# 8. DEVELOPMENT OF SOIL QUALITY CRITERIA FOR CONTAMINATED SITE REMEDIATION

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## 8.1 INTRODUCTION

There can be little argument that contaminants are now a ubiquitous presence in our environment. Though large-scale efforts to deal with contaminant issues have traditionally focused on water and air media, it has become increasingly apparent that contaminated soil is also placing human and environmental health at risk, not only in Canada but world-wide ( Foote 1989; Gaudet *et al.* 1992). In response to the urgency of the problem, large-scale national programs such as the U.S. EPA Superfund and Canada's National Contaminated Site Remediation Program (NCSRP) have been created to promote the cleanup of high priority contaminated sites. Implementation of such programs presents unique regulatory and scientific challenges in the development of an effective and scientifically-defensible infrastructure to guide the assessment and remediation of contaminated soils. This challenge is accentuated not only by the short time-frame over which these programs have been developed (Sheppard et al. 1992) and the broad range of contaminants and sources that must be dealt with (**Table 1**), but by a still evolving understanding of the effects of contaminants in the complex soil environment and on the myriad of uses it sustains.

**Table 1:** Profile of contaminated site problems in Canada

| | Primary Concern |
|---|---|
| **Treatment/Disposal of Wastes** | |
| Municipal sanitary landfills (dumps) | methane, toxic organics and inorganics |
| Industrial waste landfills (dumps) | toxic organics and inorganics |
| Mine tailings | heavy metals, radionuclides, acids |
| **Industrial/Commercial Activities** | |
| Chemical and petrochemical facilities | toxic organics, inorganics, hydrocarbons |
| Metallurgical Facilities | heavy metals |
| Foundries/steel mills | heavy metals, hydrocarbons |
| Wood preservation facilities | chorophenolics, metals |
| Coal gasification facilities | polyaromatic hydrocarbons (PAH) |
| Scrap yards/ shipyards/ rail yards | metals, solvents, hydrocarbons, asbestos, PCBs |
| Storage sites | pesticides, PCBs, PAH (tires), heavy metals (batteries) |

While technologies for the remediation of contaminated soils are undergoing a rapid evolution and now range from innovative bioremediation techniques to vitrification, solidification, thermal desorption and vapour extraction, (e.g., AWMA 1990), remediation will not have long-term effectiveness in restoring and sustaining functional soil systems and associated uses without the concomitant development of measurable endpoints of acceptable soil quality or health that can serve as remediation goals. Because it is rarely feasible to clean up to pristine levels, these endpoints (referred to as soil remediation or soil quality guidelines/criteria) are usually based on a systematic consideration of the existing and potential risks of soil contaminants to the environment and human health. In this paper we outline the major issues, challenges and directions in the development of soil quality criteria for the remediation of contaminated sites in Canada.

## 8.2 THE NATIONAL CONTAMINATED SITES REMEDIATION PROGRAM

In recognition of the potential magnitude of the contaminated site problem in Canada, and the lack of a consistent national approach to deal with it, the Canadian Council of Ministers of the Environment (CCME) initiated the National Contaminated Sites Remediation Program in October 1989. The Program was established to:

1. promote a coordinated, nationally consistent approach to the identification, assessment and remediation (cleanup) of contaminated sites in Canada which have the potential to impact on human health or the environment;

2. provide the necessary government funds to remediate high risk "orphan" sites for which the responsible party cannot be identified or is unable to carry out the work; and

3. stimulate the development and demonstration of new and innovative remediation technologies.

To ensure national consistency and effective implementation, the NCSRP is based on the following general principles:

1. jurisdictions will have the necessary laws, regulations and programs in place

to ensure remediation of high-risk contaminated sites where the responsible party can be held accountable, consistent with the *polluter pays principle*; and

2. common assessment and remediation criteria/guidelines will be used in the management of contaminated sites.

Over the first five years of the Program, \$250 million has been committed to the remediation of high risk orphan sites based on a federal/provincial cost-sharing formula. An additional \$50 million has been committed to promote the development and demonstration of innovative remedial technologies in Canada.

### 8.2.1 A National Framework for Contaminated Site Assessment and Remediation

In order that site assessment and remediation could be initiated as soon as possible, the development of common assessment and remediation tools was identified as an urgent priority in the NCSRP. Based on the results of two multi-stakeholder workshops held in the first year of the Program (Environment Canada 1990 a,b), a framework for contaminated site assessment and remediation was developed (**Figure 1**). This framework encompasses: **(1)** a National Classification System (CCME 1992) for screening contaminated sites in terms of the existing or potential risk to human and environmental health; **(2)** Canadian Environmental Quality Criteria for Contaminated Sites - assessment and remediation criteria that serve as benchmarks in evaluating the nature and extent of contamination at a site and in setting remediation goals that are protective of human health and the environment (CCME 1991a); and, **(3)** nationally consistent approaches to the development of site-specific remediation objectives.

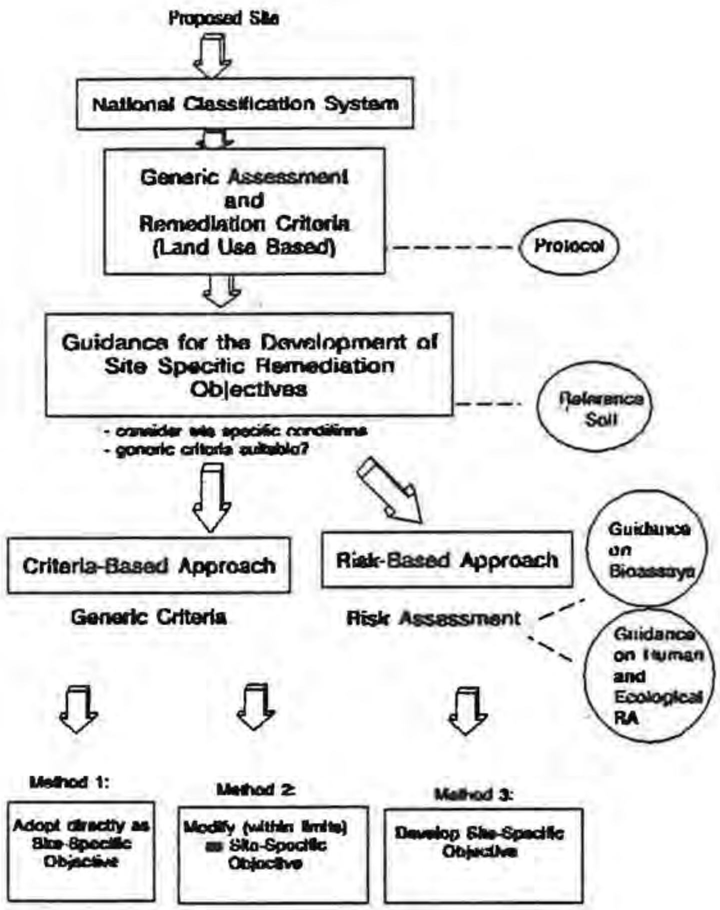


**Figure 1: National Framework for Contaminated Site Assessment and Remediation in Canada**

Accordingly, the CCME Subcommittee on Classification of Contaminated Sites and the CCME Subcommittee on Environmental Quality Criteria for Contaminated Sites, representing Provincial Ministries of the Environment, Environment Canada and Health and Welfare Canada, were formed to guide the development of these common assessment and remediation tools.

## 8.3 ENVIRONMENTAL QUALITY CRITERIA FOR CONTAMINATED SITES

### 8.3.1 Generic or Site-Specific: Resolving the Conflict

Though there is currently a myriad of approaches to the development of remediation goals for soil quality (Sheppard *et al.* 1992), most approaches fall generally into two categories: absolute (generic) and relative (site-specific). Absolute approaches are based on the development and application of soil quality criteria that recommend levels of contaminants in soil considered to be generally protective of human health and/or the environment across a broad range of potential sites and conditions. Absolute approaches provide simple, consistent and objective benchmarks for evaluating and remediating contaminated soil which can be easily understood, communicated, and incorporated into legislative or other regulatory processes. However, this approach has been criticized because it does not consider site-specific circumstances, potentially leading to situations where clean-up levels (and therefore ensuing costs) are established beyond that required to protect human health and the environment. Currently there is no consistent approach to the derivation of generic criteria and they are variously based on weight-of-evidence, defined exposure scenarios for different land uses or professional judgement. Not only internationally but even within Canada, existing soil quality criteria vary widely both in terms of their underlying scientific rationale and their application to contaminated site remediation (**Table 2**).

