attention.

In the current report indicator proposals for toxic contaminants rely on measuring concentrations of contaminants in exposed media. In the case of exposed animals there is considerable scope for measuring the biological effects of contaminants. This ‘effects based’ approach is more in line with the intent of the Resource Management Act. However, to date such ‘biomonitoring’ systems for effect are still being developed. Further investigation of these methods

The majority of the indicators proposed here are indicators of state assessed by measuring chemical concentrations. There is clearly a need to further investigate indicators that reflect the effect of chemical contaminants on the environment and human health. Such monitoring is mandated by the RMA and would be invaluable in the indicators programme.

It should be emphasised that any development of an EPI programme would be best implemented in a staged fashion. As was discussed earlier in Chapters 4 and 7, there are a number of indicators which are either in the initial investigation and research stages or are being used overseas but have not been used or adapted for New Zealand. It would be advantageous during discussions regarding specific nature of any EPI programme to view the programme as dynamic. A staged approach allows for new tools to be considered or used which are being developed as part of international research as well as, through various research programmes within New Zealand.

It has been recommended that TCIs be included in a New Zealand EPI via the implementation of four indicators in addition to the development of a TCR. These are the measurement of toxic contaminants in:

- Air
- Freshwater eels or mussels
- Marine sentinel organisms (mussels)
- Human breast milk

Other TCIs have been identified for inclusion in the EPI at a later date.

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10. GLOSSARY

Air quality
The condition of the air we breathe.

Air toxics
A number of airborne compounds which may have adverse effects on human health.

Acute exposure
Exposure to a chemical for 14 days or less.

Alkanes
Chemical classification relating to the structure of hydrocarbons: alkanes have carbon atoms arranged in chains and contain no double or triple bonds.

Alkenes
Chemical classification relating to the structure of hydrocarbons: alkenes have carbon atoms arranged in chains and contain one or more double bonds.

Alkyl
Chemical classification of hydrocarbon groups attached to compounds: alkyl groups have carbon atoms arranged in chains and contain no double or triple bonds.

Alkynes
Chemical classification relating to the structure of hydrocarbons: alkynes have carbon atoms arrange in chains and contain one or more triple bonds.

Ambient air
The surrounding air.

Aromatics
Chemical classification relating to the structure of hydrocarbons aromatic hydrocarbons have carbon atoms arranged in rings with some of the electrons shared over the whole ring, for example benzene and naphthalene.

Aryl
Chemical classification of hydrocarbon groups attached to compounds: aryl groups have carbon atoms arranged in aromatic rings.

Biomagnify
To become more concentrated in tissues as a contaminant is passed through the food chain i.e., from soil to plants to grazing animals and finally to humans and birds.

Bioconcentration Factor

The number of times more concentrated a contaminant is in an organism than the surrounding media.

Bioassay
Exposing test organisms to samples (of water, sediment etc) and comparing their response with organisms exposed to control or reference treatment.

Bioconcentrate
To become more concentrated in the tissues of plants and animals.

Biodegradable
Able to be broken down into basic compounds by micro-organisms.

Biogenic emissions
Emissions from natural sources including vegetation and soil.

Carcinogen
A chemical capable of inducing cancer.

Carcinogenic
Able to induce cancer.

Chronic exposure
Exposure to a chemical for 365 days (1 year) or more.

CRI
Crown Research Institute, New Zealand

Diffuse emissions
Emissions of wastes from sources other than point sources.

Dusts
Are discrete particles suspended in air, originating from the attrition of solids (primary dusts) or the stirring up of powders or other finely divided materials (secondary dusts). Dusts encountered in the workplace typically contain particles covering a wide range of sizes.

Ecotoxic
Toxic to the environment.

EC_{50} & EC_{10}
The effective toxicant concentration resulting in a 50% or 10% response (respectively) of a given parameter at a specific time of exposure (e.g., reduced growth or reproduction). Effective concentration (EC) refers to a range of effect measures (e.g., mortality, growth reduction) and thus the terminology may include lethal concentration (LC) values.

Emissions
Substances being released to the environment.

Emissions inventory
Substances being released to the environment.

Fugitive emissions
Substances that escape from a source not associated with a specific process but scatter throughout the plant, e.g., leaks from equipment, dust blown from stockpiles.

Fumes
Are airborne particulates with diameters generally less than 1 µm. They may be formed by both thermal mechanisms (e.g., condensation of volatilised solids, or incomplete combustion) and chemical processes (e.g., vapour phase reactions). Agglomeration of fume particles may occur, resulting in the formation of much larger particles.

Genotoxic
Genetic material.

Halocarbon
A hydrocarbon with some hydrogen atoms replaced by halogen atoms such as chlorine or fluorine.

Halogenated
Containing one or more halogen atoms, i.e., fluorine, chlorine, iodine, bromine or astatine.

Histopathology
Medicine concerned with cause, origin and nature of disease in animal or plant tissues.

Heavy metals
Metals such as lead, arsenic, chromium and nickel.

Herbicide
Chemical poison used to destroy plants, especially weeds.

Hydrocarbons
Substances composed of carbon and hydrogen only.

Indicator
Something that acts as a sign.

Inorganic
Chemicals not containing carbon-carbon bonds.

Inventory
A detailed, complete list.

Ion
An atom or group of atoms which have gained or lost one or more electrons and thus, carry a positive or negative charge.

Lethality
The end point normally associated with acute toxicity.

Lowest observed effect concentration (LOEC)
The lowest measured concentration of an effluent or a toxicant that causes a significant observed effect on a test organism. The effect measured may differ between tests (e.g., lethality, growth reduction).

Macroinvertebrate
Freshwater insects, molluscs, crustaceans, annelids, hydroids and flatworms living amongst surficial stream bed substrate or on instream vegetation.

Media
The surrounding in which an organism naturally lives or grows or an environmental compartment.

Micrograms per cubic metre ($\mu g/m^3$)
One millionth of a gram of a substance in a cubic metre of air.

Milligrams per cubic metre (mg/m^3)
One thousandth of a gram of a substance in a cubic metre of air.

Mists
Are droplets of liquid suspended in air. They may be formed by the condensation of a vapour, or mechanical actions such as the atomisation of liquids in spray systems.

Mobile source
A source of wastes which is in motion during its normal operating mode.

Mutagen
A substance that causes mutations - changes to the genetic material in the body.

Nanograms per cubic metre (ng/m^3)
One billionth of a gram of a substance in a cubic metre of air.

No observed effect concentration (NOEC)
The highest measured concentration of an effluent or a toxicant that causes no observed effect on a test organism.

Organic
Chemicals containing carbon-carbon bonds.

Organotin
An organic compound containing bonds to tin.
Oxidant, oxidising agent
An oxidant is a substance that accepts electrons during chemical reactions.

Oxygenates or oxygenated hydrocarbons
Compounds that contain carbon, hydrogen and oxygen, for example alcohols.

PAH
Polycyclic aromatic hydrocarbon.

Periphyton
Group of organisms that grow on surfaces of stable objects in water and includes bacteria, protozoa, fungi and algae.

Persistent
Does note breakdown easily in the environment.

Pesticide
Chemical poisons used to kill pests. Includes herbicides, insecticides and fungicides.

Photochemical reactions
Chemical reactions that occur in the presence of sunlight.

Photochemical smog
Air pollution formed from the chemical reaction of nitrogen oxides and reactive organic compounds in the presence of sunlight to produce "secondary" pollutants such as ozone.

Phytotoxicity
Toxic to plants.

Picograms per cubic metre
1 thousand billionth of a gram of a substance in a cubic metre of air, soil or water.

PM_{10} & $PM_{2.5}$
Particles less than 10 micrometers in diameter (a micrometer is one millionth of a metre); also known as "respirable particles".

Point source emissions
Emissions of wastes from significant, fixed sources such as large industrial premises.

Pollutant

A chemical that may reduce the quality of the environment.

Possible carcinogen
Compound that has shown some evidence for carcinogenity in animals but for which there is no human data.

PPB
Parts per billion.

PPHM
Parts per hundred million.

PPM
Parts per million.

Precursor
A substance which may participate in, or influence, a reaction in the air to produce another substance.

Probable carcinogen
Compound that has shown some evidence of carcinogenity in humans, or, lacking adequate data on humans, there is sufficient evidence of carcinogenity in animals.

