City of Greater Sudbury 2001 Urban Soil Survey

Investigators/Authors:
Randall Jones
Laura Fiore
Kyle Davis
Catherine Eby

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Ontario Ministry of the Environment
Environmental Sciences and Standards Division
Environmental Monitoring and Reporting Branch
Biomonitoring Section
Phytotoxicology Investigations Unit
125 Resources Rd., North Wing, 2nd flr., Toronto, M9P 3V6

Ontario

Acknowledgments

This document represents the largest sampling program ever undertaken by the Ontario Ministry of the Environment (MOE) for any community in Ontario, with approximately 770 properties sampled, 7,000 samples collected, and approximately 150,000 laboratory analyses completed. This document could not have been produced without the hard work and dedication of the many people outlined below.

The Sudbury Soils Study was co-ordinated by the Northern Region of the MOE. This team included Brian McMahon as the supervisor, as well as, Maxine Kasper, Ron Paolin, Kathy McDonald, Suzanne Arsenault, Brian Cameron and Nicole Catojo. Sample collection, data management and report preparation was completed by Phytotoxicology Unit scientists of the Environmental Monitoring and Reporting Branch (EMRB) of the MOE.

Our field crew worked tirelessly, under sometimes adverse conditions, to complete all of the sampling in just one field season (5 months). A big thank you to an amazing sampling crew including Aden Takar, Taskin Shirazi, Claire Hanlon, Tim Lanthier and lead investigators Laura Fiore and Randall Jones of EMRB and from the Northern Region, Cindy Mann, Maureen Spinney, Jonathon Roy, Marc Donato, Derek McDonald, Shelly Wainio, Shelley Baggio, investigator John Negusanti and all others on short term contracts.

Once samples were collected, they were sent to the EMRB - Phytotoxicology processing lab in Toronto. Thank you to Debbie Terry, Danuta Roszak, and Jennifer Newman, as well as Aden, Taskin, Claire and Tim for all your hard work. Due to the large volume of samples collected, a large portion of our soil samples were processed externally at Agat Laboratories in Toronto under the direction of Jackie Takeuchi. Once samples were processed, soil samples were submitted to Lakefield Research Laboratory for analysis under the direction of Teresa Switzer. All produce samples and some soil samples were analyzed internally by the MOE Laboratory Services Branch (LSB) under the direction of Rusty Moody. A special thank you must go to Rusty for also performing quality control verification on all Lakefield data. Thank you as well to Bill Tobin of LSB for his assistance in laboratory quality control.

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1.0 INTRODUCTION

The Ontario Ministry of the Environment (Ministry or MOE) report entitled *City of Greater Sudbury 2001 Urban Soil Survey* is a comprehensive discussion of all soil and produce data that was collected by the Ministry in the City of Greater Sudbury during the period of July to November of 2001. Individual appendices have been prepared with full descriptions and results for sampling of residential property soil and vegetable gardens, schools and daycares, municipal parks, market gardens, commercial berry producers, and wild blueberry patches. All data presented in this report will contribute to the human health and ecological risk assessments that are currently underway in the City of Greater Sudbury.

1.1 Objectives of Study

1) To provide a screening level assessment of metal and arsenic concentrations in the upper 20 centimetres of soil within the City of Greater Sudbury;

2) To determine if localized areas of higher metals and arsenic concentrations exist in the upper 20 centimetres of soil within the City of Greater Sudbury;

3) To determine if metal and arsenic concentrations change with depth in the upper 20 centimetres of soil, in order to identify if element concentrations are related to aerial deposition from smelter emissions in the City of Greater Sudbury;

4) To determine the strength of relationships between metal and arsenic concentrations in the upper 20 centimetres of soil within the City of Greater Sudbury in order to identify if element concentrations are related to smelter emissions;

5) To identify metal and arsenic concentrations in produce grown within the City of Greater Sudbury, in order to support exposure estimates for the human health risk assessment;

6) To identify additional work that may be appropriate to support the Human Health Risk Assessment (HHRA) and the Environmental Risk Assessment (ERA) based upon this screening level study.

2.0 SCOPE OF STUDY

The scope of this study was to obtain soil chemical data to fill data gaps remaining following the review of the Ontario Ministry of Environment report *Metals in Soil and Vegetation in the Sudbury Area (Survey 2000 and Additional Historic Data) - September 2001.* Based on this report, it was determined that additional sampling and further action was warranted with regards to Sudbury residential and publically- accessible urban green spaces and communities adjacent to the three smelting centres of Copper Cliff, Coniston, and Falconbridge.

The purpose of this extensive sampling program was to fill the knowledge gaps with screening level information. The scope of the sampling program was not to exhaustively characterize the soil metal status of all possible sample sites, rather it was to collect soil data that was representative of each sampled property. The need for further and more intensive sampling will be decided by the consultants carrying out the human health and ecological risk assessments in consultation with the

Ministry. The sampling program is described in more detail in Section 5.0.

The soil sampling conducted by the Ministry was not the only sampling that was conducted to characterize the contaminant status within the City of Greater Sudbury in 2001. Over the summer and fall of 2001, Inco Limited and Falconbridge Limited collected surface soil samples in remote areas around the Sudbury basin in an attempt to 1) confirm the local background concentrations for the contaminants of concern, and 2) accurately determine the spatial extent of the metal and arsenic deposition associated with the mining and smelting activities, having defined local background. Over the same time period, the companies also characterized the soil contaminant status of their land holdings in areas adjacent to residential communities.

The soil information obtained from the 2001 sampling program, in conjunction with the data from *Metals in Soil and Vegetation in the Sudbury Area (Survey 2000 and Additional Historic Data)* (MOE 2001) and the extensive existing Sudbury environmental data base, form the essential building blocks upon which an ecological and human health risk assessment for impacted communities in the City of Greater Sudbury will be developed.

3.0 BACKGROUND

3.1 Ontario Ministry of the Environment Investigations

Between the years 1938 and 2001, various Ontario government departments and agencies have conducted numerous investigations to document the impact of Inco and Falconbridge's emissions on vegetation and soil in and around the Sudbury Basin (Balsillie, *et al* 1978, Dreisinger 1970, McIlveen, *et al* 1979, McIlveen, *et al* 1984, ODM 1964, MOE 1973, MOE 1975, MOE 1978, MOE 1979, MOE 1984, MOE 1985, MOE 1990, MOE 2001). During the early years, these investigations were mainly concerned with sulphur dioxide injury to crops and native vegetation, in particular white pine. In the early 1970's, the Ministry established two long term studies in the Sudbury region to look at the impacts of emissions from the Inco and Falconbridge operations on native vegetation and soil chemistry. All of the sampling locations for these studies were established in undeveloped rural locations. In 1998 the number of sampling locations was expanded to better determine the extent of the impact of emissions on surface soil chemistry. While many of the new sampling locations were in the urban part of the City of Greater Sudbury, they were all on undeveloped land. There were other smaller investigations conducted in the Sudbury area by the Ministry over this time period, but there was not any systematic soil sampling of the developed urban areas in Sudbury.

The Ministry investigations concluded that emissions from over half a century of processing nickel ores had resulted in elevated levels of metals and arsenic in soil in various locations throughout the Sudbury area. Nickel, copper and cobalt concentrations in surface soil (0 - 5 cm depth) were elevated in rural areas adjacent to the companies and for a considerable distance downwind (east-northeasterly) of the smelting operations to levels which could or did cause injury to vegetation (phytotoxicity). The observed severe vegetation impacts, mainly caused by sulphur dioxide fumigations, generally affected farm crops and white pine east of Inco. The MOE 2001 report, in which the bulk of the two long term study results were reported, identified the lack of urban soil chemistry data for the Sudbury region and recommended that a systematic sampling program be carried out to properly characterize the urban soil in Sudbury.

