5. DETERMINING THE NATURE AND EXTENT OF CONTAMINATION - DEVELOPMENT OF A WORK PLAN

Once an initial investigation of a site is complete and the site is considered to warrant further investigation, a site specific work plan needs to be developed to determine the nature and extent of contamination. In developing a work plan, thought needs to be given to potential health and environmental impacts, occupational health and safety considerations and a community participation program. The following sections outline what may be required depending on site specific factors.

The level of detail to be included in a work plan will depend on the type of site but should be based on consideration of the areas covered in the following sections.

A work plan defines the scope of work, level of investigation, costs and schedules for performing site assessment activities. In general a work plan describes what will be done.

The key parties involved in developing the work plan include the site owner/occupier, developer, consultant/s, the community, workers or unions covering those workers, the local council and relevant government authorities.

5.1 Site Investigation

Survey of Existing Information

Once a site is deemed to require further investigation, information about the specific site and the region should be collated. This will assist in the identification of surface, subsurface, atmospheric and biotic migration pathways for contaminants as well as determining the degree and extent of contamination. The information collected should include data on the local geology, hydrogeology, climate and flora and fauna. Regional information may help to identify local soil, water and air quality characteristics [6].

Information on potential contaminant exposure routes and receptors in the area surrounding the site should be compiled. Demographic and land use information will also help to identify the potential receptors of contaminants [6].
The location of any threatened, endangered, or rare animal or plant species, sensitive environmental areas or critical habitats on or near the site should be identified. Any results from previous biological studies in the area should also be compiled to document any potential for bioaccumulation in the food chain.

The site history, existing conditions, details of industrial, commercial or agricultural operations and a description of the site are compiled to:

assist in the design of a sampling and analytical program, and

assist in the preliminary assessment of exposure risk and to enable the initial identification of potential remedial technologies [6].

Site Inspection

It is essential that the investigators or assessors of a site familiarise themselves with the site. It may be beneficial for them to inspect the site with resource persons such as former employees.

The resource persons may help to identify possible areas of contamination and locations of specific industrial operations.

A site inspection should be performed at an early stage of the evaluation process and may include the following [7]:

use of field testing procedures to obtain data on volatile chemical contaminants, radioactivity and explosive hazards to determine appropriate health and safety levels,

assessment of whether any conditions could pose an imminent danger to public health or the environment,

confirmation of information contained in previous documents,

recording of observable data missing in previous documents,

updating site features and conditions if undocumented changes have occurred,

identification of possible off-site sources of contamination, and

documentation of the location of access routes, proposed sampling points and other site features, as required for the design of detailed field investigations.

Site Description

The following is a list of some of the features which may be considered in the development of a work plan and in the investigation of a contaminated site. (Not all of these factors may be appropriate for a particular site.)

<u>Surface Features</u>
vegetation
topography
surface water features
tanks
piping
disposal areas
fencing
property lines
utility lines
road ways
railways
drainage ditches
water quality

<u>Sub Surface Features</u>
depth to ground water
rate of groundwater flow
direction of groundwater flow
various services
underground structures/tanks

<u>Other</u>
flood potential
uses of surface water
uses of groundwater
accessibility
local climate
demography
surrounding land uses
air quality
soil types
regional geology
soil chemistry

climate (precipitation, temperature, wind speed and direction, presence of inversion layers, extremes in weather)

On most sites a description of current or past industrial operations will be appropriate. Operational details to be noted may include:

ownership,
location,
nature of industrial processes and operations,
waste type,
estimates of waste volumes,
chemical handling, storage and disposal practices,
previous site visits,
sampling events,
regulatory violations, and
legal actions.

The data review should be as thorough, accurate and well documented as possible given time and resource requirements. Failure to fully investigate a site and identify a potential hazard could result in detrimental impacts on public health and the environment, as well as costly litigation at some later stage.

5.2 Sampling and Analysis

Once an initial sampling and analysis program has confirmed the presence of contamination, further work is performed to collect data to permit estimation of the extent of contamination, location of contaminant sources on and off site, the identification of contaminant migration pathways, if any, and the extent of off-site movement of contamination to determine whether a contaminated site is an immediate or long term threat to public health and the environment.

The sampling and analysis plan should detail the number of samples, depth(s) and location of samples and type of physical/chemical analysis required to determine the nature and extent of contamination.

Further investigations typically involve on-site testing, sample recovery and characterisation of subsurface conditions.

A sampling and analysis plan should describe how tasks are to be carried out. The following information should be included in a sampling and analysis plan:

description of objective of sampling and analysis program,

an appropriately detailed scale map of the site, showing the area to be investigated,

estimated number of samples to be obtained in the field including off site samples and duplicates,

the locations from which the samples have been and will be recovered, including sample depths and sampling methods,

list of analyses to be performed,

requirement for leachate, bioavailability or speciation tests,

a general discussion of the accuracy and precision required, and

identification of pilot or laboratory bench studies to be performed (if any).

At some sites the ambient or background chemical level is significant and should be taken into account when designing a sampling program and subsequent interpretation of the analytical results.

Collecting an environmental sample requires careful planning and meticulous documentation to ensure that samples are representative of the original source material [8].

It is important to realise that the quality of the results of a sampling and analysis program are only as high as the quality of the sampling program.

If samples are collected without consideration of heterogeneity and variations over space and time, and without the application of correct methods and an awareness of contamination problems with equipment, the validity of the analytical data obtained is negligible [8].

The approach to a Sampling Program may depend on:

budget constraints,
deadlines,
reference materials available,
equipment available,
methods to be employed,
number of samples required,
sample handling techniques,
parameters to be analysed, and
level of accuracy required for decision making purposes.

The type of contamination is also important. Contaminants that are highly water soluble must be handled differently from those that are immiscible in water (eg. petrol).

Physical constraints must also be taken into consideration. These include: the solid-carrying capacity of a liquid; stratification of liquid based on density, immiscibility or temperature gradients; solid distributions based on particle size, density or surface characteristics and any other contributing parameters.

Clearly, the particular soil type(s) encountered will have a major influence on the contaminant of interest. For this reason, it is recommended that fundamental soils information such as soil type, pH, salt content, permeability, porosity, texture and cation/anion exchange capacity, percent organic material, moisture content and absorptivity be obtained.

The number of locations sampled is based on the known history of the site and its size. At each location, where environmental parameters are of concern, samples should be taken at least two depths, commonly three. The depths at which samples are taken will be dependent on the soil type, subsoil type, where a change of texture is observed, suspected contamination on the site, and upon the depth to natural ground surface in the case of filled sites. While from a health perspective, the surface layer is usually the most important, from an environmental perspective the extent of contamination both at surface and at depth is extremely important to ascertain.

Where appropriate, surface water, groundwater and air samples should also be taken.

There are major problems associated with sampling and analysing the large numbers of samples typically required to assess the actual nature and extent of contamination at a site [9]. A number of methods, are being developed to assist in the programming of sampling and subsequent analysis.

It is prudent to allow adequate time and resources for a multiple stage sampling program. Single stage sampling may be expedient, but lacks the flexibility to cater for any feedbacks from sampling and analysis. The sampling plan may need to be altered at times for numerous reasons including unforeseen physical structures on site such as the discovery of underground storage tanks and encountering concrete foundations. The plan may need modifications in response to observations of strata, odour and unusual appearances of the soil.

Analysis

Precise and representative chemical analysis of soil samples may be difficult because of the interference related to a complex soil matrix [10]. However, screening for a range of inorganic and organic indicator chemicals should be considered to check whether any previous illegal or accidental discharge of unsuspected contaminants has occurred.

To obtain useful results from site sampling, the analytical methods used must:

- be able to be assessed for accuracy and reproducibility;
- have an appropriate detection limit;
- have a known response to possible interfering species; and
- be suitable in terms of time and cost.

Soil also needs to be analysed for physical parameters such as clay content, organic matter content, particle size, and others deemed appropriate.

Analytical Methods

Analyses should be performed in accordance with the protocols approved by the relevant authorities.

Analytical methods needed for site assessment fall into three categories:

- Field measurements that can be performed "in situ";
- Laboratory based broad screening methods used to determine the type of contamination present; and
- Methods specific for contaminants that are known or expected to be present.

Approved Methods

Analytical methods should be approved and then listed. Analytical techniques need not be restricted to existing USEPA or similar standard methods. However, non standard methods will require validation before they are approved for routine use. Such methods should be detailed in assessment reports for the evaluation and review of the relevant authorities.