A relative approach considers a diverse group of methods for determining a site-specific clean-up level by weighing the many factors relevant to a particular site (Sheppard et al. 1992). The establishment of site-specific clean-up levels can be based on human health or ecological risk assessment, as well as other factors including cost-benefit and social issues. Typically this approach requires a detailed, and often

**Table 2: Historical overview of the development and application of generic soil quality criteria.**

| Jurisdiction<br><br>Program Initiation | Criteria/Guidelines | Application | Scientific Basis and Factors Considered | Reference |
|---|---|---|---|---|
| US EPA<br><br>1977 | Multimedia Exposure Goals (MEGs) for soil, water and air | assessing environmental conditions | - based on limited information<br>- simple equations convert existing federal guidelines or toxicity information into MEGs | Cleland and Kingsbury 1977 |
| United Kingdom<br><br>late 1970s | U.K. Trigger Concentrations for Contaminants in Soil<br><br>1) threshold trigger<br>2) action trigger | - below **threshold** trigger: soil is "uncontaminated" / no restrictions;<br>- greater than **threshold** trigger: investigation/ professional judgement required to decide action needed<br>- greater than or equal to **action** trigger: remedial action required | - professional judgement<br>- factors include human health, phytotoxic effects, hazards such as explosion, background levels | United Kingdom, 1990 |
| Netherlands Ministry of Housing Planning and Environment<br><br>1983 | "ABC" Soil Quality Guidelines | A - the boundary between contaminated and uncontaminated land;<br>B - potential for harmful effects and need for investigation;<br>C - contamination at a level that presents an intolerable risk to man and the environment and remedial action/investigation required. | - professional judgement<br>- factors include background levels, analytical detection limits, toxicity, solubility, accumulation<br>- standard approach has been developed and values currently being revised based on soil characteristics (clay fraction and organic content), ecotoxicological and human health effects data | Moen 1988 |

| Jurisdiction<br><br>Program Initiation | Criteria/Guidelines | Application | Scientific Basis and Factors Considered | Reference |
| --- | --- | --- | --- | --- |
| Ontario Ministry of the Environment<br><br>1984 | MOE Soil Clean-Up Guidelines<br><br>- based on two categories of land use (agricultural/ residential and parkland; commercial/ industrial) and two categories of soil texture (medium/fine and coarse) | - threshold values for remedial action.<br>- proponent may elect to develop site-specific guidelines | - based primarily on considerations of phytotoxicity, human health and health of grazing animals | Ontario MOE 1989 |
| Ministere de l'Environnement du Quebec (MENVIQ)<br><br>1988 | "ABC" Soil Guidelines | - between A and B, soil is considered "slightly contaminated" and action may be required for sensitive land uses<br>- between B and C soil is "contaminated" and investigation/ remedial action or certain land use restrictions may be required<br>- above C it may be necessary to take prompt remedial action/ restrict all land uses. | - professional judgment in adoption and modification of existing criteria from other agencies<br>- factors include background levels in Quebec soils, toxicity, carcinogenicity | MENVIQ 1988 |
| New Jersey Department of Environmental Protection (DEP)<br><br>mid-1980s | Interim Soil Action Levels (ISALS) | - identify the presence of contamination and need for investigation.<br>- site-specific clean-up objectives are developed on a case-by-case basis | - professional judgement<br>- factors include background levels, potential human health effects and protection of groundwater quality.<br>- methods for including direct exposure to soil (e.g., ingestion) are under development | New Jersey Dept. of Environmental Protection 1990 |

| Jurisdiction<br><br>Program Initiation | Criteria/Guidelines | Application | Scientific Basis and Factors Considered | Reference |
|---|---|---|---|---|
| Alberta Environment<br><br>1990 | Alberta Tier 1 Criteria for Contaminated Soil Assessment and Remediation | - represent upper limits of a "healthy soil system".<br>- option for Tier 2 (site-specific) criteria development | - professional judgement<br>- factors include consistency with other guidelines, animal health, plant health, background conditions | Alberta Environment 1990 |
| British Columbia Ministry of the Environment<br><br>1989 | Criteria for Managing Contaminated Sites<br><br>(ABC) | - dependent on the land use, the criteria will serve as investigation criteria (above which site investigation is needed) and remediation criteria (above which remedial action is required) | - values adopted from other agencies based on consideration of potential human exposure associated with levels of acceptable lifetime cancer risk, background levels, existing standards | B.C. MOE 1989 |
| Canada<br><br>National Contaminated Sites Remediation Program<br><br>1989 | Environmental Quality Criteria for Contaminated Sites<br><br>• assessment criteria<br><br>• remediation criteria for agricultural; residential/parkland; and commercial/industrial land uses | - assessment criteria represent contaminant levels at which no action is required<br>- remediation criteria are considered to be generally protective of specified uses of soil and serve as benchmarks for evaluating the need for remedial action/ investigation, and as the basis for setting site-specific remediation (clean-up) objectives | - interim criteria based on a critical evaluation of existing values from other agencies<br>- values will be updated based on standard protocols incorporating human health effects /exposure pathways for specified land uses, ecotoxicological effects (plant, invertebrate, microbial), bioaccumulation (livestock , wildlife), background levels, analytical detection limits, soil condition (organic content, pH, clay) | CCME 1991a |

expensive characterization of the site and use of computer models to estimate the fate of contaminants (Sheppard et al. 1992). However, the relative approach is criticized because it does not provide a consistent basis for decision making, especially during early stages of site assessment and investigation. This may lead to a great differences in the level of protection afforded to the environment (including human health).

Given the fundamental difference between these two approaches, it is hardly surprising that there has been a great deal of controversy over whether the absolute or relative approach is best suited to setting clean-up levels for contaminated sites. Though generic and relative approaches are often viewed as competing, each with inherent strength and weaknesses (**Table 3**), the potential for application of both site-specific and generic approaches in assessing and managing contaminated soils is now emerging as an important marriage of options (Gaudet et al. 1992). In the NCSRP, a combination of both approaches is used in order to target clean-up efforts as efficiently and effectively as possible.

### 8.3.2 NCSRP's Tiered Framework

In recognition of the need for both generic and site-specific approaches in a comprehensive framework for contaminated site assessment and remediation, the NCSRP has adopted a tiered framework that combines the strengths of each. Generic national criteria (Canadian Environmental Quality Criteria for Contaminated Sites) are intended to provide a consistent scientific basis for evaluating contamination with respect to potential effects on human health and the environment, and in the development of remediation strategies. However, it is recognized that generic criteria cannot be applied directly to setting remediation endpoints for contaminated sites without due consideration of site-specific factors (CCME 1991a).

**Table 3: Advantages of the Absolute versus Relative Approach to Establishing Clean-up Levels**

| | GENERIC | SITE-SPECIFIC |
|---|---|---|
| ADVANTAGES | - simple and objective | - uses site information |
| | - facilitates broad-based soil protection programs | - can give estimate of risk level |
| | - inexpensive | - allows the management of risk to only the 'necessary level' |
| | - consistent | |
| DISADVANTAGES | - site-specific circumstances not considered | - may lead to inconsistent decision making |
| | - criteria lacking for many substances | - change in site or receptors may invalidate analysis |
| | - implies level of knowledge that may not exist | - many assumptions required |
| | | - expensive |

For this reason, emphasis has also been placed on the development of a consistent national approach to setting site-specific remediation objectives for contaminated sites. Dependent on circumstances, such a site-specific approach may include direct adoption or adaptation of existing generic criteria incorporating site-specific factors such as background levels of contaminants and potential land use. Alternatively, ecological/human-health risk assessment may be conducted to provide a detailed evaluation of existing and potential risk to the human and ecological receptors in consideration of factors such as contaminant transport and fate in the various media, and land use patterns at a particular site.