Reference toxicant
A standard chemical used to measure the sensitivity of the test organisms in order to establish confidence in the toxicity data obtained from the test material. In most instances a toxicity test with a reference toxicant is performed to assess the sensitivity of the test organisms at the time the test material is evaluated, and the precision of results obtained by the laboratory for that chemical.

Respirable dust
Corresponds to the fraction of total inspirable dust that is able to penetrate and deposit in the lower bronchioles and alveolar region.

Response
Reaction by organism or environment.

Risk factor for carcinogens
The extra risk of getting cancer due to exposure to a particular level of a carcinogenic substance; set by the USEPA or the WHO.

ROC
Photochemically-reactive organic compound. ROCs are those VOCs which are precursors to ozone.

Solvent
A substance that dissolves or dilutes another for the purpose of the NPI, a solvent is a volatile substance composed of hydrocarbons, for example, methylated spirits, petrol, kerosene.

Sources of emissions
An activity or process that can lead to the release of a pollutant to the air.

Standard
The legally permitted concentration of a toxicant in the water. Determined from a considered judgement of the criteria.

Taxa
Species or group of species.

Terpenes
A class of volatile aromatic hydrocarbons.

Threshold effect concentration (TEC)
Calculated as the geometric mean of the NOEC and LOEC.

Toxicity test
The means to determine the toxicity of a chemical or an effluent using living organisms. A toxicity test measures the degree of response of an exposed test organism to a specific chemical or effluent.

Trivalent
An atom able to bond with three other atoms.

TSP
Total suspended particles.

USEPA
United States Environmental Protection Agency,

Volatile
Readily evaporates at room temperature.

Volatile organic compounds
Large and diverse group of chemicals, including hydrocarbons oxygenates and halocarbons, including 1, 3-butadiene, benzene toluene, xylenes, styrene, some PAHs, formaldehyde, methyl ethyl ketone, methyl isobutyl ketone, dichloromethane, dichlorobenzene, tetrachloroethylene and acrylonitrile.

WHO
World Health Organisation.

WHO guideline values
An indication of the concentrations of a substance to which people may be exposed without adverse health effects; set by the WHO.

REVIEW OF PRIORITY TOXIC CONTAMINANTS LISTS

1. **POPs**
2. **Metals**
3. **PAHs**
4. **Solvents**
5. **Agricultural Chemicals**

TABLE 1: POPs

Type	Chem	CAS	EPA	CERCLA '97	PSL Canada	NPRI Canada	TRI USA	OECD HPV	Rationale
POPS	DDT	50-29-3	X	13				X	POP, EDC
	Aldrin	309-00-2	X	25			X		POP, EDC
	Dieldrin	60-57-1	X	18					POP, EDC
	Endrin	72-20-8	X	39					POP, EDC
	Chlordane	57-74-9	X	20			X		POP, EDC
	Heptachlor	76-44-8	X	30			X		POP, EDC
	HCB	118-74-1	X	93	T		X	X	POP, EDC
	Mirex	2385-85-5							POP, EDC
	Toxaphene	8001-35-2	X	31			X		POP, global t
	PCBs	1336-36-3	X	6			X		POP, cancer I
	PCDD (2,3,7,8-TCDD)	1746-01-6	X	66	T				POP, cancer I
	PCDF (2,3,7,8-TCDF)	51207-31-9	X		T				POP, cancer I
Herbicides	simazine	122-34-9					X	X	
	atrazine	1912-24-9					X	X	
	trifluralin	1582-09-8					X		
	malathion	121-75-5		267			X	X	abundance
	parathion	56-38-2		143			X	X	abundance
	2,4-D	94-75-7		238			X	X	abundance
	2,4,5-T	93-76-5							abundance
	paraquat	4685-14-7					X	X	abundance
	diquat	231-36-7							abundance

CAS Chemical Abstracts Registry number.
EPA Priority Chemical List (1989).
CERCLA '97 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The top 275 chemicals are ranked from based on toxicity likelihood of human exposure and prevalence at 'Superfund' sites.
PSL Canada Priority Substances List under the Canadian Environmental Protection Act (CEPA).
NPRI Canada - National Pollutant Release inventory. This inventory system does not include releases of pesticides/herbicides or currently unregistered chemicals such as PCBs
OECD HPV list This list is from the Organisation for Economic Cooperation and Development (OECD): "X" chemicals produce or imported in quantities of at least 1,000 tonnes by a member country in 1997. "S" chemicals prioritised for the collection of a Screening Information Data Set (SIDS) to permit a more comprehensive risk assessment.
WMPT Score = The chemicals score extracted from the US EPA Waste Minimisation and Prioritisation Tool (WMPT) based on the Persistence, Bioaccumulation and Toxicity to humans and ecosystems
EDC: Endocrine Disrupting Chemical

TABLE 2: Metals

Type	Chem	CAS	EPA	CERCLA '97	PSL Canada	NPRI Canada	TRI USA	OECD HPV	Rationale
Metals	Lead	7439-92-1	X	2		X	X	X	Toxic
	Mercury	7439-97-6	X	3		X	X		Toxic
	Cadmium	7440-43-9	X	7	T	X	X	S	Toxic
	Arsenic	7440-38-2	X	1	T	X	X		Toxic
	Copper	7440-50-8	X	136		X	X	X	Toxic
	Zinc	7440-66-6	X	65		X	X	S	Toxic
	Chromium	7440-47-3	X	69	T	X	X	X	Toxic

CAS Chemical Abstracts Registry number.
EPA Priority Chemical List (1989).
CERCLA '97 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The top 275 chemicals are ranked from based on toxicity likelihood of human exposure and prevalence at 'Superfund' sites.
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TABLE 3: PAHs

Type	Chem	CAS	EPA	CERCLA '97		PSL Canada	NPRI Canada	TRI USA	OECD HPV	Rationale
PAHs	naphthalene	91-20-3	X	72	)			X	S	Cancer, ongoing sources
	acenapthylene	208-96-8	X		)					Cancer, ongoing sources
	acenapthtene	83-32-9	X	155	)				X	Cancer, ongoing sources
	fluorene	86-73-7	X	260	)					Cancer, ongoing sources
	phenanthrene	85-01-8	X	232	)			X		Cancer, ongoing sources
	anthracene	120-12-7	X	265	)		X	X	X	Cancer, ongoing sources
	fluoranthene	206-44-0	X	96	)					Cancer, ongoing sources
	pyrene	129-00-0	X	236	)					Cancer, ongoing sources
	benzo(a)anthracene	56-55-3	X	38	)					Cancer, ongoing sources
	chrysene	218-01-9	X	116	)	PAHs				Cancer, ongoing sources
	benzo(b)fluoranthene	205-99-2	X	9	)					Cancer, ongoing sources
	benzo(k)fluoranthene	207-08-9	X	59	)					Cancer, ongoing sources
	benzo(a)pyrene	50-32-8	X	8	)					Cancer, ongoing sources
	indeno(123cd)pyrene	193-39-5	X	177	)					Cancer, ongoing sources
	dibenzo(ah)anthracene	53-70-3	X	17	)					Cancer, ongoing sources
	benzo(ghi)perylene	191-24-2	X		)					Cancer, ongoing sources

CAS Chemical Abstracts Registry number.
EPA Priority Chemical List (1989).
CERCLA '97 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The top 275 chemicals are ranked from based on toxicity likelihood of human exposure and prevalence at 'Superfund' sites.
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TABLE 4: Solvents

Type	Chem	CAS	EPA	CERCLA '97	PSL Canada	NPRI Canada	TRI USA	OECD HPV	Rationale
Solvents	hexachlorobutadiene	87-68-3	X	19	(2)		X	S	common
	benzene	71-43-2	X	5	T	X	X	S	petroleum, (
	toluene					X	X	S	petroleum, (
	xylenes	1330-20-7		83	N	X	X	X	petroleum, (
	trichlorobenzene	12002-48-1	X			X	X		
	tetrachloroethylene	127-18-4	X	33	T	X	X	X	
Other	asbestos	132207-33-1	X	86			X		human tox
	Substance 1080	62-74-8					X		abundance,
	PCP	87-86-5	X	45			X		toxic, dioxin
	endosulfan	115-29-7	X	53				X	
	alachlor	15972-60-8					X		
	nemagon (DBCP)	96-12-8		54			X		
	methyl bromide	74-83-9	X				X	S	
	Bis(2-ethylhexyl) phthalate	117-81-7				X	X	S	EDC
	Butyl benzyl phthalate	85-68-7				X		S	EDC
	Di-n-butyl phthalate	84-74-2				X	X	S	EDC
	Diethyl phthalate	84-66-2				X		X	EDC
	Dimethyl phthalate	131-11-3				X	X	X	EDC
	Di-n-octyl phthalate	117-84-0				X		X	EDC