Groundwater

Groundwater samples should be taken in areas with a shallow depth to groundwater and where a site may have been used as a landfill, for lagooning of wastes, underground product storage and where a suspected contaminant is extremely mobile. Siting and construction of sampling bores must take into account a contaminant's physicochemical properties and the nature of the local hydrogeology in order to target contaminated zones while preventing the spread of contaminants through inappropriate or careless bore installation. A general hydrogeological assessment including the level of groundwater, rate of movement and direction of flow needs to be obtained prior to groundwater samples being taken, as subsequent interpretation of data will be made difficult.

Groundwater investigations should be professionally supervised, preferably by a hydrogeologist specialising in contaminant hydrology, who should be involved in the design, supervision, and follow up phases.

Where little is known of factors such as aquifer type and permeability, depth to water table and gradient of water table, it is best to plan the program in two phases. The second phase (monitoring bore design and lay out) being dependent on the findings of the first phase (hydrogeological data gathering).

Obviously decisions must be made when designing a bore program as to what information is required from the bores. Examples of this being the direction of movement of groundwater and which indicators are to be analysed, as some determinations may be masked or suffer interference from bore construction and sampling materials.

Factors which need to be considered regarding site conditions are:

- depth to aquifer under investigation;
- width of source, as this can affect plume shape and bore pattern;
- geology and hydrogeology in the area, including type and amount of permeability and likely gradient;
- depth to water table;
- site accessibility for a drilling rig;
- established or likely background values for the parameters required;
- current usage of the shallow aquifer groundwater in the area.

These and other factors will influence the optimum design of the drilling program, including location, number and depth of bores.

Generally, a minimum of three bores per site (for example over a hectare) is acceptable for an initial survey. However, as with soil sampling, this number can vary from site to site. Therefore, each site will need to be assessed individually.

Under relevant local legislation, all bores will generally be required to be registered with an appropriate authority and licensed drillers employed.

5.3 Health Considerations

Protection of the health and safety of the public and site workers is a concern once a site has been identified and during site investigation and clean-up. The workplan needs to address these concerns and ensure that potential problems are identified and prevented. Where appropriate, efforts must be made to inform and educate the public. Actions undertaken may be as simple as constructing a secure fence to restrict access, or as complex as the creation of an evacuation plan in the rare occasions where this is a real concern.

It is important that professional expertise is sought.

The public health implications need to be explicitly addressed for all sites. This will involve some level of risk assessment.

It is not necessary or practicable to perform detailed analysis for every site, since there may be no population at risk, or decisions may be made on other grounds.

For the majority of sites, clinical or epidemiological evaluation has no role. It is difficult to equate health effects with concentrations of contaminants in soil.

Health Monitoring [14]

From Australian and international experience, health effects are likely to be found in only a very limited number of situations of extreme soil contamination. Subtle effects may only be able to be determined on a group basis rather than on an individual basis (e.g. subtle neuro-developmental effects determined by sophisticated testing in groups of children with different lead exposures). Problems of causation relating to individual findings rather than group findings arise if the putative effects are common in the general population e.g. headache, fatigue. Health effects are rarely as specific to an exposure as chloracne with some chlorinated hydrocarbon exposures.

Health monitoring for specific health effects is warranted only where environmental or biological monitoring has indicated a significant risk of effects e.g. specific tests of renal function if urinary cadmium levels above the levels of concern are detected in biological monitoring.

When health monitoring is done it should rarely be done in isolation from environmental and/or biological monitoring. Clearly defined health effects should be sought with specific case - definition criteria. Records of other symptoms and clinical findings should also be kept to enable epidemiological assessment of other potential health effects.

Biological Monitoring [14]

Biological monitoring is a measuring procedure whereby validated indicators of the uptake of contaminants, or their metabolites, and people's individual responses are determined and interpreted. Biological monitoring is only of use in limited circumstances when dealing with contaminated sites. It is most likely to be appropriate if there are high levels of contamination extending over a large area e.g. regional contamination by lead from a smelter.

It is more likely to be useful in monitoring chronic exposure for substances with long biological half-lives.

If biological monitoring is appropriate and practicable it can be more valuable than environmental monitoring in determining the level of risk from an environment as it will measure whether exposure is occurring and the level of exposure.

Before biological monitoring is undertaken the following are necessary:

1. The objective of the biological monitoring must be defined clearly.
2. A normal range of results must be established that is applicable for the population under study.
3. Consideration must be given to how people with abnormal results are to be managed.
4. A centralised collection point for results must be established to enable consistent analysis and epidemiological appraisal of results.

Meaningful results are only available for a limited number of substances. Quality assurance is always a major problem with biological monitoring. The following substances are the only ones likely to be suitable for biological monitoring: lead, cadmium, arsenic, mercury, polychlorinated biphenyls (PCBs), organochlorine pesticides and organophosphorus pesticides.

If there are multiple potential exposures it may be appropriate to measure a specific indicator analyte e.g. if lead and cadmium are both present, the measurement of lead alone may act as a surrogate measure of cadmium exposure.

Biological monitoring should be undertaken only with specialist medical or toxicological supervision. A biological monitoring program should be assessed by the way in which the testing program is organised, the way the results are evaluated and communicated to people, and the way abnormalities are pursued [12]. It is recommended that the normal ranges for differing age groups in the Australian situation be determined for the listed substances: lead, cadmium, arsenic, mercury, polychlorinated biphenyls, organochlorine pesticides and organophosphorus pesticides.

Risk Communication

There will often be significant differences in the risk perceptions of the public health authorities and members of the community.

Risk perception will be affected by factors such as the involuntary nature of the exposure (e.g. is there a gaseous contaminant that will unavoidably be inhaled); whether the contaminant is familiar (e.g. tobacco) or seen as exotic (e.g. PCB); and the nature and dread of the potential effect (respiratory tract irritation or lung cancer).

Aesthetic concerns and the stigma of living near a contaminated site may also influence public attitudes.

The importance of public perceptions and opinions should not be dismissed. Effective risk communication will be needed to address public concerns and anxiety and to enable a productive discourse between public authorities and the community.

The USEPA [13] highlights several important features of risk communication:

accept and involve the public as a legitimate partner,

carefully plan and evaluate your efforts (there will be different audiences and concerns),

listen to the public's specific concerns (the public are unlikely to listen to you if you are not perceived as listening to their problems),

be honest, frank and open as trust and credibility are important assets that are hard won and easily lost,

co-ordinate and collaborate your messages with other credible sources,

address the needs of the media, and

avoid jargon and provide detail where possible (discuss actions that are underway and the limitations of possible action).

Counselling and Support

A factor often not considered is the psychological stress of those living or working in the surrounding area, once a potentially contaminated site has been identified.

Where risk assessment suggests substantial exposure may have occurred (substantial future exposure being preventable), then it is essential to provide information to the community as discussed to above, and to put in place appropriate facilities for counselling and appropriate referrals to clinical specialists. Detailed information packages should be made available to family medical practitioners, community clinics and other sources of primary health care.

