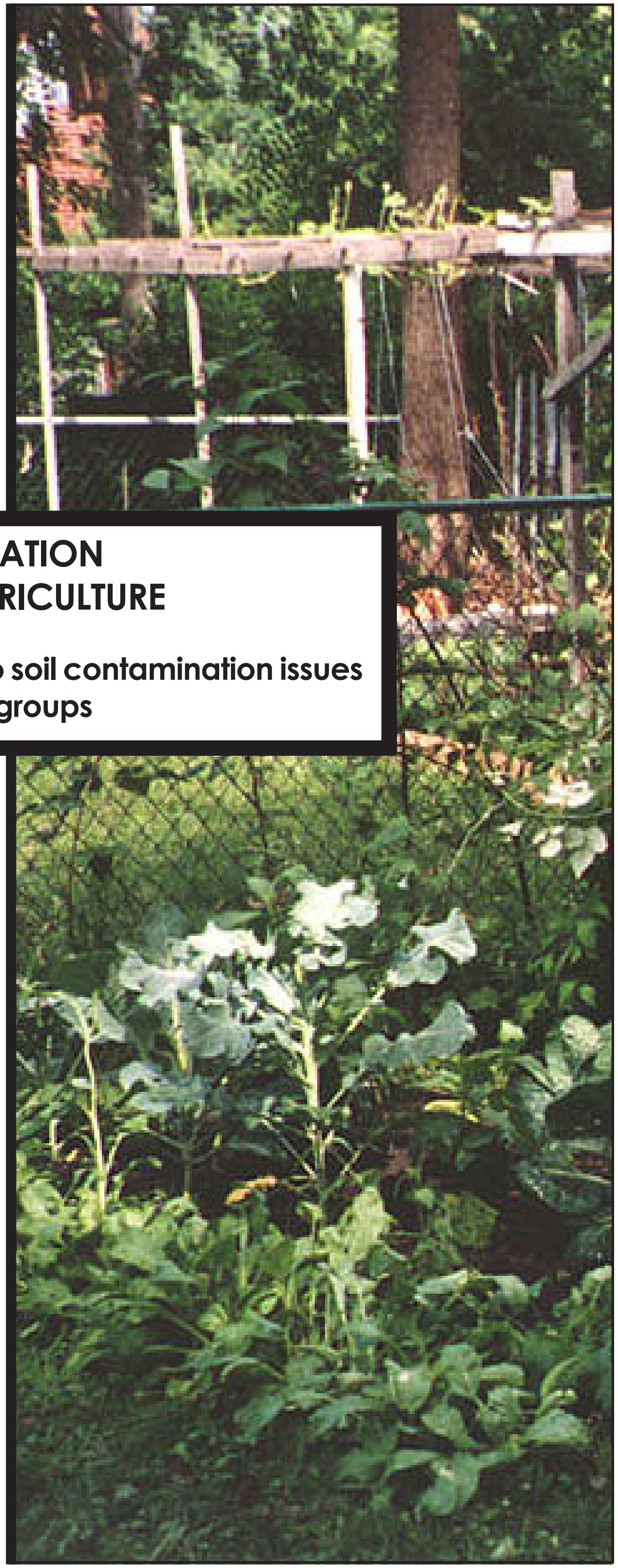
SOIL CONTAMINATION AND URBAN AGRICULTURE

A practical guide to soil contamination issues for individuals and groups



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This guide is written as a primer on soil contamination, as it relates to gardening in an urban setting. It seeks to provide individual gardeners or community groups with the necessary background information to address this issue. There are several important aspects of soil contamination which are addressed in this guide, including the dangers of gardening in contaminated soil, the potential sources of contamination, ways to evaluate the level of contamination present in the soil, and your options for addressing the problem. At the end of this document there are several appendices with information pertaining to the topics discussed here. Most of these are Montreal- and Canada–specific, but should provide some good starting points for similar resources in other cities and countries.

What are the dangers of soil contamination for urban agriculture?

Soil contamination can be seen as a problem at several levels. The contaminants can end up in plants which are growing in the soil; the groundwater which interacts with and goes underneath the soil can become contaminated as a result of soil contamination; animals that eat the vegetation growing in the soil can absorb contaminants as well. Similarly, when humans eat plants grown in these soils, they can absorb contaminants which were present in the soil, and then in the plants.

