

Community Garden Heavy Metal Study

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List of Abbreviations

BCF	Bioconcentration Factor
CCME	Canadian Council of Ministers of the Environment
COAG	The Committee on Agriculture
FAO	Food and Agricultural Organization of the United Nations
GM	Geometric Mean
HRM	Halifax Regional Municipality
ICP-OES	Inductively Coupled Plasma Emission Spectrometry
LOI	Loss on Ignition
MEC	Mineral Engineering Centre
NASGLP	North American Soil Geochemical Landscapes Project
NSAC	Nova Scotia Agricultural College
OM	Organic Matter
OMOE	Ontario Ministry of Environment
ppm	Parts per million = mg kg^{-1} = $\mu\text{g g}^{-1}$
ppb	Parts per billion = 10^{-3} ppm = $\mu\text{g kg}^{-1}$ = ng g^{-1}
UPA	Urban and Peri-urban Agriculture

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Chapter 1: Introduction

The rural population in Canada has decreased dramatically in the past few decades. Today, only 20 percent of Canadians live in rural communities (Government of Canada, S.C., 2006a). In Nova Scotia, 55 percent of the population lives in urban and sub-urban areas (Government of Canada, S.C., 2006b) with only a small contribution to Canadian food production. There is growing interest in more local and community-based food production and distribution systems, particularly in urban areas. The impetus for this movement stems from a variety of issues, such as: a concern over food supply and food security in urban areas; recognition of the health benefits of community-produced vegetables; the social benefits of local gardens; and the sense of community local gardens engender. Brown and Carter (2003) capture the essence of the community gardening movement: *“A community enjoys food security when all people, at all times, have access to nutritious, safe, personally acceptable and culturally appropriate foods obtained through normal food distribution channels and produced in ways that are environmentally sound and socially just.”*

Urban and Peri-urban Agriculture (UPA) is an alternative way of producing food within cities. The Committee on Agriculture (COAG) of the Food and Agricultural Organization of the United Nations (FAO) defines UPA as: “agriculture practices within and around cities which compete for resources (land, water, energy, and labor) that could also serve other purposes to satisfy the requirements of the urban population” (Van Veenhuizen and Danso, 2007). Food production can take place on rooftops and in backyards, community vegetable and fruit gardens and unused or public spaces (Van Veenhuizen and Danso, 2007). In addition to increasing the community’s food security, urban agriculture promotes skill development, urban greening and community building. Urban agriculture can potentially contribute to the household food supply and even create an important source of income, especially for the urban poor. Urban agriculture also creates employment opportunities within the community, and helps the local economy by keeping the money in the community. Urban food production can provide ways of better

waste management such as using organic wastes. Consuming local foods can eliminate or decrease the transportation of food from long distances, thereby reducing the net carbon emissions and other environmental impacts. Implementing effective food preservation and distribution methods can significantly decrease refrigerating and packaging costs (Fairholm and LifeCycles, 1998). UPA also increases urban bio-diversity by not only growing a wider range of foods, but through providing habitat for urban wildlife. Other potential benefits are: better management of storm water, production of oxygen, noise reduction, and temperature control via shade and transpiration (Fairholm and LifeCycles, 1998). Socially, urban food production contributes to a sense of community. It has educational and skill development benefits for society, helping to nurture cultural and horticultural knowledge of food production and usage (Fairholm and LifeCycles, 1998).

Urban agriculture is part of a survival strategy for the urban poor throughout the world. Its contribution to food security is substantial in many developing cities. Smit and Nasr (1992) reported that there are 200 million urban farmers in the world supplying food to 800 million people, or about 12% of the world's population. They point out that in many Asian cities food production is promoted and recognized as a critical urban function. For example, Hong Kong, one of the world's most densely-populated cities, produces two-thirds of the poultry, one-sixth of the pigs and close to half of the vegetables eaten by its citizens (Smit and Nasr, 1992).

Over the last few years, urban gardening has gained significant importance in HRM with more than 20 active community gardens, including a few school gardens. However, several North-American studies have shown that the urban soils can have high concentrations of certain trace elements. The presence of these heavy metals may pose a human health risk, particularly for children. Lead and other heavy metals in soil can enter the human body through inhalation or ingestion of dust and soil and, to a lesser extent, through the consumption of produce grown in contaminated soil, as plant tissue has the ability to bioaccumulate lead and other heavy metals (Clark et al., 2006). A variety of sources might contribute to the urban soil heavy metal concentration such as industrial

wastes, vehicle emissions, and coal-burning waste (Manta et al., 2002). Moreover, the lead concentration of exterior soil can contribute to indoor dust lead contamination (Rasmussen et al., 2001). Various environmental agencies, including the Canadian Council of Ministers of the Environment (CCME), have published soil quality guidelines to help protect environmental and human health.

This study was conducted to assess the level of heavy-metal contamination in the soils of urban gardens in the HRM. Four elements were chosen, and their concentrations in existing and potential urban gardens were measured. Soil samples were taken from specified locations following standard protocols. The following issues were addressed:

- Development of survey design, sampling and analytical protocols;
- Identification of potential and existing urban gardens in the HRM;
- Selection of heavy metals of concern;
- Collection, preparation and analysis of soil samples;
- Comparison of the results of this study to studies conducted in other Canadian cities, and to background levels for native soils in Nova Scotia; and
- Investigation of potential spatial pattern for contamination occurrence within the HRM.

A principle objective was to develop preliminary recommendations for existing and future gardens for managing and mitigating heavy metal contamination in the urban garden soil. This is a preliminary study and it provides only an indication of soil's heavy-metal contamination in the sampled gardens, rather than an absolute assessment of heavy-metal contamination of the soils of HRM.

Chapter 2: Literature Review

2.1 Sources of metals in soils

Weathering of rock and anthropogenic sources are the two main pathways of metal input to soils. Turpeinen (2002), reported that anthropogenic sources of metal contamination can be divided into five major groups:

1. Metalliferous mining and smelting (arsenic, cadmium, lead, and mercury)
2. Industry (arsenic, cadmium, chromium, cobalt, copper, mercury, nickel, and zinc)
3. Atmospheric deposition (arsenic, cadmium, chromium, copper, lead, mercury and uranium)
4. Agriculture (arsenic, cadmium, copper, lead, selenium, uranium and zinc)
5. Waste disposal (arsenic, cadmium, chromium, copper, lead, mercury and zinc)

2.2 Background information

2.2.1 Lead (Pb)

Lead predominantly exists in the nature in its stable plumbous ion (Pb^{2+}). It alloys with other metals such as arsenic, zinc and copper. Lead is usually found in ore in association with zinc. Most lead mines in Canada are in New Brunswick and British Columbia. Canada produced 76,566 thousand tons of lead in 2006 (Government of Canada, N.R.C., 2006), an increase of almost 4.9% from the previous year (Government of Canada, N.R.C., 2005). The production rate of 2006 was 21.4% lower than in 2003 (Government of Canada, N.R.C, 2003). There was no lead mining and production in Nova Scotia in 2006 (Government of Canada, N.R.C., 2006). In Canada, lead is mainly used to produce antimonial lead –such as battery grids, copper alloys and lead alloys – and also semi-finished products - such as pipe, sheet, traps, bend, and blocks for caulking and ammunition for both military and sports purposes. In addition, lead and its compounds are consumed in the production of solder, pigments, glass and ceramics, and in lithographic processes. Some fertilizers also have various concentrations of lead. Land application of sewage sludge, animal wastes from animal production, coal residues,

municipal refuse incineration, wastewaters, and auto emissions are all anthropogenic sources of lead in soil. McKeague and Wolynetz (1980) reported the mean concentration of total lead in uncontaminated Canadian soils which were remote from ore bodies to be $20 \text{ mg}\cdot\text{kg}^{-1}$. Slightly higher value ($21 \text{ mg}\cdot\text{kg}^{-1}$) was reported for the Appalachian regions (McKeague and Wolynetz, 1980).

2.2.2 Arsenic (As)

Arsenic can occur in four oxidation states as arsine (As^{3-}), arsenic metal (As), arsenite (As^{3+}), and arsenate (As^{5+}). Since the oxidation state of arsenic determines its toxicity, determination of the speciation of arsenic is important. Arsenic covalently bonds with most metals and non-metals. Currently in Canada, arsenic is used mainly in metallurgical applications and in the production of wood preservatives (CCME, 2001). The anthropogenic form of arsenic most frequently released to the environment is As^{3+} . In Canada, arsenic enters the environment through the use of insecticides, herbicides, fungicides, and pesticides, as well as wood preservatives, base-metal and gold-mining activities, burning of coal, and the disposal of domestic and industrial wastes. Most anthropogenic releases (80%) of arsenic in the environment will ultimately end up in the soil. The concentration of arsenic in the surface soil can also result from the presence of arsenic in the soil parent material and through volcanic eruptions (CCME, 2001). Arsenic exists in major types of rocks with the concentration range from 0.5 to 2.5 ppm (Kabata-Pendias and Pendias, 2001). As part of the North American Soil Geochemical Landscapes Project (NASGLP), Goodwin et al. (2009), reported concentration of arsenic in Nova Scotia to be in the range of 2.2 ppm to 345.7 ppm, with a mean concentration of 22.3 ppm, and a median value of 12.3 ppm. The highest arsenic concentrations were found in the southern mainland Nova Scotia, relatively close to the HRM (Goodwin et al., 2009).

Arsenic is rarely found in its elemental form in soil, occurring most commonly as inorganic As^{+3} and As^{+5} . Many oxide minerals of arsenic are a result of oxidation of

sulfide deposits. These are arsenites and arsenates in which arsenic is combined with metals such as iron, nickel, copper and cobalt (CCME, 2001).

2.2.3 Copper (Cu)

Copper occurs in four oxidation states of Cu, Cu^{1+} , Cu^{2+} , and Cu^{3+} . However the Cu^{2+} is the most common form. Most copper deposits exist in the form of sulfide minerals.

