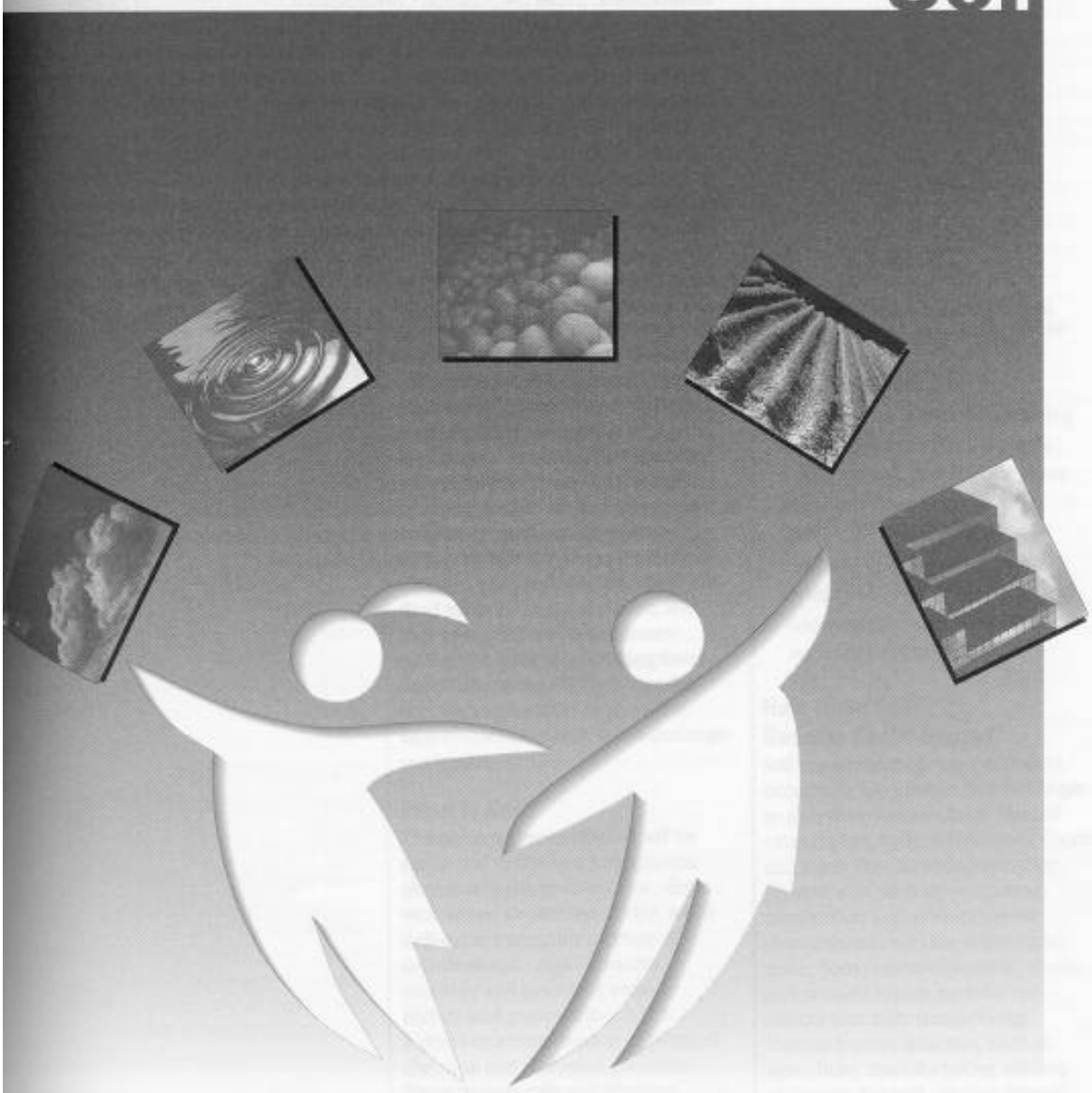
Soil



Chapter Highlights:

Soil contaminants may pose a human health risk as a result of the accidental ingestion of soil particles or as a result of their migration into air, water and food. Few soils exist that have not been contaminated to some degree, however small, although the extent of contamination varies widely from place to place.

