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Soil Quality

SOIL QUALITY

Soil contamination is emerging as a key environmental issue in Canada.

It has become increasingly apparent that soil contamination is placing human and environmental health in Canada at risk (Cureton et al. 1992).

Sources of soil contamination include factories; junk yards; coal tar pits; scrap yards; mine tailing wastes; municipal landfill sites; leaking underground storage tanks; hazardous waste sites; pesticides sprayed on fields, lawns and golf courses; and oils and asphalt applied to roads and lots. Soils may also be contaminated by vehicle exhaust, particulates from industrial smokestacks, and by atmospheric deposition of pollutants (e.g., particulate matter). (For more information on particulate matter in air see Chapter 7: "Outdoor Air Quality and Human Health" and *Contaminant Profiles*.)


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Contaminated soil can pose not only a direct hazard to people through ingestion but also indirect hazards. For example, some chemicals in the soil can leach into groundwater, as well as into streams via run off. In addition, some crops and vegetables can absorb the soil contaminants, (e.g., cadmium uptake in wheat) which thus enter the food chain.

For volatile contaminants, the inhalation of vapours in basements is often a dominant exposure pathway. Volatile organic compounds have migrated into basements of homes from underground storage tanks leaking petroleum-based fuels, and from hazardous waste landfills where vinyl chloride was improperly disposed. Once in a building, the vapours become part of the indoor air and pose a potential health risk to the occupants.

Soil contamination can cause long-term problems due to the high cost and difficulty of removing contaminants from soil.

9.1 Exposure to Contaminants in Soil

It is very difficult to monitor overall exposure to toxic substances from soil and dust. Exposure to contaminated soil occurs though ingestion, inhalation or through skin contact.

People eat plants grown in soil, drink water that passes through soil and inhale air that has been in contact with soil. People and livestock can also eat and inhale some soil particles directly and can be exposed by playing in or walking on soil. Exposure can also occur by inhaling vapours from soil and groundwater. Contaminated or remediated sites are additional sources of exposure. Exposure to soil varies according to climate (e.g., wind), time spent outdoors and season.

Ingestion is the most important route of exposure to contaminants in soil or dust. Children from four months to four years of age are the most susceptible group for exposure through ingestion, because they often put objects and their hands into their mouths. Children typically ingest very small quantities of dust and dirt between 0 to 2 years, the largest quantities between 2 and 7 years of age, and nearly insignificant amounts thereafter. It has been estimated that up to 80 percent of the entire lifetime dose of some persistent chemicals present in contaminated soil occurs during the first five years of life. Adults do not generally ingest a lot of dirt but they may accidentally ingest some dirt on fruits and vegetables and through poor personal hygiene (Paustenbach 1989).

LEAD IN SURFACE SOIL IN RESIDENTIAL COMMUNITIES IS OFTEN HIGHER THAN 200 PARTS PER MILLION (PPM). IN OLDER, LARGER URBAN RESIDENTIAL AREAS LIKE TORONTO, LEAD IN SOIL MAY EXCEED 500 PPM, EVEN WHERE THERE IS NO INDUSTRIAL SOURCE. LEAD IN SOIL IN SMALLER COMMUNITIES IS USUALLY BELOW 100 PPM. THE MINISTRY OF ENVIRONMENT AND ENERGY ADVISES THAT THERE IS MINIMAL RISK FROM EXPOSURE TO SOIL WITH LEAD LEVELS BELOW 200 PPM.
ONTARIO MINISTRY OF ENVIRONMENT AND ENERGY (OMOEE), NOV. 1995

Contaminant exposure through **inhalation** of soil usually involves such small amounts that they are not considered a threat to health. Exposure through inhalation depends on factors such as the contaminant concentration, soil type, moisture content, and porosity, and is governed by the specific physical properties of the contaminant (e.g., volatility).

The absorption of contaminants from soil or dust **through the skin** (dermal absorption) depends on a number of factors such as the area of contact; the duration of contact; the chemical and physical attraction between the contaminant and the soil; and the ability of the contaminant to penetrate the skin; (i.e., the size and weight of individual molecules of the particular contaminant; and how well the contaminant dissolves in water or in oils and fats).