5.4 Environmental Considerations

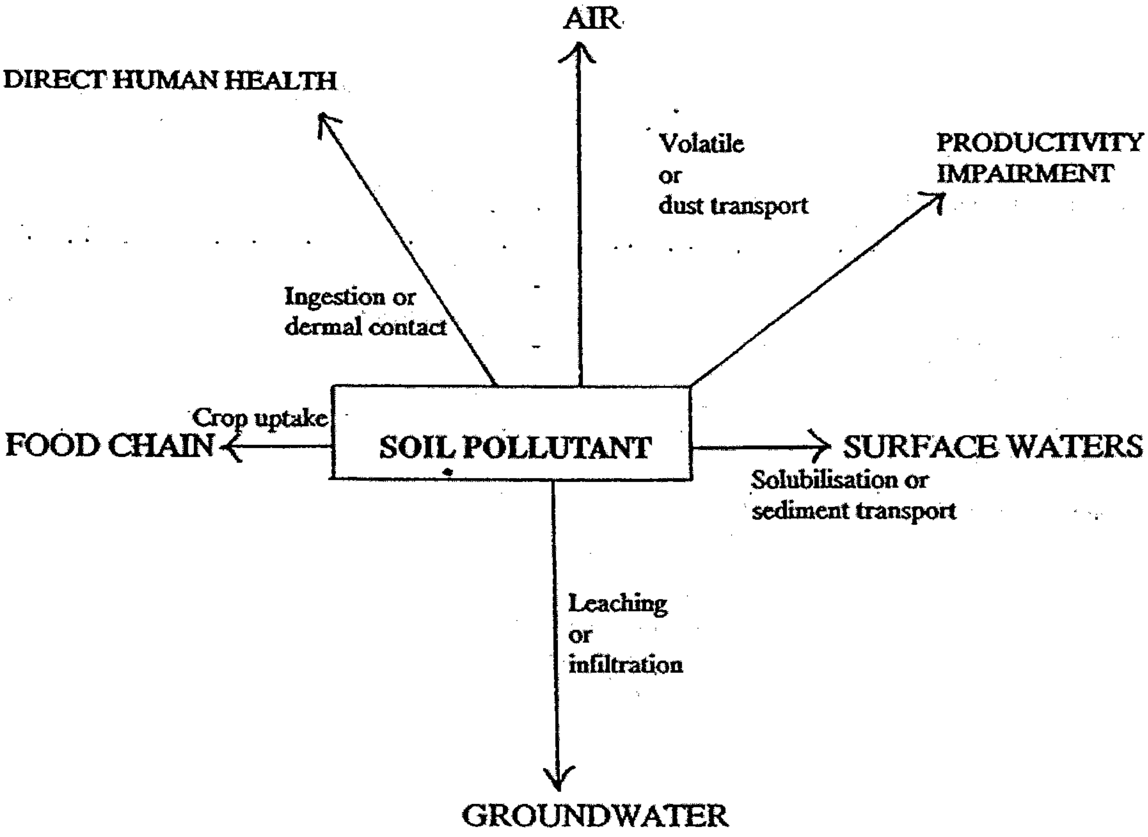
Environment protection requirements need to be clearly identified and taken into account during the investigation, clean-up and management of an identified contaminated site.

The development of a workplan, therefore, needs to take into consideration the environmental parameters which may be relevant to a particular site and how these may be tested and protected.

The following diagram simplifies the sectors in an ecosystem which need to be considered.

Fig 5.4

Environmental Impact of Soil Pollutants



Site and ecosystem characteristics are likely to differ markedly between one location and another. Soils alone may vary dramatically. This, together with the great diversity of plant and animal species which may be involved and variations in hydrogeological conditions and land uses, make it difficult to develop a general checklist of environmental considerations for inclusion in a work plan.

Nevertheless, some specific aspects which should be considered are as follows:

physico chemical characteristics of contaminants (speciation, mobility, solubility etc.);

soil characteristics such as pH and clay content;

site characteristics (likelihood of exposure to contaminants in air, water and soil both on and off-site);

identification of exposure routes and receptors, e.g. plants, water bodies;

toxicity of contaminants to animals and plants, both terrestrial and aquatic;

bioaccumulative and biomagnification capacity;

bioavailability of the contaminant to the range of receptors in a given ecosystem;

the health of the environment with respect to biological species distribution and number (including microbes); and

microbial degradation rates, as these may affect productivity and integrity of the soil.

5.5 Community Consultation and Involvement [14]

Consultation will be required where issues are contentious or where a site may have effects on a community. An effective consultation includes all affected people and uses strategies that ensure that all who wish to participate in the consultation are able to do so. Public meetings should not be regarded as the only form of public consultation. When public meetings are held some of the potential problems can be addressed by: collaborating with a local agency which is trusted or perceived as impartial and being sensitive to the choice of venue; being honest, accurate and non-patronising in the presentation of factual information; planning the meeting carefully to allow time for all perspectives to be presented and for discussion; not assuming what the outcome of the meetings will be. A meeting should not be called to ratify a decision which has already been made elsewhere and perceptions that this is occurring tend to be destructive for any form of consultation. The use of a skilled facilitator may be required if the situation is, or is likely to become, particularly sensitive.

The information which makes up a consultation protocol should include [15]:

"1. A brief, clear statement of the issue in plain English, and a summary of any background information needed to understand the issues.

2. A clear statement of any issues which are or are not negotiable wihtin the consultation, and the reasons for this, e.g. a decision has already been made at another level of government, but where input is sought on how a change should actually be implemented.

3. A broad description of who is affected by the issue or the proposal, and a list of relevant groups, organisations or channels through which their input can be sought.

4. A statement of what kind of input is being sought, e.g. comments on existing proposals or activities.

5. A time line for the consultation which includes sufficient time for organisations and individuals to discuss and form opinions on the issue and prepare a response. A time line is also needed for reporting on the outcomes of the consultation to those who are affected or who have participated in the consultation.

6. A list of consultation strategies to be used, which reflects any particular difficulties of those who are affected by the issue (e.g. inviting comments by telephone is useful for many people with mobility problems, but not very useful for non-English speaking people). Examples are small discussion groups, telephone hotlines, surveys and questionnaires, public meetings, and doorknocking.

7. A list of resources which are available for consultation e.g.
   - staff with relevant skills and knowledge
   - funding for preparing written material, advertising, child-care, interpreting and transport
   - funding for facilitators for meetings
   - resources for relevant groups or organisations to collect information for the consultation.

8. If public meetings are planned, a discussion of issues about the choice of venue, speakers, and timing of the meetings".

5.6 Occupational Health and Safety Considerations [14]

It is expected that employers will provide:

a health and safety policy; a safe work environment and safe systems of work;
adequate facilities for the welfare of employees;
information, instruction, training and supervision necessary to ensure the health and safety of employees;
appraisal and monitoring of working conditions and the workplace.

The legislative, and ethical obligation to protect the health and safety of workers applies to all worksites including contaminated land. Consideration must be given to appropriate occupational health and safety measures from the time of the preliminary assessment of a site.

At all times the exposure of workers to contaminants involved in contaminated site assessment or management should not exceed legislated limits, where they exist. Otherwise exposure should not exceed the most recent National Exposure Standards declared by the National Occupational Health and Safety Commission [16].

The following information is required to enable appropriate control of employees' exposure to contaminants;

> the types of contaminants present, their form and likely concentrations. For workers physically involved in sampling procedures for initial assessment of the site, some idea of possible contamination of the site may be gained from the site history;
>
> the toxicity of contaminants (via all exposure routes) as well as other safety hazards posed (e.g. explosion potential from specific gases or vapour);
>
> the types of operations to be carried out on site.

Given this information, a range of measures to minimise workers' exposures may be considered by an appropriately skilled occupational health and safety professional:

(1) Type of equipment and processes used on site to minimise airborne-generation of contaminants.

(2) Dust suppression techniques (e.g. water spray, or conducting operations during winter)

(3) Enclosed, air filtered cabins on vehicles.

(4) Personal protective equipment which may include overalls, boots, helmets, goggles/face visor and respiratory protection.

(5) Personal hygiene precautions
    - provision of adequate facilities for washing and showering
    - provision for disposal of contaminated clothing before leaving site
    - maintaining the cleanliness of crib rooms
    - supervision

(6) Worker education and training
Worker awareness of the nature of the risk is vital. Specifically, worker education must address: the nature of contaminants; the degree of contamination; the risks of exposure; the potential routes of exposure, the risks of transferring these contaminants into the home, and an understanding of the precautions to be taken to minimise exposure. This knowledge will provide a better' perception of the actual risk of working on a contaminated site and an appreciation of the control measures to be used.

(7) Other safety equipment requirements dependant on the work being undertaken (e.g. testing devices for vapours, gases).

(8) Where there are high levels of contamination, consideration will need to be given to airborne monitoring of contaminants in the breathing zone of workers to ensure that the precautions being taken are suitable. Occupational hygienists and occupational physicians can provide specialist advice on these matters.

Biological monitoring as part of a health surveillance strategy undertaken by an occupational physician, may need to be considered. This may be used to ensure that proper personal hygiene precautions are being undertaken and that personal protective equipment is adequate and being used.

6. Determination of the Environmental And Health Impact of Contaminants

Each identified chemical contaminant should be considered for its potential impact on humans and the environment.

This is generally done by looking at:

the physicochemical characteristics of the contaminant (e.g species, mobility, reactivity, sorptivity) and soil characteristics such as pH, clay content etc. which may influence bioavailability and mobility,

the toxicity of the contaminant to humans, animals and plants,

the likelihood of exposure of humans, animals or plants to contaminants in soil, air, or water ,

the natural background levels of the area, and

bioaccumulation and biomagnification capacity.