- More than 10 000 public waste disposal sites have been identified in Canada, of which 10% are believed to pose a potential risk to human health or the environment. Under the National Contaminated Sites Remediation Program, federal and provincial governments provided funding for the development of new soil remediation technologies and sponsored the clean-up of several high-risk contaminated properties. The Canadian Council of Ministers of the Environment has established soil quality guidelines for many of the most hazardous pollutants found at contaminated sites.
- During the 1970s and 1980s, more than 1500 leaks were reported in Canada from surface and underground motor fuel and oil storage tanks. Up to 20% of an estimated 200 000 storage tanks still in use have the potential to leak their contents. The leakage of a single litre of gasoline can render up to one million litres of water undrinkable.
- Older homes are a potential source of lead-based paint dust and contaminated soil. Young children are at highest risk of exposure because of their habit of placing objects or dirt into their mouths. Elevated lead levels in blood are associated with behavioural and developmental problems in children and with adverse reproductive effects in adults. Average blood lead levels in Canadian children are significantly lower today than in the 1970s. To estimate the number of children for whom a concern may exist, it is assumed that 5–10% of urban children have more lead in their bloodstream than the lowest level (10 µg/dL) at which adverse effects have been identified.
- Wood preservatives can migrate out of treated wood and waste materials into soil and may contaminate groundwater supplies. Treatments are added to products to prevent decay, rot and insect infestation.

SOIL

Introduction

A cornerstone of our environment, soil plays a central role in our planet's life support system. Soil stores and recycles essential nutrients such as nitrogen and thus supports the plant and animal life that form the basis of our food chain. To a limited extent, soil also serves as a natural waste treatment plant. Micro-organisms found in soil break down and recycle dead plant and animal matter, and they even feed on chemical contaminants, gradually breaking them down into (generally) less harmful substances. However, when soil is heavily contaminated, it can endanger our health.

What Is *Soil*?

The ancient Greeks labelled *soil* (or earth) one of the four fundamental elements of the environment, along with water, air and fire. Today, soil is defined as a complex mixture of crumbled rock, organic matter, moisture and gases that varies in texture and composition. Soil is formed by a combination of physical, chemical and biological processes. These include rain and flooding, gravity, wind, radiation, temperature changes and the collective labours of various soil organisms, which recycle decayed plant and animal products into the molecular building blocks necessary for creating new life.[446,447]

Did you know?

Healthy soil is literally crawling with living creatures. A single ounce of soil may contain more than a billion bacteria. One hectare of land can harbour millions of earthworms, mites, centipedes, beetles and ants and can contain more than 10 t of micro-organisms.[446,447]

How Does Soil Become Contaminated?

Soil contamination was a common occurrence long before humans began to alter their surroundings. Natural catastrophes, such as volcanoes, floods and forest fires, as well as everyday phenomena, such as weathering, combustion and erosion, release contaminants into the soil environment. Some micro-organisms, plants and animals release harmful substances into their surroundings. Various human activities, such as agriculture, manufacturing, mining and waste disposal, are also responsible for vast amounts of pollutants entering our soil environment each year.

Soil contaminants released by natural sources include metals, such as lead, mercury and cadmium; radioactive elements, such as uranium and radon; and microbial toxins, such as aflatoxins and botulin, which causes botulism. Contaminants released by human sources include organic compounds, such as pesticides, chlorinated dioxins and furans and petroleum and its by-products; and inorganic compounds, such as heavy metals. From the soil, these substances may ultimately end up contaminating our food, air or water.

Soil Quality and Our Health

Soil contaminants may pose a health risk to Canadians either directly or indirectly. For example, soil quality affects the quality of crops, which in turn affects human health. Additionally, people may ingest small amounts of soil, particularly when produce has not been adequately washed, or may inhale airborne soil particles during outdoor activities. Infants and toddlers may consume soil (or house dust) directly, or inadvertently by finger sucking, until they are old enough to understand the consequences. Tiny amounts of soil may also enter our bodies through skin absorption or may be ingested from dirty hands.