Often, not all of the contaminant in the soil is available to the skin for absorption. Many organic chemicals are firmly attached to organic matter in soil, so that they can move through the skin only with difficulty. The amount of a contaminant that can be absorbed from the soil can be tested. The results of such an experiment give a "bioavailability factor" specific to the contaminant.

Exposure to Lead in Soil

Soil and dust can be important sources of exposure to lead. Exposure will depend on levels, location, particle size, climate and soil characteristics. Lead discharged into the atmosphere eventually reaches the ground and persists in soil where it is released and carried to other areas.

Lead can be present in soil many years after it was originally deposited. Lead content tends to be significantly higher in soils around homes, which are (or were) located close to busy highways; industries, which have used lead; lead-battery recycling factories; and large buildings or steel structures, such as bridges and water towers, which may have deteriorating lead-based paint. Lead in foundation soil can migrate into basements of homes. In addition to soil, interior point sources, such as lead-based paint, are also regarded as very significant sources of exposure. (For more information on lead and home renovations see Chapter 10. "Home Environments" and *Contaminant Profiles*.)

In general, mean lead levels in urban soils are higher than in rural areas. Older urban communities generally show much higher background lead levels in dust, likely due to the historic use of leaded paints that are now weathering, past deposition along roadsides and in heavy traffic areas from the combustion of leaded fuels, and old point sources.

While the mean levels are lower in rural settings, some agricultural soils, particularly fruit orchards, do have high lead levels because of past use of pesticides containing lead. Lead arsenate pesticide, (now banned) was used as late as 1975 in Ontario orchards. Commercial fertilizers and sewage sludge (sometimes used for agricultural fertilizer) also contain lead, though OMEE places restrictions on agricultural lead levels in soil.

The amount of exposure will depend on many factors such as time spent indoors or out, cleaning habits, play activities of children and the amount of dust and soil carried into the home on shoes, on clothing, or by pets. Lead can also contaminate fruit and vegetables grown in contaminated garden soil.

Because they are more likely to play in and ingest soil/dust, young children are also more likely to have a higher daily intake of lead. Children ingest an average 80 milligrams of soils and dust each day while playing, and depending on the levels of lead in the soil, may develop high levels of lead in their blood (OMOEE 1996).

Q. Is pressure-treated wood a source of arsenic exposure?

A. There is concern that chromated copper arsenate (CCA) pressure-treated wood, used in the construction of garden bed frames, backyard decks and children's play structures, has a tendency to leach arsenic (As), chromium (Cr) and copper (Cu) into soil. The wood is treated with CCA to protect it from bacterial, fungal and insect decay. CCA-treated wood can be recognized by its greenish tinge.

A recent study conducted in New Haven, Connecticut, found that soil samples taken from beneath CCA wood decks contained, on average, 20 times more As than the control soil, and as much as 35 times (350 mg/kg; 350 ppm) the legal limit for As in soil (10 mg/kg; 10ppm) (Stilwell and Gorny 1997). Soil samples were found to contain Cr and Cu levels of, on average, 2 and 4 times that of the control soil, respectively. The authors found that As leaches quickly from treated wood. For example, soil samples taken from beneath a four-month old deck already contained an average of 3.5 times more As than control soil. The amount of contaminants in soil tend to increase with deck age. CCA leaching may be retarded if the decks are painted with oil paint or oil-based stain soon after construction, or if they are sheltered from rain, snow or ice.

A Canadian study found that background levels of As, Cr and Cu in soil samples taken near outdoor play structures were all less than 1 mg/kg (ppm) (Galarneau et al. 1990). Sand samples taken below the structures contained from 0.03–9.6 ppm (32–9573 µg/kg), with a mean of 3 ppm (3 mg/kg) of As. Another Canadian investigation found that the quality of pressure-treated wood is not consistent, and that much of the treated wood did not meet the standards set by the Canadian Standards Association (Pépin 1990).