CAS Chemical Abstracts Registry number.
EPA Priority Chemical List (1989).
CERCLA '97 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The top 275 chemicals are ranked from based on toxicity likelihood of human exposure and prevalence at 'Superfund' sites.
PSL Canada Priority Substances List under the Canadian Environmental Protection Act (CEPA).
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EDC: Endocrine Disrupting Chemical

TABLE 5: Agricultural Chemicals

Type	Chem	CAS	EPA	CERCLA '97	PSL Canada	NPRI Canada	TRI USA	OECD HPV	Rationale
Agric. Chemicals	Chlorothalonil	1897-45-6					X		Abundance
	diazinon	333-41-5		100			X	X	EDC
	dinoseb	88-85-7					X	X	Abundance
	isazophos	42509-80-8							
	lindane(gamma-HCH)	58-89-9	X	32			X	X	POP
	permethrin	52645-53-1					X		
	phorate	298-01-2		206					
	benomyl	17804-35-2					X		
	carbaryl	63-25-2					X		
	maneb	12427-38-2					X	X	
	metolachlor	51218-45-2							
	oryzalin	19044-88-3					X		
	chlorfenvinphos	470-90-6							
	chlorpyriphos	2921-88-2		120					

	coumaphos	56-72-4				
	cyhalothrin	91465-08-6				
	cypermethrin	52315-07-8				
	deltamethrin	52918-63-5				
	dichlofenthion	97-17-6				
	propetamphos	31218-83-4		X		
	nonyl phenols	25154-52-3	(2)		S	EDC
	alkys phenols					EDC
Paper	resin acids					
Industry	chlorinated guiacols etc					
	chloroacetic acids					
	chloro resin acids					

TABLE 5: Agricultural Chemicals (Cont'd)

	diterpene hydrocarbons					
	EDTA	60-00-4			S	
Mining	cyanide	57-12-5	269	X		toxic

CAS Chemical Abstracts Registry number.
EPA Priority Chemical List (1989).
CERCLA '97 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The top 275 chemicals are ranked from based on toxicity likelihood of human exposure and prevalence at 'Superfund' sites.
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WMPT Score = The chemicals score extracted from the US EPA Waste Minimisation and Prioritisation Tool (WMPT) based on the Persistence, Bioaccumulation and Toxicity to humans and ecosystems
EDC: Endocrine Disrupting Chemical

EPI TOXICS PROGRAMMES: CASE STUDIES

1. **The Great Lakes**
2. **USEPA Environmental Indicators**
3. **State of North Carolina**
4. **Chesapeake Bay Programme**
5. **International Mussel Watch**
6. **NOAA National Status and Trends Program - Sediment**

11. 1. THE GREAT LAKES

General

The Great Lakes contain 20% of the worlds freshwater and an estimated 20% of the United States population lives within the Great Lakes drainage basin. The large populations centres including Detroit, Chicago, Green Bay and Toronto are known for their heavy industry. In addition the access to the sea via the St Lawrence river from Minnesota to the Atlantic Ocean has lead to a concentration of industrial activity in the region. This industrialisation in conjunction with the lakes slow water turn-over rate has lead to the accumulation of high levels of a wide range of toxic contaminants within the Great Lakes ecosystem. As such, the Great Lakes ecosystem represents a system severely impacted by environmental contaminants.

Agreements

The trans-boundary nature of the Great Lakes ecosystem was acknowledged by the United States and Canada with the signing in 1909 of the "Boundary Waters Treaty" which established the International Joint Commission (IJC) to administer the use and preservation of the Great Lakes. Growing concern over pollution in the ecosystem led to the signing of "The Great Lakes Water Quality Agreement" in 1972. This agreement committed the two governments to "...restore and maintain the chemical, physical and biological integrity of the Great Lakes Basin Ecosystem ..". The most significant toxic contaminants were also identified in revisions of the agreement in 1978 and 1989 (refer to section 2). In particular the 1989 revision called for the 'virtual elimination' of discharges of persistent organic compounds to the lakes and also specified required monitoring activities.

Contaminants

The contaminants of particular concern in the Great Lakes ecosystem are persistent organic compounds that have accumulated in sediments and act as an ongoing source of contamination within the Great Lakes. Most notable of the contaminants are the PCBs however dioxins and a range of pesticides and other organic compounds pervade the lakes. Heavy metals are also of concern in some locations.

Current levels of contamination in the Great Lakes have decreased considerably from peak levels but it now appears that contaminant levels are stabilising. This is of concern as current levels of contamination are still resulting in adverse effects in various wildlife species. In addition flood events mobilise contaminated sediments and can lead to catastrophic effects on wildlife (Ludwig, *et al.* 1993).

Effects

During the 1960s and early 1970s adverse effects of chemical contamination in the Great Lakes ecosystem were first observed. Most notable were the depletion of lake trout (*Salvelinus namaycush*) stocks and the near extirpation of fish eating water birds from the lakes. The latter effect was primarily due to poor reproductive success caused by DDT group compounds causing egg-shell thinning (Ludwig & Tomoff 1966).

With the virtual elimination of DDT from use there has been a considerable resurgence of fish eating water-birds to the Great Lakes over the past two decades (Ludwig 1984). However along with increased nesting success there has been a dramatic increase in hard tissue deformities noted in young water birds (Gilbertson, Kubiak, *et al.* 1991). Intensive studies on these populations have identified TE from dioxins and PCBs as the causative agent (Gilbertson, *et al.* 1991) (Giesy, *et al.* 1994).

Salmonid stocks in the Great Lakes were previously of significance both for recreational and commercial fisheries. Depletion of these stocks was hastened by the invasion of sea lamprey into the lakes. To replenish the once abundant salmonid stocks, the United States have been involved in stocking with Pacific salmon for many years. However limited natural reproduction of these species has occurred. Much research has been conducted on this phenomenon and the "blue sac disease" syndrome which kills most fry at the time of 'swim-up' has again been demonstrated to be related to toxic contamination mainly due to dioxin like chemicals (Mac, *et al.* 1993). The accumulation of the contaminants by the growing fish is followed by deposition of the contaminants in eggs which then results in poor viability of the fry. So severe were the population level effects of this contamination that despite rapidly decreasing levels on contamination over the past decades it was not until the mid-1990s that the first 'naturally' produced lake trout fry was identified in the Great Lakes.

The presence of high concentrations of contaminants in salmonids also produces significant risks in species which feed on these species and other fish. This is particularly the case for mink and bald eagles which take advantage of the annual spawning runs of salmonids. Several studies have demonstrated that access of these species to Great Lakes contaminated fish severely reduces reproductive success. Studies are on-going to finalise the cause-effect relationship between persistent organics pollutants and these adverse effects (Bowerman, *et al.* 1995); (Heaton, *et al.* 1995).

The effects of environmental contamination on humans living in the ecosystem have are also being investigated. In a cohort study of children born to mothers consuming significant amounts of fish caught from the Great Lakes (Jacobson, *et al.* 1990) (Jacobson, *et al.* 1990). This study has demonstrated subtle but significant alterations in the cognitive ability of children whose mothers consumed significant amounts of Great Lakes fish containing PCBs (Jacobson, Jacobson, *et al.* 1990).

Monitoring and Research

There has been extensive monitoring and research carried out on the Great Lakes ecosystem. Much of this research is over-seen and/or funded by various government agencies. The assessment of chemical concentrations has been extensively used to characterise contaminated areas and to attempt to provide a 'mass-balance' for inputs and exports from the various areas of concern.

Due to the observed adverse effects in wildlife much monitoring has focused on the concentrations of contaminants in the tissues of wildlife. Probably the most significant monitoring data group is that on contaminant concentrations in fish tissue (DeVault, *et al.* 1986). This arises from the concern for public health due to consumption of sport fish. The high levels of contamination in these fish in many case require the issuing of "Fish Consumption Advisories" at the state level and some limitations on the interstate trade in fish at the federal level. The number and extent of such fish consumption advisories have been suggested as an environmental indicator for the Great Lakes ecosystem.