The detail required for such an assessment should be based on the nature and degree of contamination, the size of the site and proximity to sensitive land uses.

For the majority of sites, a complete risk assessment will not be required. However, consideration of the toxicity of the contaminants of interest and the various routes of exposure should form part of the process of assessing the likely impact of contamination.

6.1 Toxicity Assessment

Although a considerable amount of effort is required to correctly identify the target species and the degree of exposure to a toxicant due to the presence of contaminated soil, the evaluation of the hazard is not complete until the potential absorbed dose is compared with a standard or guideline for acceptable intakes of specific chemicals [17]. These are usually derived from studies involving animals.

Where the environment is of concern, there are usually data available to complete such comparisons. There is a range of established environmental quality guidelines for a variety of media from various countries.

Relevant information about toxic substances includes, but is not limited to [18]:

physical and chemical properties,

routes of exposure,

metabolic and pharmacokinetic properties,

structure-activity relationships,

phytotoxicological effects,

human toxicological effects,

acute animal studies,

chronic (long term) animal studies, and

human epidemiological studies.

A regular review of available data is imperative.

Traditional toxicological procedures define a safe level of exposure for humans and a range of terrestrial and aquatic species as some arbitrary fraction of the dose/level at which no effects were observed in a group of animals, usually termed the "no observed effect level" (NOEL) [17].

Where effects other than cancer are concerned, an acceptable daily intake has often been established by dividing the NOEL by a safety factor of 100. The purpose of the safety factor is to account for the possibility that humans may be up to ten times more sensitive than the animal species tested and that a ten fold variation within the human population may exist [17].

The magnitude of this factor may be altered depending on the chemical, pharmacokinetic properties, the severity of the effect and the quality of the available toxicological data [17].

In addition to the use of safety factors, models may be developed to attempt to estimate safe doses. These models try to identify safe doses based on extrapolation of data obtained from animal tests [17].

Contaminants at a site can have diverse short-term and long-term effects. In order to account for these varying effects over time, non-carcinogenic acute and chronic toxicity should be determined as well as carcinogenic chronic effects for both children and adults [17].

Pharmacokinetic factors, when available, can account for differences in absorption and metabolism due to different exposure routes. Without inclusion of pharmacokinetic factors, the same toxicity value used for different exposure routes may not adequately represent the hazard level. For example, toxicity due to ingestion may be different from that due to inhalation.

It is important that both the traditional toxicological methods of assessing the hazard of a particular chemical be used for assessing the toxicity of a given contaminant to humans in conjunction with the results of human epidemiological studies where available.

Toxicity assessment as part of the risk assessment process usually considers:

> the types of adverse health or environmental effects associated with individual and multiple chemical exposures,
>
> the relationship between the magnitude of exposures and adverse effects, and
>
> related uncertainties such as the weight of evidence for a chemical's potential carcinogenicity in humans [6].

The following are disadvantages of the toxicity assessment process [1]:

> there is a limited range of substances for which toxicological data are available and from which to derive acceptable daily intake levels for humans,
>
> there are limited data available on the toxicity of contaminants to plants and animals in Australia,
>
> much of the experimental data are derived from animal studies which rely on standard application factors to estimate corresponding acceptance concentrations for humans,
>
> all toxicity data are derived from studies utilising pure chemicals. The reduction in activity of a toxicant in a soil matrix or synergistic effects of multiple toxicants being present have not as yet been evaluated, and
>
> standards derived for a specific contaminant may be too stringent when considering a site composed of clayey soil or conversely may under estimate the level of harm when considering a sandy site overlying a potable groundwater supply.

The reference texts for toxicological data for human health include:

1. Toxicological Profiles prepared by the Agency for Toxic Substances and Disease Registry (US Public Health Service) in collaboration with US Environment Protection Agency.

2. Environmental Health Criteria' published by the World Health Organisation.

3. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans' published by the International Agency for Research on Cancer, World Health Organisation.

Where information is unavailable in these texts, secondary texts may be consulted including:

> Klaassen CD, Amdur MO, Doull J (eds). Casarett and Doull's Toxicology. The basic science of poisons, 4th ed. New York: Macmillan, 1991.

In many instances, expert toxicological interpretation will be required.

6.2 Exposure Assessment

Exposure can be defined as contact with a chemical or physical agent. The magnitude of the contact is determined by measuring or estimating the amount of an agent available at the exchange boundaries (e.g. lungs, skin) during some specific time [17].

Once the agent is absorbed across these boundaries, the absorbed amount becomes a dose. Exposure assessment is the qualitative or quantitative determination/estimation of the magnitude, frequency, duration and route of exposure and often also describes the resultant absorbed dose [17].

The main receptors of soil contaminants are humans, plants and animals in both aquatic and terrestrial environments and buildings (including service conduits).

For humans, direct pathways include the following [19]:

ingestion of contaminated soil,

inhalation of vapours, gases or mists or contaminated dust,

skin contact,

uptake of contaminants in food (plants, animals) and subsequent ingestion, and

contamination of drinking water, surface or ground water.

Classifications of this type are necessarily simplified and alternative routes of exposure could be determined and may need to be considered. Each exposure needs to be investigated in turn. For instance, with building materials, consideration should be given to the type of contaminant and how it may impact on health and safety of the occupants and the environment as well as its impact on the building itself.

It is important to note that intake is not equivalent to the absorbed dose as absorption from the lungs, gastrointestinal tract and skin may be substantially affected by numerous factors. This difference between intake and absorbed dose is described by the term 'bioavailability' which indicates the overall proportion of a substance that is absorbed into the body [14]. Information on bioavailability is required for assessment of impact. It should be noted that bioavailability in this context is quite different from that for plants.

The following issues are important to consider in exposure assessment from a public health perspective [14]:

1. Children usually receive a higher exposure to soil contaminants per unit body weight than adults [20];

2. Soil ingestion by small children is usually by far the most important exposure route (ibid);

3. One exposure route will normally predominate (ibid);

4. The inhalation route will be important for highly volatile contaminants but, as they rapidly evaporate, they will quickly disappear from a site unless new sources are added (ibid);

5. In large-scale contamination (i.e. regional) more exposure pathways are likely to be involved than in small-scale (very localised) contamination.

6. All exposure pathways must be considered for health risk assessment. Existing Australian data for other exposure pathways (e.g. contaminant levels in food, water and air) need to be appraised to enable comparisons.

For the purpose of exposure assessment, it is recommended that a soil ingestion level for children (1 - 5 years) of 100 mg/day of soil from all routes is used. This incorporates a wide margin of safety (i.e. it is a conservative estimate which overestimates typical exposures). Inhalation and skin routes of exposure are considered relatively insignificant (except for certain volatile contaminants). This figure should be used for preliminary risk assessment but there must be an awareness of the very small number of children who have a soil eating habit and who may ingest more than this level [14].

Table 6.2 details recommended soil intakes for exposure assessment purposes.

TABLE 6.2 SOIL INTAKE ESTIMATES [14]

Age (years)	Soil Intake (mg/day)
0 - 1	negligible
1 - 5	100*
5 - 15	50*
Adult	25*

conservative estimates.

In most situations, the person most exposed to contaminated soil will be a child aged 2 to 3 years. This has been demonstrated by the blood lead levels of children affected by environmental contamination in Port Pirie [21]. The average weight of a 2 and a half year old child for risk estimation purposes should be taken as 13.2 kg [22]. The average weight of an adult should be taken as 70 kg.

Background exposures from food and water will be required for exposure assessment. Food intakes and levels of substances in foods should be derived from the most recent Commonwealth Department of Community Services and Health National Dietary Surveys [23][24][25][26] and the NHMRC Market Basket Survey [27].

The amount of fluid ingested daily is estimated to be 0.03 litres/kg body weight for an adult and 0.05 litres/kg body weight for a child [28].

The amount of air breathed will be highly dependent on the degree of activity and age. An adult involved in physically active work may inhale more than $20m^3$ of air per day. A child aged 2 to 3 years will inhale $4\text{-}5m^3$ of air per day [28][29].

The sorts of factors considered for plants in terms of uptake and contact are species variation, stage of development, nutritional status and availability of the toxic substances to the plant.