Currently, site-specific guidance is in the early developmental stages. The focus of the current paper is on the development of generic (absolute) soil quality criteria for Canada.

### 8.3.3 Interim Environmental Quality Criteria

The CCME Subcommittee has released a set of "Interim Canadian Environmental Quality Criteria for Contaminated Sites", which are numerical limits for contaminants intended to protect, maintain or improve current and future uses(s) of soil and water at contaminated sites. The interim criteria include both assessment criteria (approximate background concentrations or analytical detection limits for contaminants that when exceeded indicate that investigative actions should be considered), and remediation criteria for soil that are considered generally protective of specified land uses (agricultural, residential/parkland and commercial /industrial). The interim remediation criteria also include the Canadian Water Quality Guidelines (CCREM 1987) and the Guidelines for Canadian Drinking Water Quality (HWC 1989) for uses of water likely of concern at contaminated sites.

To meet the urgent needs of the NCSRP, these criteria were adopted directly from values currently in use in Canada based on a critical evaluation of their underlying rationale (CCME 1991a; Gaudet et al. 1992). Several characteristics considered desirable in a set of national criteria were used as the basis for this evaluation (**Table 4**). Based on an initial review of twenty-one jurisdictions from across Canada, the U.S., The Netherlands, United Kingdom, Australia, West Germany and France, ten agencies were selected as potential candidates for NCSRP criteria. **Table 5** summarizes the extent to which these ten agencies met the desired characteristics. Because the interim soil quality criteria generally lack adequate supporting rationale, and did not fulfil all of the characteristics expected in a set of national criteria, it was decided that the interim values would be updated on an ongoing basis to reflect emerging information on the effects of contaminants to environmental and human health. Though the CCME advocates the protection of all media of concern at contaminated sites, the initial emphasis of the Program is on the soil media due to the critical need to build a consistent scientific basis for the development of soil quality criteria not only in Canada, but world-wide (Sheppard et al. 1992). Accordingly, the CCME Subcommittee on Environmental

**Table 4. Desired Characteristics of NCSRP Environmental Quality Criteria for Contaminated Sites**

- be applicable to a wide range of sites, site conditions, and contaminants
- consider all environmental media or compartments
- consider various exposure pathways and associated risks
- adapt to missing data
- consider present and future land use(s)
- place equal emphasis on the environment and human health
- consider aesthetics and phytotoxicity
- consider background or ambient concentrations of contaminants
- consider analytical detection limits

Quality Criteria for Contaminated Sites was formed to guide a research and development program to produce scientifically defensible effects-based soil quality criteria for use in contaminated site assessment and remediation that place equal emphasis on protection of human health and the environment. Over the first five years of the program, emphasis will be placed on evaluation and recommendation of generic effects-based soil remediation criteria for protection of human health and the environment in Canada.

**Table 5: Evaluation of Criteria from Primary Agencies for Use in the NCSRP According to NCSRP Desirable Characteristics**

| AGENCY | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Characteristic | Alta. | B.C. | Calf. | CCME (PAH) | CCME (PCB) | Neth. | N.J. | Ont. | Que. | U.K. |
| Widely Applied | L | Y | Y | N | N | Y | L | L | Y | L |
| All Media | N | L | L | L | Y | L | N | N | L | N |
| All Routes of Exposure | N | L | Y | N | Y | N | N | N | N | L |
| Various Receptors | N | L | Y | N | Y | N | L | N | L | L |
| Missing Data | L | L | L | N | N | N | N | N | L | N |
| Various Land Uses | L | Y | Y | L | Y | Y | L | Y | Y | Y |
| Neighbours | N | N | N | N | N | N | N | N | N | N |
| Environmental Health = Human Health | L | L | Y | N | N | ? | ? | L | ? | L |
| Aesthetics | ? | ? | N | N | N | ? | N | L | ? | L |
| Phytotoxicity | N | ? | N | N | N | N | N | Y | N | Y |
| Background | Y | Y | N | L | L | Y | Y | Y | Y | Y |
| Detection Limits | Y | Y | N | N | N | Y | N | N | Y | N |

Notes: Y = Yes N = No L = Limited ? = Uncertain

## 8.4 DEVELOPMENT OF EFFECTS-BASED SOIL QUALITY CRITERIA

### 8.4.1 Soil: A Multifunctional Resource

The development of effects-based soil quality criteria for the assessment and remediation of contaminated sites is a complex task that must begin from the fundamental re-evaluation of what is meant by soil quality. A unique challenge in the development of generic criteria is in determining the combination of factors that should be considered in the development of a generic soil quality criterion for a specified land use that will not lead to adverse human-health or ecological effects. Protection and restoration of "soil quality", and the development of soil quality criteria, requires a fundamental shift in the way we view soil - from an inert physical medium that can be measured in terms of stoniness or organic content, to a dynamic and multifunctional ecological system critical to sustaining the terrestrial environment and associated uses. Moen (1988) provides a definition of a soil of good quality as one which "must pose no harm to any normal use by humans, plants or animals; not adversely affect natural cycles or functions, and not contaminate other components of the ecosystem". Though this definition does not provide any positive quantitative estimate or measures for soil of "good" quality, it does set the stage for considering soil as a multifunctional resource.

There are significant challenges in the development of soil quality criteria. Soil is a complex heterogeneous medium that consists of variable amounts of mineral material, organic matter, water and air, and is capable of supporting organisms, including plants, bacteria, fungi, protozoans, invertebrates and other animal life. The derivation of effects-based soil quality criteria must provide a sufficient level of protection such that soil returned (remediated) to the criteria level will be a healthy functioning ecosystem capable of sustaining the current and likely future uses of the site by ecological receptors and humans, including the protection of groundwater. Not only must the physical and biotic integrity of the soil medium be protected, but consideration must be given to all supporting and associated uses. In addition, criteria must not be protective only of immediate concerns, but ensure long-term sustainability of soil quality in its broader context.

### 8.4.2 Wheels Within Wheels

Development of soil quality criteria that are protective of human and environmental health must be based not only on direct estimates of the toxicity of a contaminant, but on a comprehensive understanding of the fate and effects of contaminants in the soil environment and the various routes of exposure to human and ecological receptors. Though the scientific information required is diverse and transcends a number of disciplines, the scope and nature of the problem is greatly clarified when viewed in the context of three key areas: **(1)** contaminant fate and behaviour; **(2)** exposure assessment; and, **(3)** biological effects (toxicity) assessment (**Figure 2**). Essentially, it is the interaction between these three areas that serves as the basis for estimating the "risk" of soil contaminants to the environment and human health and as the basis for soil quality criteria development. It is, however, an extreme oversimplification to suggest that the task is not a complicated one. Within these broadly overlapping areas, there exists an infinite number of possible receptors, exposure pathways and toxicity endpoints to be considered, all of which may be modified by existing soil conditions. For example, soil supports a number of different uses, which in turn will affect the potential receptors and exposure pathways that are of concern. These exposure pathways can vary from direct contact or ingestion of soil to uptake through the food chains. Soil characteristics such as pH, clay and percent organic content will further affect not only the availability of contaminants to receptors, but this effect may vary widely depending on the particular contaminant under consideration.