Another significant result of the extensive research on Great Lakes wildlife has been the establishment and use of wildlife tissue banks (Turle, *et al.* 1991). Such tissue banks have allowed the identification of time trends in contamination (Turle, Norstrom, *et al.* 1991) (Waller, *et al.* 1995) and this data has demonstrated an apparent levelling-off in the decline in contaminant concentrations (Stow 1995).

Data Presentation

Information on the Canadian performance indicators is available on the world-wide web at (http://199.212.18.79/~ind/English/Toxic/Bulletin/tx_toc_e.htm) along with other information on environmental performance indicators. As well as a brief discussion of toxic contaminant issues the data is presented in simple graphical format.

The monitoring activities on the Great Lakes is available from the USEPA Great Lakes National Programme Office at http://www.epa.gov/glnpo/monitor.html. This location provides both scientific data on research/monitoring activities and data more applicable to environmental indicators such as beach closures.

Information and reports from the IJC are available at http://www.ijc.org/.

Water Quality Monitoring

Through the Great Lakes Water Quality Agreement, the United States and Canadian Governments have committed to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes. Studies on the Great Lakes have been on-going for more than 30 years. The International Joint Commission, identified indicators to evaluate the Agreements progress and an Indicators task force was established in 1993 to assist in developing the framework with particular emphasis on integrative indicators of ecosystem integrity.

The assessment of indicators (International Joint Commission 1996) examined a wide range of indicators. In relation to toxic contaminants, a range of diverse desired outcomes were identified (ranging from swimming and angling through to ecosystem and human health) from which a short list of possible indicators were identified. Of the indicators few related directly to water quality. These included:

In relation to Swimming: Beach closings due to persistent toxic contaminants.

A number of other areas included indicators that indirectly related to water quality. These included:

In relation to aesthetics and perception: Reductions in loadings and concentrations of chemicals; Expenditures for public waste water treatment.

In relation to wildlife health: Contaminant levels in tissues.

In relation to commercial and subsistence fishing: Number of closures due to persistent toxics.

Overall, development of an integrated indicators programme has been a recent advent within the Great Lakes programme. The development of the indicators programme has resulted in the development of integrated indicators with no specific indicators involving actual toxics monitoring in water.

Biological Performance Indicators

Canada has introduced two environmental indicators of the contamination of aquatic food chains with organic contaminants. These indicators are:

- **Contaminant Levels in Double-Crested Cormorant Eggs: DDE and PCBs**
- **Contaminant Levels in Double-Crested Cormorant Eggs: Dioxins and Furans**

The fact that the indicator species chosen has a nation-wide distribution is important in allowing comparison between regions. The fact that the cormorant is near the top of the aquatic food chain also means it acts as an integrator and concentrator of contaminants over relatively wide areas.

These indicators are of considerable relevance to the Great Lakes as the organic contaminants monitored are currently the major cause for concern in this ecosystem. The historic data from studies of this species demonstrated a steady decline in contamination up to the early 1990s. Thereafter the decline has decreased and a slight increase has been suggested in some studies. Cormorants are also included in regional indicator programmes such as the Fraser River in western Canada.

The United States has not yet established federal indicators pertaining to the Great Lakes. The development of these indicators is currently in progress and due for completion at the State of The Lakes Ecosystem Conference (SOLEC) ’98 in October 1998. It is intended that the Great Lakes indicators will be presented at this conference. Among the proposed indicators for the region are several relating directly to toxic contaminants that have been determined by several inter-governmental agencies such as the IJC and the Great Lakes Fisheries Commission (GLFC). Proposed indicators/goals include:

- The virtual elimination of inputs of toxic contaminants (IJC).
- Toxic contaminants in lakes Erie and Michigan (GLFC).
- Fish consumption advisories in lakes Superior Erie and Michigan (GLFC).

12. 2.

USEPA ENVIRONMENTAL INDICATORS

Water Quality

The USEPA has developed indicators to measure progress towards a series of milestones for 12 national goals that set a 10 year target to be reached by the year 2005 (USEPA 1996). Each of the milestones uses water quality indicators to measure progress. Five water quality objectives specify how the national goals are met. These are noted below. Indicators are used to measure the progress to meeting the water quality goals, milestones and objectives. The information produced provides indications of trends in environmental quality.

Objective 3: Support uses designated by the States and Tribes in their water quality standards.

State tribal water quality standards establish the goals of and provide the requirements for the US national water quality - based improvements programs. States are required under the Clean Water Act (section 305b) to assess and report on the degree to which surface waters in their state support their designated uses. Results are provided to the USEPA every 2 years.

Indicator 10b: Fish and shellfish Consumption Designation Use

The indicator identifies the % of assessed water bodies that have attained shellfish consumption use designated by States and tribes as part of their water quality standards. The results are provided to and published by EPA. In the 1994 inventory, 95% of the assessed river and streams (17% of the US streams and rivers were assessed), 82% of assessed lakes and reservoirs and 92% of assesses estuaries provided fish safe for human consumption. 74% of assessed estuaries provided shellfish safe for human consumption. The results reported in the national Inventory are used to track changes in the indicator. The USEPA notes however, that States and tribes do not use identical methods to survey or to assess compliance even-though efforts have been made to develop similar benchmarks to allow better comparison of information.

The question has been raised by the USEPA as to whether the indicator provides a fair representation of waterways in the United States because of bias towards particular types of waterways with suspected or actual pollution problems.

In relation to toxic contaminants, the USEPA program shows that sources of pollution (e.g., urban stormwater, point sources) contributes to excessive concentrations of persistent contaminants in fish and shellfish and that these contaminants accumulate in sediments.

Indicator 10c: Recreation designated Use

As with indicator 10b, this indicator provides information on water quality as it pertains to a designated use. The indicator does not directly provide information on toxic contaminants.

Indicator 10d: Aquatic life designated use

As with indicator 10b, this indicator provides information on water quality as it pertains to a designated use. In the 1994 National inventory, 69, 69 and 70.5% of assessed rivers, lakes and estuaries met their aquatic life designated uses.

As with other indicators there are limitations in the use and interpretation of the information collated. The USEPA is endeavouring to further define aquatic life uses and habitat types and improve monitoring tools.

USEPA tracks toxic contaminant concentrations via state monitoring in relation to designated uses of surface waters.

Objective 4: Conserve and improve ambient conditions

Measures of ambient water quality evaluate the overall impacts of various sources of pollution and stressors. The measurement can be seen as providing information about potential risk to human health and potential risk to ecosystem health.

USEPA considered that the measurement of water quality indicators completes the picture of how water quality objectives support and build upon one another.

The United States does not have a linked national water quality monitoring programme that can provide statistically valid picture of water quality. In its absence separate sets of water quality data need to be collated and examined.

States within the United States report to the EPA, data on pollutants found in ambient waters when assessed. That data when compiled allows a statement to be made on the general quality of water bodies (whether impaired or not).

USEPA 1995 reported that metals were responsible for impairment in 9%, 21% and 17% of miles (or acres in the case of lakes) examined in estuaries, lakes and rivers. Pesticides accounted for 11% of the impaired acres in lakes. Priority organic toxic chemicals accounted for 10% and 8% of the impaired miles (or acres) in estuaries and lakes respectively.

Indicator 12: Surface water pollutants

EPA tracks a number of constituents in surface water as a measure of trends in surface water quality. None of these are toxic contaminants. The parameters are dissolved oxygen, dissolved solids, suspended solids, nitrate, total phosphorus, faecal coliforms.

EPA uses data from the USGS National Water Quality Assessment Program monitoring database to examine trends. Data has been examined from 1980 to 1989 and covers up to 424 stations.

EPA has indicated that it intends to track a number of toxic contaminants via this indicator programme. These include: cadmium, copper, lead, mercury, phenol and total residual chloride. In addition, the programme will also track ammonia in addition to other conventional pollutants.

A wide variety of water quality data bases are available in the United States which can be used to track trends in water quality. The available data bases have been summarised by Parker (1996a, b).

As such the current program does not track trends in the concentration of toxic contaminants in surface waters. It is intended to include a selected group of contaminants in the program.

Indicator 13: Selected coastal surface water pollutants in shellfish

EPA identified this specifically because of the importance of estuarine areas to people (ports and towns) and to marine organisms (nursery areas etc.).