4.0 MOE SOIL GUIDELINES

Throughout this document the results of the soil chemical analysis are compared to the MOE *Guideline for Use at Contaminated Sites in Ontario* (MOE 1997) Table A and Table F soil criteria. A brief description of the Table A and F soil criteria is given below.

4.1 MOE Ontario Soil Background Criteria (Table F)

The numbers listed as being "Ontario Soil Background Criteria", or Table F, are derived from the MOE document *Ontario Typical Range (OTR) of Chemical Parameters in Soil, Vegetation, Moss Bags and Snow* (MOE 1993c). The actual OTR_{98} values are the 98th percentile of the concentrations of various chemical parameters detected in background soil in Ontario. These chemical data were derived from a province-wide soil sampling program conducted to determine the range of background chemical concentrations in surface soil in Ontario resulting from natural geological processes and human activity but remote from the influence of known point sources of pollution. Soils were analyzed for approximately 39 inorganic and 119 organic parameters. Complete details on the OTR background development process can be found in the MOE report *Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags and Snow* (MOE 1993c). The Table F background-based generic soil criteria in the *Guideline for Use at Contaminated Sites in Ontario* are derived from the OTR_{98} values. For most elements and chemicals, the Table F generic guideline is the OTR_{98} plus two Coefficients of Variation. The resulting Table F values tend to be higher than the OTR_{98} values, although there are exceptions. The exceptions occur when the generic effects-based Table A guideline is less than the OTR_{98} number, in which case both the Table A value and the Table F value are set at the OTR_{98} value. Details of the generic background-based Table F soil criteria development process can be found in the MOE report *Guideline for Use at Contaminated Sites in Ontario* (MOE 1997).

Soil concentrations above the Table F background levels are likely indicative of the impact of a local pollution source. Although, in some cases Table F exceedences may be the result of local geological deposits.

4.2 MOE Soil Remediation Criteria (Table A)

The MOE soil remediation criteria have been developed to provide guidance in assessing and triggering certain decisions for soils that have elevated soil concentrations. These criteria are not action levels, in that exceeding one or more of the criteria does not automatically mean that a clean-up must be conducted, but that further study of the potential human and/or ecological risks is warranted.

Consideration of the following factors is required when the criteria are exceeded:

- a demonstrated presence or likelihood of an adverse effect to human health and/or the natural environment;

- an understanding of the type of protection provided by the criteria gained through knowledge of the exposure pathways and receptors (i.e. humans, animals, plants) which were considered in the development of the criteria, and a thorough understanding of how that combination of pathways and receptors relate to those which could be found in the community;

- local environmental conditions that are known to modify chemicals availability and toxicity; and

- an understanding of the relationship between dose and health response for sensitive receptors from all exposure pathways, including the safety and uncertainty factors that have been used in the development of the criteria.

In each case, the decision-making process should consider all of these factors plus any additional factors specific to the community in question. When the decision is made that action is needed, it is generally accepted that a human health and/or ecological risk assessment(s) are required to assess the level of risk to the community, identify the major contributing factors to risk, and, if warranted, develop intervention levels for remediation.

The soil remediation criteria are effects-based concentrations set to protect the most sensitive receptor against the potential for adverse effects to human health, ecological health, and/or the natural environment. The most sensitive receptor is often a plant or soil dwelling animal. The assumption is that by protecting the most sensitive receptor and the most sensitive endpoint that the rest of the environment will be protected. There are different criteria for land use, soil texture, soil depth, and groundwater use. The criteria have also been established so that there will not be a potential for adverse effects from chemicals transferred from soil to indoor air, from groundwater or surface water through release of volatile gases, from leaching of chemicals in soil to ground water, or from groundwater discharge to surface water.

Currently there are criteria for approximately 25 inorganic elements and 90 organic compounds. Criteria were developed only if there were sufficient, defendable, effects-based data on the potential to cause an adverse effect. The development of Soil Remediation Criteria is a continuous program and criteria for more elements and compounds will be developed as additional environmental data become available. Similarly, new information could result in future modifications to the existing criteria.

For more information, please refer to the MOE report *Guideline for Use at Contaminated Sites in Ontario* (MOE 1997).

5.0 METHODS

This section has been organized into four sections: 5.1 Soil Sampling Methods; 5.2 Produce Sampling Methods; 5.3 Data Analysis Methods; and 5.4 Laboratory Processing and Analysis Methods

5.1 Soil Sampling Methods

In this document we define three main types of soil samples; Soil, Sand and Gravel.

The Soil sample type consisted of soil material (less than 2 millimetres (mm) in diameter), ranging in texture from sand to silty clays, on which grass, vegetables or berries were growing. This group was further subdivided into Urban Soil (developed, grassed areas), Urban Garden Soil (residential vegetable gardens), Agricultural Soil (commercial market garden and berry farms) and Undisturbed

Natural Soil (undeveloped, naturally vegetated areas).

The Sand sample type was subdivided into Play Sand and Beach Sand. Play Sand was the material used around play structures (i.e. swings, slides, etc.), in sand boxes, and in long jump pits found in schools, daycares, and parks. Generally, this material originated off-property and was brought in for landscaping purposes. Beach sand, on the other hand, tended to be naturally occurring and was collected from the parks that had beaches.

The Gravel sample type was subdivided into Crushed Stone and Playground Gravel. Crushed stone, usually limestone, was used extensively for baseball diamond infields. This was a white to grey material, generally no larger than 5 mm in diameter, and contained a large proportion of very fine material. Playground Gravel was used in a number of school playgrounds and consisted of stones approximately 10 - 12 mm in diameter underlaid by fine powder mixed with soil. In the case of playground gravel it was the fine powder mixed with soil that was sampled. Both crushed stone and playground gravel generally originated off-property and were brought in for landscaping purposes.

The sand and gravel sample types were collected in addition to the soil sample type as these materials were observed extensively throughout the City of Greater Sudbury at schools and parks and tended to be substantially different in physical structure than the adjacent urban soil. Sand and gravel, unlike grass covered urban soil, can come in direct contact with skin, thereby increasing the risk of exposure.

For all soil sample types, a hand-held soil corer was utilized to collect a minimum of fifteen soil cores along a grid, “W”, or “X” pattern that was applied to a designated sampling area representative of the property. Refer to Appendices A, B and C. The size of each designated sampling area varied between sampling locations due to the variation in property size. Each soil core was divided into three depth intervals (0 - 5 cm, 5 - 10 cm and 10 - 20 cm) and the fifteen core sections for each of the three sample depths (e.g., 0 - 5 cm) were placed in one labelled polyethylene bag. The fifteen core sections per bag per designated sampling area are referred to as a composite soil sample. A duplicate soil sample was collected by performing the soil sampling procedure a second time across the same designated sampling area. It should be noted that the third depth interval (10 - 20 cm) was double the sample volume of the other two depth intervals. This should be taken into consideration when interpreting the data.

Generally, soil samples (soil, sand or gravel) were not collected within one metre of driveways, walkways, building structures, fences and/or debris to reduce the likelihood of encountering local sources of elevated concentrations (e.g., driveway spills, eroded paint from painted surfaces). Prior to sampling, authorization was obtained from all property owners and landscaping information was requested. Residential yards were discrete sampling areas usually separated by physical structures such as driveways, fences, and buildings, while school and park play areas were indicated by goal posts and/or other physical structures.

5.1.1 Residential Properties and Gardens

During the months of September and October of 2001, Ministry representatives collected soil from front and back yards of 51 properties in Falconbridge, 75 properties in Coniston, and 74 properties in Copper Cliff. Soil samples were also collected from front or back yards from 239 properties throughout the City of Greater Sudbury. A front and back yard were usually identified and sampled separately at each property while on some properties a side yard was also included. All samples were collected in duplicate and at three depths, 0-5 cm, 5- 10 cm., and 10 - 20 cm, where possible according to Ministry protocols (MOE 1993).