Methods of exposure assessment include [17]:

direct measurement of exposure involving direct, real time measurements of the contact of chemical or substance with an organism, biological assessment including measurement of chemical or other indications of changes in body tissues, fluids, growth, reproduction etc., and

predictive exposure assessment which involves estimation of contact intensity, frequency, duration and route by estimation of concentration in media and/or estimation of the habits/activities of individuals or populations that bring them into contact with the chemical or which uses a fate model.

6.3 Risk Assessment

The risk assessment process attempts to estimate the likelihood of an adverse effect occurring in a receiving population due to the presence of contaminants in soil. It is a tool to assist in the decision making process and should not be seen as the only method of determining criteria.

It should be emphasised that the majority of sites will not require risk modelling and guidance values may be sufficient. The potential for contaminant migration and the likelihood of human exposure should, none the less should be considered in the decision making process.

The risk assessment process assumes:

knowledge of the risk level for a human population or for flora and fauna associated with specific doses of chemicals, and

knowledge of the dose which would result from direct or indirect exposure to soil containing a given concentration of chemicals.

The process involves four stages [29]:

data collection and evaluation of the chemical condition of the site;
toxicity assessment of contaminants;
exposure assessment for the population on or near the site;
risk characterisation. (Some texts use `risk assessment' only to refer to risk characterisation)

Data collection entails the acquisition and analysis of information about chemicals on a site that may affect human health and which will be the focus for the particular risk assessment [29].

Since risk assessment involves extensive use of animal toxicological data, the results of such an analysis need to be interpreted with care.

Perception of risk is an extremely important factor and may alter the types of criteria and degree of clean-up required for a given site. For instance, although the risk associated with driving, or being driven in a motor car is comparatively high, it is widely accepted [8]. On the other hand, while the use of chemicals is readily accepted, chemical residues in the environment are not accepted [8]. The benefits of the motor car are obvious, however, the benefits of chemicals are not widely appreciated.

The concept of voluntary and involuntary exposure needs to be considered when assessing how risks are rated.

In assessing risk, therefore, it is important to consider the following [8]:

the nature and degree of the potential health hazard to humans or other species,

the techniques used for estimating the risk at low doses of substances that are believed to have genotoxic or carcinogenic properties,

the notion of 'acceptable risk',

the assumptions underlying human (or other species') exposure to compounds in air, drinking water, soil food, as well as exposures from other routes, the assumptions underlying human (or other species') exposure to compounds in air, drinking water, soil food, as well as exposures from other routes,

the importance given to organ specific and behavioural toxicity,

the ways in which uncertainty factors are applied to guard against either excessively pessimistic or optimistic projections,

potential problems associated with extrapolation from animal studies to different species and humans,

application of results from studies using pure chemicals to situations involving complexed chemicals in the soil or environment, and

possible synergistic or antagonistic effects of multiple chemical exposure, compared with results form single chemical studies.

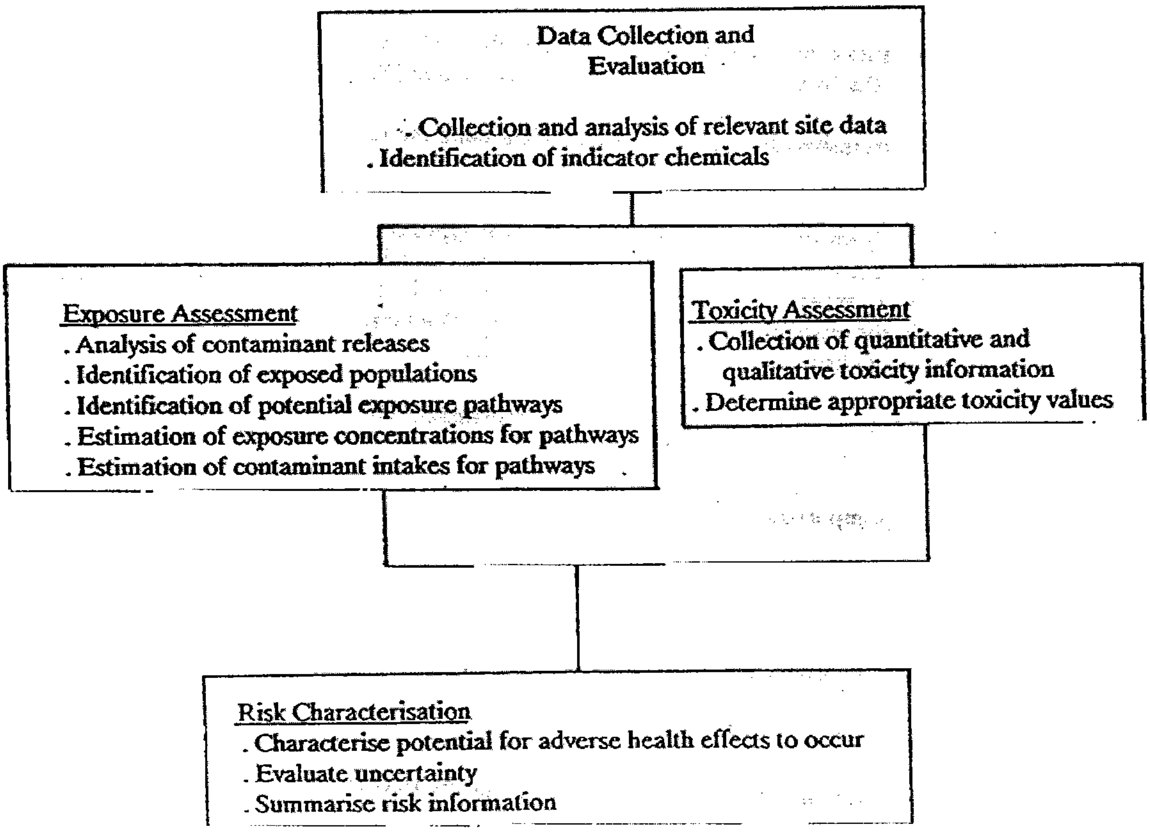
It is important to stress that all risks are relative.

Risk estimation is a process of prediction and is therefore, unlikely to be precise. For some risks of very low probability, uncertainties by factors of ten are commonplace [8]. However, making even a rough estimate may be better than making no estimate at all. This will depend on the accuracy and precision of the model and the information on which it is based.

Figure 6.1 represents the process of risk assessment and indicates the information required to assess risk.

Figure 6.1

Risk Assessment Model



adapted from USEPA, 1989 [29].

7. DEVELOPMENT OF SITE SPECIFIC CRITERIA

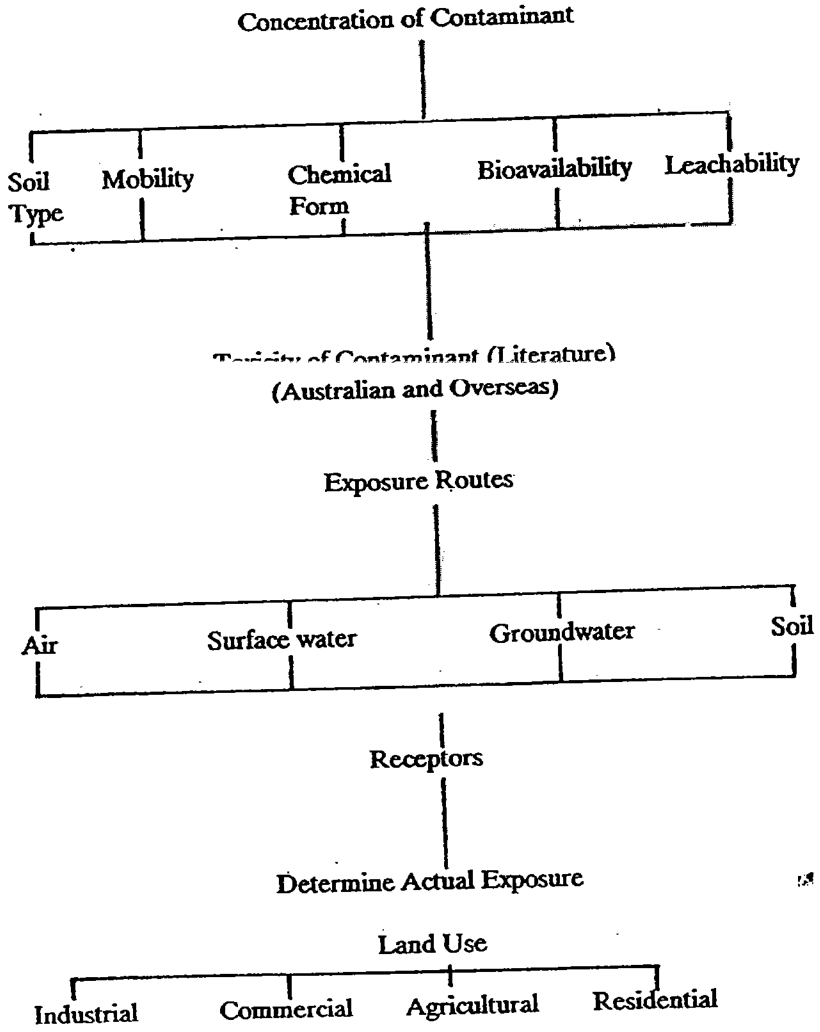
One of the most problematic phases of a contaminated site management/clean-up program is determining "how clean is clean".