In other words, our immediate concern relating to soil contamination is for human health. The health risks of exposure to a wide range of soil contaminants have been observed and documented. Some examples of these contaminants include heavy metals, pesticides, and PCB's. More detailed information on contaminants can be obtained through the web resources in Appendix A of this guide.

An important aspect of soil contamination is the **level** to which the contaminants are present in soil. By this we mean the concentration of a given contaminant in the soil, usually expressed in mass per unit mass soil (e.g. mg/kg), ppm (parts per million), or ppb (parts per billion).

What are some sources of soil contamination?

Soil contamination can come from many different sources. Past land uses may have used substances which then entered the soil as a contaminant. A good example of this is a gas station or mechanics garage, where different fuels and lubricants may have entered the soil inadvertently through poor storage practices or spillage onto the ground. There are many other examples like this, however other sources of contamination may be more indirect. Examples of these sources of contamination include rain runoff from roofs, roads, and other structures that may introduce heavy metals such as lead or mercury into the soil.

Other sources of soil contamination may not have originated on or near your site at all. Contaminants can be introduced from adjacent properties through the movement of groundwater and soil water. Depending on the specific hydrological features of the surrounding area, contaminants can later end up in the soil in which you wish to garden.

We have included a list of web resources relating to potential sources of contamination in appendix A of this guide, for your own information. Next, it is useful to discuss the role of agricultural soil standards in the context of soil contamination.

What levels of soil contamination are acceptable for urban agriculture?

Ideally, garden soils should have no contaminants, besides the levels that are naturally present in the soil. However, particularly in urban settings, it is inevitable that soil contaminants will exceed natural levels. This raises the question – how much contamination is acceptable?

There are standards for acceptable levels of soil contamination which exist at all levels of government It is important to note that there are different standards– usually pertaining to the industrial, residential, or agricultural use of land. Of these three, agricultural is the most strict, as it is important to have relatively minimal levels of contaminants present in soils that will be used to grow food. As an example of this, included at the end of this document Canada's and Quebec's soil agricultural standards (see Appendix B).

These standards will be useful to keep in mind, as we move to the next section – determining the level of contamination present in the soil.

How can the level of contamination be evaluated?

Finding out the level of contaminants present can be difficult. However, we aim to provide some useful starting points that can make the process easier.

The main form of evaluating soil contamination is soil testing. This generally involves having a private firm perform several samples on the property, then taking them to a lab for analysis. The cost of testing can vary greatly, depending on the range of contaminants that are being addressed by the test. The more contaminants which are being tested for, the more costly the testing will be. A partial listing of soil testing laboratories in Canada is listed in Appendix C of this document.

Having said this, there are certain steps which can be taken to reduce the cost of testing. In order to narrow the range of contaminants which need to be tested for, a review of previous land uses can be undertaken, to determine if there have been any obvious potential sources of contamination.

The following steps for determining land use history are described in general. Resources specific to Montreal are listed in Appendix D of this document.

Determining Land Use History

1. Find the lot number of the property, available at City Hall.

2. With this information, you can contact previous land owners, and search for past land uses. There are a variety of resources which can help: city archives, courthouse records, and map libraries (governmental and academic). Montreal-specific examples of these are listed in Appendix D.

As mentioned above, if you may be able to determine certain types of land use that have easily associated types of contamination. If this is the case, you can choose to include these contaminants in your soil tests. Likewise, you may choose to exclude certain contaminants from your soil testing if the land use history is not associated with these contaminants.

What options are available to address soil contamination?

Once you have established that there are levels of contaminants that exceed maximum levels for agricultural use, it is necessary to look at what options you have in order to deal with the contamination. First, we will examine some techniques for **soil remediation** – or ways to reduce the level of contamination in the soil. Some of these methods are more practical than others. We have included only those methods which have applicability for a relatively small garden (e.g. the size of vegetable gardens one would find in residential backyards). These remediation techniques can be evaluated for the purposes of urban agriculture based on several criteria. These include:

Accessibility: Is this technique readily available to non-expert individuals and groups? Is it commercially available, or still in the development phase?