NOAA collects data on the concentration and effects of persistent contaminants in coastal waters of the United States. The data collected comprises information on six key contaminants at 140 locations around the United States. Shellfish were selected because of their importance in both human food source and because of the important role they play in estuarine and coastal food webs.

Shellfish are good indicators of contaminants presence in coastal waters because they filter water as they feed and as such they tend to integrate contaminant concentrations from food and water.

The contaminants included are three metals (copper mercury and lead) and organic chemicals (PAHs, DDT and PCBs). USEPA (1996) indicates that dioxins are being added to the toxic contaminants being measured.

Selected priority metals and organic compounds are monitored in shellfish as an integrated reflection of surface water quality (refer sections 4.4.3 and 4.4.4). The indicator data is obtained through programmes co-ordinated by NOAA.

Objective 5: Reduce or prevent pollutant loadings and other stressors

Water quality is affected by a range of stressors. A number of indicators were identified that relate to pollutant loads. The system in the United States uses regulations and permit limits to control point source discharges. Indicators were identified to measure progress in controlling both non-point and point source pollution.

Indicator 16a: Selected point source loadings to surface water

For surface waters, the major point sources of pollution are sewage treatment plants, industrial discharges and stormwater discharges. The USEPA Permit Compliance System (PCS) contains information on a range of toxic contaminants. The data in the permits has the capability of providing data on changes in loads to surface waters.

Data from the PCS indicated for one of two key pollutants monitored (Biological oxygen demand and lead), that in 1995, 48% of States within the United States reported that loads of lead were decreasing or stable while 52% reported increasing loads. Information is available on other contaminants. It is intended to include cadmium, copper, mercury, phenol, total residual chlorine and ammonia in the assessment list (in addition to other conventional pollutants). USEPA (1996) identified a number of limitations to the permit assessment system and considered that revisions to the permitting system would be necessary to allow the data to be better used within the indicator programme.

Overview

The USEPA has developed an indicators programme that is focused on providing information in relation to a series of specific objectives that relate to the provision of clean water for human and ecosystem health. To date, the focus of the programmes has not been on the direct measurement of toxic contaminants in waters although this is changing with the introduction of key contaminants into a number of indicator programmes. Toxic contaminants in surface waters is primarily dealt with through their measurement in shellfish (as integrators) and sediments (as a sink).

Sediment Quality

The USEPA indicators programme under objective 4 (Conserve and Improve ambient Conditions) includes the assessment of sediment quality as a water quality indicator.

Indicator 15: Contaminated Sediments

The USEPA use the indicator as potential risk to ecological and human health. The % of concentrations exceeding risk levels provides the basis of the indicator. The data is collected as part of the National Sediment Inventory (NSI). The USEPA report to congress every 2 years as to sediment quality around the United States. The USEPA acknowledges that although the data base is large that the data represents only a small part of the United States. The NSI (USEPA 1997), was established to provide a national screening-level assessment of contaminated sediment over a time period of the past 15 years. The NSI inventory was based upon a number of major agency databases and other published data. The approach used in the evaluation focused upon the risk to benthic organisms exposed to contaminated sediments, the risk to human consumers of organisms exposed to sediment contamination. A range of different aquatic life and human health criteria were used in the assessment. The sampling programme focused upon areas of probable concern in relation to adverse effects associated with the presence of contaminants in sediments.

The NSI includes data on some 230 different chemicals or chemical groups.

The NSI has shown that elevated concentrations of the key contaminants PCB, mercury, DDT and PAHs were most commonly associated with probable adverse effects at a Tier 1 site. It should be noted that divalent metals other than mercury were not used to categorise sites with probable adverse effects unless the site had data on the amount of acid volatile sulphide.

The USEPA NSI provides a national picture of sediments quality as it relates to effects on benthic biological communities. Sites are classified into 3 tiers. Tier 1 being a site where associated adverse effects are probable; Tier 2 being a site where associated adverse effects are possible but expected infrequently and Tier 3 being a site a site where there is no indication of adverse effects. The NSI data base has been developed based upon data collected up to 1993.

13. 3.

STATE OF NORTH CAROLINA

The State of North Carolina, initiated the concept of an EPI programme for the state in 1988. In 1992, the State Center for Health and Environmental Statistics within the Department of Environment, Health, and Natural Resources began developing the indicators programme. The programme has been running since 1993 and was initially limited to air, water and waste. The indicators data for the period 1989 to 1993 is summarised in DEHNR (1994). The indicators assessment programme has a strong emphasis on use-impairment. Comments are provided in relation to air quality and drinking water.

Measurement of contaminants such as carbon monoxide is carried out for North Carolina's ambient air quality monitoring network. Data is entered into the USEPA Aerometric Information Retrieval System. The data is assessed for exceedence of air quality standards and air quality trends. It is noted by DEHNR that the evaluation of standards violations is not sufficient to assess overall trends in air quality. The collected data is also used to identify areas on non-attainment. Non-attainment is a formal administrative process under the Clean Air Act and requires that control measures be implemented to eliminate non-attainment. The DEHNR also monitors radioactivity as there are a number of nuclear power plants, research reactors and fabrication plants in the State.

In relation to drinking water, maximum contaminant levels (MCLs) are set under the Federal Safe Drinking water Act in the US. The North Carolina Drinking Water Act, requires regular monitoring of drinking water quality. Contaminants such as trihalomethane and lead are key toxic contaminants monitored and compared to the MCLs in the Drinking Water Act.

14. 4.

CHESAPEAKE BAY PROGRAMME

The Chesapeake Bay Programme has an EPI programme associated with it to evaluate the progress in the Chesapeake Bay restoration effort and disseminate the information obtained in the programme to the public and other parties. The hierarchy within the EPI consists of a series of levels:

1. Actions by EPA/State regulatory agencies.
2. Responses of the community.
3. Changes in discharges/emission quantities.
4. Changes in ambient conditions.
5. Changes in uptake and or assimilation.
6. Changes in health, ecology or other effects.

Within the hierarchy, identifies toxics as an area of focus (in addition to nutrients and living resources). The EPI programme tracks a number of toxic contaminant related indicators. For example:

- Industry reported releases and transfers of toxic contaminants.
- The area under integrated pest management.
- Pesticide collection, disposal and container recycling programmes.
- Bald eagle population counts.
- Consumption bans and advisories.
- Kepone in finfish tissues.
- Declines in oyster tissue contaminants.
- Tributyltin concentrations.
- Trends in rainfall metal concentrations.
- Copper concentrations in sediments.
- Benzo[a]pyrene concentrations in sediments.

The Chesapeake Bay programme can be found on the world-wide web at http://www.chesapeakebay.net/bayprogram/measure/ and useful information on the indicators programme at http://www.chesapeakebay.net/bayprogram/measure/indicatr/
indover.html.

15. 5.

INTERNATIONAL MUSSEL WATCH

History

The “mussel watch” programme was originally established by the USEPA in 1970 to assess the extent of chemical contamination in US coastal waters. Samples for this programme were collected from about 100 coastal sites in 1976-1978. In 1986 NOAA initiated the National Status and Trends (NS&T) Mussel Watch programme. This programme samples and analyses bivalve samples from 200 coastal sites on a biennial basis (Lauenstein 1995). As well as immediate sample analysis sub-samples of tissue are archived for possible future analysis. This procedure is seen as critical to any monitoring programme as it allows for retrospective analysis of any “new” environmental hazards and also allows for re-analysis of previous samples in light of recent advances in technology (Lauenstein 1995).

As well as the mussel watch programme the NS&T programme monitors sediment concentrations of contaminants at some of the same sites. “The Benthic Surveillance Programme” is another component of NS&T and monitors chemical concentration in fish tissues and biological responses of the fish to that contamination (the sediment programme is discussed below). Such large scale monitoring programmes are of course expensive. For example, the west coast portion of the Benthic Surveillance Programme costs in the region of $US 1,000,000 per year. In view of the relatively low levels of contamination in the New Zealand environment and the size of the New Zealand economy, such programmes would be cost prohibitive.

Scope

The NS&T program covers 240 sites in all the States within the United States with a coast line. The ‘mussel watch’ portion of the programme measures a range of chemical contaminants in both mussel and oyster tissues. Chemicals analysed include 16 metals, 24 polycyclic aromatic hydrocarbons, 6 DDT group compounds, 11 chlorinated pesticides, 18 PCB congeners and organotin compounds.