Copper has a wide range of applications in industry and agriculture, used extensively in the manufacture of textiles, antifouling paints, electrical conductors, plumbing fixtures, pipes, coins and cooking utensils. Copper compounds are often found in wood preservatives, pesticides and fungicides, and copper sulfate is used as a fertilizer (CCME, 1999a). Sewage sludge may also have an elevated copper content, thus affecting the copper concentration level of sewage-sludge-treated soils. The background concentration of copper in soils depends on the parent materials and soil-formation processes (Kabata-Pendias and Pendias, 2001).

Due to the high solubility of sulfite (SO_3^{2-}) minerals, especially in more acidic surroundings, copper ions are naturally released to the environment. The mobility of copper in soil depends on the soil pH and the content of organic compounds and other minerals with which copper might interact. Copper precipitates with various anions such as sulfide (S^{2-}), carbonate (CO_3^{2-}) and hydroxide (OH^{1-}) which are rather immobile elements in the soil. Overall, the variation of total content of copper in soil profile is small. In addition, clay fraction of the soil has a significant effect on the copper content and usually clay soils have higher concentration of copper. Most copper exists in the surface layers of the soil mainly due to the recent anthropogenic sources of copper as well as bioaccumulation of the element. As a consequence, the copper concentration in soil can be extremely high, reaching concentrations of 3500 ppm close to industrial sources of pollution, and 1500 ppm in agricultural areas (Kabata-Pendias and Pendias, 2001).

2.2.4 Zinc (Zn)

Zinc is a transition metal and its most common oxidation form is (Zn^{+2}). Zinc mostly occurs as single sulfides (ZnS) in nature. The primary use of zinc is to produce galvanized products for automobiles, and for structural components in the construction industry. Zinc is also used in brass and bronze production in plumbing as well as heating and cooling systems components. Zinc oxide is an important element in tire and other rubber goods production and is widely used in batteries (CCME, 1999b). It is estimated that 1.18 million tons of zinc is released annually in the Canadian environment. While weathering and other natural sources are the most important pathways, anthropogenic sources are responsible for 35% of zinc released. In Canada, the major sources of anthropogenic zinc in the environment are: electroplaters, smelting and ore processors, mine drainage, domestic and industrial sewage, combustion of solid wastes and fossil fuels, road surface runoff, corrosion of zinc alloy and galvanized surfaces, and erosion of agricultural soils (CCME, 1999b). The background level of total zinc is 81 ppm in the Appalachian Region of Canada, higher than 64 ppm, the estimated mean zinc concentration for worldwide soils (McKeague and Wolynetz, 1980).

Zinc in its elemental form is not soluble while its compounds can be both extremely soluble (sulphates and chlorides) and insoluble (oxides, carbonates, phosphates and silicates) (CCME, 1999b). The important factors controlling zinc mobility in soil are similar to that of copper. However, zinc exists in more readily soluble forms than copper. The most important factors controlling the zinc solubility in soil are clay minerals, hydrous oxides, and pH. Organic matter content and precipitation of zinc as hydroxide, carbonate, and sulfide compounds have less importance in the solubility of zinc in soil. In most soils, zinc accumulates in the surface horizons as a result of its bonding with organic matters (Kabata-Pendias and Pendias, 2001).

2.3 Trace elements in plants

2.3.1 Lead

The high lead content in vegetables grown in contaminated areas can potentially pose a health risk to consumers. Uptake rate of lead vary among and within species and is highly related to soil pH. Bioavailability of lead is higher in soils with lower pH (CCME, 1999c). Lead is absorbed by root hairs and stored mainly in cell walls. The lead concentration of different organs of the plant is different and the translocation of lead from roots to tops is very limited. It is reported that only 3% of lead absorbed via the root will accumulate in the shoot. The distribution of lead in different organs of corn plants grown in the soil with 300 ppm lead is as follows: Roots (over 100 ppm), leaves, stems, sheaths, and nodes (all around 5 ppm) (Kabata-Pendias and Pendias, 2001). The BCF, bioconcentration factor (the concentration of a chemical in the sampled tissue per concentration of that chemical in the soil) of lead for most plants generally ranges from 0.001 to 0.03. The Ontario Ministry of Environment (OMOE) adopted a conservative soil- to-plant BCF of 0.039 for common backyard fruits and vegetables (CCME, 1999c).

The concentration of lead in plants grown on uncontaminated sites ranges between 0.1 to 10 ppm, with the mean value of 2 ppm (dry weight). Table 2-1 summarizes the mean lead concentration of plants grown on uncontaminated sites. The highest bioaccumulation of lead is reported for leafy vegetables, especially lettuce, grown on contaminated areas close to smelters with aerial exposure to lead. Plants absorb lead from both soil and atmosphere (Kabata-Pendias and Pendias, 2001).

Table 2-1 Mean lead content of plant foodstuffs

Plant	Tissue sample	Dry weight of lead (ppm)
Sweet corn	Grains	0.88, 3, <0.3
Bean	Pods	2, <1.5
Beet (red)	Roots	2, 0.7
Carrot	Roots	3, <1.5, 0.5
Lettuce	Leaves	0.7, 2, 3.3, 3.6
Cabbage	Leaves	1.7, 2.3
Onion	Bulbs	2, 1.3, 1.1
Potato	Tubers	3, 0.5
Tomato	Fruits	3, 1, 1.2
Apple	Fruits	0.05, 0.2

* adapted from (Kabata-Pendias and Pendias, 2001)

2.3.2 Arsenic (As)

It is known that plants only uptake the soluble arsenic. Since over 80% of total arsenic is strongly associated with iron (Fe) and aluminum (Al), a limited fraction of total arsenic is readily available for plants to uptake. This depends on various factors including plant species, the chemical form of arsenic and temperature (CCME, 2001). Wetting and drying the soil decreases the availability of arsenic to rice plants. Where the soluble arsenic concentrations are lower than 10 ppm, the application of materials producing precipitates with arsenic (e.g. ferrous sulfite, calcium carbonate) also showed positive results in lowering the arsenic's bioavailability in soil. In addition, application of fertilizers - mainly phosphorous - also decreased its bioavailability. Arsenic also creates stable compounds with organics (Kabata-Pendias and Pendias, 2001).

There is a relationship between the arsenic content of vegetation and in soil. Some plants, such as Douglas fir, show a remarkable ability to uptake arsenic (Turpeinen, 2002). In lower concentration of arsenic, the higher accumulation of this element was seen in the old leaves. However, at high concentration, the highest content of arsenic occurred in both old leaves and roots. Table 2-2 shows the concentration of arsenic in plants grown in uncontaminated sites. It can be concluded that leafy vegetables have higher ability to accumulate arsenic, while fruits have the lowest content of arsenic. Mushrooms and pasture herbage also showed high ability to uptake arsenic (Kabata-Pendias and Pendias, 2001). The presence of arsenic in soil reduces the yield of several plants such as spinach, beans and radishes (CCME, 2001).

Table 2-2 Arsenic content of food and Forage plants

Plant	Tissue sample	Dry weight of arsenic (ppb)
Barley	Grains	3-18
Oats	Grains	10
Wheat	Grains	50, 3-10
Brown rice	Grains	110-200
Sweet corn	Grains	30-400,30
Snap beans	Pods	7-100
Cabbage	Leaves	20-50
Spinach	Leaves	200-1500
Lettuce	Leaves	20-250
Carrot	Roots	40-80
Onion	Bulbs	50-200
Potato	Tubers	30-200
Tomato	Fruits	9-120
Apple	Fruits	50-200
Orange	Fruits	11-50
Edible mushroom	Whole	280
Clover	Tops	20-160
Grass	Tops	280-330

* adapted from (Kabata-Pendias and Pendias, 2001)

2.3.3 Copper (Cu)

Phytotoxic effects were seen at concentration of copper as low as 50 ppm in the dry soil (CCME, 1999a). Although the rate of copper uptake differs widely with the species of metal, anthropogenic Cu showed higher uptake rate than the naturally existing copper in the soil. CCME (1999a) reported a soil-to-plant BCF of 0.2645 for several species. Most of this copper stays in the root and to a lesser extent in old leaf tissues. In general, copper has low mobility in plants relative to other elements (Kabata-Pendias and Pendias, 2001).

The appropriate content of copper is essential for some enzymatic reactions in the human body (CCME, 1999a). Copper content in US foods has been reported as (ppm of fresh weight):

- vegetables: range 0.1 – 3.2, the lowest value for celery roots and the highest for garlic cloves;
- fruits: range 0.3 – 4.0, the lowest value for grapes and the highest for avocados without skin;
- cereals: range 0.3 – 13, the lowest value for oats, whole grain, and the highest for rye, whole grain; and
- nuts: range 0.2 – 23.8, the lowest value for fresh coconut meat, and the highest for shelled Brazil nuts.

It is estimated that 30% of daily copper intake by adults in Europe is from cereal and potato consumption (Kabata-Pendias and Pendias, 2001).

2.3.4 Zinc (Zn)

Similar to copper, 50 ppm of zinc is toxic to plants. Higher zinc concentration in the soil resulted in the reduced concentration of iron in plants (CCME. 1999b). It was also shown that the presence of Ca in the soil can reduce the concentration of zinc in the plant. The zinc uptake in plants is linear with the zinc concentration in the soil. However, the rate of Zn absorption differs between plant species. Unlike copper and lead, zinc is a relatively

mobile element in the plant. Generally, roots contain higher concentration of zinc than tops (Kabata-Pendias and Pendias, 2001).

This is true in contaminated soils, but in areas where zinc is in airborne pollution, the concentration in the tops of plants is higher. The reported zinc concentration of plants grown in highly contaminated sites can potentially cause a human health risk. Zinc content in US foods has been reported as (ppm of fresh weight):

- vegetables: range 0.7 – 8.0, the lowest value for celery roots and the highest for spinach;
- fruits: range 0.4 – 3.0, the lowest value for grapes and the highest for currant;
- cereals: range 0.7 – 32.5, the lowest value for barely pearls (cooked), and the highest for rye, whole grain; and
- nuts: range 5 – 42.3, the lowest value for fresh coconut meat, and the highest for shelled Brazil nuts (Kabata-Pendias and Pendias, 2001).