Cost: Relatively inexpensive techniques are desirable, as the gardens generally don't generate revenue to pay back the costs of remediating. The costs of consulting and soil testing are separate from this cost, as they are a necessary first step in every situation.

Timeframe: Some techniques are implemented and completed over the course of a few days, while others may take years to be effective. This can be an important factor, depending on when you are considering implementing the garden.

Effectiveness for urban agriculture: This refers to the ability of the technique to bring the soil up to agricultural standards. Some techniques can do this in every situation, some depend on the nature and extent of contamination, and some are not effective at this time. For the purposes of the summary tables (Table 1 and Table 2), a scale of 1 – 3 is used. 1 is unconditionally effective, 2 is conditionally effective, and 3 is ineffective.

Environmental effects: Remediation techniques will vary in how environmentally sound they are. Some have toxic by-products, others involve placing materials in the soil that are not biodegradable, while still others have no adverse environmental effects. Often, the disposal of contaminated soil is required at a landfill. These issues are provided for further consideration by you or your group.

Using this framework we can examine the various remediation techniques that are available. These techniques can be categorized as **physical** or **biological**.

Physical soil remediation techniques

These techniques generally involve the use of technology for remediation purposes. They include excavation, capping with geotextiles, soil washing, and soil vapour extraction. Note that the descriptions of these techniques are by no means comprehensive, as we seek to highlight the main advantages and drawbacks of each technique. There is extensive literature available on most of these techniques, available for further reading.

Excavation

Excavation refers to physically removing contaminated soil, normally for disposal at a landfill. Excavation is accomplished with heavy machinery, at a relatively high cost. However, it can take place quickly. New soil is needed after the excavation, at extra cost.

Geotextiles

Geotextiles are a synthetic blanket-like material. They can be used after the excavation process to provide a protective barrier, impermeable to contaminants which may otherwise migrate into the new soil after excavation. Geotextiles are relatively low-cost themselves, but must be combined with excavation. One concern with geotextiles is that the fabric can tear, allowing contaminants to pass through into the new soil.

Soil Washing

Soil washing is a technique which involves the physical removal of the contaminated soil, followed by treatment at a plant on or off-site. After the contamination is removed through the treatment process, the soil is put back into the ground. This technique is generally high-cost, and the disposal of the removed contaminants must be addressed after the process is complete.

Soil Vapor

Soil vapor extraction involves the installation of wells and pipes in the soil, through which soil contaminants are extracted. This is the most costly procedure of the physical remediation techniques listed here, but is effective at removing the contaminants.

In general, these physical remediation techniques are all available for the purposes of urban agriculture, are relatively fast to

implement, and are effective at remediating soil to agricultural standards. However, they can be very costly, and have other environmental drawbacks – such as disposal of contaminants/ contaminated soil, and air pollution from machinery. We have selected **excavation**, with or without **geotextiles** as the physical remediation technique most useful to small-scale urban agriculture. The main benefits of these techniques are relative low cost, and fast and effective remediation of contamination. These conclusions are illustrated in Table 1.

Note: Prices are for a hypothetical small backyard garden. The prices are intended for purpose of comparison to other techniques, and actual costs may vary.

TABLE 1

Summary of Physical Remediation Techniques

	Excavation	*Geotextiles*	*Soil washing*	*Soil vapor extraction*
Access	yes	yes	yes	yes
Cost ($CAD)	$5000- $10 000	<$1000 +excavation costs	$1000- $5000	$10 000+
Timeframe	short <1 season	short <1 season	short <1 season	short <1 season
Effectiveness for UA	1	2	1	1
Environmental Effects	energy use air pollution disposal	energy use air pollution disposal	energy use air pollution disposal	energy use air pollution disposal

Biological soil remediation techniques

Unlike physical remediation techniques, biological techniques are generally performed *in situ* (directly on-site). These techniques include microbial remediation, phytoremediation, fungal remediation, and composting techniques. Again, the descriptions are not comprehensive, as we seek to highlight the main benefits and drawbacks of each technique, and provide a comparison for a range of techniques. There is also extensive literature on these techniques available for further reading.