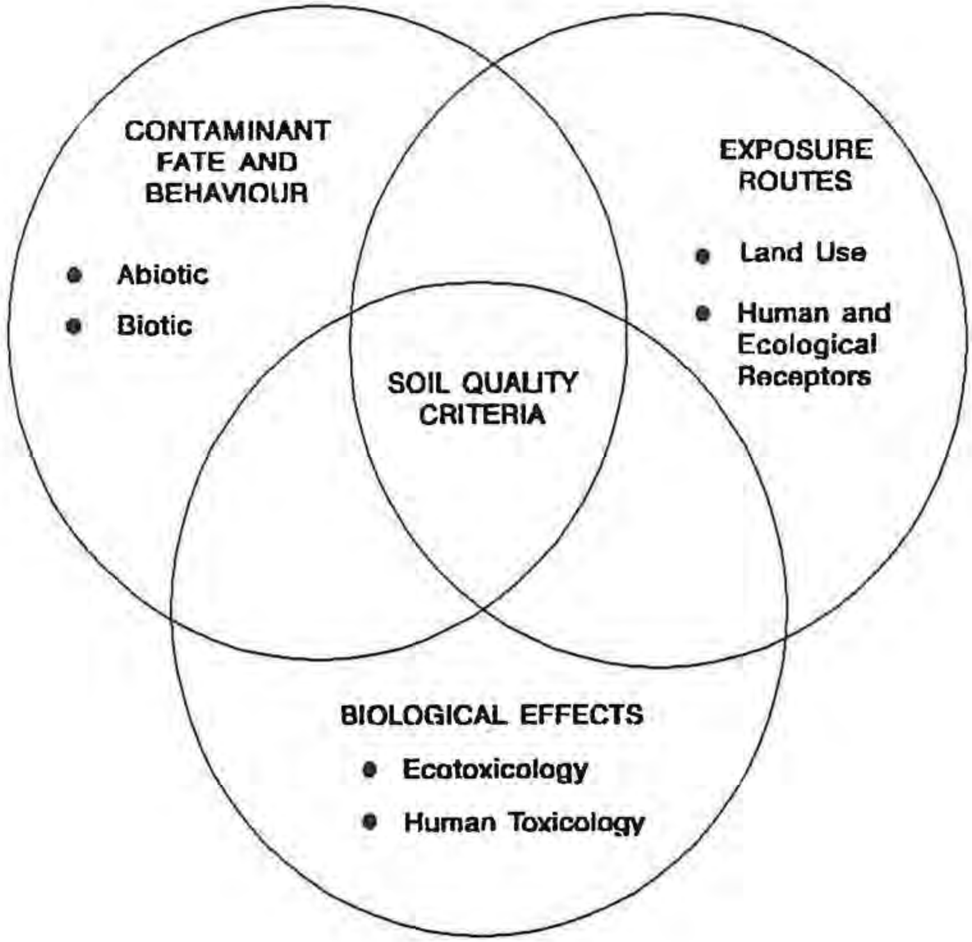


**Figure 2: Information Required for the Development of Ecological Effects-Based and Human Health-Based Soil Quality Criteria**

Though many of these questions may be answered at the site-specific level through a detailed analysis and evaluation of contaminant effects relevant to the particular conditions, receptors and exposure pathways at a site, the derived criterion is relevant only to that site and cannot be generalized to other sites or conditions. Generic criteria, on the other hand, are intended to provide conservative estimates of potential ecological and human-health effects that are applicable to a broad range of sites and conditions. Accordingly, they are usually based on standardized toxicological endpoints for representative or sensitive receptors (e.g., Denneman and van Gestel 1990) and/or generic exposure scenarios (e.g., Linders et al. 1992). The incorporation of underlying conservative assumptions (such as protection of the most sensitive species) ensure that recommended levels are generally protective. At the same time, it is recognized that not only soil characteristics such as clay content, but also existing or expected land use at a site can greatly affect the receptors, exposure pathways and ultimate effects that may be of concern in setting remediation goals for contaminated sites. Although generic criteria, by definition, do not consider site-specific conditions, a degree of specificity can be gained through consideration of receptors and exposure pathways, including uptake through the food chain, that are relevant to major land uses and/or soil types (e.g., B.C. MOE 1989; CCME 1991a; Ontario MOE 1990). Given the broad range of soil conditions in Canada and the influence of master variables (pH, % clay, % organic matter) the concept of a reference soil is emerging as an important component in the development of generic criteria (e.g., Lexmond et al. 1986). By specifying a reference soil condition for Canada, guidance can be provided to users of the generic criteria on the range of soil conditions (as specified by the master variables) within which the generic criteria apply. If soil conditions at a particular site fall outside of the reference soil condition, then the generic criteria may not be directly applicable to the site. The development of a site-specific remediation objectives will therefore be required. Currently, research in being initiated to define a range of reference soils for Canada to aid in the development and application of the generic criteria.

**Table 6** shows some of the potential receptors, exposure pathways and toxicological endpoints that may be of concern with regard to key land uses in Canada. Despite broad overlap, significant differences exist in the approach and scientific data required for development of generic criteria for human and ecological receptors. These differences reflect not only differences in sensitivity and exposure to soil contaminants between human and non-human receptors, but also differences in concepts of "acceptable risk", and the availability of toxicological and exposure data.

The current challenge is to define realistic, scientifically defensible approaches to the development of national generic criteria that not only take into account critical differences in receptors, sensitivity, and direct and indirect exposure to soil contaminants with respect to land uses, but that, at the same time, address a level of generality that will afford environmental protection across a broad range of sites and conditions. The following sections address the key considerations in the development of human health-based and ecological effects-based soil quality criteria.

Despite comparability in basic principles, soil quality criteria for human and ecological receptors are derived using substantially different methodologies and are addressed separately in this chapter. This difference in approach is due not only to differences in the state of knowledge and the availability of toxicity and exposure data for each of these groups, but also to the fact that only one receptor (and sensitive life stages) is considered when dealing with the relationship between soil quality and human health while "ecological-effects-based" criteria must consider the relationship between soil quality and virtually all other system attributes. At this time, an evaluation of the effects of soil contaminants on sensitive and/or key receptors provides a reliable and consistent basis for derivation of such ecological effects-based soil quality criteria.

However, in the evolution of this field, increasing emphasis must be placed on developing integrated indicators and measures of soil quality which consider important interrelationships and processes critical to the sustainability of the soil "ecosystem".

**Table 6: Examples of land uses, receptors, toxicological endpoints and exposure routes that should be considered in the derivation of generic soil quality criteria.**

| EXISTING OR POTENTIAL LAND USE | POTENTIAL RECEPTORS OF CONCERN | CONTAMINANT CHARACTER-ISTICS | TOXICO-LOGICAL ENDPOINTS | POTENTIAL EXPOSURE PATHWAYS | INFLUENC-ING SOIL CHARACT-ERISTICS |
|---|---|---|---|---|---|
| AGRICULTURE<br><br>RESIDENTIAL/ PARKLAND<br><br>COMMERCIAL/ INDUSTRIAL | soil invertebrates<br><br>plants/crops<br><br>microbial activity<br><br>livestock<br><br>wildlife<br><br>human (child/ adult) | bioaccumulation potential<br><br>volatility<br><br>solubility<br><br>persistence | survival<br><br>reproduction<br><br>growth<br><br>behaviour<br><br>carcinogenicity | direct soil contact/ dermal absorption<br><br>direct ingestion of soil<br><br>ingestion of food/produce grown on soil<br><br>inhalation of soil/dust particles<br><br>inhalation of vapour (volatiles)<br><br>drinking water | organic matter<br><br>pH<br><br>clay content<br><br>redox potential<br><br>moisture content |

## 8.5 DEVELOPMENT OF HUMAN HEALTH-BASED SOIL QUALITY CRITERIA

This section of the this chapter will describe the important aspects of developing soil criteria for the protection of human health. Of prime concern in developing soil remediation criteria is considering the possibility of adverse human health effects from exposure to a particular contaminant. The process of setting site-specific standards is usually done by performing a baseline risk assessment and comparing the results with a risk assessment at a contaminated site. Setting generic criteria uses risk assessment to quantify the exposure and the toxicology for defined reference conditions for an "average Canadian".

### 8.5.1 Human Health Risk Assessment

A risk assessment consists of four main areas: hazard identification, toxicological assessment, exposure assessment, and risk characterization (**Figure 3**). Each of these areas provides an important part of the risk associated with a specific contaminant.

8.5.1.1 *Hazard Identification.* Under hazard identification, general information about a contaminant, such as physical and chemical properties, persistence, bioaccumulation potential, and toxicity, is gathered. This step helps identify candidate chemical parameters which require additional information provided by subsequent steps in the risk assessment. It provides general qualitative information on the toxicology and persistence of a contaminant.

8.5.1.2 *Toxicological Assessment.* The toxicological assessment provides the "acceptable" level of exposure, either as an allowable daily intake (ADI) for a non-carcinogen or the virtually safe dose (VSD) at a specific risk level for carcinogens. This information is derived from the dose-response information about a specific chemical. It is the quantitative investigation of the response by an organism to a specific amount (or dose) of a contaminant.