5.1.2 Schools and Daycares

During the month of July 2001, MOE representatives collected soil, play sand, crushed stone, and gravel samples from each school and daycare within the City of Greater Sudbury. At each site, samples were collected in duplicate from child play areas and especially from areas where school children could come in direct contact with bare soil. Samples were collected in different ways from different locations as described below. The sampling location and pattern of sampling is indicated on each school map attached in Appendix B. The school maps are provided to indicate the sampling locations on the property and may not be spatially accurate.

Gravel playgrounds, containing slag in some instances, were prevalent at schools within the older urban areas of the City of Greater Sudbury. Since this was the only area for school children to play, duplicate samples were collected from the gravel playground by pushing aside the larger stones and, with a trowel, scraping the underlying fine gravel material. All samples were collected while walking in an “X” pattern across the gravel playground. For this type of sampling, the purpose was to collect the fine particles that would be airborne when school children run and/or slide on the gravel.

Sand samples were collected from sanded play areas including those with play structures and sand boxes. Due to the constant mixing of sand and the homogenous nature of the sanded areas, sand samples were collected with hand trowels to represent the 0-15 cm depth. In most cases, one sample was collected from the interior of the play area in an “X” pattern below the play structure, while the other sample was collected from the perimeter of the sanded play area adjacent to the pressure treated wood border and/or soil. This type of sampling should indicate if there is an effect from either the pressure treated wood border and/or surrounding soil to the interior of the play area. If there was no wooden border, both sand samples were collected from the interior of the sanded play area in an “X” pattern. In most cases, duplicate sand samples were collected; however, at some locations single sand samples were collected.

Soccer and football fields were sampled in duplicate with a hand held soil corer in an “X” pattern over the entire length of the field. Cores were separated into three depths, 0-5 cm, 5 - 10 cm, and 10 - 20 cm where possible. In addition, duplicate samples were taken in any worn area where bare soil was visible; most predominately at soccer goal posts and centre field. Due to the compacted nature of these areas, surface soil samples were taken with a trowel to represent the 0-5 cm depth.

Baseball diamond infields were in most cases crushed stone and very compacted. Therefore, duplicate surface samples were taken with a trowel. In most cases, one surface sample was collected while walking along the baseline, while the other was collected while walking an “X” pattern from home base to 2nd base and from 1st to 3rd base. This type of sampling should indicate if there is an effect of the chalk lines applied to the baseline compared to the interior of the infield.

Baseball diamond outfields were sampled in duplicate with soil corers in an “X” or “W” pattern. Cores were separated into three depths, 0-5 cm, 5 - 10 cm, and 10 - 20 cm where possible. Where the infield was grassed, samples were collected with a soil corer either as a separate site or combined with the baseball diamond outfield.

Sand from long jump pit landing sites was sampled in duplicate in an “X” pattern. A hand trowel was used to sample the 0 - 15 cm layer due to the constant mixing of the sand in this location.

Samples were also taken from any grassed greenspace area where school children would play. Cores were separated into three depths, 0-5 cm, 5 - 10 cm, and 10 - 20 cm where possible.

Outdoor ice rinks were not sampled based on the premise that they would only be used when the soil was covered by ice. The remaining paved areas were not sampled.

5.1.3 Parks and Sports Complexes

During the months of September and October 2001, MOE representatives collected soil, and sand samples from major parks and sports complexes within the City of Greater Sudbury. At each site samples were collected in duplicate from play areas and especially from areas where young children could come in direct contact with bare soil. Samples were collected in different ways from different locations as described below. The sampling location and pattern of sampling is indicated on each park map in Appendix C, Section C4.

Sand samples were collected from beneath play structures and/or beach areas. Due to the constant mixing of sand and homogenous nature of the sanded areas, sand samples were collected with hand trowels or corers to represent the 0-15 cm depth. Duplicate samples were collected in a reproducible and representative manner of the sanded areas (i.e. “X” pattern)

Soccer and football fields were sampled in duplicate with a soil corer in an “X” pattern of the entire length of the field. Cores were separated into three depths, 0-5 cm, 5 - 10 cm, and 10 - 20 cm where possible. In addition, duplicate samples were taken in any worn area; most predominately at soccer goal posts and centre field. Due to the compacted nature of these areas, surface soil samples were taken with a trowel.

Baseball diamond infields were in most cases crushed stone and very compacted. Therefore, duplicate surface samples were taken with a trowel or corer while walking along the baseline. Baseball diamond outfields were sampled in duplicate with soil corers in an “X” or “M” pattern. Cores were separated into three depths, 0-5 cm, 5 - 10 cm, and 10 - 20 cm where possible. Where the infield was grassed, samples were collected with a soil corer either as a separate site or combined with the baseball diamond outfield.

Samples were also taken from any grassed area where school children would play. Cores were separated into three depths, 0-5 cm, 5 - 10 cm, and 10 - 20 cm where possible.

Outdoor ice rinks were not sampled based on the premise that they would only be used when the soil was covered in ice. The remaining paved areas were not sampled.

5.2 Produce Sampling Methods

Produce sampling was conducted by Ministry staff from residential gardens, commercial market gardens, commercial berry farms and wild blueberry patches within the City of Greater Sudbury for preliminary screening purposes only. Sample types collected included root vegetables, fruit vegetables, leafy vegetables and berries. Duplicate samples were collected where available. All produce samples were kept on ice during transportation and shipping.

Interpretation of the produce results was based on comparisons with data from the following control locations: 2 control locations for raspberries, 1 control location for strawberries and blueberries, and 1 market garden control station. No control locations were available for residential gardens. Control sites were chosen based on current knowledge of the range and extent of elevated soil metal levels in the Sudbury area and were located approximately 125 km and 245 km west and 70 km northwest of the Copper Cliff superstack.

5.2.1 Residential Gardens

During the period of August and September of 2001, garden produce and soil samples were collected at a subset of the residential properties sampled in five of the local communities. Nine gardens were sampled in Falconbridge, 15 gardens in Coniston, 9 gardens in Copper Cliff, and 3 gardens each in Gatchell and Lively. Due to the small size of the residential gardens, only single samples of each vegetable were collected. Garden soil samples were collected in duplicate as a 0-15 cm core to represent the homogenous nature of the cultivated area.

5.2.2 Market Gardens, Commercial Berry, and Wild Blueberry Sampling

During the period of July and August of 2001, soil and produce samples were collected from 7 commercial berry farms, 3 wild blueberry patches, and 6 commercial market garden produce growers within the City of Greater Sudbury. At each site produce was collected in duplicate if enough produce was available and soil was collected from the vicinity in which the produce was grown. Soil was sampled in duplicate and since these areas are cultivated on a regular basis, soil cores of 0 - 15 cm were taken (MOE 1993). In areas with shallow bedrock, soil samples of 0 - 10 cm were taken. It should be noted that most berry samples, especially strawberries and raspberries, were collected late in the season and were therefore extremely ripe. In order to collect samples large enough for duplicate analysis it was necessary to sample from large areas of the farms, some of which had closed for the season.

5.3 Data Analysis Methods

Data analysis within this document was accomplished using various statistical methods including descriptive statistics, exceedences of applicable Ministry guidelines, spatial distribution of chemical concentrations, concentration depth profiles, and statistical correlations between elements. Chemical concentrations that were below analytical method detection limits (MDL) were tabulated as one half of the MDL for data analysis.

Descriptive statistics were generated to summarize the data and included: minimum, maximum, mean, median, geometric mean, 10th and 95th percentiles, quartile concentrations, standard deviation, coefficient of variation, kurtosis, skewness, and upper and lower confidence intervals for the mean. Each data set included replicate sample results from each sampling location. The replicate sample results were not averaged for this analysis.