Microbial Remediation

Microbial remediation refers to the use of microbes in degrading contaminants into a less toxic form. This technique can be very effective in the treatment of hydrocarbons, PAH's, pesticides, and PCB's. Cost is generally relatively low, and timeframe is short. However, there is the possibility of increased toxicity of certain metals.

Phytoremediation

Phytoremediation is the process of using plants to extract contaminants or to degrade them in the soil. As with microbial remediation, the cost is low. However, the timeframe can be longer than several years. Effectiveness in bringing soil up to agricultural standard varies, as one species of plant is generally used on one type of contaminant, potentially leaving a range of contaminants behind. As well, the contaminated plants used for extraction must be disposed of.

Fungal Remediation

Fungal remediation refers to the use of certain species of fungus to degrade contaminants. This technique is still in the development phase and is not commercially available as of now.

Compost Remediation

Compost remediation involves the addition of compost to the soil. This is cheap, and quick to do. However, it is not a true remediation technique, as the contaminants generally remain intact in the soil. The addition of compost can, however, be used to create a raised bed, in which the plant roots may not reach the contaminated soil.

In general, bioremediation techniques are conditionally effective in bringing soil up to agricultural standard. There can be great uncertainty in the treatment of the contamination – as the original soil remains intact, there may still be some contaminants that remained unaffected by the technique used. Phytoremediation can take long periods of time to take effect, and the plants used must be disposed of after the project. However, these techniques are generally inexpensive, easy to implement, and environmental effects are low. Overall, we have selected **microbial remediation** as the bioremediation technique most useful to urban agriculture. The main benefits of this technique are relative low cost, and short timeframe. These conclusions are illustrated in Table 2.

One last comment about bioremediation techniques: Although they may not be as unconditionally effective at remediating soil to agricultural standards as excavation, they have great potential for future use, as much research on these methods is underway.

***Note*:** Prices are for a hypothetical small backyard garden. The prices are intended for purpose of comparison to other techniques, and actual costs may vary.

TABLE 2

Summary of Bioremediation Techniques

	Microbial remediation	*Phyto-remediation*	*Fungal remediation*	*Compost remediation*
Access	yes	yes	no	yes
Cost ($CAD)	<$1000	<$1000	n/a	<$1000
Timeframe	short <1 year	2-5+ years	n/a	short <1 season
Effectiveness for UA	2	2	3	2-3
Environmental Effects	potential metal toxicity	disposal of toxic plants	potential metal toxicity	none

Non – remediation options

Outside of these remediation techniques, there are some other options for dealing with the soil contamination issue. The alternatives involve growing the produce in a seperate container or bed above the contaminated soil. **Raised beds** or **containers** can be used in an effort to prevent plant roots from reaching the contaminated soil. Similarly, technologies such as **aquaponics** are another way to avoid growing directly in the soil.

Alternately, if the site turns out to be heavily contaminated, you may consider trying to find another piece of land for the garden. As we hope to have stressed at the beginning of this guide, the health risks of growing food in contaminated soil can be significant.

A final note: Subsidies

Given that some of these remediation techniques can be relatively expensive, the issue of government subsidies is useful to discuss.

An example of a subsidy program in Québec at this time is Revi-Sols, a provincial program. At this time, the program would not likely benefit urban agriculture projects, as a criteria for funding is that the land be redeveloped in a way that is economically productive (e.g. creates jobs, pays taxes etc.). However, there is the possibility that future programs may be expanded to allow for subsidies for urban agriculture. For more information, see the program website:

http://www.menv.gouv.qc.ca/sol/terrains/programme.htm

An example from the United States is a program initiated by the Environmental Protection Agency named the Brownfields Federal Partnership Action Agenda. The EPA has programs in place to fund soil remediation projects, with provisions for urban agriculture. For more information, see the EPA website:

http://www.epa.gov

Contaminants and sources of contamination resources

Agency for Toxic Substances and Disease Registry (USA):
http://www.atsdr.cdc.gov/