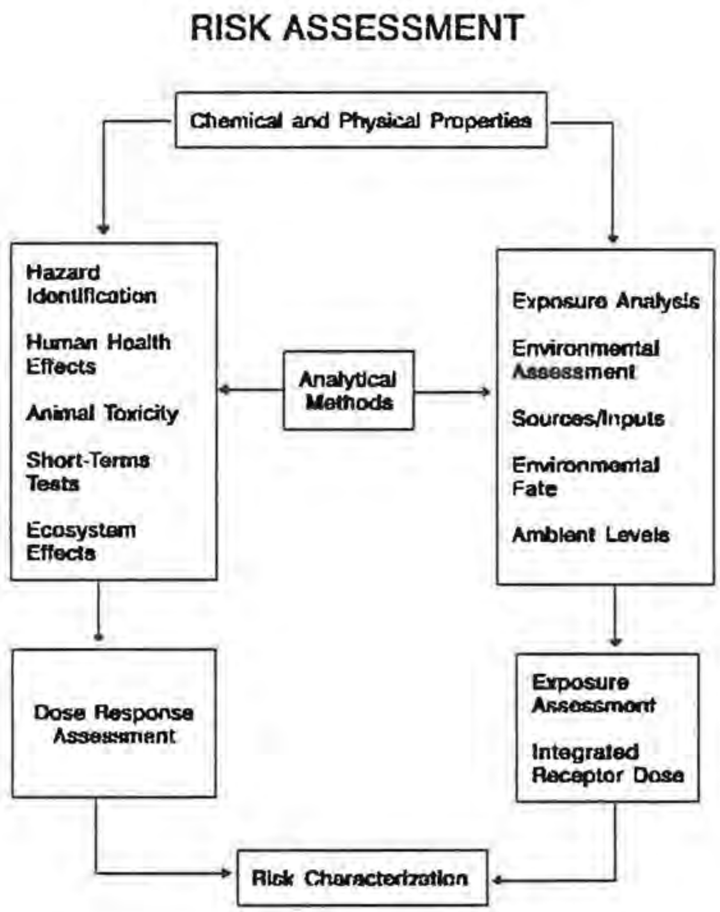


**Figure 3: Generalized framework for human health risk assessment**

The best measurement of the dose would be the amount of a chemical reaching the target organ. However most often this information is not available. The risk assessor relies on contaminant concentrations in air, soil or water, and makes some assumptions about their uptake or absorption into the body and their distribution within the body to the target organ. In addition, for many contaminants there can be metabolic activation or deactivation of a specific chemical leading to either enhanced or reduced toxicity, respectively. Target organs for a contaminant can vary according to the specific uptake route. For example, inhalation of a particular contaminant could lead to lung cancer, whereas its ingestion could lead to different effects or even no effect.

The risk assessor prefers to use long term or chronic studies to assess the risk from a contaminant. Often such studies are not available and data from acute toxicological studies are used. In the latter studies, animals are exposed to very high doses of a contaminant or toxic substance so as to produce a particular adverse effect, such as death or development of tumours in a short period of time. Use of acute studies results in another difficulty, extrapolating the effects of a concentrated time to the effects of a lifetime exposure to a very low contaminant exposure.

There is a fundamental difference in the dose-response curves for carcinogens and non-carcinogens. With non-carcinogens, it is expected that there is some threshold concentration or amount of exposure below which an organism will show no adverse effects (no-observable adverse effect level, NOAEL). For a carcinogen, theoretically, there is no threshold below which there is no risk of developing cancer.

For non-carcinogens, which have a threshold effects level, toxicologists often apply a safety factor of ten to the results of acute toxicological studies. Other safety factors attempt to account for extrapolation of results between species (e.g., from rat toxicity to human toxicity) and for protection of sensitive individuals within a population. Therefore, the allowable daily intake (ADI) is the product of toxicological data and the application of safety factors.

For carcinogens, a number of extrapolation models, such as the linear multi-stage and the "model-free" or one-point model have been developed to estimate the incremental cancer risk at low contaminant concentrations. Each model has its own strengths and weaknesses. As different models can result in different estimates, this area of high to low dose extrapolation continues to be an important research area.

For carcinogens, the slope factor is derived from the extrapolated dose-response curve. This slope provides the potency factor or the risk-specific dose. The intake of a contaminant over a lifetime is estimated to provide the excess incidence or the incremental risk of developing cancer over a lifetime resulting from exposure to a particular concentration of a carcinogen (i.e., risk per unit dose). Depending on the specific extrapolation model used, this slope factor may represent an upper bound estimate of the risk.

8.5.1.3 *Exposure Assessment.* The third area of a risk assessment is the exposure assessment. This investigation provides information on whether an organism will come in contact with a contaminant, and if so, it will quantify the duration and the concentration into an "exposure estimate". No matter how toxic a chemical is, there is no risk if there is no exposure to an organism.

**Figure 4** schematically diagrams a multi-media exposure pattern. It starts at the bottom of the diagram with the main exposure media, soil, air, water, and food (consumer goods have not been included). The arrows represent different exposure pathways that contribute to the overall total exposure. It becomes readily apparent how complicated an exposure assessment is. In addition, there are other factors to be considered in any exposure assessment. **Table 7** lists some of these. The contaminant concentration in different media must be measured, as well as the exposure frequency and duration. The latter factors often vary with age, and can be difficult to measure. While criteria are generic in nature, it is important in an exposure assessment to identify subpopulations whose exposure to a contaminant is not well represented by the general case.

Factors such as amount of soil ingested by children, the amount of soil in contact with the skin, and the rate of dermal absorption from soil in contact with the skin are important areas which require research to provide more accurate estimates of exposure.

It is also important to identify the specific toxic endpoints associated with particular routes of exposure. For example, exposure to a contaminant through inhalation could lead to lung cancer, while exposure to the same contaminant through ingestion of food or water could be associated with a very different toxic endpoint, such as liver or kidney toxicity. For other contaminants, the toxic endpoint is the same, whatever the exposure pathway.

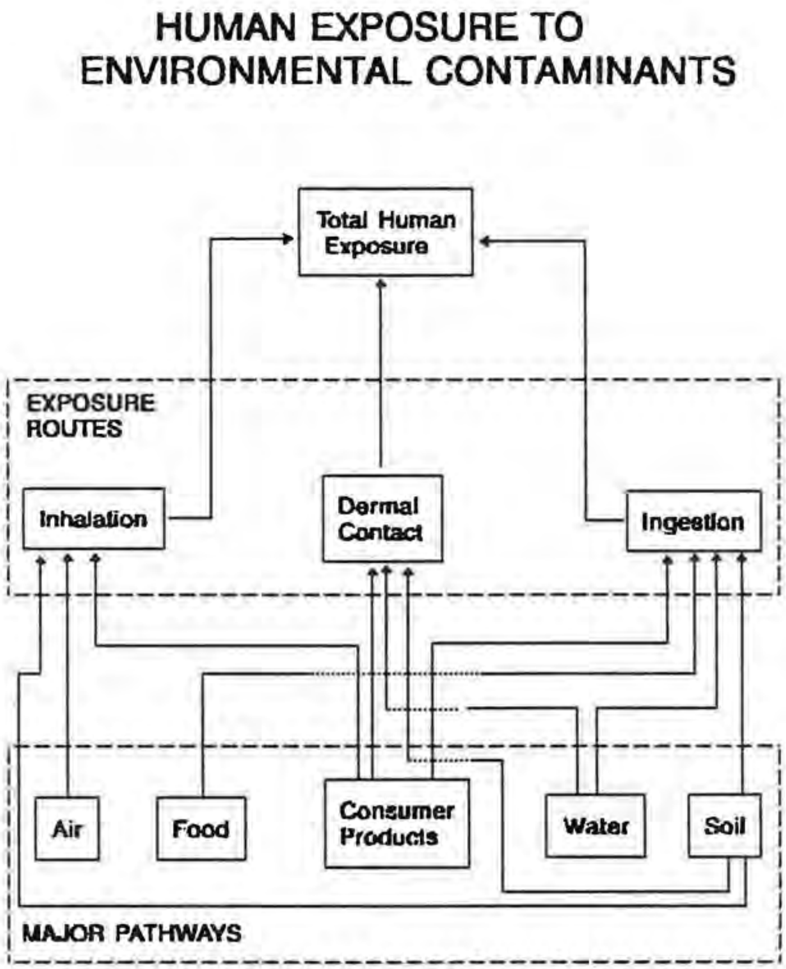


**Figure 4: Significant Pathways of Human Exposure to Contaminated Soil.**

8.5.1.4 *Risk Characterization.* This step in the risk assessment process integrates the information gathered in the exposure and toxicological assessments. It characterizes or describes the probability of occurrence of adverse health effects. By comparing the risks of adverse effects for baseline conditions to those at a contaminated site, one is able to quantify the added or incremental risk at contaminated sites. An important piece of information necessary for completing the risk characterization step is called the apportionment of the ADI. This step divides the allowable daily intake of a contaminant among the exposure media (air, soil, water, and food).