In addition, pollutants present in soil may reach us through more indirect routes. Soil gases such as radon may seep into our houses, offices and other buildings, contaminating the air we breathe. Crops grown in contaminated soils may take up various pollutants and be eaten by people or by livestock, which are, in turn, consumed by humans. Soil pollutants may also leach into water bodies, particularly groundwater (approximately 26% of Canadians rely on groundwater for domestic use).[242]

How Clean Is Our Soil?

Around the world, few soils exist that have not been contaminated by human activities, although the extent of contamination varies from place to place. Even in the Canadian Arctic, thousands of kilometres from the industrial belts of North America, Europe and Asia, persistent pollutants of industrial and agricultural origin have been detected as a result of their long-range transport in the global atmosphere.[238]

Although soils have an inherent capacity for "self-cleaning," the rate at which contaminants enter soil often exceeds the rate of turnover from natural processes, such as the breakdown of chemical substances by soil micro-organisms, chemical processes or physical processes. Few data are available on historic levels of soil pollutants in Canada. However, in many areas, soil quality has been adversely affected by population increases, urban sprawl, the increased use of agricultural chemicals, unsound waste management practices and other factors.

In sheer numbers, as well as their potential to cause harm, old or inadequate waste disposal sites are among the principal sources of soil (and groundwater) contamination today. The majority of waste disposal sites in Canada are rather primitive facilities in which garbage is piled in layers, and few precautions are taken to prevent leachate from leaking into the surrounding soil.[238] Across the country, more than 10 000 active, closed or abandoned public waste disposal sites have been identified, excluding privately owned landfills. Approximately 10% of these sites are believed to pose a potential risk to human health or the environment.[448] These include contaminated industrial sites, municipal waste dumps and locations where large chemical spills have occurred.

In 1989, the Canadian Council of Ministers of the Environment (CCME) launched the National Contaminated Sites Remediation Program to address the legacy of contaminated property throughout Canada.[449,450] For information on this program, see the section entitled "Major Initiatives to Protect Our Health" later in this chapter.

Key Issues

This section discusses the health issues associated with important soil contaminants, including leaking motor fuels and oils, lead and pesticides. Other contaminants commonly found in soil are addressed in the Air, Food or Water chapters, to reflect the principal routes by which we come in contact with these substances. Waste management issues are discussed in The Built Environment chapter.

Leaking Motor Fuels and Oils

During the 1950s and 1960s, thousands of underground gasoline and diesel fuel tanks were installed across Canada as a convenient means

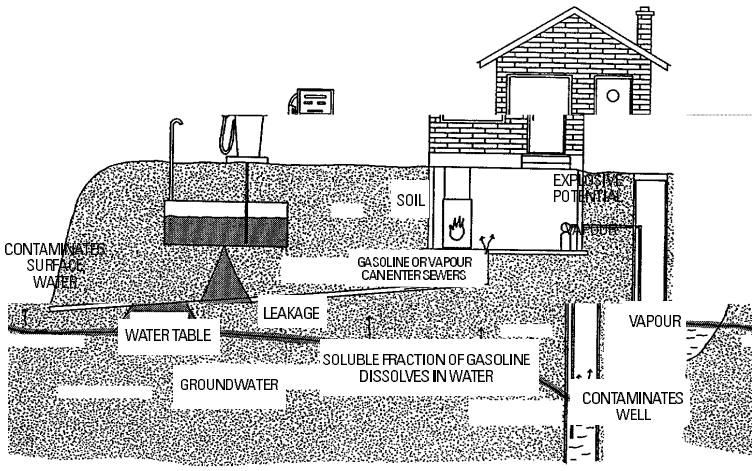


Figure 23
Leaking Underground Petroleum Storage Tanks: Tank Leakage Can Cause a Number of Problems

Source: Adapted from ***Leaking Underground Storage Tanks. Fact Sheet,*** *Environment Canada, 1987. Reproduced with permission of the Minister of Public Works and Government Services Canada, 1997.*

of storing gasoline and oil. Almost half of these tanks are located at service stations, with the remainder owned by taxi and bus fleets, farms, industries, governments and institutions such as hospitals and schools. Most of the tanks, however, were not built to withstand corrosion.[451] During the 1970s and early 1980s, more than 1500 leaks were reported from surface and underground storage tanks.[452]