The analyses for the program are carried out by a variety of participating laboratories. Analytical procedures are tightly specified to ensure comparability of results between laboratories. Data handling and presentation are managed by NOAA.

Indicators

NOAA does not use any “performance indicators” terminology in relation to the mussel watch programme. However the large extent of the programme makes it an ideal data set for extracting environmental performance indicators. As well as scientific publications (Farrington, *et al.* 1983) (Goldberg, *et al.* 1978) (Lauenstein 1995) much of the information and raw data is available on the world-wide web (at (http://wwworca.nos.noaa.gov/projects/nsandt/nsandt.html). This site provides an extensive overview of the programme in lay terms as well as detailed scientific information. To facilitate lay uptake statistical terms are explained and data results are provided in simple graphical form. As an example, the overall trends in heavy metal contamination are provided in Table 5.1 as increases or decreases and in addition, the overall trend from 1986 to 1990 is presented.

TABLE 5.1: National trends in heavy metal in molluscs tissue 1986/1990. United States National Status and Trends programme.

	Period				
Contaminant	**86/87**	**87/88**	**88/89**	**89/90**	**86/90**
TBT				D	
Ag	-	-	-	I	-
As	D	-	D	I	-
Cd	D	-	-	-	I
Cr	D	-	-	-	-
Cu	-	-	-	-	-
Hg	-	-	-	-	-
Ni	-	D	D	-	D
Pb	I	-	D	I	
Se	-	I	D	-	-
Zn	D	-	-	I	-
Total PCB	D	-	-	-	D
Total DDT	-	D	-	D	-
Chlordane	I	D	-		
Total PAH			-	-	D

Note: D: Decrease. I: Increase.

The extensive data set also allows the identification of contamination 'hot-spots'. This analysis is carried out by calculating the geometric mean for all sites and defining a 'high' concentration as that mean plus one standard deviation (refer Table 5.2).

This approach immediately highlights "areas of concern" or areas deserving priority for future monitoring and/or remedial actions. The log normal distribution of contaminant concentrations also clearly demonstrates the presence of hot-spots, a normal distribution of data points would indicate a an even distribution of contaminants.

International Implementation

Since it's inception in the USA the Mussel Watch programme has been extended internationally to become "The International Mussel Watch Programme". This programme involves the Inter-Governmental Oceanographic Commission (IOC) of UNESCO, UNEP and NOAA. The initial phase of this programme was launched in Latin America and the second phase is currently being formulated for the Asia/Pacific region. The leader of the Asia Pacific initiative is Prof. Shinsuke Tanabe of Ehime University in Japan.

TABLE 5.2: Example of toxic contaminant data in molluscs in the NS & T programme (all data dry weight).

Chemical	Geometric Mean	"High"
Molluscs (Mussels and Oysters)		
As	10 µg/g	17 µg/g
Cd	2.7 µg/g	5.7 µg/g
Hg	0.094 µg/g	0.24 µg/g
Ni	1.7 µg/g	3.3 µg/g
Se	2.5 µg/g	3.5 µg/g
tPAH	260 ng/g	890 ng/g
LMW	110 ng/g	280 ng/g
HMW	190 ng/g	650 ng/g
tDDT	37 ng/g	120 ng/g
tPCB	110 ng/g	470 ng/g
tChlordane	14 ng/g	31 ng/g
tButyltin	81 ng/g	350 ng/g
Mussels only		
Ag	0.17 µg/g	0.58 µg/g
Cr	1.7 µg/g	3.0 µg/g
Cu	8.9 µg/g	11 µg/g
Pb	1.8 µg/g	4.3 µg/g
Zn	130 µg/g	190 µg/g
Oysters only		
Ag	1.9 µg/g	3.7 µg/g
Cr	0.48 µg/g	0.93 µg/g
Cu	150 µg/g	360 µg/g
Pb	0.52 µg/g	0.94 µg/g
Zn	2400 µg/g	5200 µg/g

As well as this co-ordinated effort several groups have used the mussel watch concept to monitor temporal (Picer & Picer 1990) and spatial (Tavares, *et al.* 1988) trends in contamination of marine ecosystems.

16. 6.

NOAA NATIONAL STATUS AND TRENDS PROGRAM - SEDIMENT

Sediments were specifically identified in the USEPA case study in Section 5.2.2 above. Marine sediments are included in that programme. The NOAA National Status and Trends Program has monitored coastal sediment contamination since the mid-1980s. The data has linked contaminant concentrations to adverse effects in a number of specific locations. This work is specifically focused on toxic contaminants in the coastal environment in particular harbours and estuaries (refer O'Connor 1990).

The NOAA Status and Trends Program measures the concentration of a number of metals (cadmium, chromium, copper, lead, mercury, silver and zinc) and organic compounds (DDT, Total chlordane, Total PCB and Total PAH) in sediments. Since 1988 total PCB data has been obtained from the sum of the concentration of 18 individual PCB congeners and Total PAH data has been obtained from the sum of 18 individual PAH compounds.

The NOAA data provides information on the spatial distribution of the key contaminants. One of the key difficulties with the assessment of temporal trends in the sediment data is that the concentration is dependant upon the rate of sedimentation and the degree of bioturbation. As such two sites sampled to the same depth can represent different periods of time integration in relation to the contaminant present.

The NOAA programme has produced a huge database of toxic contaminants in sediment around the United States. The data provides a picture of coastal sediment contamination on a regional and national basis. There are considerable difficulties in utilising the data for fine trend analysis without further detailed or refined sampling and supplementary information collection.

Table 1. Major aquatic contaminant sources and environmental monitoring studies in New Zealand. (Source C Hickey, NIWA, 1998)

Industry	Contaminants	References
• agriculture - dairy - tannery - piggery - horticulture	NH_3, H_2S, Cd, pesticides	[1-14]
• mining	heavy metals, suspensoids	[15-18]
• forestry - pulp and paper - timber treatment - forestry operations	resin acids, chlorinated organics, dioxins. Cu, Cr, As, PCP, chlordane.	[7,19-33]
• geothermal	Hg, As, B	[34-37]
• stormwaters	heavy metals, PAH, suspensoids	[38-42]
• harbour dredging	heavy metals, organics	[43-46]
• municipal wastes	NH_3, H_2S, pesticides	[47]
• municipal wastes	various	[48-50]
• estuarine sediments	various	[46,51-74]
• marine biota	various	[58,75-86] [87-108]
• marine waters	various	[109]
• freshwater sediments	various	[25,29,30,49,60,68,110-119]
• freshwater biota	various	[78,118,120-144]
• freshwaters	various	[35-37,113,145-159]
• groundwater	various	[160-163]

• estuarine birds	various	[164,165]
• source reviews	various	[15,34,166-169]

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The U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program for Evaluating Contaminants in Tissues of Freshwater Biological Organisms (Crawford & Luoma, 1994[7]).

Beginning in 1986, Congress annually appropriated funds for the U.S. Geological Survey (USGS) to test and refine concepts for a National Water-Quality Assessment (NAWQA) Program. The goals for a full-scale programme are to:

1. Provide a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources;

2. Define long-term trends (or lack of trends) in water quality; and

3. Identify; describe, and explain, as possible, the major factors that affect observed water-quality conditions and trends.

This information, would be made available to water managers, policy makers, and the public to provide an improved scientific basis for evaluating the effectiveness of water-quality management programs and for predicting the likely effects of contemplated changes in land- and water-management practices (Crawford & Luoma, 1994).

Biological measurements will be used in the surface-water component of NAWQA to assist in:

1. Determining the occurrence and distribution of waters contaminated by faecal material; Determining the occurrence of potentially toxic substances, including trace elements and organic compounds, through the use of tissue analyses;
2. Assessing the relations between the physical and the chemical characteristics of streams and the functional or structural aspects of the biological community through ecological surveys; and
3. Defining and quantifying biological processes that affect the physical and chemical aspects of water quality.

Specific approaches to address these objectives have been developed and tested in the pilot program (Crawford & Luoma, 1994).

[7] Crawford, J.K.; Luoma, S.N. 1994. Guidelines for studies of contaminants in biological tissues for the National Water-Quality Assessment Programme. U.S. Geological Survey.

A summary of these characteristics, with some modifications appropriate for $NAWQA_1$ is shown below.