**Table 7: Factors to Consider in Human Health Exposure Assessment**

**Exposure Pathways**

air: inhalation (indoors and outdoors), during showering/bathing

soil: ingestion of soil/dust, contaminated food, dermal uptake

water: ingestion, dermal uptake during showering/bathing

**Other Factors to Consider**

| | |
|---|---|
| Exposure Frequency | Exposure Duration |
| Exposure Concentration (contact rate) | Estimates of Chemical Uptake (bioavailability) |
| Subpopulations | |

This multi-media approach is important so that no one medium is allocated 100% of the allowable exposure to a contaminant, resulting in a population that is overexposed to a contaminant from that medium. This is a management decision which involves other considerations, such as scientific (exposure and toxicology), socio-economic factors, and technological factors. The ease and cost of pollution controls must be also examined. It may be that it is impossible or very expensive to reduce the exposure through one route. A management decision could be to apportion a larger amount of the ADI to one medium, with a resulting smaller proportion to another medium, which is more feasible and less expensive to control. In deciding the apportionment, it is important to study the pattern of exposure which is found in the multi-media exposure assessment. Using this as starting point, the other socio-economic and technological factors can modify the apportionment factors. This is an area which has been a stumbling block in guideline development. In most cases, criteria are developed for a single medium and there is no appropriate regulatory body to make this decision.

### 8.5.2 Soil Guideline Development

8.5.2.1 *Multi-Media Approach.* Many contaminants have become so ubiquitous that people are exposed to a specific chemical from many different sources and through different pathways. The multi-media approach to setting health-based guidelines was developed to deal with this situation. People are exposed to chemicals through different media - air, water, soil, food and consumer products. Since this occurs, the regulator must take into account exposures from other media when setting a standard for a single medium.

The multi-media approach requires a comprehensive review and evaluation of all scientific data, but has a number of benefits. First, by considering human exposure from all media, the regulator can ensure that the total exposure of a person to a contaminant does not exceed the maximum allowable intake. Second, this is an integrated approach which promotes consistency in the handling of a particular contaminant. Thus, risk estimates based decisions concerning different exposure pathway are consistent and provide the framework for more consistent management. Third, criteria for that contaminant in other media can be readily developed. Thus there needs to be no duplication of effort, resulting in considerable savings in time and resources for standard setting jurisdictions.

8.5.2.2 *Identification of Significant Exposure Pathways.* In developing soil remediation criteria to protect human health, one must ensure that exposure to a remediated soil concentration will not result in adverse human health effects. The process of setting soil criteria is one of working backward from an allowable daily intake (ADI) of contaminant through the soil exposure pathways to a soil concentration. There are a number of important steps in this process.

**Figure 4** provides a schematic diagram of soil exposure pathways. These pathways can be the result of a direct exposure to soil or an indirect exposure to soil, i.e., a cross-media transfer from soil to another medium, such as water, air, or food. Direct exposure pathways include ingestion of soil/dust, dermal uptake of contaminants in contact with the skin, and inhalation of soil particles into the lungs. Indirect exposure pathways include ingestion of food contaminated soil and inhalation of contaminated vapours resulting from the volatilization of contaminants from soil into air. An extremely important indirect exposure is the ingestion of groundwater contaminated by the leaching of contaminants from soil into groundwater.

The physical and chemical properties of a contaminant will determine its environmental fate. These properties will also focus the possible important exposure pathways to humans. For example, the dermal exposure pathway will be primarily important for contaminants which are lipophilic and can readily cross the epidermal layer of the skin. Also, only contaminants with a high vapour pressure are likely to volatilize from soil to inhaled air.

### 8.5.3 Calculation of Soil Criterion

Using the identified direct pathways from the first step above, the following general equation can be used to generate an approximation of the soil criterion.

soil quality criterion =

$$\frac{\text{allowable exposure or intake of contaminant from soil pathway}}{\text{estimated exposure from direct soil pathways}}$$

One can now see that the soil guideline is backcalculated from the "safe" or allowable intake from soil exposure divided by the estimated exposure from soil pathways.

### 8.5.4 Modification of Criteria for Indirect Exposure Pathways

As mentioned previously, cross media transfer of a chemical from contaminated soil to another medium, such as water, air, or food, can result in indirect exposure to contaminants from soil. Each of these cross-media transfers can be modelled using a number of assumptions about the exposure scenario. For example, the uptake of soil contaminants by plants and the subsequent ingestion of backyard garden produce by people can be estimated from a given soil contaminant concentration. Similar estimates can be made of the migration of vapours from soil into the basement of a house and the exposure via inhalation of contaminated gases. The information from these models can then be compared to allowable daily intakes for these media to ensure that safe levels are not exceeded. If levels resulting from cross-media transfer are too high, then soil criteria can be modified. Another iteration of comparison with the modelled values can then be performed.

## 8.6 DEVELOPMENT OF ECOLOGICAL EFFECTS-BASED CRITERIA

To date, little work has been done on the development of approaches that incorporate ecotoxicological information in the derivation of soil quality criteria. Currently, only The Netherlands has proposed a defined mathematical approach to developing soil quality guidelines (criteria) based on ecotoxicological evidence (Dennemen and van Gestel 1990; van Strallen and Dennemen 1989). However, one common element that is apparent in current or proposed procedures for deriving environmental quality guidelines or criteria for three media (i.e., soil, sediment and water), is the use of a reference toxicological endpoint (e.g. NOEC/NOEL, $EC_{50}/LC_{50}$) with an applied safety (uncertainty) factor (e.g., CCME, 1991a,b; Stephan et al. 1985; U.S. EPA/OTS 1984; van Straalen and Dennemen 1989). This approach is generally paralleled in the development of ecological effects-based soil quality criteria for contaminated site remediation as discussed in the following sections.

### 8.6.1 Ecological Basis for Developing Soil Quality Criteria

An important distinction between soil and underlying regolith material is the presence of an active biota. Most soil biological activity is heterotrophic and depends on energy from organic matter added by plants. The combined activities of the soil biota serve to decompose plant residues and recycle organically-bound nutrients back to growing plants. As such, the vitality of soils is critically linked to an unencumbered plant-decomposer system. A principal property of soil quality criteria for contaminants must be that they ensure the proper functioning of the soil-plant system within the expectations of a given land use. Specifically, our expectations are to sustain biotic values, including the ability to extract commodities, such as crops. In addition, sustainability of the soil-plant system relies on the functioning of the complete suite of soil biota, as well as, other important physical and chemical properties of the soil. Ultimately, protection of desired plant species can only be accomplished through protection of soil organisms. However, controversy exists over how to best accomplish protection of the soil ecosystem.

Ecosystems have been described as hierarchical entities with populations nested in communities, and organisms nested in populations etc. Stressors such as a contaminant may affect an ecosystem at one or more levels of organization. Because of the complexity of biotic interactions in soil, linking these levels has proven difficult - even in the absence of contaminants. Pastorak and Sampson (1992) proposed that, for examining effects due to contaminants, an ideal scale of descriptive resolution is the functional web. Progress has been made in functional web analysis of soils, but knowledge is still well short of what is needed for development of generic soil quality criteria.