2.4 Maximum acceptable concentration of heavy metals

CCME is comprised of the environment ministers from the federal, provincial and territorial governments with the intention of protecting Canada's environment. CCME developed the Canadian Soil Quality Guidelines for the protection of environmental and human health. These guidelines protect the ecological receptors in the environment and / or human health for various land applications. Land uses were classified into the following four categories: agricultural, residential/parkland, commercial, and industrial (CCME, 1999d).

To protect the key ecological receptors in the environment, toxicological data (dose-response data) was used to determine the threshold level. The maximum acceptable level is the highest concentration at which diverse health effects cannot be seen in the exposed receptor. Direct soil contact is the primary exposure pathway for residential / parkland, commercial, and industrial land uses. Soil and food ingestion was considered the major

exposure pathway in agricultural land use. The dose-response models used to develop human health soil quality guidelines are more sensitive. For carcinogens presenting some risk at any level of exposure, guidelines are based on estimated lifetime incremental cancer risk from exposure to soil (CCME, 1999d).

Canada is not the only country to set a guideline for the maximum acceptable concentration of heavy metals in soil. Table 2-3 shows the allowable concentration of some heavy metals for residential/recreational land use (not the agricultural land uses). Considerable differences are seen between countries and regions. In some regions there is a different criterion for soil with the pH below and above 7. As it is shown, Canadian regulation is one of the most conservative.

Table 2-3 Maximum acceptable limits (ppm) of heavy metals in soil in various countries and regions for residential and recreational land uses

Country or region	Cr	Ni	Pb	Zn	Cu
Spain-Andalucía ^{abc}	250-400/250-400	80-200 / 100-300	250-350 / 400-500	300-600 / 500-1000	150-300 / 300-500
Canada	64	50	140	200	63
Spain – Euskadi	400	500	450	-	-
Italy	150	120	100	150	120
Portugal ^{ab}	200/300	75/110	300/450	300/450	100/200
Quebec	250	100	500	500	100
Slovenia ^{ad}	100/150/380	50/70/210	85/100/530	200/300/720	60/100/300
Sweden ^e	120	35	80	350	100
UK ^f	200	75	450	-	-

^aNo distinction is made for any particular land use. ^bDifferent values are given for pH below and above 7. ^c„Research required“ values (ranges instead of single values are given). ^d„Limit“, „warning“ and „critical“ values. ^e„KM“, land with sensitive use (residential areas, kindergarten, agricultural, etc.). ^fTypical CLEA Soil Guideline Values.

*adopted from (Madrid et al., 2006)

2.5 Case studies

Lead and other heavy metal contaminations in urban soils, especially in urban garden soil, has been studied in many cities (Rasmussen et al., 2001; Manta et al., 2002; Clark et al., 2006; Clark et al., 2008; Wu et al., 2010; Bell et al., 2010).

Clark et al. (2008), studied 141 backyard gardens and 23 raised-bed gardens in Roxbury and Dorchester, MA, USA. The approximate average size of each garden was 10-20 m², and garden soil was generally adjacent to buildings. A minimum of four samples, generally two from surface horizon (0-10 cm) and two from the rooting depth (30-40 cm), was collected. In a previous study, Clark et al. (2006), showed that the soil lead

concentration is relatively homogenous due to many years of gardening activities. Therefore, the collection of approximately five samples per garden provides a representative profile of soil lead concentration. The values of lead concentration in backyard gardens ranged from 80 to 3680 ppm with the mean value of 950 ppm. The mean value of lead concentration in raised-bed gardens was 336 ppm.

Manta et al. (2002), studied the heavy-metal contamination of green areas and parks in the city of Palermo, Sicily, Italy. A total of 70 non-stratified topsoil samples (depth 0-10 cm) were collected. At each sampling point, three sub-samples, within a 20×20 cm surface area were taken, and then mixed to obtain a bulk sample. All samples were air dried for 24 hours within 12 hours after the sampling. The reported median values of lead, zinc, copper and mercury concentrations of the sampled soils were 202, 138, 63, and 0.63 ppm, respectively.

In a review conducted by Wei and Yang (2010), heavy-metal concentrations in urban soils, urban road dusts and agricultural soils in China were compared. The urban and agricultural soil samples were mainly collected to a depth of 10 or 20 cm. The urban soil samples were collected mostly from urban parks, green lands and city roadsides. Composite sampling was used in urban and agricultural sites. The road dust samples were collected by sweeping the 1 m² area of the road surface. The total concentration of heavy metals was measured and indicated that nearly all the concentrations of heavy metals were higher in urban centers than in agricultural soils. In addition, they found that the concentrations of heavy metals vary significantly among the cities and concluded that the contamination of Cr, Ni, Cu, Pb, Zn, and Cd is widespread in urban soils in China.

Zheng et al. (2008), studied the heavy-metals concentration of topsoil in Beijing. 773 topsoil samples (depth 0-20 cm) were collected from all over the city. Composite samples with five sub-samples were collected at each sampling site using a stratified sampling technique. They identified the spatial variability and main sources of heavy metals. Contour maps were constructed to visualize the spatial distribution of As, Cd, Cr, Cu, Ni, Pb, and Zn in the soil samples. The centre of the city had the highest concentration of

these heavy metals, leading the authors to conclude that vehicle exhaust and smelters were the main anthropogenic sources of heavy-metal contamination in Beijing.

Madrid et al. (2006), compared the concentration of Cu, Cr, Ni, Pb, and Zn in urban parks in six European cities with a different climate and industrial history. They chose visually homogeneous parks, or areas within parks, centrally-located and as far as possible from current point sources of pollution. All the parks bordered major roads, and only conventional maintenance operations were normally performed. A sampling grid of at least 25 points (50×50 m apart) was defined at each site. A surface sample (depth 0–10 cm) and a sub-surface sample (depth 10–20 cm) were collected at each sampling point using a trowel or (plastic-lined) corer. As expected, concentrations of heavy metals were higher in older and more industrialized cities such as Glasgow. The study found that Cu, Zn, and Pb contamination tends to occur together at the same site, while the same was true with Ni and Cr contamination.

Chapter 3: Methodology

3.1 Sampling method

A total of 220 samples from 44 locations were collected within the HRM. Since the study's focus is on community gardens, active and established gardens, as well as potential garden locations, were selected as sampling locations. Potential gardens were mostly located at municipal parks and also along roadway medians. Some of these areas have been used for gardens in the past. A majority of the gardens sampled were using the location's existing soil; however, soil samples were also collected from a few raised-bed gardens to compare the level of contamination in brought-in soil with the native soil.

Standard Practice for Field Collection of Soil Samples for Subsequent Lead Determination (ASTM, 2005), was followed in this study. Five non-stratified soil samples were collected from each location (depth = 0-10 cm). For each sample, three sub-samples within a (0.60 m) diameter circle were taken and then mixed to obtain a bulk sample. An aluminum trowel was used to eliminate contamination from sampling equipment.

3.2 Analytical method

Soil samples were air dried, ground with a mortar and pestle and then sieved through a 2-mm sieve (USS # 10 sieve) to achieve a homogenous sample. Soil pH was measured in distilled water, using a pH meter (Cole Palmer, Model 05669-20), with a soil: solution ratio of 1:1.

Loss-on-ignition (LOI) was used as an indicator for soil organic matter content following the procedure developed by Dean (1974). A sample of 5 – 10 grams of oven-dried soil was transferred into a crucible with a known weight. Total weight loss was measured after two hours in a muffle furnace at 550 °C (Lindberg Hevi-Duty made by Sola Basic). Organic matter is combusted at a temperature between 500 and 550 °C to ash and carbon dioxide (Craft et al., 1991). It is possible to estimate the organic carbon content of the soil

using various developed regression models (Dean 1974; Craft et al., 1991; and Santisteban et al., 2004). However, these relationships are affected by soil composition and are site specific (Santisteban et al., 2004). For this study, the relationship between LOI and OM implemented in the NS soil labs, Equation 3-1, (obtained through personal communication with the technical laboratory operations supervisor at NSAC) was used to estimate the organic matter content.

Equation 3-1

An acid digestion was used to extract bioavailable arsenic, lead, copper and zinc from the soil samples (USEPA, 1996). EPA Method 3050B is not a total digestion technique but will bring into solution almost all the elements that could become environmentally available. It does not extract elements bound with silicate structures. Following this method, one gram of oven-dried soil was digested using concentrated nitric acid, hydrogen peroxide, and concentrated hydrochloric acid.

Soil sample pretreatment, pH and LOI measurement, as well as digestion procedures were carried out at the NSAC analytical chemistry laboratory. The extracts were analyzed, using inductively coupled plasma emission spectrometry (ICP-OES), at the Mineral Engineering Centre (MEC) at Dalhousie University.

Chapter 4: Results and Discussion

4.1 Physico-chemical parameters

The pH and the Loss On Ignition (LOI), in order to estimate the Organic Matter (OM) content, were determined for the soil samples collected from current and potential gardens in the HRM. Values of pH ranged from 4.07 to 6.88 with the median value of 5.89. This suggested slightly acidic conditions for all the soil samples. The OM of soil samples had larger range. The samples lost a minimum of 2% and maximum of 32% of their weight after one hour in the muffle furnace at 450 °C following the method developed at the NSAC to measure soil organic matter. The OM content of all the soil tested for this study ranged from 1.93% to 20.47% with the median value of 5.02%.

4.2 Determining heavy metals of concern

Initially, samples from four different locations were analyzed for the concentration of 17 heavy metals using ICP-IOIS following the standard digestion U.S. Environmental Protection Agency Method 3050B, Revision 2, Acid Digestion of Sediments, Sludges, and Soils. Concentrations of these elements were compared with the CCME soil quality guideline for agricultural land use (Table 4-1). On the basis of this comparison, four elements – lead, arsenic, copper and zinc – were chosen for this study, because they may present at concentrations greater than the guidelines, as shown in a geographically close and historically similar city – St. John’s, NL (Bell, 2003).