According to Environment Canada, up to 20% of an estimated 200 000 storage tanks currently in use have the potential to leak their contents.[453] When the contents of underground storage tanks leak into the surrounding soil, gasoline and oil may contaminate groundwater supplies or seep into basements (see Figure 23). The leakage of a single litre of gasoline can contaminate up to one million litres of water and make it undrinkable, whereas the fuel fumes represent a fire and health hazard.[451]

Gasolines and diesel fuels are complex mixtures that contain a wide range of organic and inorganic substances. The most relevant components from a human health perspective are the "BTEX" compounds: benzene, toluene, ethylbenzene and xylenes. Together, these chemicals account for up to 33% of gasoline blends.[452]

Water supplies that are contaminated with gasoline or diesel fuel seeping from nearby soil are unlikely to be consumed by Canadians because of the unpleasant taste and smell. When present in drinking water, toluene, ethylbenzene and xylenes can be detected by humans at levels that are well below those associated with adverse health effects.[454]

By contrast, the migration of motor fuel vapours through soil poses a potential health risk to home-owners in the area. In many cases, the threat of an explosion has forced the evacuation of homes. Short-term exposure to gasoline vapours may also cause health effects ranging from lung and throat irritation to neurological symptoms, such as dizziness and lower attention spans.[301,453,455]

What You Can Do

Fuel leaks are often difficult to detect and even harder to clean up, so it is vital to prevent leaks from occurring in the first place. If you own or operate an underground storage tank, the following steps will reduce the chance of a leak occurring[451]:

- Determine the age of your tanks and the material of construction. Underground storage tanks made of stainless steel that were installed in the 1950s and 1960s are more likely to leak and should be replaced.
- Conduct accurate and regular inventories to identify leaking as early as possible.
- Ensure that your existing installations meet government regulations and industry standards and that new tanks are installed by qualified contractors, according to provincial government regulations.
- Ensure that any storage tanks taken out of service are properly decommissioned to prevent gasoline or diesel fuel leaks.
- Report the location of any old, abandoned underground storage tanks on your property to the responsible agency in your province or territory, such as the Ministry of the Environment or the Fire Marshall's Office.

For more information, obtain *Environmental Code of Practice for Underground Storage Tank Systems Containing Petroleum Products and Allied Petroleum Products*, 1993 edition, published by the CCME, which is available from the Manitoba Statutory Publications Distribution Centre.

Lead

Lead has been used by humans for thousands of years, resulting in its widespread distribution in soils around the world. Today, landfills account for a large proportion of the lead that is discharged into our environment. Other significant sources include industrial emissions and lead-based paint dust. Lead levels are often higher in the soil around homes located near smelters and metal refineries and around large buildings or steel structures coated with peeling lead-based paint.[85,201]

Older homes are also a major source of lead-based paint dust. The natural weathering of exterior walls covered with leaded paint can contaminate gardens or children's sandboxes.[292] Therefore, people who live in older homes may be at higher risk of exposure to lead.

Did you know?

Some original or repainted playground structures may contain protective coatings that exceed the 0.5% by weight lead content. This may be a hazard to young children, who may ingest, from their hands, paint chips or dust originating from playground structures having chipping or peeling paint. Health Canada has advised the Federation of Canadian Municipalities (FCM) about this hazard. The FCM is informing its membership not to use lead-based paints on playground equipment and is advising them of the appropriate remedial measures to take where lead-based paint has been previously applied.

Lead present in soil can enter our food supply after contaminating plants. Another common route of exposure is via soil or dust that is tracked indoors. For young children, the direct ingestion of soil (or household dust) can be a significant route of exposure, because of their habit of placing objects in their mouths[200,292] (see Figure 24). Depending on the chemical form of lead, some skin absorption may also occur.[203] Once inside the body, lead is stored in bone and other tissues, where it may remain for more than a decade, although the levels will gradually decline if individuals successfully avoid further exposure to lead.

Did you know?

The average child ingests an estimated 0.1–0.2 mg of soil per day. However, children with an abnormal craving for non-food substances can eat from 5 to 10 g of soil per day (i.e. up to 10 000 times more soil).[91] For comparison, a typical soda cracker weighs about 3 g.