Pressure-treated wood should never be burned, as it can produce toxic fumes and ash. Rather, this wood should be disposed in a landfill made to hold hazardous waste or should be delivered to other special collection sites for toxic wastes.

(For more information on arsenic, see the *Contaminant Profiles*.)

Reducing Exposure to Lead in Soil

To reduce children's exposure to lead from these sources it is important to wash hands before eating, prevent the tracking of dirt and dust into the home, and to keep the home and toys as clean as possible. Soil and dust should be vacuumed regularly, (especially deep pile carpets which trap dust). Play areas should be kept free of dirt and dust. Hard surfaces should be damp-mopped. Children should not be allowed to play near peeling paint and cribs should also be kept away from these potential sources of lead.

The degree of human exposure to soil contaminants generally depends on the contaminant concentration at the soil surface, (top 0-3cm), rather than the contamination at lower depths. If outdoor lead levels are found to be very high, soil can be covered with grass to reduce the amount of exposed dirt, or the contaminated soil layer can be removed. A large mat at the door will help to reduce amounts of soil tracked indoors if it is cleaned often. Boots and shoes can be left outdoors. Gardens and play areas should be kept away from sources of lead.

Clean Up

While several soil remediation technologies are available, the preferred method in Ontario is still excavation and removal of contaminated soils. The Phytotoxicology section of OMEE will test for lead in a homeowners' soil if screening indicates a demonstrable concern such as proximity to a known source (i.e., secondary lead smelter) or a recorded elevated blood lead level in a family member. When the test results are sent to the homeowner, a fact sheet is provided to help interpret the results and reduce future exposure to lead.

Lead: Soil Guidelines for Decommissioning and Clean up of Sites

200 ppm	Residential/parkland
200 ppm	Agricultural
1000 ppm	Industrial/Commercial

Sludge Utilization Guidelines

60 µg/g	maximum permissible content in soil

Sediment Quality Guideline
31 ppm

Compost Guideline
150 pm

Some of the above information on lead was adapted from *Why Barns Are Red: The Health Risks from Lead and Their Prevention. A Resource Manual to Promote Public Awareness* released by the Metropolitan Toronto Teaching Health Units and the South Riverdale Community Health Centre. Metropolitan Toronto, Ontario in 1995.

(For more information on the health effects of lead, see *Contaminant Profiles.*)

Q. Do vegetables grown in contaminated soil become contaminated?

A. Chemicals and metals such as lead are taken up by vegetables grown in contaminated soils. The amount of contaminant taken up by a plant depends on the type of vegetable, the type of soil, gardening practices and the particular kinds and levels of contaminants in soil.

Usually it is thought that root vegetables and tubers store more contaminants than leafy vegetables, but this is not true in the case of lead. Lead is normally higher in older plants and will be stored differently in roots and in plant leaves. Lettuce leaves can store seven times more lead than the roots of carrots. Beet leaves contain more lead than beet roots. (OMOEE 1996.)

9.2 Domestic Pesticide Use

Many Canadians have voiced concern to health professionals about the safety of domestic pesticides and herbicides used by municipalities and by home-owners to control weeds. For example, 2,4-D is a phenoxy herbicide that is used extensively to control broadleaf weeds in both agricultural and domestic settings. (For information on 2,4-D see *Contaminant Profiles*.)

Exposure to pesticides can occur following residential and institutional application; this is called bystander exposure. For instance, children or pets playing on recently treated grass may be exposed. While research shows that such exposure to lawn care products does not appear to be a health concern, many municipalities and home owners are choosing to reduce the overall burden of environmental contamination by using integrated pest management (IPM) to combine the wide variety of available techniques. (For more information on IPM see Chapter 3 "Contaminants.")

Higher levels of organochlorine pesticides have been found in and around homes of agricultural families compared with homes in which parents do not work in agriculture and do not live close to farms (Simcox 1995). This means that children from agricultural families have a higher potential exposure to pesticides. Current research is investigating the extent of actual pesticide exposure of children in agricultural and non-agricultural homes.

(For a more detailed discussion about the safe handling of pesticides in the home environment, see Chapter 10 "Home Environments.")