Table 4-1 Mean concentration (ppm) of heavy metals in topsoil samples

Sample	Ag	As	Ba	Be	Cd	Co	Cr	Cu	Mn	Mo	Ni	Pb	Sb	Se	Sn	V	Zn
512PA	4	55	4	1	2	9	22	72	305	6	25	510	<1	<1	18	104	188
53PA	3	9	7	1	<1	10	21	16	582	<1	16	26	<1	<1	<1	24	70
62CG	<1	9	7	1	<1	9	18	17	488	<1	15	17	<1	<1	<1	27	129
63CG	<1	12	7	1	<1	7	14	19	337	<1	14	74	<1	<1	<1	33	95
guideline	20	12	500	4	10	50	64	63	770	10	50	70	20	1	50	130	200

4.3 Bioavailable heavy metal content

4.3.1 Lead

In total, 220 soil samples were collected from 26 community and private gardens as well as 18 municipal public parks and lands across the HRM. Lead concentration ranged from 10 to 767 ppm with the mean value of 109 ppm. Canadian soil quality guideline for lead is 70 ppm for agricultural lands (CCME 1999c). This would be the highest allowable concentration for land used for food production. As shown in Table 4-2, 15 locations or almost 34% of sampling sites had average lead concentration above the CCME guideline. The results are highly skewed with 50% of the samples below 43 ppm.

Data presented in Table 4-2, presents sampling locations in open spaces, community and backyard gardens, and raised-bed gardens. Open spaces are medians and public parks. Most of the samples were collected from active gardens in schools and community gardens, and a few backyard gardens. Lands that might be turned into community gardens were also sampled. Gardens with raised bed were classified separately from the private and community gardens in the following table in order to determine their distinctive lead concentration.

The concentration was significantly lower in raised-bed gardens than in native soils. However, one raised bed had higher lead concentration than the CCME guideline. Possible sources of contamination in raised-bed soils might be anthropogenic sources

such as atmospheric deposition or migration from adjacent soil due to the lack of efficient lining. It is also possible that the brought-in soil was contaminated. The wide range of lead concentration in the top soil (10 – 767 ppm), suggests an anthropogenic source for lead contamination. The mean value of lead concentration in the raised-bed gardens is significantly smaller than the lead concentration of other sampling locations using the two-sample t-test for unequal variances, $t(40) = 3.03$, $p \leq 0.004$. As expected, the mean value of lead concentration in open spaces is not significantly smaller than the lead concentration in community and backyard gardens, $t(30) = -0.25$, $p \leq 0.8$.

Table 4-2 Descriptive Statistics for soil lead concentrations

Sample category	N	Mean	SE	Min.	Median	Max.	Number above the guideline
Open spaces	18	121	38	17	59	585	7 (~39%)
Community and backyard gardens	17	137	49	10	52	767	7 (~41%)
Raised-bed gardens	9	32	10	11	19	101	1 (~11%)
All	44	109	25	10	43	767	15 (~34%)

Figure 4-1 shows the mean concentration of lead in sampled sites using a bar chart. Only the mean value of lead in raised-bed gardens is lower than the CCME guideline. The mean value of lead concentration in community gardens and backyard soils is higher than the open spaces. This might be due to dumping coal ashes or other waste materials into backyards. The error bars show a range of lead contamination in each type of garden. The backyard and community gardens have the widest range. In other words, the level of contamination in community gardens and backyards is not the same.

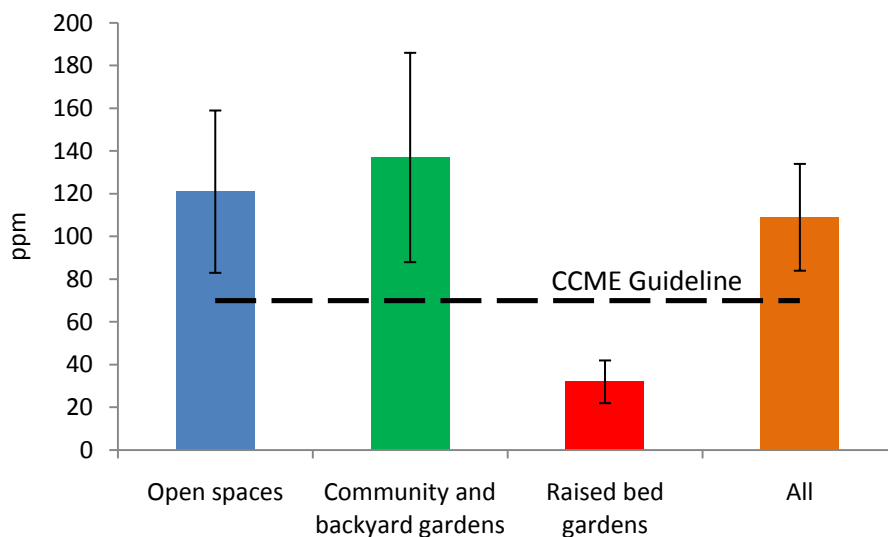


Figure 4-1 Mean concentrations of lead in sampled sites

Figure 4-2 shows the spatial distribution of lead in all sampled sites. No obvious trend can be seen in this map. The lead content of garden soil is very site specific, varying considerably from even in the same neighborhood. The hypothesis of a significant contribution from the Halifax explosion to the lead content of Halifax soil can also be rejected as the area close to the explosion site does not show a higher concentration of lead.

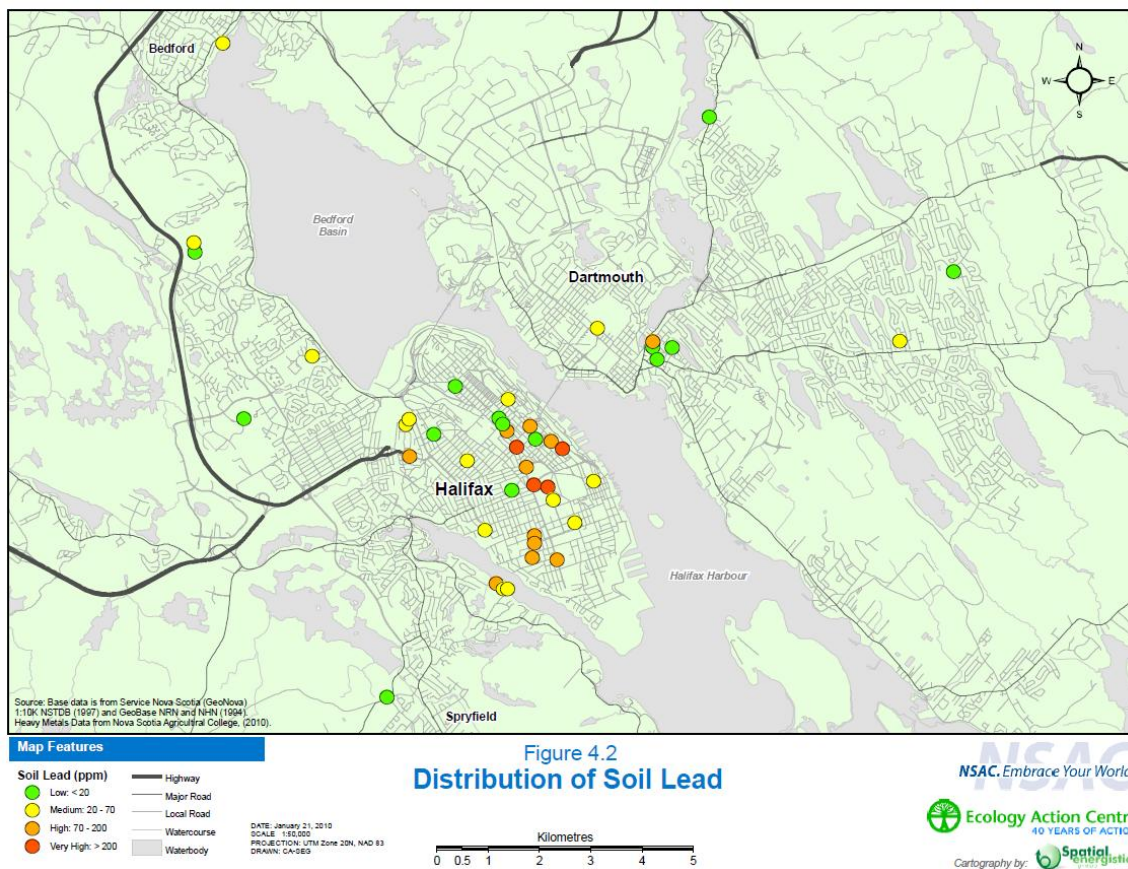


Figure 4.2
Distribution of Soil Lead

Figure 4-2 Distribution of Soil Lead

In order to study the lead content of the original soil, the lead level of raised-bed gardens was excluded in Figure 4-3. It shows that the lead concentration of soil in the Halifax peninsula is higher than outside the peninsula. Higher lead concentrations were also seen in two sampling locations in downtown Dartmouth. Elevated lead level in downtown areas has been seen in other studies, including in St. John's, NL (Bell et al., 2010). This shows the importance of anthropogenic sources of contamination, such as old paint, in the lead content of the soil.