Recent research suggests that there may be no level of exposure below which lead does not have some impact, however small, on human health. Elevated blood lead levels are associated with behavioural and developmental problems in children and with adverse reproductive effects in adults.[201] Children are more susceptible to the health hazards of lead because they are developing rapidly and they absorb a higher proportion of the lead that they ingest.[408]

The average lead levels measured in children's blood in Canada have dropped steadily since the early 1970s, primarily because of the phase-out of leaded gasoline.[30] To estimate the number of children for whom a concern may exist, it is assumed that 5–10% of urban children have more lead in their bloodstream than the

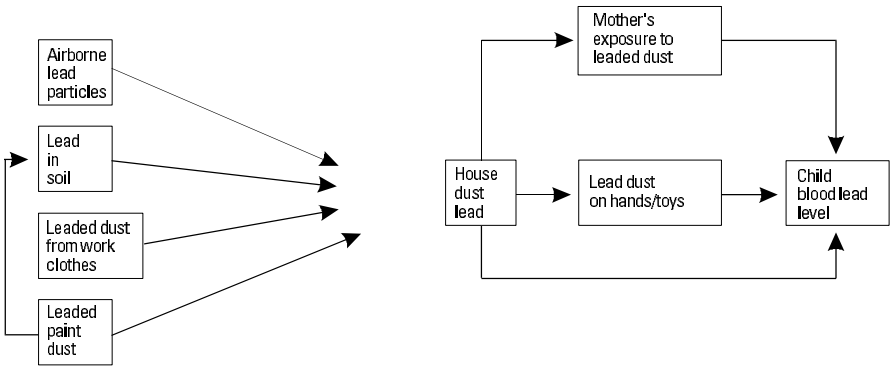


Figure 24
Childhood Exposure to Leaded Dust

Source: "Lead in Paint—An 'Old' Problem Revisited" in ***Environmental Health Review,*** *Winter, 1992, Myres AW & Easson E. Reproduced with permission from the authors, 1997.*

lowest level (10 µg/dL) at which adverse effects have been identified.[456] Children who live in older homes may have a particularly high risk of exposure to lead.

Protecting Our Health

Over the past two decades, the federal government, in partnership with industry, has introduced measures to reduce the amount of lead entering our environment from consumer products such as household paint. In 1976, the *Hazardous Products Act*, which is administered by Health Canada, limited the amount of lead in interior paint to 0.5% by weight. Since then, most manufacturers have stopped using lead entirely. Some exterior paints still contain lead, but they must carry a warning label. Health Canada is now proposing to introduce new regulations limiting the lead content of all consumer paints to 0.06% by weight.

Under the *Hazardous Products Act*, protective coatings on playground structures that are imported, sold or advertised for sale in Canada must not exceed a lead content of 0.5% by weight. Health Canada is also participating with industry and other interested parties in the development of an updated Canadian Standards Association publication, *A Guideline on Children's Playspaces and Equipment,* expected to be finalized at the end of 1997. This guideline will reference a lead content limit of 0.06% by weight in protective coatings on playground structures and will apply to coatings used in the maintenance of playgrounds.

What You Can Do

You can find out if your soil is contaminated with lead using a home test kit, which can be purchased through pottery supply outlets, or by sending a soil sample to a laboratory for analysis. Your local public health department may have a testing program, or you can call the nearest provincial/territorial government agriculture or environment office for advice.[292]

For more information about lead and household paint, the following publications are available from Health Canada and the Canada Mortgage and Housing Corporation:

- *Renovation: Lead in Your Home*; and
- *Old Paint, Lead and Your Family's Health.*

Pesticides

Pesticides may enter the soil environment after being sprayed on land, from waste disposal sites or as a result of atmospheric transport and deposition. Canadians are exposed to pesticide residues in soil primarily through indirect routes, via contaminated food or water. People may also come into direct contact with pesticide residues in soil, depending on the product used, last time of use and climatic conditions.

Did you know?

The risk of exposure to pesticides is highest at the time of application.