Percentiles were calculated by sorting the data from the highest to lowest concentration and then calculating the value of which *x*% of the data was below. For example, the median is the 50th percentile and therefore, half of the data would fall below the median value. The quartiles are the 25th, 50th and 75th percentiles. These values divide the data set into four equal sections. A mean or arithmetic mean is the arithmetic average of the non-transformed data set. The geometric mean is the back-transformed mean of the logarithmically transformed data set. This means that after the data set is logarithmically transformed, the mean of the log transformed data is calculated and then this mean is transformed back into the original scale. Generally, the geometric mean is less then the arithmetic mean.

Standard deviation is a measurement of the spread or variation in the data set. The more widely spread the data set, the larger the standard deviation. Coefficient of variation measures the spread of a data set as a proportion of the mean. It is defined as the standard deviation divided by the mean and is expressed as a percentage. Upper and lower confidence limits for the mean provide a range of values, with an associated level of probability, within which the actual population mean will be located.

Skewness and kurtosis are two measures of the deviation of the data distribution from normality. Skewness measures the symmetry of the distribution. The data distribution is said to be skewed when one tail of the curve is extended farther than the other. A skewness value of 0 indicates the data distribution is symmetrical and therefore normal while a skewness value different from 0 indicates that the distribution is asymmetrical and therefore non-normal. Kurtosis measures the "peakedness" or height of a data distribution curve. A kurtosis value for a normal distribution is 0 and if the kurtosis value deviates from 0, then the distribution is either more flat or more peaked than a normal distribution.

Concentrations for each community grouping were compared to the MOE Table F and A guidelines. Exceedences of these guidelines were highlighted and discussed. Each data set included replicate sample results from each sampling location. The replicate sample results were not averaged for this analysis. As discussed in Section 4.1, the Table F guidelines represent background soil concentrations obtained from a MOE province-wide parkland sampling program. As discussed in Section 4.2, the Table A soil guidelines are effects-based and were derived to protect both human health and the natural environment, whichever is potentially affected at the lowest concentration.

Spatial distribution of chemical concentrations in the urban soil data was assessed using concentration dot maps. The concentration dot maps include urban soil sampling locations only. All sample locations were rounded to the nearest 100 metres. The dots represent replicate soil sample results from each sampling location, and were not averaged. A dot represents a range of concentrations, with the dot size increasing as chemical concentrations increase. Dot colours were used to help differentiate between dot size. The MOE Table F and A concentrations were used as the upper limit of concentration ranges where possible in the concentration dot maps. Other concentration ranges were selected to help illustrate trends in the spatial distribution of chemical concentrations. Station location maps were also created and include all sand, gravel and soil (urban,

urban garden, agricultural and undisturbed natural soil) sampling locations.

Depth profiles were created to illustrate the change in chemical concentrations for each element between different depth intervals. With aerial deposition of metals and arsenic onto soil there is a pattern of decreasing concentration with increasing soil depth. Elements will migrate to lower depths at varying rates, depending on several factors including element chemistry and form, soil characteristics, climate, and period of exposure. Urban soil samples were collected at three depth intervals, 0 - 5 cm, 5 - 10 cm and 10 - 20 cm, where possible. For analysis purposes, the sample replicates at each sampling location were averaged at each depth for all elements. It should be noted that the third depth interval (10 - 20 cm) was double the sample volume of the other two depth intervals. This should be taken into consideration when interpreting the data.

A trend of decreasing concentration with increasing depth, typical of aerial deposition, was observed in communities in the City of Greater Sudbury, however, two other trends were also present. The second trend observed was maximum concentrations occurring at 5 - 10 cm, with lower concentrations at 0 - 5 cm and 10 - 20 cm. The third trend observed was increasing concentration with increasing depth. In both of these trends, elevated concentrations may be attributed to aerial deposition which has been buried by landscaping practices at individual properties. Landscaping practices may have included adding, grading, removing and/or mixing of urban soils. For discussion purposes, these three trends were labelled Group A through C. Sample locations in Group A exhibited a trend of decreasing concentrations with increasing soil depth, typical of aerial deposition. In Group B, maximum concentrations were observed at 5 - 10 cm while lower concentrations were observed at both 0 - 5 cm and 10 - 20 cm. In Group C, concentrations increased with increasing soil depth, and maximum concentrations were observed at 10 - 20 cm, the maximum depth of investigation.

The depth data was differentiated into Groups A, B and C within each community grouping using the following equations:

$$CriteriaA = Max\left(\frac{[Ni]_{5to10} \times (\log[Ni]_{0to5} - \log[Ni]_{5to10})}{[Ni]_{0to5}}, \frac{[Ni]_{10to20} \times (\log[Ni]_{0to5} - \log[Ni]_{10to20})}{[Ni]_{0to5}}\right)$$

$$CriteriaB = \frac{[Ni]_{5to10} \times (\log[Ni]_{0to5} - \log[Ni]_{5to10})}{[Ni]_{0to5}} - \frac{[Ni]_{10to20} \times (\log[Ni]_{0to5} - \log[Ni]_{10to20})}{[Ni]_{0to5}}$$

The procedure used to separate the three groups of data was based on the ratios and differences of nickel concentrations at each sampling location between depths. *Criteria A* was calculated for each sampling location and the sampling locations were ranked from lowest to highest based on *Criteria A*. All locations with a *Criteria A* value less than or equal to zero made up group A. *Criteria B* was calculated for the remaining locations and the sampling locations were ranked from lowest to highest based on *Criteria B*. All locations with a *Criteria B* value less than or equal to zero made up group B and the remainder made up Group C.

For each community grouping the data was first divided into Groups A, B, and C as described above.

The data for each group was then ranked from lowest to highest based on the nickel concentration at 0 - 5 cm for Group A, 5 - 10 cm for Group B and 10 - 20 cm for Group C. The ranked data was finally divided into sections (quarters, thirds or halves), depending on the sample size. This ranking was completed to differentiate between the strengths of trends within the Group A, B or C data. Typically, the highest concentrations of the data displayed the strongest respective trend (i.e. Group A, B or C) while the lowest concentrations of the data displayed the weakest respective trend. For graphing purposes, concentrations of each quarter, third or half were averaged and graphed at each depth interval for twelve elements.

Correlations between 20 elements in urban soil were analyzed using Pearson's and Spearman's Correlations, and scatter plots with linear regression lines were generated. Each data set included replicate sample results from each sampling location. The replicate sample results from each sampling location were not averaged for this analysis. The majority of the data is not normally distributed. As a result, the scatter plots are presented as non-transformed and log transformed. The non-transformed scatter plots are presented for simplicity, while the transformed plots are more statistically correct.

The Pearson's Product Moment Correlation Coefficient R measures the strength of the linear correlation between two elements. It assumes both variables are normally distributed and their joint distribution is bivariate normal. The Spearman's Ranked Correlation R_s is the non-parametric counterpart of Pearson's and measures the relationship of the ranks of the data. Spearman's does not assume that the distributions are normal. The differences between Pearson's R and Spearman's R_s are an indication of outliers or a highly skewed, non-normal distribution in the data. For the correlation analyses the non-transformed data was used. Due to the large sample size, R values for the correlations above 0.3 were statistically significant. For discussion purposes, R values greater than or equal to 0.75 were used for defining a strong significant correlation while R values less than 0.75 but greater than or equal to 0.7 were used for defining a moderate significant correlation.

Box and whisker plots describing analyte concentrations, for fifteen of the twenty analytes, by community group were discussed. As box and whisker plots may not be familiar to all readers a brief description is provided below.

A box and whisker plot simultaneously displays the central tendency of a data set (median), the degree of asymmetry (the relative sizes of the "boxes" around the median), and can indicate whether outliers are present in the data set. When box and whisker plots are placed side-by-side, the equality of medians and homogeneity of variance may also be visually assessed.