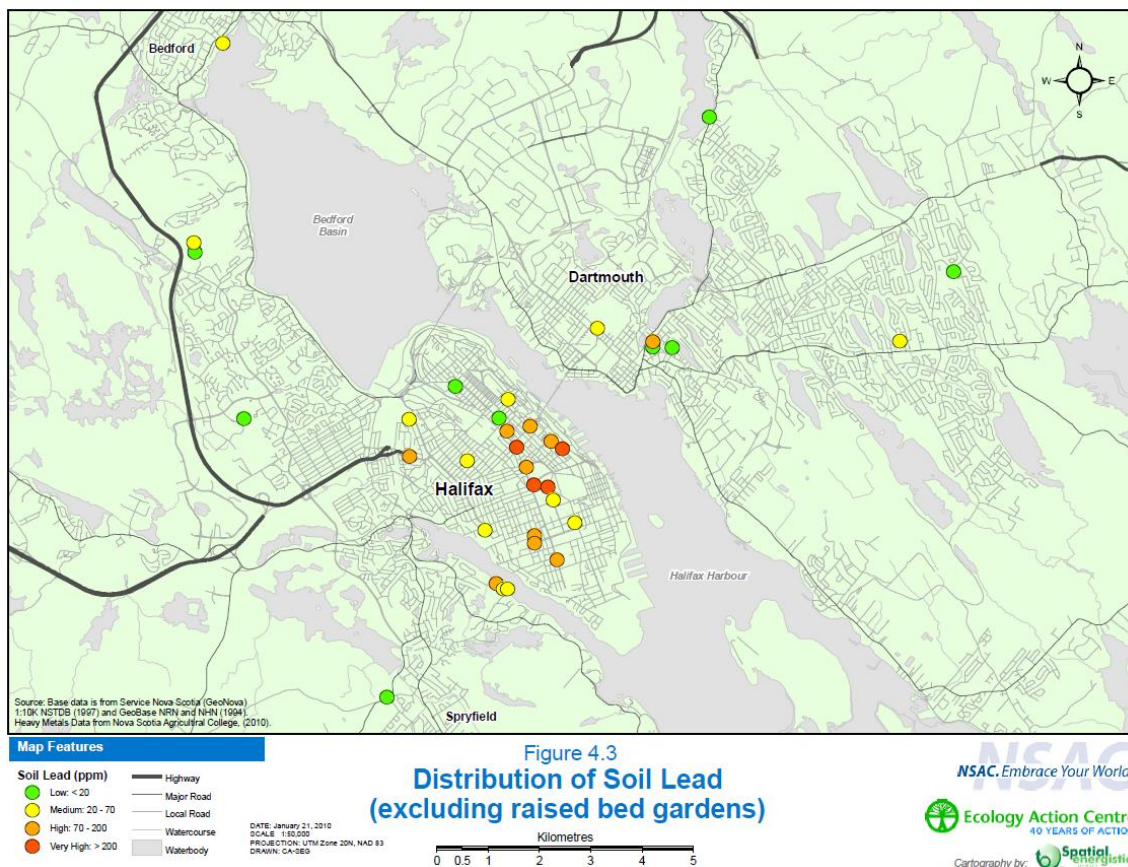


Figure 4-3 Distribution of Soil Lead (excluding raised bed gardens)

4.3.2 Arsenic

Table 4-3 shows the descriptive statistics of arsenic concentration in collected soil samples. Arsenic concentration ranged from 4 to 153 ppm with the mean value of 21 ppm. The Canadian soil quality guideline for inorganic arsenic is 12 ppm for agricultural lands (CCME, 2001). Twenty-one of 44 sampling locations (~ 48%) had the average concentration of above 12 ppm. It is important to note that arsenic naturally exists in elevated levels in Nova Scotia. Goodwin et al. (2009), reported that the majority of the soil samples collected from Southern Nova Scotia exceeds CCME guidelines for arsenic. They reported that the arsenic concentrations in C-horizon soil samples ranged from a low of 2.2 ppm to a high of 345.7 ppm, with a mean concentration of 22.3 ppm, and a median value of 12.3 ppm. Manta et al. (2002), also demonstrated the enrichment of heavy metals in the topsoil because of bedrock.

Table 4-3 Descriptive Statistics for soil arsenic concentrations

Sample category	n	Mean	SE	Min.	Median	Max.	Number above the guideline
Open spaces	18	31	11	6	13	153	9 (~50%)
Community and backyard gardens	17	16	3	6	13	45	9 (~53%)
Raised-bed gardens	9	10	2	4	9	20	3 (~33%)
All	44	21	5	4	12	153	21 (~48%)

Columns in Figure 4-4 show the mean concentration of arsenic in sampled sites.

Concentration of arsenic in raised beds is lower than other sampled locations and the range is relatively small suggesting non-anthropogenic sources of contamination in the brought-in soil. Arsenic concentration was very high in two parks sampled for this study. Excluding these two results, the difference between the mean value of the arsenic concentration in open spaces and community and backyard gardens is not significant, $t(29) = -0.195$, $p \leq 0.8$.

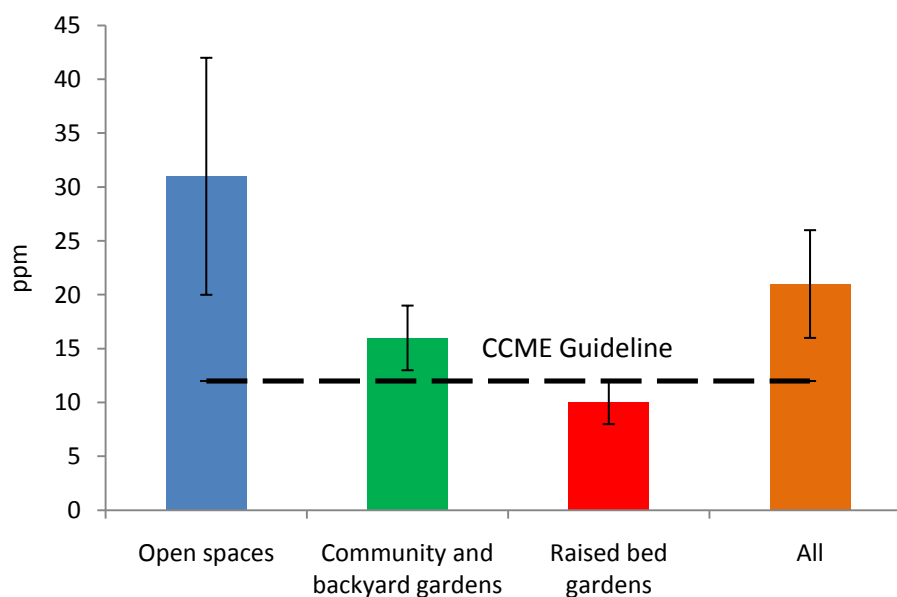
**Figure 4-4 Mean concentrations of arsenic in sampled sites**

Figure 4-5 shows the map of mean arsenic concentration in all sampled sites. Few locations have low level of arsenic contamination. It seems that the concentration of arsenic is higher closer to the downtown Halifax; however, few low concentrations exist in the peninsula. Similar to lead, the arsenic level of garden soil is very site specific, and varies considerably even in the same neighborhood.

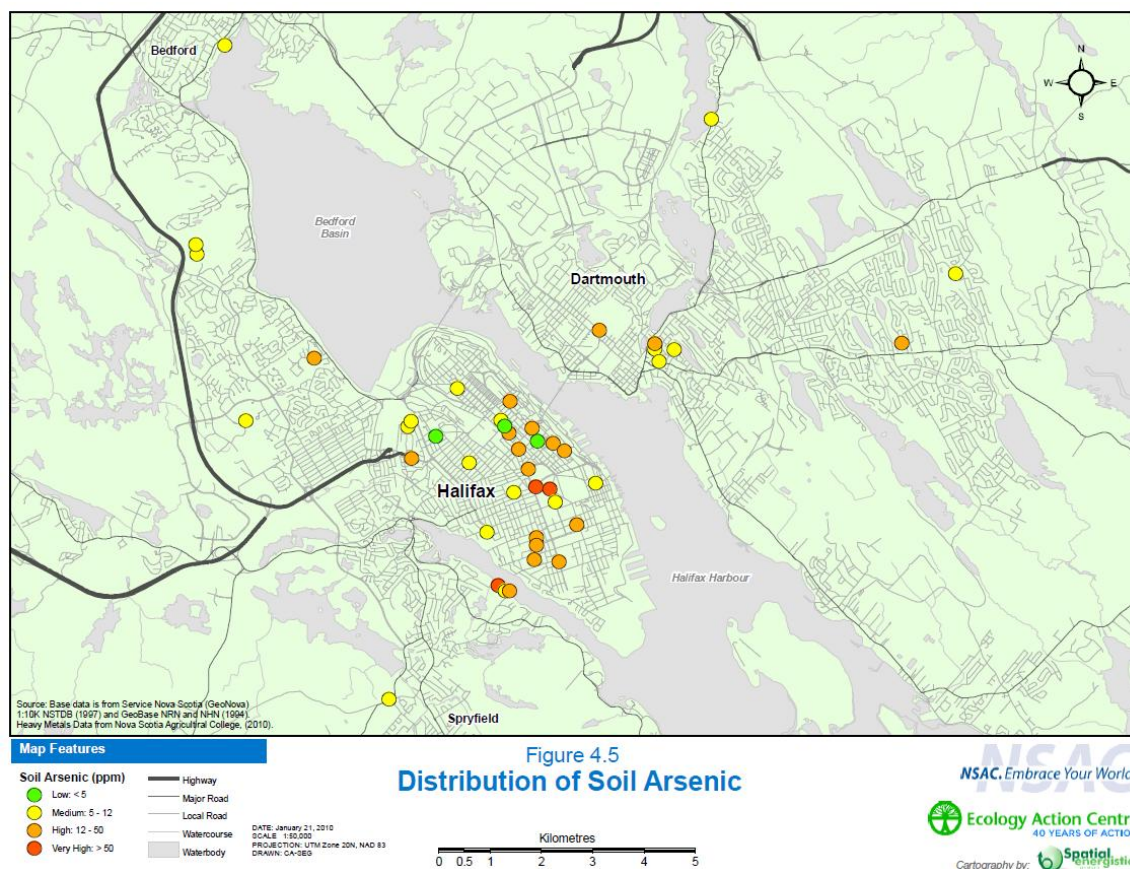


Figure 4-5 Distribution of Soil Arsenic

It is useful to study the arsenic content of the original soil so arsenic concentration of raised-bed gardens was removed from the previous map. Figure 4-6 shows that all the sampling locations with high and very high concentrations of arsenic are located inside of, or very close to, the downtown area. This shows the importance of anthropogenic sources of arsenic contamination in the soil. Few sampling locations with low arsenic

content were raised-bed gardens with brought-in soil. Overall, the arsenic content of the HRM soil is high.