Environmental Protection Agency:
http://www.epa.gov/

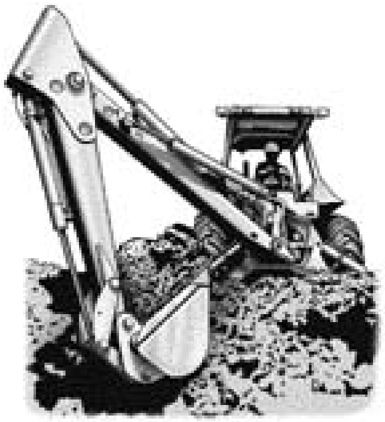
Extoxnet:
http://ace.ace.orst.edu/info/extoxnet/pips/tebuthiu.htm

Organic Pollutants:
http://pacific.fws.gov/ecoservices/envicon/pim/reports/contaminantinfo/contaminants.html

Phthalates Information Center:
http://www.phthalates.org/

Spectrum Laboratories (USA):
http://www.speclab.com/compound/price3.htm

Web Elements:
http://www.webelements.com/



Canada and Quebec Agricultural Soil Standards

Contaminant	Canada Concentration (mg/kg)	Quebec Concentration (mg/kg)
Arsenic	12	6
Barium	750	200
Benzene	0.05	0.1
Non-chlorinated benzene compounds		
2,6-dinitrotoluene	-	0.7
Chlorobenzene	-	0.2
1,2-dichlorobenzene	-	0.2
1,3-dichlorobenzene	-	0.2
1,4-dichlorobenzene	-	0.2
Hexachlorobenzene	-	0.1
Pentachlorobenzene	-	0.1
1,2,3,4-tetrachlorobenzene	-	0.1
1,2,4,5-tetrachlorobenzene	-	0.1
1,2,3,5-tetrachlorobenzene	-	0.1
1,2,3-trichlorobenzene	-	0.1
1,2,4-trichlorobenzene	-	0.1
1,2,5-trichlorobenzene	-	0.1
Bromide	-	6
Cadmium	1.4	1.5
Carbon tetrachloride	-	0.1
Chlorinated ethanes		
1,1-dichloroethane	-	0.2
1,2-dichloroethane	-	0.2
1,1,1-trichloroethane	-	0.2
1,1,2-trichloroethane	-	0.2
Chlorinated ethenes		
1,1-dichloroethene	-	0.2
1,2-dichloroethene (cis and trans)	-	0.2
1,1,2-Trichloroethene (Trichloroethylene, TCE)	0.1	0.2

Contaminant	Canada Concentration (mg/kg)	Quebec Concentration (mg/kg)
1,1,2,2-Tetrachloroethene (Tetrachloroethylene, PCE)	0.1	0.2
Chloroform	-	0.2
Chloropropane		
1,2-dichloropropane	-	0.2
Chloropropene		
1,3-dichloropropene (cis and trans)	-	0.2
Chromium	64	85
Hexavalent chromium (Cr(VI))	0.4	-
Cobalt	-	15
Copper	63	-
Cyanide	0.9	2
DDT (2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane; Dichloro diphenyl trichloroethane)	0.7	-
Ethylbenzene	0.1	0.2
Ethylene glycol	960	-
Flouride	-	200
Formaldehyde	-	1
Lead	70	50
Manganese	-	770
Mercury	6.6	0.2
Molybdenum	-	2
Nickel	50	50
Petroleum hydrocarbons C10 to C50	-	300
Phenols	3.8	-
Chlorinated phenols		
Chlorophenol (2,3, or 4)	-	0.1
2,3-dichlorophenol	-	0.1
2,4-dichlorophenol	-	0.1
2,5-dichlorophenol	-	0.1
2,6-dichlorophenol	-	0.1
3,4-dichlorophenol	-	0.1