1. Concentrations of chemicals in the test organism should be responsive to environmental exposures.
2. Uptake of contaminants by the test organism should be rapid relative to release or metabolism of the contaminants.
3. Contaminants should be concentrated in the organism above the ambient concentrations in water.
4. The organism should not be so highly sensitive as to be killed by low levels of the contaminant to be measured.
5. Concentrations in the test organism should possess low variability within sites.
6. The organism should be sufficiently sedentary to reflect contaminant concentrations in the study area.
7. The organism should be abundant and widespread in the study area (and in the region for a national study such as NAWQA).
8. The organism should be of reasonable size, to provide sufficient tissue for analysis.
9. The organism should be sufficiently long-lived to integrate environmental exposures of at least several months.
10. The organism should be easy to sample and hardy enough to survive in the laboratory, allowing excretion of material in the digestive tract before analysis (if desired) and permitting laboratory studies of pollutant uptake.
11. Data employed in comparisons of tissue contaminant concentrations must be from the same species and the effects of size or age on the data must be recognized. Comparisons among species and size/age classes can be conducted if comparability is empirically demonstrated in the scientific.

The USGS programme provides a comprehensive review of the monitoring being undertaken in the US (Tables 2, 4 & 5 below), provides guidance on the selection of biomonitoring organisms, and a decision tree relating to the selection of contaminants for analysis.

Table 2.--Overview of the tissue analysis component of the National Water-Quality Assessment Program compared to other tissue analysis programs of national scope in the United States

[SAS, Statistical Analysis System; STORET, Storage and Retrieval System; USEPA, U.S. Environmental Protection Agency; NIST, National Institute of Standards and Technology; NFCRC, National Fisheries Contaminant Research Center; x, included in the program; -, not included]

Element	Program					
		National Status and Trends Program [1]				
	National Water-Quality Assessment Program [2]	Benthic Surveillance Program	Mussel Watch	National Study of Chemical Residues in Fish [3]	Environmental Monitoring and Assessment Program, Surface Waters Component [4]	National Contaminant Biomonitoring Program [5]
Objectives						
Establish data base	x	x	x	-	-	-
Create specimen bank	-	x	x	-	-	x
Develop new techniques	-	x	x	-	-	-
Estimate environmental quality	-	-	x	-	x	-
Determine prevalence of contaminants	x	-	-	x	-	x
Identify chemicals of concern	-	-	-	x	-	-
Describe spatial variability	x	x	x	-	x	x
Identify regional variability	x	-	-	-	x	x
Identify areas needing more study	-	x	x	x	-	-
Evaluate contamination in vicinity of sources	-	-	-	-	x	-
Establish baseline concentrations	x	-	-	-	x	-
Detect temporal change	x	x	x	-	x	x
Determine contaminant fate	x	-	-	-	-	-
Determine contaminant bioavailability	x	x	-	-	-	-
Evaluate human health effects	-	-	-	x	x	-
Evaluate contaminants in game fish flesh	x	-	-	x	x	-
Resources targeted	Freshwater streams	Coastal and estuarine	Coastal and estuarine	Freshwater streams and lakes	Freshwater streams and lakes	Large rivers and Great Lakes
Geographic coverage	Nationwide	Nationwide	Nationwide	Nationwide	Nationwide	Nationwide
Number of sampling stations	~600	~50	~150	400	Subset of 6,400	112
Sampling frequency	Annual[6]	Annual	Annual	One-time only	Annual [7]	Bi-annual
Duration of program	-	1984 - present	1986 - present	1988	-	1967 - present

Table 2.--Overview of the tissue analysis component of the National Water-Quality Assessment Program compared to other tissue analysis programs of national scope in the United States--Continued

[SAS, Statistical Analysis System; STORET, Storage and Retrieval System; USEPA, U.S. Environmental Protection Agency; NIST, National Institute of Standards and Technology; NFCRC, National Fisheries Contaminant Research Center; x, included in the program; -, not included]

Element	Program					
		National Status and Trends Program [1]				
	National Water-Quality Assessment Program [2]	Benthic Surveillance Program	Mussel Watch	National Study of Chemical Residues in Fish [3]	Environmental Monitoring and Assessment Program, Surface Waters Component [4]	National Contaminant Biomonitoring Program [5]
Target organisms						
Bivalve mollusks	x	-	x	-	-	-
Bottom-feeding fish	x	x	-	x	x	x [8]
Sport/commercial/game fish	x	-	-	x	x	x [6]
Crayfish	-	-	-	-	-	-
Insects	x	-	-	-	-	-
Aquatic plants	x	-	-	-	-	-
Organs tested	Whole organism, fish livers, fish flesh	Fish livers, plus bile	Whole mollusk	Whole fish, fish fillets	Whole fish	Whole fish
Target variables						
Chlorinated organic compounds						
Organochlorine pesticides	x	x	x	x	x	x
PCB's	x	x	x	x	x	x
Dioxins	x	-	-	x	-	-
Polynuclear aromatic compounds	x	x	x	-	-	-
Trace elements	x	x	x	-	x	x
Additional data collected						
Water chemistry	x	x	x	-	x	-
Sediment chemistry	x	x	x	-	x	-
Sediment grain size	x	x	x	-	x	-
Fecal sterol	-	x	x	-	-	-
Coprostanol	-	x	x	-	-	-
Clostridium	-	x	-	-	-	-
Fish disorders	x	x	-	-	-	x
Lipid content	x	x	-	x	x	x

Table 2.--Overview of the tissue analysis component of the National Water-Quality Assessment Program compared to other tissue analysis programs of national scope in the United States--Continued

[SAS, Statistical Analysis System; STORET, Storage and Retrieval System; USEPA, U.S. Environmental Protection Agency; NIST, National Institute of Standards and Technology; NFCRC, National Fisheries Contaminant Research Center; x, included in the program; -, not included]

	Program					
		National Status and Trends Program [1]				
Element	National Water-Quality Assessment Program [2]	Benthic Surveillance Program	Mussel Watch	National Study of Chemical Residues in Fish [3]	Environmental Monitoring and Assessment Program, Surface Waters Component [4]	National Contaminant Biomonitoring Program [5]
Additional data collected --Continued						
Histopathology	-	x	x	-	x	-
Age	x	x	-	-	x	x
Gonadal index	-	-	x	-	-	-
Data storage	In-house distributed information	In-house microcomputer	In-house microcomputer	SAS data set and STORET	Unknown	U. of Missouri mainframe as SAS data set and NFCRC
Sample archival	In-house	NIST	NIST	USEPA lab, Duluth	Unknown	NFCRC

[1] National Oceanic and Atmospheric Administration (See Robertson and O'Connor, 1988, for an overview of the program).

[2] U.S. Geological Survey.

[3] U.S. Environmental Protection Agency (See U.S. Environmental Protection Agency, 1986, for an overview of the program).

[4] U.S. Environmental Protection Agency (See Whittier and Paulsen, 1992, for an overview of the program).

[5] U.S. Fish and Wildlife Service (See Jacknow and others, 1986, for an overview of the program).

[6] NAWQA will sample annually during a 3-year intensive phase, then reduce sampling for a 6-year non-intensive phase.

[7] EMAP will sample one-quarter of the 6,400 sites annually, rotating sites on a 4-year schedule.

[8] The National Contaminant Biomonitoring Program also targets birds for analysis.