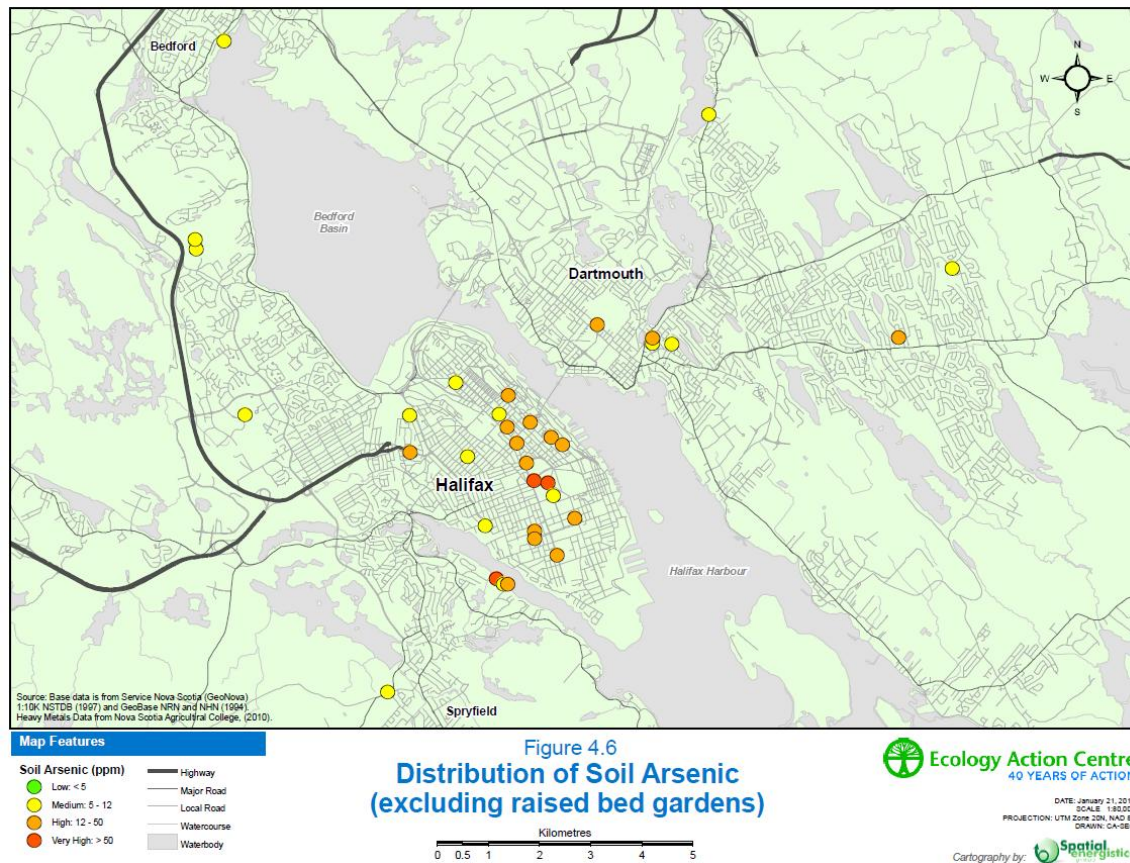


Figure 4-6 Distribution of Soil Arsenic (excluding raised-bed gardens)

4.3.3 Copper

Table 4-4 shows the summary of copper concentration in the sampled locations. Copper concentration ranged between 11 and 108 ppm with the mean value of 30 ppm. Canadian soil quality guideline for total copper is 63 ppm for agricultural lands (CCME 1999a). Using digestion method 3050B, only environmentally available copper was measured in this study. Therefore, the measured values underestimate the actual concentration of total copper in the sampled soils. The highest copper concentration was seen in a community garden with high concentration of other heavy metals as well. The site had been a junk yard for many years.

Table 4-4 Descriptive Statistics for soil copper concentrations

Sample category	n	Mean	SE	Min.	Median	Max.	Number above the guideline
Open spaces	18	27	4	13	20	79	2 (~11%)
Community and backyard gardens	17	35	6	15	30	108	1 (~6%)
Raised bed gardens	9	25	4	11	20	52	0 (0%)
All	44	30	3	11	23	108	3 (7%)

The mean values of copper contamination in all three categories of soil samples do not differ significantly from each other after performing t-test for unequal variances. As it is shown in Figure 4-7, all three categories of sampled sites had lower concentration of copper than the CCME guideline. As a result of one very contaminated site, the mean concentration of copper in backyard and community gardens is higher than other sampled locations.

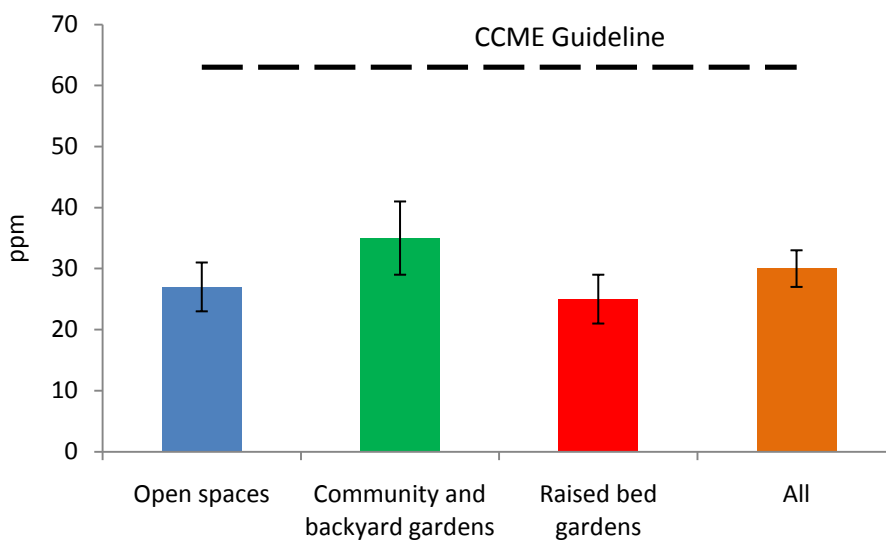
**Figure 4-7 Mean concentrations of copper in sampled sites**

Figure 4-8 shows the spatial distribution of the mean concentration of copper in all sampled sites. Most locations have low level of copper contamination except for

relatively higher concentrations in the downtown area of Halifax and Dartmouth. Few high and very high concentrations of copper were found close to downtown Halifax. Similar to arsenic and lead, the copper level of garden soil is very site specific, and it might vary considerably even in the same neighborhood.

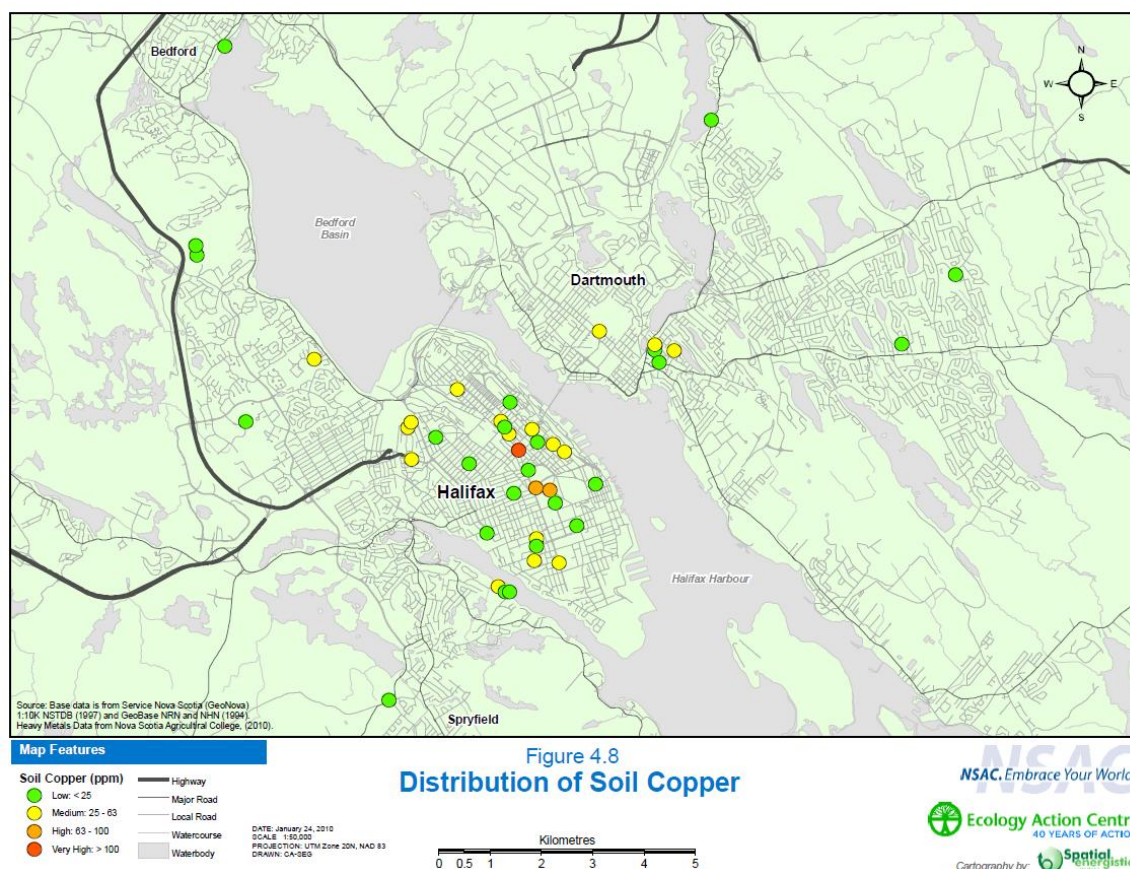


Figure 4-8 Distribution of Soil Copper

4.3.4 Zinc

Table 4-5 shows the summary of zinc contamination in the topsoil samples collected for this study. Zinc concentration ranged between 42 to 350 ppm with the mean value of 107 ppm. Half of the sampled locations had zinc concentrations of below 92 ppm. The high range of zinc concentration suggests anthropogenic sources of contamination. Canadian soil quality guideline for total zinc is 200 ppm for agricultural lands (CCME 1999b). Similar to copper, the concentrations of zinc in the soil samples were underestimated.