9.3 Guidelines for Soil Quality

Human health soil quality guidelines provide concentrations of contaminants in soil, at or below which no appreciable human health risk is expected. The Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines (CCME 1996) considers direct soil exposure pathways, and accounts for indirect soil exposure through air, water, and food. Key components of the human health guidelines include a multimedia exposure assessment of background exposure unrelated to contaminated sites and a generic human exposure scenario relevant to each land use (agricultural, residential/parkland, commercial, industrial). The soil quality guideline is established after accounting for the multimedia exposure, so that the total tolerable contaminant intake is not exceeded.

Health Canada is responsible for assessing the human health risks posed by federally regulated contaminated sites. The guiding principles for the derivation of generic soil quality guidelines protective of human health are as follows:

1. There should be no appreciable risk to humans from a contaminated site. For each specified land use, there should be no restrictions as to the extent or nature of the interaction with the site. All activities associated with the intended land use should be free of any appreciable health risk.
2. Guidelines are based on defined, representative situations. Deriving numerical guidelines necessitates defining specific scenarios within which the exposure likely to arise on the site can be predicted with some degree of certainty.
3. Guidelines are derived by considering exposure through all relevant pathways. The total exposure from soil, air, water and food is considered in the development of guidelines.
4. A critical human receptor is identified for each land use. To ensure that the guidelines do not limit the application of a site within the intended land use category, the defined exposure scenarios are usually based on the most sensitive receptor to the chemical, and the most critical health effect.
5. Guidelines should be reasonable, workable and usable. Guidelines are developed by applying scientifically derived information, along with professional judgement where information gaps occur. Occasionally, defined exposure-based procedures produce numerical guidelines either far below background levels of contamination occurring naturally in the soil, or below analytical detection limits. When this occurs, guidelines cannot be below background levels, and guidelines should be established based on the background soil concentrations or the analytical detection limit.

There are many uncertainties in assigning the relative exposures from different sources. They can be considered as geographical (e.g., national vs. regional, urban vs. rural, proximity to pollution source), temporal (e.g., changes in measurement techniques), toxicokinetic (e.g., toxic effects associated with different routes of exposure), analytical (e.g., errors in measurement, representativeness of the sample), and philosophical or sociological (e.g., questioning the nature or purpose of the guidelines, how far might society go to safeguard groups who are particularly at risk).

Guidelines For Use at Contaminated Sites

The Ontario Ministry of Environment and Energy has developed a revised guideline, *Guideline For Use at Contaminated Sites in Ontario (June, 1996)*, for use when property owners are cleaning up and/or redeveloping a contaminated property in Ontario. Through the *Environmental Protection Act*, the ministry has a mandate to deal with situations where there is an adverse effect, or the likelihood of an adverse effect, associated with the presence or discharge of a contaminant.

The guideline provides advice on assessing the environmental condition of a property, when determining whether or not restoration is required, and the kind of restoration needed based on various property uses, (e.g., commercial, parkland, day-care site etc.). The guideline also suggests public communication strategies for the range of site restoration approaches.

Descriptions of three approaches for remediating a contaminated property follow:

1. **Background approach** involves the use of soil quality criteria to restore the site to naturally occurring "background" conditions. These background criteria were developed from an Ontario-wide sampling program at rural and urban parks unaffected by local point sources of pollution.
2. **Generic approach** involves the use of soil and groundwater criteria that have been developed to provide protection against the potential for adverse effects to human health, ecological health and the natural environment. The criteria may be applied to agricultural, residential/parkland and industrial/commercial land uses.
3. **Site specific risk assessment (SSRA) approach** may be used to establish site-specific criteria or a level of exposure protection based on risk assessment. Risk management decisions (e.g., engineered measures to reduce the level of risk at the site) may also be made using the SSRA approach. The risk management plan must also include provisions for ongoing monitoring.

The guideline outlines a four-step process of activities that includes site assessment, sampling and analysis, a remedial work plan, and finally, completion of the work.

The responsibility for the investigation and restoration process remains with the property owner and those undertaking the work.