Table 5.--Major metals and trace elements targeted for analysis in tissues collected in the National Water-Quality Assessment Program and currently analyzed in existing tissue analysis programs of national scope

[USGS, U.S. Geological Survey; NOAA, National Oceanic and Atmospheric Administration; USEPA, U.S. Environmental Protection Agency; FWS, U.S. Fish and Wildlife Service; +, included in the program]

Major metals and trace elements	Program				
	National Water-Quality Assessment Program (USGS)	National Status and Trends Program (NOAA)	National Study of Chemical Residues in Fish (USEPA)	Environmental Monitoring and Assessment Program, Surface Waters Component (USEPA)	National Contaminant Biomonitoring Program (FWS)
Aluminum	+	+		+	
Antimony	+	+			
Arsenic	+	+		+	+
Barium	+				
Beryllium	+				
Cadmium	+	+		+	+
Chromium	+	+		+	
Copper	+	+		+	+
Iron	+	+		+	
Lead	+	+		+	+
Manganese	+	+			
Mercury	+	+	+	+	+
Molybdenum	+				
Nickel	+	+		+	
Selenium	+	+			+
Silicon		+			
Silver	+	+		+	
Thallium		+			
Tin		+		+	
Vanadium	+				
Zinc	+	+		+	+

Table 4.--Synthetic organic compounds targeted for analysis in tissues collected in the National Water-Quality Assessment Program and currently analyzed in existing tissue analysis programs of national scope--Continued

[USGS, U.S. Geological Survey; NOAA, National Oceanic and Atmospheric Administration; USEPA, U.S. Environmental Protection Agency; FWS, U.S. Fish and Wildlife Service; +, included in the program]

Chemical name	Program: National Water-Quality Assessment Program (USGS)	National Status and Trends Program (NOAA)	National Study of Chemical Residues in Fish (USEPA)	Environmental Monitoring and Assessment Program, Surface Waters Component (USEPA)	National Contaminant Biomonitoring Program (FWS)
Miscellaneous industrial compounds--Continued					
1,2,3-Trichlorobenzene			+		+
1,2,4-Trichlorobenzene	+		+		+
1,3,5-Trichlorobenzene	+		+		+
Triphenyl phosphate	+				+
Polychlorinated biphenyls					
Monochlorobiphenyls			+		
Dichlorobiphenyls		+	+		
Trichlorobiphenyls		+	+		
Tetrachlorobiphenyls		+	+		
Pentachlorobiphenyls		+	+		
Hexachlorobiphenyls		+	+		
Heptachlorobiphenyls		+	+		
Octachlorobiphenyls		+	+		
Nonachlorobiphenyls		+	+		
Decachlorobiphenyls			+		
Total PCBs	+		+		
PCB congeners (selected)	+			+	
Aroclor 1242					+
Aroclor 1248					+
Aroclor 1254					+
Aroclor 1260					+
Chlorinated Dioxins and Furans					
2,3,7,8-TCDD	+		+		
1,2,3,7,8-PeDD	+		+		
1,2,3,6,7,8-HxDD	+		+		
1,2,3,7,8,9-HxDD	+		+		
1,2,3,7,8-HxDD	+		+		
1,2,3,4,6,7,8-HpDD	+		+		
2,3,7,8-TCDF	+		+		
1,2,3,7,8-PeDF	+		+		
2,3,4,7,8-PeDF	+		+		
1,2,3,6,7,8-HxDF	+		+		
1,2,3,7,8,9-HxDF	+		+		
1,2,3,4,7,8-HxDF	+		+		
2,3,4,6,7,8-HxDF	+		+		
1,2,3,4,6,7,8-HpDF	+		+		
1,2,3,4,7,8,9-HpDF	+		+		

[1] Not targeted for analysis in vertebrates.

Table 4.--Synthetic organic compounds targeted for analysis in tissues collected in the National Water-Quality Assessment Program and currently analyzed in existing tissue analysis programs of national scope--Continued

[USGS, U.S. Geological Survey; NOAA, National Oceanic and Atmospheric Administration; USEPA, U.S. Environmental Protection Agency; FWS, U.S. Fish and Wildlife Service; +, included in the program]

Chemical name	Program				
	National Water-Quality Assessment Program (USGS)	National Status and Trends Program (NOAA)	National Study of Chemical Residues in Fish (USEPA)	Environmental Monitoring and Assessment Program, Surface Waters Component (USEPA)	National Contaminant Biomonitoring Program (FWS)
Organochlorine insecticides--Continued					
Diphenyldisulfide					+
Endrin	+		+	+	+
Heptachlor	+	+	+	+	+
Heptachlor epoxide	+	+	+	+	+
Hexachlorocyclohexane(HCH), alpha	+	+	+		+
Hexachlorocyclohexane(HCH), beta	+	+	+		+
Hexachlorocyclohexane(HCH), delta	+	+	+		+
Hexachlorocyclohexane(HCH), gamma (Lindane)	+	+	+	+	+
Hexachlorocyclopentadine	+				
Kepone (Chlordecone)	+		+		+
o, p'-Methoxychlor	+		+		+
p, p'-Methoxychlor	+		+		+
Mirex	+	+	+	+	+
n-alkanes					+
Nitrofen			+		+
Nonachlor, cis	+		+		+
Nonachlor, trans	+	+	+	+	+
Oxychlordane	+		+		+
Pentachloroanisole	+		+		+
Perthane	+		+		+
Toxaphene					+
Trichloronate	+				+
Herbicides					
Butachlor	+				
Isopropalin	+		+		+
Trifluralin	+		+		+
Fungicides					
Hexachlorobenzene (HCB)	+	+	+	+	+
Pentachloronitrobenzene (PCNB)	+		+		+
Miscellaneous industrial compounds					
Octachlorostyrene	+		+		+
Pentachlorobenzene	+		+		+
Pentachlorophenol (PCP)	+		+		+
1,2,4,5-Tetrachlorobenzene	+		+		+
1,2,3,4-Tetrachlorobenzene	+		+		+
1,2,3,5-Tetrachlorobenzene	+		+		+

Table 4.--Synthetic organic compounds targeted for analysis in tissues collected in the National Water-Quality Assessment Program and currently analyzed in existing tissue analysis programs of national scope

[USGS, U.S. Geological Survey; NOAA, National Oceanic and Atmospheric Administration; USEPA, U.S. Environmental Protection Agency; FWS, U.S. Fish and Wildlife Service; +, included in the program]

Chemical name	Program				
	National Water-Quality Assessment Program (USGS)	National Status and Trends Program (NOAA)	National Study of Chemical Residues in Fish (USEPA)	Environmental Monitoring and Assessment Program, Surface Waters Component (USEPA)	National Contaminant Biomonitoring Program (FWS)
Polynuclear aromatic hydrocarbons[1]					
Acenaphthene	+	+			
Acenaphthylene	+				
Anthracene	+	+			
Benz(a)anthracene	+	+			
Benzo(b)fluoranthene	+				
Benzo(k)fluoranthene	+				
Benzo(g,h,i)perylene	+				
Benzo(a)pyrene	+	+			
Benzo(e)pyrene		+			
Biphenyl		+	+		
Chrysene	+	+			
Dibenz(a,h)anthracene	+	+			
2, 6-Dimethylnaphthalene	+	+			
Fluoranthene	+	+			
Fluorene	+	+			
1-Methylnaphthalene		+			
2-Methylnaphthalene		+			
1-Methylphenanthrene		+			
Naphthalene	+	+			
Perylene		+			
Phenanthrene	+	+			
Pyrene	+	+			
Organochlorine insecticides					
Aldrin		+		+	+
Chlorbenzilate			+		
Chlordane, cis	+	+	+	+	+
Chlordane, trans	+		+		+
Chlorpyrifos			+		+
o, p'-DDD	+	+		+	+
p, p'-DDD	+	+		+	+
o, p'-DDE	+	+		+	+
p, p'-DDE	+	+	+	+	+
o, p'-DDT	+	+		+	
p, p'-DDT	+	+		+	
Dicofol (Kelthane)	+		+		+
Dieldrin	+	+	+	+	+
Diethylhexylphthalate (DEHP)					+

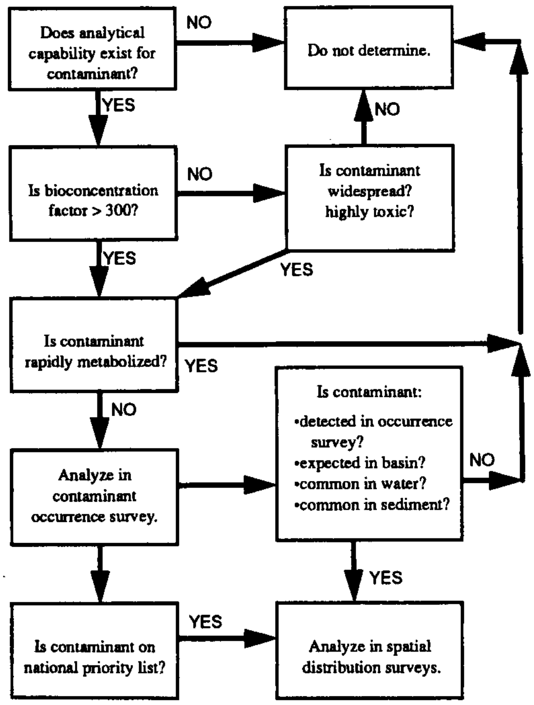

Figure 4.--Decision tree for selecting target synthetic organic compounds for analysis in tissues collected in the National Water-Quality Assessment Program.