Table 4-5 Descriptive Statistics for soil zinc concentrations

Sample category	n	Mean	SE	Min.	Median	Max.	Number above the guideline
Open spaces	18	95	12	43	84	219	2 (~11%)
Community and backyard gardens	17	121	18	56	104	350	2 (~12%)
Raised bed gardens	9	103	15	42	104	194	0 (0%)
All	44	107	9	42	92	350	4 (~9%)

Figure 4-9 shows the mean concentration of zinc in sampled sites. In contrast with other heavy metals, it was higher in community and backyard gardens and it was the lowest in open spaces. This might be due to implementation of metal fences and barriers around gardens. Galvanized fences are an important anthropogenic source of zinc contamination in soil. The mean values of all three categories of sampled locations are lower than the CCME guideline.

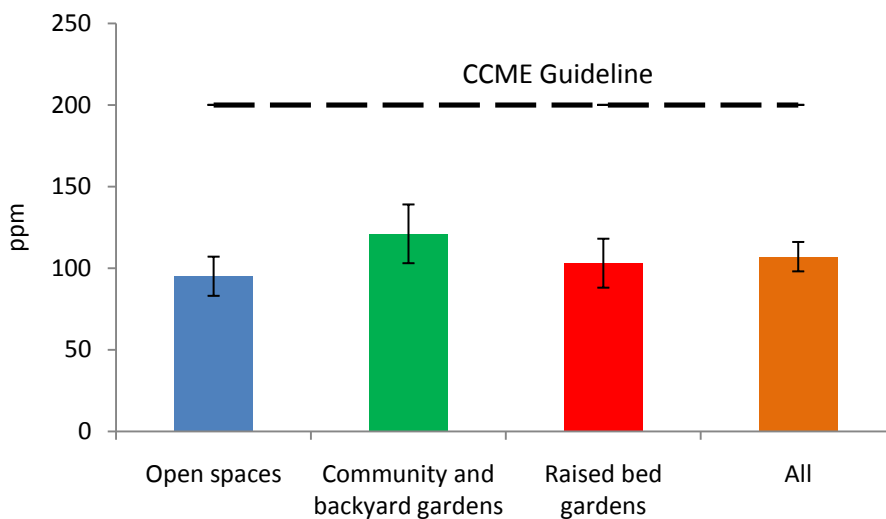
**Figure 4-9 Mean concentrations of zinc in sampled sites**

Figure 4-10 shows the spatial distribution of the mean concentration of zinc in all sampled sites. Most locations have low level of zinc contamination. Note that nearly all

sites with medium, high and very high concentration of zinc happen to be in the downtown area of Halifax and Dartmouth. Similar to other heavy metals studied for this project, the concentration of zinc in the garden soil is very site specific, and it might vary considerably even in the same neighborhood.

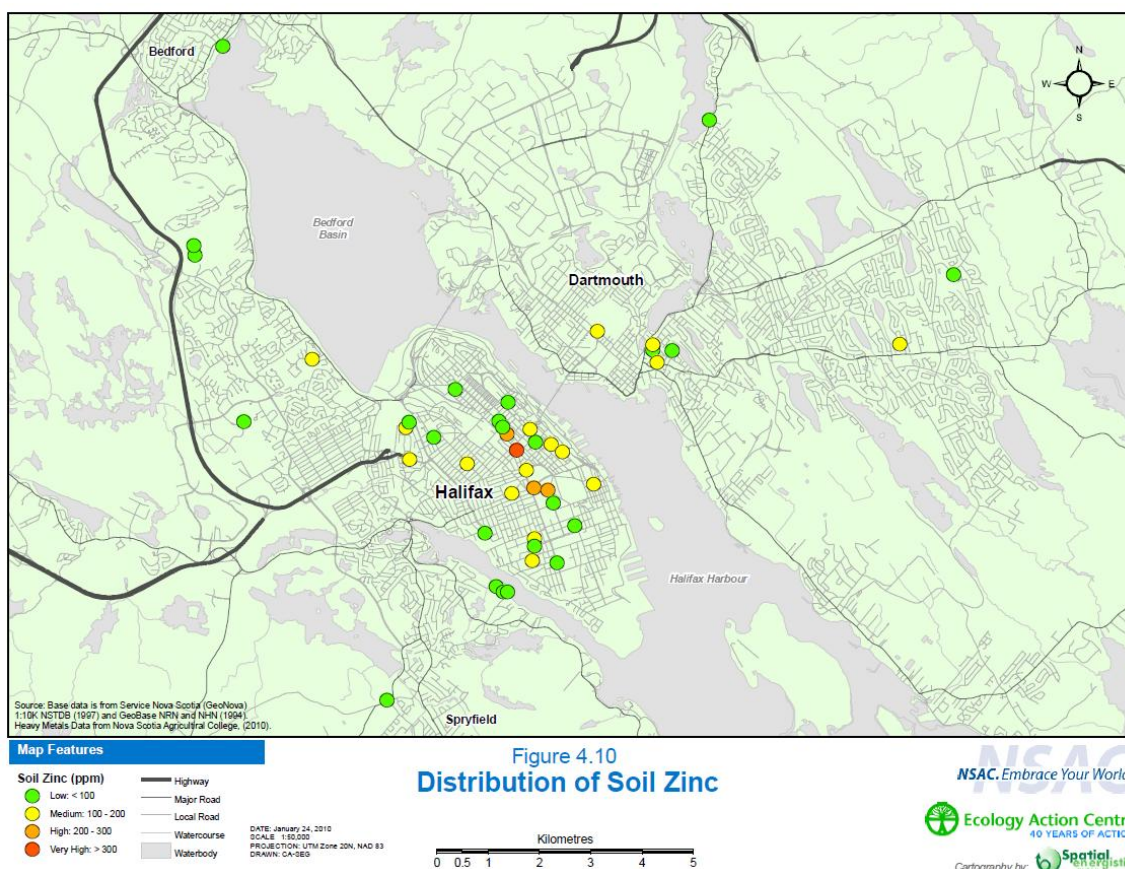


Figure 4-10 Distribution of Soil Zinc

Correlations between the concentrations of heavy metals were also studied. Arsenic was not strongly correlated with lead ($r = 0.56$), copper ($r = 0.50$), and zinc ($r = 0.34$). It suggests that the source of arsenic contamination is probably different than that of other elements. On the other hand, lead was well correlated both with copper ($r = 0.86$) and zinc ($r = 0.79$). Lead, copper and zinc are all commonly used in paint. The correlation might be also due to coal burning. Bell (2003), also found the same pattern in a study conducted in St. John's, NL. Copper concentration is also well correlated with zinc ($r =$

0.86).

To conclude, the Halifax peninsula has higher concentrations of heavy metals. In addition, the soil brought in to the gardens from other places had lower concentration of heavy metals. The hypothesis of considerable contribution of the Halifax explosion to the heavy metal content of Halifax soil can be rejected as the area close to the explosion site does not show a higher concentration of these elements.

Bell et al. (2010), reviewed the results of various Canadian studies (Table 4-6), also included in the following table. The median soil lead concentration of the HRM (43 ppm) is higher than the reported values for Sudbury, Ottawa and Iqaluit. However, it is significantly lower than values reported for soil lead concentration in Sydney and Trail where there is a point source of contamination. It is important to note that the sampling strategy and locations, as well as the sample digestion technique used for each study, plays an important role in the measured lead concentration.

Table 4-6 Soil lead contamination for Canadian cities. The data for Halifax are from this study

City	Population	Metric	Lead (ppm)	Sample type
Halifax, NS	418,261	Median	43	Garden soil, parks, medians, school yards
This study		Mean	109	
St John's, NL	95,000	Median	148	Residential soil collected from open spaces, along foundations, and by roadsides
		GM	162	
Belledune, NB	1,711	Median	43-136	Roadside
Sydney, NS	24,115	Median	340	Residential soil collected away from buildings and roads near the coke ovens
Victoria, BC	75,000	Median	90	Boulevards, parks, schoolyards
Trail, BC	7,575	GM	756	Residential soil collected from two to three areas of exposed soil where children play
Port Colborne, ON	18,600	Median	167	Residential topsoil collected at least
Sudbury, ON	157,857	Mean	30	Various locations downwind from three Ni- and Cu-smelters
Ottawa, ON	323,340	Median	34	garden soil collected from five locations in yard
		Mean	65	
Iqaluit, NU	4,220	Median	13	Commercial and residential sites sampled at grid intersections and also targeted samples from playgrounds, roads, and culverts

*Adapted from (Bell et al., 2010)

Chapter 5: Conclusion and Recommendation

The concentration of lead, arsenic, copper and zinc was measured in samples collected from current and potential gardens in the HRM. Within each site, random samples were collected to obtain a representative estimation of heavy metal contamination in each garden. Partial digestion of soil samples was carried out to estimate the bioavailable concentration of heavy metals. Soil heavy metal concentrations were compared to the CCME soil quality guidelines for agricultural lands in order to assess the level of contamination and potential risk to human and ecological health. The results of this study indicate that more than one third of samples had higher concentration of lead than the CCME guideline. Arsenic contamination was also seen widely in the sampled sites, with a concentration higher than the CCME guideline in almost half of the sampled locations. This was expected due to the high background concentration of arsenic in Nova Scotia soils and bedrock. Copper and zinc were also measured for this study and only a few sampled locations had higher concentration of these elements than the CCME guideline. However, the concentration of zinc and copper might have been underestimated due to the selection of the digestion method.