Contaminant	**Canada** Concentration (mg/kg)	**Quebec** Concentration (mg/kg)
3,5-dichlorophenol	-	0.1
Pentachlorophenol (PCP)	7.6	0.1
2,3,4,5-tetrachlorophenol	-	0.1
2,3,4,6-tetrachlorophenol	-	0.1
2,3,5,6-tetrachlorophenol	-	0.1
2,3,4-trichlorophenol	-	0.1
2,3,5-trichlorophenol	-	0.1
2,3,6-trichlorophenol	-	0.1
2,4,5-trichlorophenol	-	0.1
2,4,6-trichlorophenol	-	0.1
3,4,5-trichlorophenol	-	0.1
Non-chlorinated Phenols		
Cresol (ortho, meta, para)	-	0.1
2,4-dimethylphenol	-	0.1
2,4-dinitrophenol	-	0.1
2,4-dinitrocresol	-	0.1
2-nitrophenol	-	0.5
4-nitrophenol	-	0.5
Phenol	-	0.1
Polychlorinated biphenyls (PCBs)	0.5	0.05
Polycyclic aromatic hydrocarbons (PAHs)		
Acenaphthene	-	0.1
Acenaphtylene	-	0.1
Anthracene	-	0.1
Benz(a)anthracene	-	0.1
Benzo(a)pyrene	0.1	0.1
Benzo(b+j+k)fluoranthrene	-	0.1
Benzo(c)phenanthrene	-	0.1
Benzo(g,h,i)perylene	-	0.1
Chrysene	-	0.1
Dibenzo(a,h)anthracene	-	0.1
Dibenzo(a,i)pyrene	-	0.1
Dibenzo(a,h)pyrene	-	0.1

Contaminant	**Canada** Concentration (mg/kg)	**Quebec** Concentration (mg/kg)
Dibenzo(a,l)pyrene	-	0.1
7,12-dimethylbenzo(a)anthracene	-	0.1
Flouranthene	-	0.1
Fluorene	-	0.1
Indeno(1,2,3-cd)pyrene	-	0.1
3-methylcholanthrene	-	0.1
Methyl naphthalenes	-	0.1
Naphthalene	0.1	0.1
Phenanthrene	-	0.1
Pyrene	-	0.1
Selenium	-	1
Silver	-	2
Styrene	-	0.2
Sulpher	-	400
Thallium	1	-
Tin	-	5
Toluene	0.1	0.2
Vanadium	130	-
Vinyl chloride	-	0.4
Xylene	0.1	0.2
Zinc	200	110

Source: Canadian Environmental Quality Guidelines. 1999. Winnipeg: Canadian Council of Ministers of the Environment.

Partial listing of private and provincial soil testing laboratories in Canada

Alberta

Alberta Soils and Animal Nutrition Laboratory
905 O.S. Longman Building, 6909-116 Alberts Street, Edmonton, AB, T6H 4P2
(403) 427-2727

Norwest Labs
9938-67 Ave., Edmonton, AB, T6H 4P2; (708) 438-5522 or (800) 661-7645
http://www.norwestlabs.com

British Columbia

Griffin Labs Corp.
1875 Spall Road, Kelowna, BC, V1Y 4R2; (250) 861-3234

Norwest Labs
104, 19575-56A Avenue, Surrey, BC, V3S 8P8; (604) 514-3322 or (800) 889-1433
http://www.norwestlabs.com

Pacific Soil Analysis
Unit #5, 11720 Voyageur Way, Richmond, BC, V6X 3G9; (604) 273-8226

Manitoba

Manitoba Provincial Soil Testing Lab
Dept. of Soil Sciences, Room 262, Ellis Building,
University of Manitoba, Winnipeg, MB, R3T 2N2; (204) 474-9257

Norwest Labs
Agricultural Services Complex, 203-545 University Cres., Winnipeg, MB, R3T 5S6
(204) 982-8630 or (800) 483-3448

New Brunswick

NB Agricultural Lab
NB Dept. Of Agriculture and Rural Development, Box 6000,
Fredericton, NB, E3B 5H1; (506) 453-2666 or (888) 622-4742
http://www.nbfarm.com/genfaqs.htm

Newfoundland & Labrador

Soil Plant and Feed Laboratory
Department of Forest Resources and Agrifoods,
Provincial Agriculture Building, Box 8700, Brookfield Road, St. John's, NF, A1B 4J6
(709) 729-6638
http://www.gov.nf.ca/agric/telephon/ferspec.htm

Nova Scotia

Soils and Crops Branch
Nova Scotia Department of Agriculture and Fisheries, Box 550, Truro, NS, B2N 5E3
(902) 895-4469
http://www.gov.ns.ca/nsaf/qe/analytical/soilsamp.htm