Classical toxicological approaches to criteria or guideline development have generally relied on data from single species exposed to individual contaminants (e.g., Greene et al. 1989; ISO 1991; OECD 1984). To engender confidence that a single species can provide protection to whole ecosystems, considerable effort has gone into identification of sensitive species. Cairns (1992) argues that the "most sensitive species approach" is hampered by: (1) our ability to culture specific organisms for testing; (2) variable sensitivity to a range of contaminants within a species; and, (3) poor predictive power in scaling contaminant effects from the species level to the community or ecosystem.

Notwithstanding these criticisms, no clear alternative has emerged to displace the most sensitive species approach. Developmental work is underway on binary or ternary species bioassay but reliable systems for soil species are not yet available (Keddy et al. 1992). Community-level measures of biological activity in soils are commonly performed (e.g. decomposition, respiration, nutrient cycling) and these can be applied in evaluating contaminant effects. However, difficulties exist with appropriate controls and representative assay conditions.

### 8.6.2 General Approach to Effects-Based Criteria Derivation

Effects-based criteria have been developed mainly for aquatic environments (CCME 1991b,c; Stephan et al. 1985; van Straalen and Denneman 1989), but soils have recently been addressed (Denneman and van Gestel 1990; van Leeuwen 1990; van Strallen and Dennemen, 1989). In the development of ecological effects-based criteria a soil contaminant concentration is estimated which represents a level at which no adverse effects are observed in key ecological receptors for a given land use (i.e. agricultural, residential/parkland, commercial/industrial). This can be achieved through the protection of the "most sensitive species" that can be identified in relation to the land use under consideration. Whether or not this is practically achieved (i.e., wide range of sensitivities, limited data) is a site-specific environmental management decision and does affect the process for developing effects-based criteria.

The generalized framework for developing ecological effects-based criteria is given in **Figure 5**. The process begins by drawing together all relevant scientific information on toxicology and environmental fate. Toxicological data are generally regarded as acceptable if a recognized and accepted biological testing protocol has been used in the study. Toxicological and environmental databases are assembled and evaluated. Any implications for criteria derivation related to land use are then considered. The relevant exposure pathways and receptors of contaminated soil for these land uses are identified and used in the process for deriving effects-based soil quality criteria.

In agricultural land use scenarios there must be no contaminant-imposed constraints on the ability of the soil to sustain microbial and invertebrate populations, grow crops and raise livestock of acceptable quality for human consumption. In residential/parkland land uses there must be no contaminant-imposed constraints on the ability of the soil to sustain microbial and invertebrate populations as well as native flora

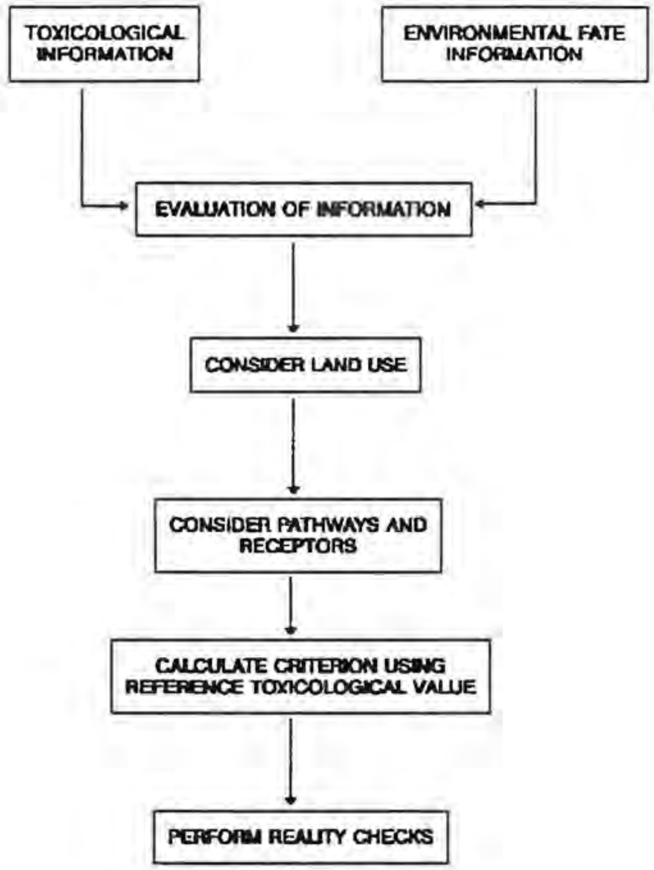


**Figure 5: Generalized Framework for Developing Ecological Effects-Based Soil Quality Criteria**

(and ornamental) and pose no-adverse effects to the health of wildlife. In commercial/industrial land use scenarios there must be no serious impairment by contaminants on the ability of the soil to sustain microbial and invertebrate populations and grow ornamental plants.

### 8.6.3 Criteria for Direct Contact with Contaminated Soil

Given the paucity of soil toxicity data and reliable models for evaluation of soil contamination at the population level, at present it appears possible only to meld "effects" information from single species assays with measures of community-level function (as a check mechanism) such as metabolic quotient and N mineralization. To be useful, such information must be based on a reference toxicological endpoint (e.g. NOEC, LC50). For soil organisms and plants these endpoints are usually obtained from dose-response studies that involve direct contact with contaminated soil (or elutriate) for the exposure (e.g. ISO 1991). Effects-based soil quality criteria developed using this information can only therefore be considered protective of soil organisms and plants from direct contact with contaminated soil and/or pore water.

#### 8.6.3.1 General Calculation of Soil Criterion

A soil quality criterion can be calculated using the general formula outlined below. Reference toxicological endpoints are usually determined from single chemical exposures applied to one species at a time. As applied to pure substances in soil, the usual chronic endpoints are the no observed effect concentration (NOEC) or lowest observed effect concentration (LOEC) whereas the common acute endpoint is the median lethal concentration ($LC_{50}$). Preferably, a reference toxicological endpoint at which no observable (adverse) effects are observed (NOEC) from a long-term study is used, but short-term endpoints (e.g., EC50) are alternatively used with an application factor to approximate NOEC conditions. NOEC values from toxicity tests are usually a function of the concentrations selected for the test and will vary from test to test. The "true" level at which no effects are observed could lie between the highest test concentration that results in no effect and the lowest test concentration that produces an effect. A standardized or scalable uncertainty factor is used to accommodate uncertainty in the estimate of the "true" level at which no effects are observed.

$$\text{Soil Quality Criterion} = \frac{\text{Reference Toxicological Endpoint}}{\text{Uncertainty Factor}}$$

### 8.6.4 Criteria for Direct Ingestion of Contaminated Soil or Food

Given the land uses previously identified, livestock and wildlife are considered to be the receptors of concern from exposures to contaminated soil from the ingestion of soil and food. Criteria that are developed to consider contaminant exposures to livestock or wildlife from direct ingestion of contaminated soil or food make use of reference toxicological values from single chemical exposures to single species, but must also take into account the rate of soil ingestion, body weight and bioaccumulation information of the organism in question. For agricultural land use scenarios this may involve contaminant exposures to livestock from the soil directly and from accumulated contaminants in plants tissues used as food. For residential/parkland land uses this may involve contaminant exposures to wildlife from the soil directly and from accumulated contaminant in invertebrates ingested as food. For commercial industrial land uses this route of exposure to livestock or wildlife is not expected to be significant given the nature of activities performed on these sites.

Information is generally available on the uptake and accumulation of chemicals from soil by plants. The consumption of contaminated plant material and soil particles by livestock is also generally known and has been identified as a significant exposure pathway (Fries, 1987; Paustenbach, 1989). Information is however, lacking on the these pathways of exposure to wildlife living in close association with soil or wildlife consumers of soil-dwelling invertebrates or plants. Currently it is feasible to develop criteria based on ingestion of contaminants from soil or food by livestock that will be suitable for an agricultural land use scenario. Further information is needed on the rate of ingestion of food and soil particles by wildlife before attempts can be made to develop criteria that can account for effects to wildlife incurred from this pathway of exposure. General calculating formulas for deriving soil quality criteria for livestock and wildlife ingestion are in the developmental stages and will be finalized at a later date.