While it is recognised that every site is different to some degree, in many cases, guideline levels will be sufficient to guide clean-up action, obviating the need to develop costly site specific criteria.

The setting of acceptance criteria or soil quality criteria for contaminated soil is difficult since site specific factors have an important influence on what concentration of contaminant might pose a hazard as previously discussed. Figure 7.1 depicts the various factors requiring consideration in the development of such criteria.

Figure 7.1

Development of Site Specific Criteria Considerations



Initially soil guidelines should be used to indicate whether a problem may exist.

Generally these numbers act as starting points in the investigation process.

Other considerations for determining clean-up guidelines are:

> the persistence, toxicity and mobility of hazardous substances,
>
> the propensity of substances to bioaccumulate,
>
> short and long term potential for adverse health effects from human exposure,
>
> synergistic effects of contaminants,
>
> the potential threat to human health and the environment associated with excavation, transportation and disposal and treatment or containment,
>
> the pre-exisiting levels of the contaminants of concern or the evaluation of background levels,
>
> relationship of the site to underground water resources and the extent of usage of these resources downstream of the site,
>
> physical features of the site,
>
> neighbouring land uses,
>
> the consequence of not reaching an agreement by all parties, for example, increases in health and environmental risks due to prolonged delays in implementing clean-up work,
>
> capacity of existing clean-up technology to achieve clean-up criteria, and
>
> resource availability to implement the clean-up plan based on appropriate criteria.

The development of site specific criteria relies on assessing the potential for movement of a contaminant from the soil matrix in which it is contained to humans and the surrounding environment [1]. Such an assessment can be done using modelling techniques.

In most instances, a combination of site monitoring and analytical data and environmental modelling results will be required to estimate chemical concentrations at points where potential exposure to a contaminant may occur [30]. The potential effect of that exposure is then determined. However, either type of information has considerable drawbacks if used in isolation. Taken together, site monitoring data and environmental modelling offer the best approach to estimating whether a particular chemical will pose a problem in a range of different situations.

Site monitoring data have several shortcomings, specifically for public health evaluation and especially for the assessment of long term effects. These are [30]:

> data may be representative of current and/or past trends, but do not give an indication of possible future conditions, and
>
> data are representative of their sampling locations, which may or may not be relevant to a risk assessment. Because chemical concentrations are spatially variable and data may not cover off-site human exposure points, monitoring data must usually be supplemented by modelling to allow an adequate assessment of public health effects.

Models may also be used to assist in the evaluation of acceptance criteria for contaminants in soil. Various models are currently available to simulate contaminant migration, to estimate likely exposure of specified populations, or to estimate the incremental risk associated with a particular environmental concentration of a contaminant.

A difficulty with the use of most models is the large amount of input data required, which are time consuming to generate. In addition, the results obtained from such models often involve subjective evaluation which can become a focus for controversy. Nevertheless, modelling can be useful in the identification of key environmental parameters or in ranking management options, even when lack of site specific data prevents reliable quantitative estimation of the modelled parameter.

Therefore, where necessary, site specific criteria can be generated or confirmed using models.

This is particularly pertinent for large-scale or sensitive site assessments where all factors of a specific site as well as pollutant characteristics are taken into account.

At sites where the potential impact on health or the environment is great, a rigorous assessment of risk and toxicity should be made in order to develop appropriate criteria.

Health Risk Assessment and Site Specificity [14]

Much of the process of health risk assessment will be the same as the process of environmental risk assessment. Health and environmental risk assessments should be complementary in planning the management of a site, as human health and the state of the environment are inseparable.

Some types of contamination will persist, presenting continuing risks to health and the environment. If the contaminants are environmentally mobile, the risks may be more complex and widespread. Health risk assessment must take a long-term perspective in the appraisal of a site.

A site-specific approach to risk assessment will often prove to be the best approach to ensuring the most appropriate management strategy is adopted, i.e. one based on its particular characteristics, history and proposed land use. However, as noted above, there will be many instances where the costs involved in generating site specific criteria will not be warranted and the most effective management strategy will be to adopt figures established in these national guidelines.

The process of health risk assessment set out in this document is intended to fulfil the following objectives:

1. To establish baseline risks and whether site remediation or other action is necessary on health grounds alone;
2. To determine a tolerable level of contaminants that can remain in situ with adequate protection of public health (assuming no unacceptable environmental impacts are involved);
3. To enable comparison of potential health impacts of various remediation techniques;
4. To provide a consistent method for appraising and recording public health risks at sites.

In most situations, a numerical estimate of risk is not feasible because of limitations in toxicological and exposure data. A semi-quantitative estimate is possible and is the preferred approach if sufficient data are available. The uncertainties at each stage of the risk assessment process should be stated and taken into account in planning the management of a site. It should be recognised that risk assessment is based on probabilities rather than absolutes and this should be reflected in decision-making.

The process of risk assessment should enable consistent decisions to be made by the specialists undertaking the process. Expert professional judgement is an integral part of the process. Site specific risk assessments should not lead to significant variations in the management of similar sites.

The following section outlines the various considerations which may be used to develop public health based criteria for a specific site and provides examples of calculations.

7.1 Development of Public Health Based Investigation Guidelines

Soil Criteria [14]

There are two prerequisites for comparison of soil test results with defined soil criteria. The first prerequisite is a uniform soil sampling methodology which provides an appropriate amount of information about the distribution and level of contaminants on a piece of land. The second is a uniform approach to data analysis to enable a meaningful interpretation of sampling results.

Final assessment of the degree of contamination should take into account any uncertainties arising from the sampling and analytical methodologies.

Site-specific evaluation of the available data and proposed land use will be required to determine whether single, occasional or typical values in excess of the investigation level will prompt the further investigation.

Levels slightly in excess of the investigation levels do not imply unacceptability or levels likely to pose a significant health risk (See Figure 7.1).

Once the further investigation(s) is (are) completed, a site-specific health risk assessment will be required to determine the presence of health risk and, if present, its nature and degree.

Overt health effects would not be expected to occur until contamination is present at levels well in excess of response levels.

The nature of the response required to protect human health will depend on the assessment of risk associated with a given level of contamination. Where the risk is assessed as being relatively low, the response may simply involve informing occupants of the site so that they are aware of hazards arising from, for example, pica behaviour in children. In cases where there is a relatively high risk, complex soil treatment may be required.

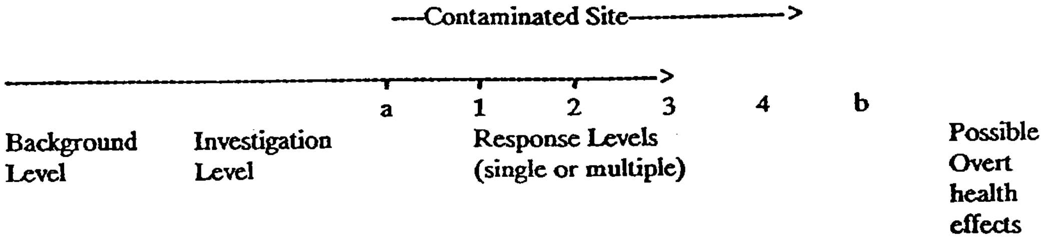
More specifically, the nature of the response will be modulated by factors including:

1. Land use e.g. residential, agricultural/horticultural, recreational or commercial/industrial.
2. Potential child occupancy.
3. Potential environmental effects including leaching into groundwater.
4. Single or multiple contaminants.
5. Depth of contamination.
6. Level and distribution of contamination.
7. Bioavailability of the contaminant.
8. Toxicological assessment of the contaminant(s) e.g. toxicokinetics, carcinogenicity, acute and chronic toxicity.
9. Physico-chemical properties of the contaminant(s).
10. State of the site surface e.g. paved, grassed or exposed.
11. Potential exposure pathways.
12. Uncertainties with the sampling methodology and toxicological assessment.