Wood Preservatives

Wood-preserving chemicals are commonly used in the manufacture and treatment (coating or impregnating) of fences, decks, play equipment, house foundations, barns, storage facilities, docks and other durable wooden structures. Treatments are added to products to prevent decay, rot and infestation by insects, such as termites. Wood preservatives can migrate out of treated wood and waste materials into soil and may contaminate groundwater supplies.[457]

In Canada, one of the most popular wood preservatives registered for domestic use is creosote. Also used on railway ties, electrical poles, embankments and cardboard, creosote is a complex organic mixture produced from coal that contains more than 300 compounds, including polycyclic aromatic hydrocarbons (PAHs), which account for up to 90% of the total mixture.[198,458] Creosote is currently under reevaluation within the Pest Management Regulatory Agency (PMRA) to address the potential for health or environmental hazards.

The PMRA has requested that all registrants of creosote revise their product labels to incorporate exposure-reducing measures.[459]

In Canada, CCA (copper–chromium–arsenate) is widely used for preserving lumber intended for outdoor uses. Because of its tendency to release arsenic, CCA-treated wood, which has a greenish tinge, should not be burned or come in contact with soil used for growing food crops, such as garden vegetables.[460,461]

What You Can Do

Here are some safety tips to help reduce your exposure to wood preservatives and other pesticides used at home[457,462]:

- Always wear gloves when handling or working with wood preservatives and other pesticides. Wash any exposed skin with soap afterwards.
- Do not use treated wood indoors.
- Do not use treated wood for fuel, because it can produce toxic fumes and ashes when it burns.
- Do not use treated wood to line water wells, conduits, backyard gardens or other containers that could come into direct or indirect contact with food, drinking water or bathing water.
- To reduce skin contact, apply a sealer to treated wood used for decks, play structures, patio furnishings, etc.

For more information about household pesticides and human health, obtain the following publications from Health Canada:

- *Pressure-Treated ("Preserved") Wood and Wood Preservatives*; and
- *Weedkiller: 2,4-D*.

Soil Erosion

Fertile soil is a precious resource. In Canada, only 5–7% of the total land area is suitable for agriculture.[463] The loss of agricultural soil as a result of wind and water erosion is a growing problem, particularly in the Prairie provinces. Prairie farmers first became aware of the impact of soil erosion during the 1930s, when the damage from decades of intensive farming combined with a prolonged drought turned wheat-growing areas into a dust bowl.[464] A 1986 study conducted for Agriculture Canada found that the economic costs of soil erosion exceed $1 billion per year in lost crop production. Although no estimates are available for Canada, U.S. data suggest that the environmental costs of air and water pollution resulting from soil erosion "may be even higher."[465]

Soils are normally protected from erosion by plants. Plant roots bind and anchor soil particles in place, whereas the leaves and stems protect soil from wind and rain.[466] Certain agricultural practices increase the risk of soil erosion, including overgrazing of pasture by farm animals; planting only one crop per field, which leaves the entire field bare at harvest time; row cropping, in which the soil between each row of crops is exposed; tilling or ploughing, which brings loose topsoil to the surface; and the removal of organic matter, such as leaves and stems, at harvest.[464,466]

Controlling Soil Erosion

According to the 1991 Census of Agriculture, 177 487 of 280 043 farms across Canada (63%) practised at least one erosion control method, such as crop rotation, which was the most popular technique (36.9% of farms). In addition, 31% of the total agricultural land in Canada was prepared for seeding either without turning over the soil or with no tilling at all. Overall, some form of erosion control or conservation practice was employed on 84.6% of agricultural land across the country.[464,465] In Canada, the Prairie Farm Rehabilitation Administration (PFRA), a branch of Agriculture and Agri-Food Canada, promotes sustainable agricultural practices, including soil conservation. For example, the PFRA Shelterbelt Centre in Indian Head, Saskatchewan, distributes millions of tree seedlings each year to protect crop land from soil erosion.[467]

Emerging Issues

Soil Remediation

Over the past few decades, steady progress has been made in our ability to clean up heavily contaminated soils. For example, using the best methods available during the 1980s, clean-up crews were unable to remove more than 50% of the contaminants from the average gasoline leak or spill.[451] Today, much more can be achieved, thanks to some promising new technologies, such as bioremediation, which involves the use of natural soil organisms to break down stubborn contaminants.[468,469] In one project co-ordinated by Environment Canada, a bioremediation facility was designed to clean up 3600 t of petroleum-contaminated soil from a military base using hydrocarbon-degrading bacteria. After six months, the organisms used for the job had reduced contaminant levels present in the soil by 97%.[470]