In the box and whisker graphics, the thin black line corresponds to the median and the thick red line corresponds to the mean. The two outer lines delineating the box represent the 25th and 75th percentiles of the sample. The lines or "whiskers" extend upward and downward from the box by 1.5 times the inter-quartile range. Observations beyond these points are plotted individually and may be considered as outliers

5.4 Laboratory Processing and Analytical Methods

Due to the large volume of samples collected, samples were processed and analyzed by both MOE and contract laboratories. However, overall data management and quality control for both sample processing and metals analysis was overseen and co-ordinated by MOE staff.

5.4.1 Soil Processing and Analytical Methods

Soil samples were delivered to the MOE Phytotoxicology laboratory where they were organized and shipped to Agat Laboratories for processing. Agat followed MOE Standard Operating Procedures which include air drying and sieving samples to obtain the 2 mm size fraction, and then further grinding the sample using a mortar and pestle to pass though a Number 45 mesh (0.355 mm) sieve (MOE 2000). Finally, the ground material was stored in glass jars. Trace amounts of non-soil material (i.e. grass, roots etc.) observed in the soil samples was removed during the sieving process.

Lakefield Research Laboratories (Lakefield) was selected and funded by local Sudbury industries (ie. Inco & Falconbridge) to analyze all Sudbury soil samples. Lakefield conducted analysis for the following elements: aluminum (Al), antimony (Sb), arsenic(As), barium (Ba), beryllium (Be), calcium (Ca), cadmium (Cd), cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), selenium (Se), strontium (Sr), vanadium (V), and zinc (Zn). One in ten samples were also analyzed for pH, electrical conductivity (EC) and total organic content (TOC).

At Lakefield, all samples were prepared prior to analysis by Lakefield Method 9-2-37 and analyzed using quantitative analysis by Inductively Coupled Plasma- Optical Emissions Spectrometry (ICP-OES) (Method 9-4-2) or by hydride generation and Atomic Absorption Spectroscopy (AAS) (Method 9-8-1). Depending on sample characteristics, Lakefield Method 9-25-4, Determination of Multi Elements in Low Mineralized Samples by Aqua Regia - Microwave Digest by Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS), was also used for the determination of various elements in low mineralized samples. MOE data management and quality control procedures for both soil sample processing and metals analysis carried out by contract laboratories is outlined in Appendix F.

At the end of the study, a comparison of twenty (20) high metal concentration samples uncovered a bias between MOE Laboratory Services Branch data and Lakefield data with respect to arsenic and cobalt. MOE results were approximately 20% higher than Lakefield's. The arsenic differences were not seen in the pre-project inter-comparison since most of the samples analysed in ths early inter-comparison had relatively low concentrations.

MOE took many steps to quantify the laboratory differences, with full co-operation from Lakefield Research. Following sample re-analysis using EPA methods, comparison of results with certified reference material and regression analysis of the data, it was concluded that for any health risk assessments, arsenic results provided by Lakefield Research should be corrected upwards by 10% to bring their results more in line with accepted values for certified reference materials. Cobalt results provided by Lakefield Research have been accepted as will all other results. More detailed information is available in Appendix F.

Laboratory analytical method detection limits for soil, used by Lakefield, are presented in Table 5.4.1.1.

Table 5.4.1.1: Lakefield Research Limited Soil Method Detection Limits (MDL*)

Element	MDL	Element	MDL	Element	MDL	Element	MDL
Al	2.5	Cd	0.8	Fe	5	Ni	1
Sb	0.8	Ca	10	Pb	1	Se	1
As	5	Cr	5	Mg	1	Sr	10
Ba	0.5	Co	1	Mn	2	V	2
Be	0.5	Cu	1	Mo	1.5	Zn	2.5

* - MDLs are all in µg/g

5.4.2 Produce Processing and Analytical Methods

Produce samples were delivered to the MOE Phytotoxicology laboratory for processing (MOE 2000b). The protocol for vegetation processing includes washing the produce with tap water as would be done in the home prior to consumption. All produce samples were treated in this fashion with the exception of the berries. Berry samples could not be washed due to their over ripeness (i.e. some had become almost liquified during shipping). Instead, the berry samples were poured into beakers, were oven dried, and ground in a Wiley™ mill. The chopped washed vegetables were oven dried and ground in the same fashion. The ground material was then stored in glass jars until submitted for analysis.

All produce samples were forwarded to Laboratory Services Branch, MOE, for chemical analysis including: aluminum (Al), antimony (Sb), arsenic(As), barium (Ba), beryllium (Be), calcium (Ca), cadmium (Cd), cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), selenium (Se), strontium (Sr), vanadium (V), and zinc (Zn). In addition, the vegetation analytical suite included sulphur (S), boron (B), chlorine (Cl), and potassium (K).

All produce samples were analyzed using quantitative analysis by Inductively Coupled Plasma-Optical Emissions Spectrometry (Method MET3065) or by Hydride Generation Flameless Atomic Absorption Spectrophotometry (Method HYD3245). MOE data management and quality control procedures for both produce sample processing and metals analysis is outlined in Appendix G.

Laboratory analytical method detection limits for produce, used by the MOE, are presented in Table 5.4.2.1.

Table 5.4.2.1: MOE Laboratory Produce Method Detection Limits (MDL*)

Element	MDL	Element	MDL	Element	MDL	Element	MDL
Al	5	Cd	0.1	Pb	0.5	Sr	0.5
Sb	0.2	Ca	50	Mg	20	V	0.5
As	0.2	Cr	0.5	Mn	0.5	Zn	1
Ba	0.5	Co	0.2	Mo	0.2		
Be	0.2	Cu	0.5	Ni	0.5		
Bo	1	Fe	5	Se	0.2		

* - MDLs are all in µg/g

6.0 RESULTS

To determine the extent and concentration of soil metal and arsenic contamination in the City of Greater Sudbury, Ministry representatives collected soil samples from four land uses: residential, schools, parks and agricultural. In total, 6,734 soil samples were collected from 770 properties in the City of Greater Sudbury including: 16 commercial agriculture properties, 139 schools/daycares (104/35 respectively), 169 parks and 439 residential properties. Additionally, 245 produce samples were collected from 52 residential gardens and agricultural operations. Landscaping information was received from some property owners, however, this information was limited and unsubstantiated and was therefore not used for data interpretation.

6.1 Residential Data

All of the results for residential yard and garden sampling are presented in Appendix A. This appendix consists of four Sections. The first deals with sampling and analysis methods. Section 2 is the summary data organized by communities and consists of the number of exceedences of Table F and A and descriptive summary statistics. The communities are Coniston, Copper Cliff, Falconbridge, Sudbury Core and Inner Sudbury. Section 3 consists of the actual residential yard soil, garden soil and garden vegetable results. It consists of seven tables. The first five are the residential yard results organized by the same communities as in Section 2. Table 6 is the garden vegetable results and Table 7 is the garden soil results. All results for soil and vegetables are expressed in µg/g dry weight. Section 4 is the coordinates of the residential sampling locations in both latitude and longitude, and Universal Trans Mercator (UTM) which have been rounded off to the nearest 100 metres.

6.2 School and Daycare Data

All of the school and daycare sampling results are presented in Appendix B. This appendix consists of five Sections. The first deals with sampling and analysis methods. Section 2 consists of individual school results, descriptions and maps organized by school board. Section 3 is the summary data organized by the four School Boards and consists of the number of exceedences of Table F and A and descriptive summary statistics. Section 4 consists of the actual school and daycare soil results. It consists of two tables. The Table 4.1 are the school soil results organized alphabetically by school name. Table 4.2 are the daycare soil results organized alphabetically. All results are expressed in µg/g dry weight. Section 5 is the coordinates of the school and daycare sampling locations in both latitude and longitude, and Universal Trans Mercator (UTM).