Where a site specific assessment is being carried out with a view to defining response levels, consideration should also be given to the possible risks associated with mixtures of contaminants, since in some circumstances such risks may necessitate a more or less extensive response than would be required to deal with a single contaminant.

A uniform approach should be applied in undertaking such assessments.

Figure 7.1: The relationship of soil criteria levels for substance, X.



Proposed Land Use:

1. Residential
2. Horticultural
3. Recreational
4. Commercial/Industrial

Environmental Factors:

a. Groundwater protection
b. Plant protection

(Figure not to scale)

Different response levels may be required to protect people in different exposure situations (e.g. residential, recreational, or commercial/industrial land uses).

When dealing with substances which are considered to have possible effects at very low doses (e.g. some carcinogens), a level of acceptable (or tolerable) risk will need to be established to derive the investigation and response levels.

Investigation Levels

Investigation levels provide a trigger to assist in judging whether a detailed investigation of a site is necessary.

When assessing the environmental/health significance levels of contamination above investigation level, the following factors should be considered: potential ground water contamination; land use; the history and nature of the contamination; the local background levels; and the size of the site. Exposure pathways will be more diverse for a larger site.

Separate health and environmental investigation levels have been established to take into account the different sensitivities of humans and other components of the environment. Site specific decisions need to be made to determine whether health or environmental investigation levels (or both) should be applied.

Determination of Investigation Levels [14]

Investigation levels will be determined taking into account:

1. The bioavailability of a substance. The bioavailability should be assumed to be 100% if specific information is not available;
2. The Provisional Tolerable Weekly Intake (PTWI) or Acceptable Daily Intake (ADI) as determined by the World Health Organisation/Food and Agricultural Organisation [31,32];
3. Other potential sources of the substances that comprise a proportion of the PTWI or ADI (e.g. background levels of the substance in soil, food, water and air and the amount of exposure through these routes).

The total exposure to a substance 'X' can be represented by the equation:

Total exposure to substance X = Background exposures (e.g. from food and water)

\+

Exposures from contaminated soil by ingestion, inhalation and skin absorption.

background exposures + amount of substance absorbed from soil.

BE + (Sing x Cing x Bing + Sinh x Cinh x Binh + Sskin x Cskin x Bskin)

BE + SEsoil

BE = Background Exposures (e.g. from food and water).
Sing = Amount of soil ingested.
Sinh = Amount of soil/dust inhaled and retained.
Sskin = Amount of soil on skin.
Cing = Concentration of substance in soil ingested.
Cinh = Concentration of substance in soil/dust inhaled and retained.
Cskin = Concentration of substance in soil on skin.
Bing = Bioavailability, i.e. percentage absorbed, of substance when ingested.
Binh = Bioavailability of substance when inhaled.
Bskin = Bioavailability of substance when on skin.
SEsoil = Substance exposure from soil.

Different levels of bioavailability will occur between soil ingested, inhaled and on the skin.

The investigation level guideline will be set by the NHMRC. In setting an investigation level guideline, total exposure to substance X should not exceed the ADI or PTWI, i.e. BE + SEsoil < ADI or PTWI. In some cases the proposed level will equate to total exposure below the ADI or PTWI. Developing such levels will include consideration of factors such as: the nature of the threshold effects, the completeness of toxicological data, exposure variability within a population and the relative sizes of BE and SEsoil.

When the Provisional Tolerable Weekly Intake/Acceptable Daily Intake is used for establishing investigation levels, the basis for the level set should be sought from appropriate World Health Organisation documents (e.g. WHO 1987[31], WHO 1989[32]). This information should include target organ(s) and effect(s); bioavailability; and safety factors accounting for variations in human sensitivity and extrapolations from animal studies.

It should be recognised that "short-term exposure to levels exceeding the PTWI is not a cause for concern provided the individual's intake averaged over longer periods of time does not exceed the level set" ([32]p9).

If no PTWI or ADI is available a tolerable level of risk will need to be determined (e.g. for carcinogens) and used for calculations.

Examples of how investigation levels have been determined are provided in the documentation for lead, arsenic, cadmium and benzo(a)pyrene in the publication 'The Health Risk Assessment and Management of Contaminated Sites' (South Australian Health Commission 1991)[11].

It is considered that this way of determining investigation levels would protect the entire population with few exceptions. People who may have unusual sensitivity to contaminants may need to be considered in a site assessment.

Proposed Investigation Level Guidelines

Investigation levels based on health considerations have been established using a risk assessment approach for lead, cadmium, arsenic and benzo(a)pyrene, which are frequently occurring and toxicologically important contaminants.

Further investigation level guidelines will be proposed as sufficient toxicological information becomes available and the present guidelines may also be subject to change as more information becomes available.

The levels should not be interpreted rigidly. A site with a median lead level of 290 will not be significantly different to a site with a median lead level of 310. The proposed land use, distribution of contaminants and the frequency distribution of elevated levels will all be very important in interpreting the results for a site.

Table 1. - Proposed Health Investigation Level Guidelines

Substance	Health Level mg/kg
Lead	300
Arsenic(Total)	100
Cadmium	20
Benzo(a)pyrene	1
(PAHs)[a]	(20)

[a] The level for PAHs is based on 5% of the PAHs being present as benzo(a)pyrene.

These investigation level guidelines relate to specific sampling, extraction and analytical techniques. As such, they should not be compared with other tables of values which do not use similar techniques. The Health Investigation Levels can be used only with reference to the Protocol for the Health Risk Assessment and Management of Contaminated Sites (Oct 1991) [14].

7.2 Development of Environment Investigation Guidelines

Unless specified otherwise, investigation guidelines will be based on threshold levels for:

phytotoxicity; and

uptake of contaminants which may result in impairment of plant growth or reproduction or unacceptable residue levels.

Investigation guidelines will be developed to take account of various "worst case scenarios". This requires guidelines which are framed to protect the most sensitive receptor likely to be placed at risk and to reflect a level at which there is no observed effect on that receptor.

Where there is a likelihood of run off of contaminants into surface waters, the estimated concentration can be compared with water quality standards (where available) and an acceptable level can be calculated based on estimated transport rates.

Where contamination may result in unacceptable residue levels in animals or plants, the residue levels can be compared with standards and soil guidelines can be developed by working back to estimated translocation rates.

Obviously, where a site specific assessment reveals the presence of a more sensitive receptor than any of those used to derive the values employed in these guidelines, investigation levels should be varied to reflect this.

In contrast to investigation guidelines, clean-up guidelines will be based on levels at which there is a demonstrated hazard to the environment for the majority of receptors. However, where site specific factors reveal a particularly sensitive receptor, then a clean-up guideline should reflect this.

The soil quality guidelines included in this section are interim guidelines only, intended for use until values are derived from more extensive evaluation of the behaviour and toxicity of contaminants in soil relevant to Australian and New Zealand conditions. The methodology for establishing guidelines for longer term use is currently being established and a review of overseas criteria, Australian and New Zealand conditions and the existing toxicology database is being undertaken.

To date, background levels have been established for a range of chemicals in Australian soils. The values shown in Table 2 as "Background" reflect the range of levels ascertained from a small number of soil investigations performed to date, as well as information gained from CSIRO [33,34,35]. As more information becomes available, these interim levels will be adjusted accordingly. The levels derived from these investigations should be taken as being generally representative of background concentrations.

In this context, "background" is defined as the level of contaminants typically found in the vicinity of a locality, but away from a specific activity or site. In the great majority of cases the levels shown will not represent "pristine" concentrations. The soil data employed to derive the values in Table 2 come from both rural and urban environments. It is imperative therefore, that any site assessment incorporates an evaluation of background concentrations of contaminants.

It is likely that with experience and time, different quality guidelines will be set for different soil types and that separate background levels may be specified for urban and rural settings. The Dutch are now differentiating soils on the basis of type and, more particularly, clay and organic material content [36]. This approach may also be useful for Australian and New Zealand soils.

In time, it is also conceivable that the concentration of bioavailable metal, for example, will be listed rather than total metal. This factor has more relevance to the actual impact of contaminated soil on the environment.