### 8.6.5 Reality Checks

Soil quality criteria that are developed using the general framework outlined in Figure 5 should undergo a battery of reality checks as a final step. Other factors that must be considered in a generalized approach to environmentally protective soil quality criteria include potential for groundwater contamination, detection limits, plant nutrition requirements and geochemical background.

Because traditionally effects-based criteria or guidelines developed for various media have been established using single species exposures, it is difficult to experimentally measure individual dose-effect relationships in complex soil microbial populations, which contain multiple species. Therefore a "microbial check" can be performed using community level toxicological information (e.g., $CO_2$ production, N mineralization) by comparing it to any nominated soil quality criteria to ensure that adverse effects are not expected.

If the contaminant is a naturally occurring inorganic substance (e.g. As) geochemical background databases can be consulted to determine whether any criteria nominated are above the normal range found in the Canadian environment. Normally a soil quality criterion would not be set below the upper limit of normal unless there was strong evidence that such a concentration was limiting to biota.

Plant nutrition requirements present another possible check for some inorganic substances (e.g., B, Cu, Zn). These elements are required in small amounts by plants but are toxic in high concentrations. A soil quality criterion nominee should meet plant nutrition requirements for common crops that can be grown sustainably in Canada. Finally, a soil criterion nominee must not be expected to lead to contamination of groundwater beyond some benchmark (e.g., drinking water guideline).

During execution of the above checks it may be necessary to adjust a soil criterion nominee to generate a final soil quality criterion. Such an adjustment, however, would require full scientific documentation.

## 8.7 A CANADIAN REFERENCE SOIL ?

The term "generic criteria" implies applicability across a broad, but not all-inclusive, range of site and receptor conditions. When dealing with human health protection, this broad applicability is ensured by the multi-media approach and conservative assumptions built into receptor characteristics, exposure scenarios and toxicological derivations. Conservative assumptions acknowledge the existence of variation in important parameters that are influential upon biological effects, and respond by choosing upper or lower quantile values for these parameters as necessary to achieve the desired protection.

On the environmental health side, both mobility and bioavailability of contaminants are strongly influenced by key soil parameters such as pH, and organic matter and clay contents. Mobility and bioavailability mediate, respectively, transfer of contaminants to groundwater and toxicity to soil fauna. These considerations have lead the Dutch to define a "standard" soil in terms of clay and organic matter content (Moen et al. 1986), upon which they base their generic criteria. Rather than seek a conservative boundary condition for their standard soil, the Dutch have identified a central-to-liberal condition (25% clay, 10% organic matter), attached generic criteria to that condition, and provided tools for estimating appropriate criteria for non-standard conditions (Denneman and van Gestel 1990).

Could the Dutch approach be applied in Canada? The present answer appears to be: yes, in principle and no, in practice. To effectively deal with variation in bioavailability of metals as affected by organic matter and clay contents requires extensive data collection for the range of soil types to be managed. In the Netherlands this work is well underway, likely due in part to the relatively small area and strong need for sound soil management. Variation of contaminant distribution and behaviour in Canadian soils is poorly characterized by comparison with the Netherlands situation. Because Canadian soils differ substantially from those in the Netherlands it is expected that relationships developed there may be unreliable here -- necessitating a costly and time consuming replication of the Dutch effort or an alternative approach.

The urgent need for improved remediation criteria and the expense of commissioning the necessary studies indicate an alternative is needed. It is proposed that a Canadian reference soil condition be identified by coupling a boundary condition analysis to an overview of the distribution of Canadian soil types within the NCSRP land use framework. Such an analysis would seek an optimum balance in meeting four objectives:

1. The soil condition chosen should allow a high degree of contaminant bioavailability

2. Ecotoxicological effects criteria developed for the reference soil should be protective of a large proportion of Canadian soils classified under the NCSRP land use framework

3. Areas of prevalent soil contamination should not be excluded by the

reference condition

4. At the reference condition, small changes in master variables should not result in large fluctuations in toxicity and transport for most contaminants.

Advantages of incorporating a reference soil condition in the CCME criterion development process include:

1. Judging the applicability of generic criteria to a particular site will be more straightforward. Because the master variables defining the reference condition are normally measured in routine site contaminant investigations, it will be immediately apparent whether it is appropriate to apply criteria as site-specific objectives.

2. Evaluation of existing ecotoxicological data is simplified. Studies carried out in systems approximating the reference condition could be targeted for inclusion whereas studies of insensitive soil systems might be rejected or de-emphasized.

3. Development of new bioassay systems or acquisition of new data from old systems may be improved.

4. Information gaps will be better delineated. Clear identification of soil conditions incompatible with generic criteria may better inform industrial land management strategies and spur research.

## 8.8 SUMMARY

In Canada it has been identified that there is a need to deal with the growing concern over the potential impacts of contaminated sites on human and environmental health. Under the National Contaminated Sites Remediation Program a consistent approach to the assessment and remediation of sites is being developed so that cleanup can begin. The development of environmental quality criteria play an integral part in the assessment phase as well as the defining remediation targets for cleanup.

The Canadian Interim Environmental Quality Criteria for Contaminated Sites provide a conservative set of values for the assessment and remediation of soil and water as part of an overall framework for contaminated site cleanup in Canada. The interim criteria have been adopted directly from existing agencies based on desirable characteristics for a national set of criteria. Because many of these criteria lack supporting rationale, it was determined that these values would be revised on an ongoing basis to reflect evolving information on contaminant effects to human and ecological receptors.

The development of human health-based and ecological effects-based soil quality criteria reflect a process by which current environmental behaviour and toxicological information is evaluated and used in a process to produce soil quality criteria protective of both human and environmental health. Proposals for the development of human health-based criteria involve the use of risk assessment to define hazard and exposure based on a multi-media exposure assessment. Development of ecological effects-based criteria relies on the use of a reference toxicological endpoint for key receptors for given land uses. These criteria together are intended to represent levels of contaminants in soil which present no appreciable additional risk to humans and represent no observable effects to ecological receptors.

Some of the research still needed as part of the criteria development process involves the identification of a suitable reference soil for Canadian conditions, soil ingestion and bioaccumulation rates for wildlife exposed to contaminated soil and food.

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# ENVIRONMENTAL SOIL SCIENCE

## ANTHROPOGENIC CHEMICALS

## AND

## SOIL QUALITY CRITERIA

**PROCEEDINGS OF A JOINT SYMPOSIUM**

**OF**

**THE CANADIAN LAND RECLAMATION ASSOCIATION**
**AND**
**THE CANADIAN SOCIETY OF SOIL SCIENCE**

CLRA
ACRSD

Le Sol – Fondement de la Vie
CSSS / SCSS
Soil – Foundation of Life

**held at**
**EDMONTON, ALBERTA, CANADA**
**1992**

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## SOIL QUALITY CRITERIA


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## PREFACE

The Environmental Soil Science conference was held August 8-13, 1992 at the University of Alberta, Edmonton, AB. It was sponsored jointly by the Canadian Land Reclamation Association (CLRA) and the Canadian Society of Soil Science (CSSS). The objective of the conference was to share theoretical and applied aspects of soil science. It also served to get participants from the sponsoring groups together to find areas of mutual interest. There were 330 participants from Austria, Bangladesh, Canada, England, France, Germany, India, Japan, New Zealand, Norway, Spain, the Netherlands, and USA.

Abstracts of the oral and poster papers were published in the Canadian Journal of Soil Science (Vol.72, No.3, August 1992. (p.299-353). Volunteer papers covered all aspects of land reclamation, soil science, and public participation in the environmental review process. Seventy six of the 164 volunteer papers were presented as posters.

The invited papers presented in the plenary sessions focused on soil quality and interaction of soils with anthropogenic chemicals, and are published in this proceedings. Publication of the proceedings has taken an unduly long time due to unavoidable circumstances and we apologize for the delay.

Grateful acknowledgement is expressed to our colleagues on the organizing committee (J.A. Robertson, Chair) for their contributions to the success of the conference.

Y.P. Kalra and W.W. Pettapiece, Compilers

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