6.3 Park Data

All of the park sampling results are presented in Appendix C. This appendix consists of six Sections. The first deals with sampling and analysis methods. Section 2 is the summary data organized by communities and consists of the number of exceedences of Table F and A and descriptive summary statistics. In Section 3, the results of three individual parks are discussed in the same manner as individual schools were discussed in Appendix B, Section 2. Section 4 consists of the actual park soil results organized by local community name. There are 24 tables, one for each local community, and the parks are listed alphabetically by name within each table. Some parks did not have proper names, in which case the name of street or intersection on which it was located was used. All results are expressed in µg/g dry weight. Sketch maps of each park showing the sampling locations are located in Section 5. Section 6 is the coordinates of the park sampling locations in both latitude and longitude, and Universal Trans Mercator (UTM).

6.4 Commercial Produce and Wild Blueberry Soil and Vegetation Sampling Results

All of the results for market garden, berry producers and wild blueberry sampling are presented in Appendix D. This appendix consists of four Sections. The first deals with sampling and analysis methods. Section 2 is the summary data and consists of the number of exceedences of Table F and A and descriptive summary statistics. Section 3 consists of the actual soil, vegetable and berry results. It consists of three tables. The first is the soil results . The second table is the market garden vegetable results and the third is the berry results. All results for soil and vegetables are expressed in µg/g dry weight. Section 4 is the coordinates of the residential sampling locations in both latitude and longitude, and Universal Trans Mercator (UTM) which have been rounded off to the nearest 100 metres.

6.5 pH, Electrical Conductivity and Total Organic Carbon

In addition to the twenty inorganic chemical analyses conducted on each soil sample, one in ten soil samples were analyzed for pH, Electrical Conductivity (EC) and Total Organic Carbon (TOC). Samples with sample numbers ending in “0" were selected to have these additional analysis carried out on them. In the initial sample submission to Lakefield, the laboratory mistakenly performed the three additional tests on all samples. This resulted in the quota for these analyses being used up before all samples had been analyzed. As a result only a portion of the Park soil samples were analyzed for pH, EC and TOC as the parks were sampled last. In total, 545 EC and pH analyses and 584 TOC analyses were completed. The results for the soil pH, Electrical Conductivity and Total Organic Carbon are given in Appendix E.

7.0 DISCUSSION

This section summarizes and provides limited interpretation of metal and arsenic concentrations measured in soil and produce collected in the City of Greater Sudbury in 2001. This is accomplished by summarizing and discussing trends and relationships in the metal and arsenic concentrations measured in soil and produce samples according to sample types and community / geographic locations. This discussion is not a thorough scientific or statistical analysis of this data nor does this discussion address potential ecological or human health effects of the observed metal and arsenic concentrations.

It should be noted that beryllium (Be) soil results were generally excluded from the descriptive statistics, spatial distribution, concentration depth profiles and statistical correlation analyses. This was because only ten samples in the data set had Be concentrations above the method detection limit of 0.5 µg/g. Concentrations ranged from 0.51 to 0.62 µg/g. Fifty-four additional samples had Be soil concentrations at the method detection limit of 0.5 µg/g while the Be soil concentrations for the remaining samples were below the analytical method detection limit.

During the 2001 sampling program, sample locations were organized by twenty four local communities or geographic groupings within the City of Greater Sudbury. The local communities included: Azilda, Blezard Valley, Capreol, Chelmsford, Coniston, Copper Cliff, Dowling, Falconbridge, Garson, Hanmer, Levack, Lively, Naughton, Onaping Falls, Skead, Val Caron, Val Therese, Wahnapitae, Wanup and Whitefish while the geographic groupings included Sudbury Core, Sudbury East, Sudbury South and Sudbury New. The geographic groupings were created by MOE staff for the purposes of organizing the 2001 sampling program data. The local communities are urban areas that were amalgamated with Sudbury to create the City of Greater Sudbury in 2001. For discussion purposes, these local communities and geographic groupings were ranked from highest to lowest using the 95th percentile nickel concentrations at the 0 - 5 cm soil depth. Six major groupings of communities were identified based on similar 10th, median and 95th percentiles of the nickel, copper, cobalt, arsenic, selenium, lead, cadmium, chromium, iron, zinc, and barium concentrations. The six community groupings were Outer Sudbury Communities, Inner Sudbury Communities, Sudbury Core, Coniston, Falconbridge and Copper Cliff.

The Outer Sudbury Communities grouping consisted of fourteen local communities including Blezard Valley, Capreol, Chelmsford, Dowling, Hanmer, Levack, Naughton, Onaping Falls, Skead, Val Caron, Val Therese, Wahnapitae, Wanup and Whitefish.

The Inner Sudbury Communities grouping consisted of three local communities and three geographic groupings including Azilda, Garson, Lively, Sudbury East, Sudbury New and Sudbury South. Sudbury East is defined as north of Ramsey Lake, east of Paris St. and south of the Kingsway and included the neighbourhoods of Minnow Lake, Adamsdale, and Moonlight Beach. Sudbury New is defined as north of the Kingsway, east of Notre Dame and included the neighbourhoods of Barry Downe, New Sudbury, Nickeldale and San Francisco. Sudbury South is defined as south of Ramsey Lake, south of Lorne and York Streets and included the neighbourhoods of Robinson, Lockerby, Laurentian, and Lo-Ellen.

The Sudbury Core community grouping is defined as being west of Notre Dame and north of Lorne and York Streets and included the neighbourhoods of Flour Mill, Gatchell, Little Britain and Northern Heights. The local communities of Coniston, Copper Cliff and Falconbridge made up their own individual community groupings. Figure 7.0.1 shows the locations of the local communities / geographic groupings and the community groupings. Table 7.0.1 and Table 7.0.2 show the 10th, median and 95th percentile data for each local community and geographic grouping and each community grouping for eleven elements. Each community grouping is identified by a separate colour in these tables. Recall that communities are ranked lowest to highest using the 95th percentile nickel concentrations. Section 10.1 depicts the soil sampling station maps for each community grouping, divided by land use.