The background (A) levels listed in Table 2 should be viewed as indicative values, where soils with contaminant concentrations in the range shown will generally be acceptable and no further investigation of the site will need to be undertaken. However, it must be noted that natural levels of a range of chemicals vary tremendously [34] and this must be taken into account when applying these values and when interpreting results from different soil types.

A number of interim investigation threshold (B) levels have also been listed based on environmental concerns. Generally where these levels are exceeded, an investigation should take place, but it should be stressed that the values are intended as a guide and site specific factors need to be taken into account in reaching a decision on the nature and intensity of any investigations which may be required.

These levels have been set utilising overseas information and represent conservative values which should protect the environment. In general, the numbers presented will protect the most sensitive receptor for these chemicals, as determined from overseas research and Australian data (where available). Of the receptors considered, the most sensitive and hence most stringent guidelines appear to be for protection of plant life. The rationale for setting these guidelines has been set out in section 7.

It is anticipated that in time, a response level may be developed which will represent an action level where some form of clean-up should occur or management strategy be developed, irrespective of site specific factors. Action may range from simply covering and grassing an area to applying complicated remedial techniques. This level will be based on toxicological considerations.

In summary, it must be stressed that the values listed in Table 2 should be seen as guidance values only and site specific factors will influence their use. Professional judgement must be exercised in this regard. All values are expressed as mg/kg (ppm) of dry soil unless otherwise specified. The levels refer to the total concentration of a chemical in soil when tested in accordance with approved analytical methods.

It must also be stressed that the need for clean-up action will depend on the actual levels present, together with various site specific factors.

For those chemicals not listed or for which no investigation level is listed, it is suggested that the Dutch B level be utilised as an investigation threshold for environmental concerns. This level is conservative and has been set principally for the protection of groundwater.

Table 2

Environmental Soil Quality Guidelines
(mg/kg)

	Background A	Environmental Investigation B
Heavy Metals		
Antimony Sb	4 -44	
Arsenic As	0.2 - 30(a)	20(b)
Barium Ba	20 - 200	
Cadmium Cd	0.04 - 2	
Chromium Cr	0.5 - 110*	
Cobalt Co	2 - 170	
Copper Cu	1 - 190**	
Lead Pb	<2 - 200	
Manganese Mn	4 - 12,600	500(b)
Mercury Hg	0.001 - 0.1	
MolybdenumMo	<1 - 20	
Nickel Ni	2 - 400	
Tin Sn	1 - 25	50
Zinc Zn	2 - 180	200
Mineral Pollutants		
Boron B	1 - 75	
Phenolic Compounds		
Phenols	0.03 - 0.5	
Monocyclic Aromatic Hydrocarbons (MAH)		
Benzene	0.05 - 1	1(d)
Toluene	0.1 - 1	
Polyclic Aromatic Hydrocarbons (PAH)		
PAH (total)	0.95 - 5	

Chlorinated Hydrocarbons		
PCB (total)	0.02 - 0.1	1
Pesticides		
Aldrin	<0.001 - <0.05	
Dieldrin	<0.005 - <0.05	0.2
DDT	<0.001 - 0.97	
Other Chemicals		
Sulphate	35 - 1000	2000(d)
pH	6 - 8	

	[33]	excludes known orchard soils
*	[33]	possible underestimation
(a)	[37]	
(b)	[38]	
(c)	[38,3]	
(d)	[39,3]	

When samples of groundwater, surface water and air are relevant to a particular site the following guidelines or their counterparts in other states should be consulted. For example:

Groundwater:	EPAV Draft Groundwater Policy 1992.
Surface water:	Australia Water Quality Criteria 1983 Guidelines for Use of Reclaimed Water in Australia 1987.
Drinking water:	Guidelines for Drinking Water Quality in Australia , NHMRC/AWRC 1987.
Air:	EPAV Air SEPP 1988; or National Air Quality Goals, NHMRC 1985

8. MANAGEMENT AND CLEAN-UP

The ultimate goal of site clean-up is to select a socially acceptable and cost effective management strategy which mitigates threats to and provides protection for public health, welfare and the environment as well as allowing flexibility in the future use of the land.

In site clean-up, it is important to establish the feasibility of restoring a site to productive use without causing harm to public health or the environment. In some cases, action may need to be taken even when a productive end use cannot be achieved (for example, where human health or environmental concerns necessitate clean-up).

In general, the response to dealing with contaminated soil in Australia has been to dig it up and take it to a secure landfill.

In many cases this may not be an appropriate approach for the following reasons:

potential hazard associated with the transport of contaminated soil,
limited available secure landfilling space in Australia, and
the approach does not take advantage of available contamination mitigation techniques.

The options for clean-up of contaminated sites are discussed in Section 3.1.8 on page 5 of this document.

As previously indicated, a thorough investigation of the conditions of the site and the extent and type of contaminants must be completed before any decision about clean-up can be made. Once the extent of contamination has been ascertained, options for clean-up must be canvassed and a clean up strategy determined. At present, containment or removal are the most frequently applied strategies, but in-situ treatment is an option which should be assessed.

Although the effectiveness of in-situ treatment technologies is highly dependent on the nature of the contaminants and the soil environment [40] and many forms are still developmental, such techniques are becoming much more important as the problems of excavating and transporting contaminated soil to a secure landfill become pronounced.

In-situ chemical detoxification techniques include [33]:

injection of neutralising agents for acid or caustic conditions,

addition of oxidizing agents to destroy organics,

addition of agents that promote photodegradation or other natural biodegradation processes,

extraction of contaminants,

immobilisation, and

volatilisation of contaminants.

Another option is long term storage for large volumes of contaminated materials. This usually involves specially designed landfill cells from which the material can be eventually recovered for treatment.

The cost of cleaning up contaminated sites is traditionally high. The range of clean-up technologies becoming available in Australia is likely to increase once industry is aware of the potential magnitude of the contaminated sites problem. This should have a beneficial impact on the cost of clean-up.

At present, a few alternative technologies are being trialled. To date, however, no sites have been cleaned up using them.

8.1 Health Risk Management [14]

As the risk from a site will depend on the toxicity of the contaminants and the exposure levels, risk can be reduced or removed by altering toxicity or exposure or both. Toxicity may be altered by chemical reaction (e.g. degradation of PAHs; soluble $BaCl_2$ + gypsum --> insoluble $BaSO_4$) but this approach has only limited application. Management of a site will usually rely on the feasibility of some alteration of exposure. If exposure becomes zero or negligible, so too will risk. Where a clean soil barrier is created by soil treatment or soil replacement, it is recommended that the depth of the soil barrier be determined by site specific analysis.

In determining the depth of a barrier the following factors should be considered:

1. 0.5 metre depth of clean soil is unlikely to be penetrated with normal gardening activities.
2. The nutritional roots of vegetable are unlikely to extend below 0.5 metres. In Australia's dry climate the root exploration depth will tend to be governed by the depth of water penetration from domestic watering which rarely penetrates deeper than 30cm. Larger fruit trees with more extensive root systems appear to have limited uptake of most contaminants.
3. Deep trenching for the laying of sewage mains is unlikely to extend beyond 1-2 metres.

Site-specific assessment will enable determination of the level of protection afforded by a particular thickness of clean soil over contaminated soil. In most situations, 0.5m of soil gives a high level of protection provided appropriate safeguards are established to deal with situations in which the barrier may be breached (e.g. by ditch digging).

It must be recognised that if the clean soil barrier is breached, there may be specific requirements for the management of the soil and for personal protection if exposure is likely to be hazardous. There may also be requirements for future residents to be informed and for constraints to be applied to trenching activities (e.g. occupational health and safety requirements, or specialised soil management procedures may be required).

Barriers may still leave larger shrubs and trees exposed to phytotoxic effects if their roots penetrate the contaminated zone.

Well maintained grass will cause a substantial reduction in exposure to contaminants in surface soil and may therefore provide an effective barrier in particular situations. The reduction of exposure from well-maintained grass is at least 80%.

9. VALIDATION AND FUTURE MONITORING

Once a clean-up technique or management strategy has been chosen and used, validation of the clean-up must take place to ensure the measures taken were adequate for the protection of local amenity, public health and the environment.

Monitoring data for validation purposes should be compared with the pre-determined clean-up criteria or site specific generated criteria as determined by the process outlined.

Future monitoring may be required, particularly at sites employing in-situ treatment technologies, dilution, or containment options.