Laboratory Services
176 College Road, Harlow Institute, Box 550, Truro, NS, B2N 5E3; (902) 893-7444
http://www.gov.ns.ca/nsaf/qe/analytical/soilsamp.htm

Ontario

A & L Canada Laboratories East, Inc.
2136 Jetstream Rd., London, ON, N5V 3P5; (519) 457-2575

Accutest Laboratories
146 Colonnade Road, Unit 8, Nepean, ON, K2E 7Y1; (613) 727-5692

Agri-Food Laboratories
503 Imperial Road, Guelph, ON, N1H 6T9; (519) 837-1600 or (800) 265-7175

Nutrite
Box 160, Elmira, ON, N3B 2Z6; (519) 669-5401 (in southern Ontario 800-265-8865)

Ontario Ministry of Agriculture
Food & Rural Affairs, Agricultural Information Contact Centre; (877) 424-1300
http://www.gov.on.ca/OMAFRA/english/crops/resource/soillabs.htm

Royal Botanical Gardens
Box 399, Hamilton, ON, L8N 3H8; (905) 527-1158

Soil and Nutrient Laboratory
University of Guelph, 95 Stone Road West, Guelph, ON, N1H 2W1; (519) 767-6226
http://www.uoguelph.ca/labserv/

Stratford Agri Analysis Inc.
1131 Erie St., Box 760, Stratford, ON, N5A 6W1; (519) 273-4411 or (800) 323-9089
http://www.stratfordagri.com

Prince Edward Island

P.E.I. Soil and Feed Testing Lab
P.O. Box 1600, Research Station, Charlottetown, PE, C1A 7N3; (902) 368-5631
http://www.gov.pe.ca/af/soilfeed/index.asp

Quebec

Nutrite
Box 1000, Brossard, QC, J4Z 3N2; (514) 462-2555

Bodycote Essais de Materiaux Canada, Inc
121 boul. Hymus, Pointe-Claire, QC, H9R 1E6; (514) 697-3273
http://www.na.bodycote-mt.com

Inspec-Sol Inc
4600, blvd de la Cote-Vertu, Saint-Laurent, QC, H4S 1C7; (514) 333-5151

Saskatchewan

Saskatchewan Soil Testing Lab
Department of Soil Science, General Purpose Building,
University of Saskatchewan, Saskatoon, SK, S7N 0W0; (306) 966-6890
http://www.ag.usask.ca/cofa/departments/hort/hortinfo/misc/soil2.html

Enviro-Test Laboratories
General Purpose Buildiing, 12 Veterinary Rd., Saskatoon, SK, S7N 5E3
(306) 668-8370
http://www.envirotest.com/labs/saskatoon.html

Adapted from: Canadian Gardening website. 2002.
http://www.canadiangardening.com/HTML/cg_soiltesting.html

Montreal land use history resources

Cartotheque, Bibliothèque Nationale du Québec
Location: 2275 rue Holt
Web site: http://www.bnquebec.ca
Online historical maps: http://www.bnquebec.ca/cargeo/accueil.htm

Cartotheque, Université de Montréal
Location: 520 chemin de la Côte-Ste-Catherine, Room 232
Note: Accessible by appointment only

Cartotheque (map library), Université de Québec à Montréal
Location: Bibliothèque Generale (Pavillon Hubert-Aquin), 400 rue Sainte-Catherine Est
Web site: http://www.bibliotheques.uqam.ca/bibliotheques/cartotheque/index.html
Note: Accessible by appointment only

City of Montreal Archives
Location: 275 rue Notre-Dame Est, Room 108
Web site: http://www2.ville.montreal.qc.ca/archives/archives.html

Palais de Justice de Montréal
Location: 155 rue Notre-Dame Est
Web site: http://www.barreau.qc.ca/montreal/Ang/pages/AV_06.htm

Répertoire des terrains contaminés – Environnement Québec
Web site: http://www.menv.gouv.qc.ca/sol/terrains/terrains-contamines/recherche.asp

Walter Hitschfeld Geographic Information Center, McGill University
Location: 805 rue Sherbrooke Ouest
Web site: http://www.library.mcgill.ca

McGill University
3534 University, Montreal, Quebec, Canada H3A 2A7