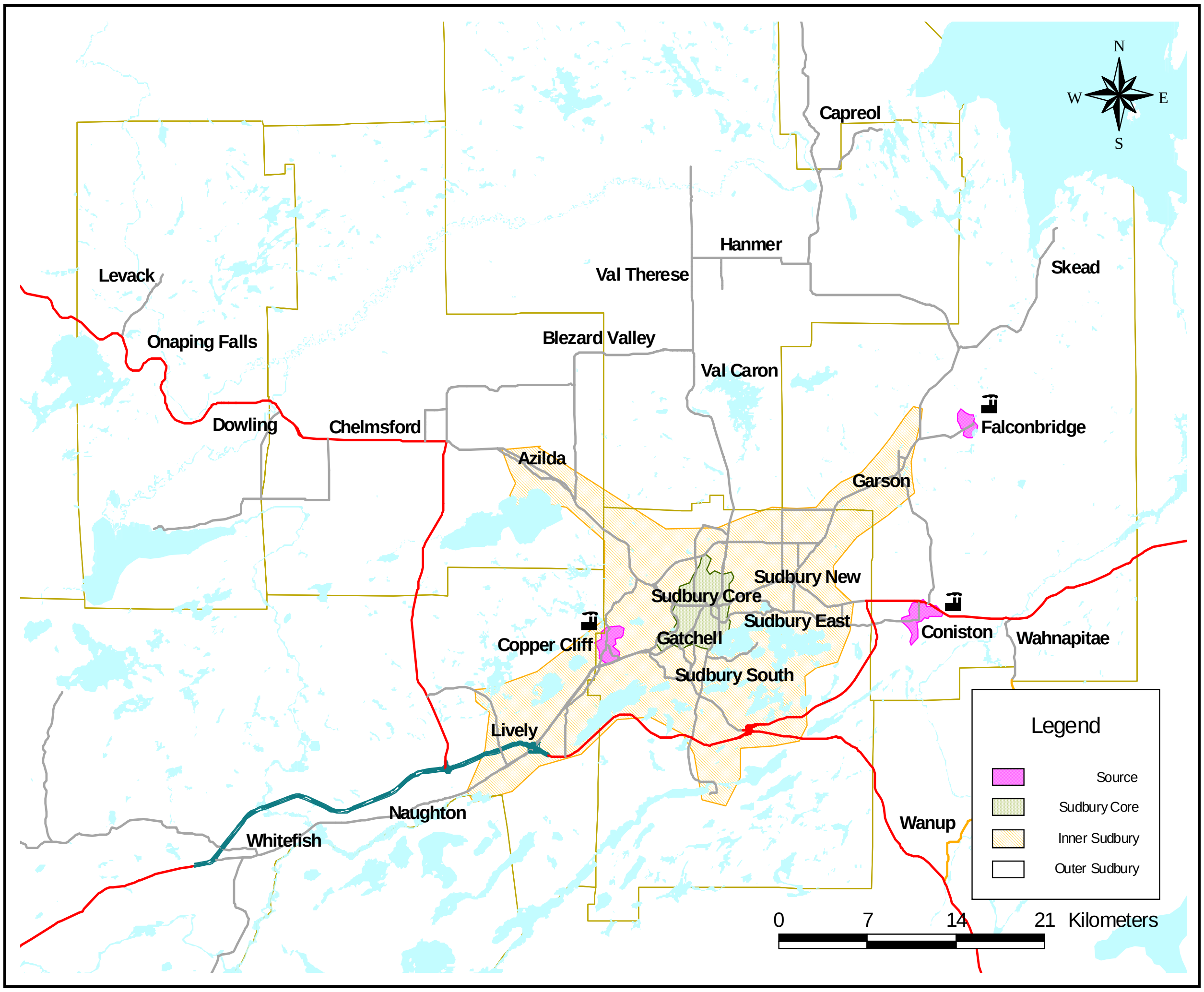


Figure 7.0.1 : Sudbury Community Groupings

Table 7.0.1: Summary and Ranking of the Concentrations of 11 Elements in the 0 - 5 cm Layer of Urban Surface Soils in the City of Greater Sudbury By Community.

Community	n	Ni			Cu			Co			As			Se			Pb		
		10th	median	95th	10th	median	95th	10th	median	95th	10th	median	95th	10th	median	95th	10th	median	95th
Onaping Falls	6	22	25	31	15	16	30	4	5	7	2.5	2.5	2.5	0.5	0.5	0.5	6	8	25
Dowling	36	36	42	49	24	26	34	5	7	12	2.5	2.5	2.5	0.5	0.5	0.5	12	14	41
Wahnapitae	11	39	48	54	25	34	43	9	9	11	2.5	2.5	4	0.5	0.5	1.0	6	11	14
Skead	10	26	45	58	15	35	56	4	5	8	2.5	2.5	6	0.5	0.5	0.6	6	10	36
Val Therese	16	33	46	59	22	35	51	4	5	8	2.5	2.5	6	0.5	0.5	0.5	7	10	14
Wanup	26	34	59	67	31	53	57	5	6	10	2.5	2.5	4	0.5	0.5	0.9	4	12	13
Hanmer	54	34	42	68	21	33	57	4	5	10	2.5	2.5	6	0.5	0.5	0.6	7	11	52
Naughton	6	36	53	72	27	36	52	5	6	7	2.5	2.5	2.5	0.5	0.5	0.5	6	10	27
Levack	32	34	42	73	22	34	47	5	7	9	2.5	2.5	4	0.5	0.5	0.8	10	13	19
Whitefish	40	31	52	76	24	42	58	5	11	15	3	3	14	0.5	0.5	0.5	10	14	34
Capreol	19	36	50	83	23	35	73	4	5	8	2.5	2.5	16	0.5	0.5	1.0	9	14	46
Chelmsford	12	32	47	88	19	28	47	4	6	16	2.5	2.5	7	0.5	0.5	0.5	8	11	23
Blezard Valley	7	51	77	88	41	51	63	4	5	6	2.5	2.5	6	0.5	0.5	0.5	12	14	16
Val Caron	10	38	51	111	27	40	77	4	5	10	2.5	2.5	5	0.5	0.5	1.0	8	11	25
Azilda	156	47	80	160	35	55	130	5	7	12	2.5	2.5	15	0.5	0.5	1.0	9	13	29
Sudbury (New)	74	56	90	194	39	74	160	6	8	14	2.5	2.5	9	0.5	0.5	1.0	9	16	40
Sudbury (East)	62	53	93	209	39	74	190	6	8	14	2.5	5	16	0.5	0.5	1.0	10	17	51
Garson	104	36	76	219	26	65	171	5	7	12	2.5	6	12	0.5	0.5	1.0	6	16	46
Lively	187	51	86	269	38	67	190	6	8	15	2.5	5	11	0.5	0.5	1.0	8	13	50
Sudbury (South)	92	41	75	318	27	63	340	5	7	15	2.5	2.5	8	0.5	0.5	1.2	6	12	120
Sudbury (Core)	324	69	200	909	56	190	829	6	12	35	2.5	6	20	0.5	1.0	4.0	9	30	140
Coniston	301	58	200	1200	49	150	800	6	12	45	2.5	7	33	0.5	0.5	3.0	12	32	150
Falconbridge	219	120	820	2110	71	780	1900	11	49	111	9	49	181	0.5	2.0	6.0	14	65	200
Copper Cliff	290	299	840	2455	360	1200	3300	12	27	79	6	14	45	2	6	16	25	69	220

Communities ranked from lowest to highest by the Nickel 95th percentile concentration. All results are in µg/g dry weight.

Table 7.0.2: Sudbury Communities as Grouped by Increasing Nickel Concentrations

Community	n	Ni			Cu			Co			As			Se			Pb		
		10th	median	95th	10th	median	95th	10th	median	95th	10th	median	95th	10th	median	95th	10th	median	95th
Outer Sudbury	284	32	48	79	21	35	59	4	5	12	3	3	7	0.5	0.5	1.0	7	11	35
Inner Sudbury	675	16	84	250	11	67	183	3	7	14	3	3	11	0.5	0.5	1.0	2	14	49
Sudbury (Core)	324	69	200	909	56	190	829	6	12	35	2.5	6	20	0.5	1.0	4.0	9	30	140
Coniston	301	58	200	1200	49	150	800	6	12	45	2.5	7	33	0.5	0.5	3.0	12	32	150
Falconbridge	219	120	820	2110	71	780	1900	11	49	111	9	49	181	0.5	2.0	6.0	14	65	200
Copper Cliff	290	299	840	2455	360	1200	3300	12	27	79	6	14	45	2.0	6.0	16.0	25	69	220

Groups ranked from lowest to highest by the Nickel 95th percentile concentration. All results are in µg/g dry weight.

Table 7.0.1: Summary and Ranking of the Concentrations of 11 Elements in the 0 - 5 cm Layer of Urban Surface Soils in the City of Greater Sudbury By Community (cont'd).