Although results like these are encouraging, many Canadians are concerned about the consequences of releasing novel micro-organisms into our environment. In theory, even well-intentioned uses for bacteria, such as the clean-up of contaminated waste sites, may pose risks to human health.[468]

To address such concerns, Health Canada scientists assess the health risks of new biotechnology products, such as soil remediation bacteria, prior to their use. The Department evaluates both the potential hazard posed by micro-organisms (and their by-products) and the potential exposure of Canadians to the organisms. If there are reasons to suspect that a product is harmful to humans, the federal government may ban or impose controls on its use. Even after a biotechnology product has been approved for use, Health Canada scientists will continue to monitor its health effects.[182]

The National Contaminated Sites Remediation Program

In 1989, the Canadian Council of Ministers of the Environment launched the National Contaminated Sites Remediation Program (NCSRP) to address the legacy of contaminated property throughout Canada. The program, which ended in 1995, provided funding for the development and demonstration of new soil clean-up technologies and sponsored the clean-up of several high-risk contaminated properties for which a responsible party either could not be found or was unable to carry out the work.[449]

The program made substantial progress towards the identification, assessment and remediation of contaminated sites under federal jurisdiction. At the same time, many provinces and the territories put in place stronger legislation requiring polluters to bear the costs of cleaning up contaminated sites.[449] As a result, although the NCSRP has ended, remediation initiatives are continuing across the country.

As part of the NCSRP, scientific tools were developed to promote consistent site clean-up activities. These include a set of soil quality guidelines for use by site managers, which specify the maximum level of different soil contaminants at which minimal health or environmental risks are anticipated. The guidelines also provide a common basis for the establishment of soil and groundwater clean-up targets at contaminated sites across Canada.[450]

Health Canada's Role

Under the NCSRP, Health Canada was responsible for assessing the human health risks associated with contaminated sites, developing scientific methods for measuring human exposure and risk and establishing health-based soil remediation guidelines for key soil contaminants.[30]

Major Initiatives to Protect Our Health

Canada has taken several steps to reduce the health risks posed by soil contaminants in our environment. In 1989, the CCME launched the National Contaminated Sites Remediation Program "to ensure that appropriate cleanup... occurs wherever contamination is a serious threat to human health and/or environmental quality."[449] Under this program, Health Canada scientists helped the CCME set soil quality guidelines for 18 common pollutants, including benzene, toluene, xylenes and lead. The guidelines, which are available through the CCME in Winnipeg, take into consideration both the direct ingestion of soil particles and indirect routes of exposure to these contaminants, such as via polluted groundwater.

In a related project, Health Canada's Laboratory Centre for Disease Control (LCDC) is studying the relationship between cancer risk and proximity to contaminated sites. LCDC has established an environmental quality database, which contains information on air, water and soil quality problems. It identifies, among other things, the location of waste disposal sites that have a high potential to contaminate local groundwater supplies. Health Canada researchers are monitoring cancer incidence rates surrounding these waste sites to determine whether residents are at increased risk.

Certain other initiatives, discussed in the Appendix, should also improve the long-term health of our soil environment. For example, the New Substances provisions of the *Canadian Environmental Protection Act* (CEPA) are designed to identify and prevent new and potentially toxic substances from entering our environment—before they can cause health problems. Similarly, CEPA aims to reduce the levels of harmful chemicals already present in the environment. In addition, Canada is an active participant in international negotiations to control the long-range atmospheric transport of pollutants from other countries.

What You Can Do

Here are a number of simple steps you can take to minimize your family's exposure to soil contaminants, such as lead, creosote and other pollutants[292]:

- Plant grass to cover any bare patches of soil on your lawn.
- Remove outdoor shoes at the door to prevent soil from being tracked into the house.
- Keep indoor play areas free of dust, which may contain soil particles tracked in from outside.
- Vacuum rugs frequently and damp-mop floors and other hard surfaces.
- Ensure that your children wash their hands regularly.
- Wash garden and supermarket vegetables thoroughly with dishwashing detergent and water before serving.