Following the correlation analysis, it was concluded that the occurrence of lead, zinc, and copper are related. There were no obvious patterns for spatial distribution of these heavy metals in the HRM. By comparing the results of this study with similar studies conducted in other Canadian cities, it was concluded that the lead concentration in the HRM was lower than Sydney, NS, Trail, BC, and St. John's, NL, and higher than Sudbury, Ottawa, and Iqaluit. It is important to keep in mind that concentrations of heavy metals between cities might not be directly comparable, as some studies use different sampling strategies and analytical methods.

Overall, raised-bed gardens had lower concentration of heavy metals; however, maintaining raised beds to prevent migration of contamination from adjacent lands is crucial. In order to reduce the influence of wind-transported contamination, it is

recommended to remove the 3 – 5 cm of soil and replace it with compost each year (Clark et al., 2008). Various other studies have investigated phytoremediation of contaminated gardens. Further research is required to study the feasibility of phytoremediation for HRM gardens, but Clark et al. (2008) concluded that unamended phytoremediation is not a viable technique for urban communities. The soil intervention also studied, and the high cost of process, makes it an impractical option for soil remediation. Clark et al. (2008) concluded that raised beds are the best option for growing food in contaminated lands as they allow gardeners to continue growing produce without replacing all the garden soil. They also reported that the remediation on a yard-by-yard scale is not effective in an urban community with regional lead contamination as a result of recontamination from wind-transported fine grain soil from adjacent contaminated lands.

Roots tend to accumulate heavy metals from the soil more than other tissues of the plant. However, direct ingestion of contaminated soil (adhering to roots) is considered the major exposure pathway of these heavy metals (Clark et al., 2008). Peeling root vegetables such as potatoes and carrots as well as washing or disposing old leaves, is recommended. Washing hands carefully after gardening is also very important. Vegetables such as spinach, cabbage, mustard, sunflower, and lettuce showed higher accumulation of heavy metals especially in their roots and older leaves.

It is important to mention that the consumption of produce from contaminated gardens contributes a small percentage of daily lead exposure. For example, in a study conducted by Clark et al. (2008), in Boston communities of Roxbury and Dorchester, MA, only 2-3% of daily lead exposure takes place through consumption of produce, while ingestion of soil contributes to 72-91% of the daily lead intake. They concluded the other sources of lead exposure to be inhalation of ambient air (2-5%) and consumption of tap water (1-5%).

This is a preliminary study providing an indication of four heavy-metal contaminations in the sampled gardens. More elements and sampling locations should be considered for the

next step of this study. By performing isotopic analysis, the source of heavy-metal contamination in the soil can be identified and remediation options for contaminated soil, specifically for the HRM, can be studied. The heavy-metal contamination of indoor dust and its relation with garden and neighborhood contamination can also be investigated.

Ecology Action Centre strongly supports organic urban gardening. For new gardens, testing the local soil for heavy metals and comparing the results with the CCME guidelines is suggested. Raised-bed gardens with clean and high quality soil are highly recommended, especially within the peninsula. Special attention should be given in selection of the wood and soil of raised beds since they can potentially contain high level of toxic materials. Lining the new gardens with appropriate barriers will further reduce the migration of heavy metals from existing soil to the garden soil.

Ingestion of soil is the most important pathway of heavy metals into a human body; it is important to clean hands after gardening and wash produce carefully. Since heavy metals tend to accumulate in roots, peeling root vegetables before eating them is a good habit to reduce the daily intake of heavy metals.

Reference list

- ASTM, 2005. E1727 - 05 Standard Practice for Field Collection of Soil Samples for Subsequent Lead Determination. DOI: 10.1520/E1727-05
- Bell, T., 2003. Lead in soils, St. John's, Newfoundland: A preliminary assessment. St. John's, Memorial University of Newfoundland, Unpublished report.
- Bell, T., Campbell, S., Liverman, D.G.E., Allison, D., Sylvester, P., 2010. Environmental and potential human health legacies of non-industrial sources of lead in a Canadian urban landscape – the case study of St John's, NL. *International Geology Review* 52, 771.
- Brown, K.H., Carter, A., 2003. Urban Agriculture and Community Food Security in the United States: Farming from the City Center to the Urban Fringe. Community Food Security Coalition, Venice, California.
- CCME - Canadian Council of Ministers of the Environment, 1999a. Canadian soil quality guidelines for the protection of environmental and human health: Copper (1999), in: Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg.
- CCME - Canadian Council of Ministers of the Environment, 1999b. Canadian soil quality guidelines for the protection of environmental and human health: Zinc (1999), in: Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg.
- CCME - Canadian Council of Ministers of the Environment, 1999c. Canadian soil quality guidelines for the protection of environmental and human health: Lead (1999), in: Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg.
- CCME - Canadian Council of Ministers of the Environment, 1999d. Canadian soil quality guidelines for the protection of environmental and human health: Introduction, in: Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg.
- CCME - Canadian Council of Ministers of the Environment, 2001. Canadian soil quality guidelines for the protection of environmental and human health: Arsenic (inorganic) (1997). Updated In: Canadian environmental quality guidelines, 1999, in: Canadian environmental quality guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg.

- Clark, H.F., Brabander, D.J., Erdil, R.M., 2006. Sources, sinks, and exposure pathways of lead in urban garden soil. *Journal of Environmental Quality* 35, 2066-2074.
- Clark, H.F., Hausladen, D.M., Brabander, D.J., 2008. Urban gardens: Lead exposure, recontamination mechanisms, and implications for remediation design. *Environmental Research* 107, 312-319.
- Craft, C., Seneca, E., Broome, S., 1991. Loss on ignition and kjeldahl digestion for estimating organic carbon and total nitrogen in estuarine marsh soils: Calibration with dry combustion. *Estuaries and Coasts* 14, 175-179.
- Dean, W.E., 1974. Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition; comparison with other methods. *Journal of Sedimentary Research* 44, 242-248.
- Fairholm, J., LifeCycles, 1998. Urban Agriculture and Food Security Initiatives in Canada: A Survey of Canadian Non-Governmental Organizations (No. 25), Cities Feeding People (CFP) Report Series. The International Development Research Centre (IDRC).
- Goodwin, T.A., McIsaac, E.M., Friske, P.W.B., 2009. The North American Soil Geochemical Landscapes Project: Report on the 2008 Sampling Program and Preliminary 2007 Results (Report of Activities 2008 No. Report ME 2009-1), Mineral Resources Branch, Report of Activities 2008. Nova Scotia Department of Natural Resources.
- Government of Canada, N.R.C., 2003. Mineral Production [WWW Document]. URL <http://mmsd.mms.nrcan.gc.ca/stat-stat/prod-prod/2003-eng.aspx>
- Government of Canada, N.R.C., 2005. Mineral Production [WWW Document]. URL <http://mmsd.mms.nrcan.gc.ca/stat-stat/prod-prod/2005-eng.aspx>
- Government of Canada, N.R.C., 2006. Mineral Production [WWW Document]. URL <http://mmsd.mms.nrcan.gc.ca/stat-stat/prod-prod/2006-eng.aspx>
- Government of Canada, S.C., 2006a. Population urban and rural, by province and territory (Canada) [WWW Document]. URL <http://www40.statcan.ca/101/cst01/demo62a-eng.htm>
- Government of Canada, S.C., 2006b. Population urban and rural, by province and territory (Nova Scotia) [WWW Document]. URL <http://www40.statcan.ca/101/cst01/demo62d-eng.htm>
- Kabata-Pendias, A., Pendias, H., 2001. Trace elements in soils and plants. 3d ed. CRC Press, Boca Raton, FL.

- Madrid, L., Diaz-Barrientos, E., Ruiz-Cortes, E., Reinoso, R., Biasioli, M., Davidson, C.M., Duarte, A.C., Grman, H., Hossack, I., Hursthouse, A.S., Kralj, T., Ljung, K., Otabbong, E., Rodrigues, S., Urquhart, G.J., Ajmone-Marsan, F., 2006. Variability in concentrations of potentially toxic elements in urban parks from six European cities. *Journal of Environmental Monitoring* 8, 1158-1165.
- Manta, D.S., Angelone, M., Bellanca, A., Neri, R., Sprovieri, M., 2002. Heavy metals in urban soils: a case study from the city of Palermo (Sicily), Italy. *Science of the Total Environment* 300, 229-243.
- McKeague, J., Wolynetz, M., 1980. Background levels of minor elements in some Canadian soils. *Geoderma* 24, 299-307.
- Rasmussen, P.E., Subramanian, K.S., Jessiman, B.J., 2001. A multi-element profile of house dust in relation to exterior dust and soils in the city of Ottawa, Canada. *The Science of The Total Environment* 267, 125-140.
- Santisteban, J.I., Mediavilla, R., Lopez-Pamo, E., Dabrio, C.J., Zapata, M.B.R., Garcia, M.J.G., Castano, S., Martinez-Alfaro, P.E., 2004. Loss on ignition: a qualitative or quantitative method for organic matter and carbonate mineral content in sediments? *Journal of Paleolimnology* 32, 287-299.
- Smit, J., Nasr, J., 1992. Urban agriculture for sustainable cities: using wastes and idle land and water bodies as resources. *Environment and Urbanization* 4, 141 -152.
- Turpeinen, R., 2002. Interactions between metals, microbes and plants - Bioremediation of arsenic and lead contaminated soils.
- USEPA, 1996. EPA Method 3050B (SW-846): Acid Digestion of Sediments, Sludges, and Soils. Revision 2. <http://www.epa.gov/sam/pdfs/EPA-3050b.pdf>
- Van Veenhuizen, R., Danso, G., 2007. Profitability and sustainability of urban and peri-urban agriculture.
- Wei, B.G., Yang, L.S., 2010. A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. *Microchemical Journal* 94, 99-107.
- Wu, J., Edwards, R., He, X.Q., Liu, Z., Kleinman, M., 2010. Spatial analysis of bioavailable soil lead concentrations in Los Angeles, California. *Environmental Research* 110, 309-317.
- Zheng, Y.M., Chen, T.B., He, J.Z., 2008. Multivariate geostatistical analysis of heavy metals in topsoils from Beijing, China. *Journal of Soils and Sediments* 8, 51-58.