Community	n	Cd			Cr			Fe			Zn			Ba		
		10th	median	95th	10th	median	95th	10th	median	95th	10th	median	95th	10th	median	95th
Onaping Falls	6	0.4	0.4	0.4	26	30	32	11500	12500	14750	22	31	37	25	30	41
Dowling	36	0.4	0.4	3.2	24	43	53	13000	17000	20000	30	37	56	35	54	72
Wahnapitae	11	0.4	0.4	0.4	30	39	41	15500	18000	19000	25	33	35	35	45	50
Skead	10	0.4	0.4	0.4	21	24	42	11000	12500	16000	16	26	46	24	38	69
Val Therese	16	0.4	0.4	0.4	25	28	32	12000	13000	14750	18	23	34	27	33	40
Wanup	26	0.4	0.4	0.7	22	25	33	10560	13000	16000	22	24	33	29	33	49
Hanmer	54	0.4	0.4	0.4	24	26	38	11000	12000	17000	19	25	45	24	32	43
Naughton	6	0.4	0.4	0.4	19	25	33	10000	12000	14900	16	25	37	28	36	45
Levack	32	0.4	0.4	0.4	31	34	42	12000	15000	17100	26	37	54	32	45	56
Whitefish	40	0.4	0.4	0.4	23	38	64	13400	20000	28100	25	56	76	31	74	141
Capreol	19	0.4	0.4	0.6	23	26	36	11000	13000	16450	19	29	56	23	34	49
Chelmsford	12	0.4	0.4	0.4	21	27	38	10300	13000	17350	20	29	42	24	34	47
Blezard Valley	7	0.4	0.4	0.4	23	24	29	9960	11000	13000	22	26	31	28	31	40
Val Caron	10	0.4	0.4	0.4	23	27	57	10900	12000	20000	19	26	43	25	30	51
Azilda	156	0.4	0.4	0.4	25	35	51	11000	14500	19000	25	33	73	28	39	68
Sudbury (New)	74	0.4	0.4	0.4	25	31	43	11600	14000	18000	23	32	57	31	44	82
Sudbury (East)	62	0.4	0.4	0.4	23	31	43	11100	14000	19000	22	35	72	31	47	85
Garson	104	0.4	0.4	0.4	21	26	35	11000	12000	15000	21	32	70	24	36	52
Lively	187	0.4	0.4	0.9	24	32	47	12000	15000	21000	22	34	64	30	48	89
Sudbury (South)	92	0.4	0.4	0.9	24	32	47	11000	14000	18250	19	29	53	29	40	82
Sudbury (Core)	324	0.4	0.4	1.9	25	32	53	12000	15000	24850	24	47	159	31	50	119
Coniston	301	0.4	0.4	1.8	22	29	44	11000	15000	24000	27	51	140	33	52	90
Falconbridge	219	0.4	2.1	4.3	27	40	73	12800	21000	38000	29	66	150	31	50	69
Copper Cliff	290	0.4	1.4	3.4	29	38	60	14000	19000	33000	38	77	180	45	67	120

Communities ranked from lowest to highest by the Nickel 95th percentile concentration. All results are in µg/g dry weight.

Table 7.0.2: Sudbury Communities as Grouped by Increasing Nickel Concentrations

Community	n	Cd			Cr			Fe			Zn			Ba		
		10th	median	95th	10th	median	95th	10th	median	95th	10th	median	95th	10th	median	95th
Outer Sudbury	284	0.4	0.4	0.4	22	27	46	11000	13000	19850	19	27	56	25	35	68
Inner Sudbury	675	0.2	0.4	0.8	17	31	46	7500	14000	19000	12	32	64	15	43	82
Sudbury (Core)	324	0.4	0.4	1.9	25	32	53	12000	15000	24850	24	47	159	31	50	119
Coniston	301	0.4	0.4	1.8	22	29	44	11000	15000	24000	27	51	140	33	52	90
Falconbridge	219	0.4	2.1	4.3	27	40	73	12800	21000	38000	29	66	150	31	50	69
Copper Cliff	290	0.4	1.4	3.4	29	38	60	14000	19000	33000	38	77	180	45	67	120

Groups ranked from lowest to highest by the Nickel 95th percentile concentration. All results are in µg/g dry weight.

As discussed in Sections 5.1 and 5.2, we defined three main types of soil samples: Soil, Sand and Gravel and four types of produce samples: Root Vegetables, Fruit Vegetables, Leafy Vegetables and Berries. The Soil sample type made up 88% of the soil (soil, sand, gravel) samples collected. This group was further sub divided into Urban Soil (developed, grassed areas, 85% of the total number of soil samples), Urban Garden Soil (residential vegetable gardens, 1% of the soil samples), Agricultural Soil (commercial market garden and berry farms, 1% of the soil samples) and Undisturbed Natural Soil (undeveloped, naturally vegetated areas, 1% of the soil samples).

The Sand sample type comprised 9% of the total number of soil samples collected. The Sand sample type was subdivided into Play Sand (8% of the total number of soil samples) and Beach Sand (1 % of the total number of soil samples). The Gravel sample type comprised 4% of the total soil samples collected and was subdivided into Crushed Stone and Playground Gravel, each comprising 2% of the total number of soil samples collected.

The Root Vegetable sample type comprised 24% of all produce collected, the Fruit Vegetable sample type 39%, Leafy Vegetable sample type 19% and the Berries sample type 18% of the total number of produce samples collected.

This section is organized into the following subsections:

Section 7.1 discusses the metals and arsenic concentrations observed in urban soil

Section 7.2 discusses the metals and arsenic concentrations in sand and gravel and compares these results to urban soil

Section 7.3 discusses the metals and arsenic concentrations observed in undisturbed natural soil and compares these results to urban soil

Section 7.4 discusses the metals and arsenic concentrations in the commercial and residential fruit and vegetable produce and compares these results to the urban garden soil.

Section 7.5 summarizes Sections 7.1 through 7.4.

7.1 Urban Soil Data Trends

This discussion focuses on the urban soil samples collected by the Ministry in the City of Greater Sudbury in 2001. Urban soil samples were generally collected from grassed landscaped areas within the City of Greater Sudbury urban area at up to three depth intervals, 0 - 5 cm, 5 - 10 cm and 10 - 20 cm. Urban soil samples consisted of all material less than 2 millimetres in diameter, ranging in texture from sand to silty clays.

The urban soil samples, discussed in this section, were collected from three land uses: residential, schools and parks. The 2001 sampling program was the first large scale Ministry sampling of residential and institutional land use in the City of Greater Sudbury. This sampling was completed to assess metal and arsenic concentrations in urban soil, potentially attributed to aerial deposition from local industry. Previous sampling conducted by the Ministry in the Sudbury area was restricted mainly to undisturbed natural areas (MOE 2001). As a consequence, the chemical concentrations contained within this 2001 Urban Soil Survey may vary from previous Ministry soil data from the Sudbury area.

In most cases, urban soils have been altered during development of the area or property. These alterations may affect the chemical concentrations found in the soil. Soil may have been added, graded, removed, mixed and/or altered by anthropogenic activities and may have occurred repeatedly over time. As a consequence of these alterations, chemical concentrations in urban soil may vary between properties and evidence of aerial deposition may be inconsistent.

As discussed previously, the 24 local communities and geographic groupings in the City of Greater Sudbury were grouped according to observed metal and arsenic concentrations in the soil samples. The selection and delineation of these community groupings was determined by interpreting the trends in the metals and arsenic concentrations of urban soil using best professional judgement and / or statistical analysis. This grouping was completed to facilitate the interpretation and discussion of the soil data.

For urban soil, pH analysis was completed on 472 samples and pH ranged from 4.3 to 8.1. The Ministry *Guideline for Use at Contaminated Sites in Ontario* (MOE 1997) states that Table A soil criteria for inorganics apply only when the soil pH is between 5.0 and 9.0. No urban soil samples analyzed had a pH value that exceeded 9.0, however, three urban soil samples had pH values below 5.0. These three samples were located at one park in Falconbridge and two schools in the Outer Sudbury Communities. In these three samples, the pH ranged from 4.32 to 4.95. The pH values for all other urban soil samples analyzed were within the range of 5.0 to 9.0. Refer to Section 10.3 for descriptive statistics and box and whisker plots.

For each community grouping, descriptive statistics, exceedences of applicable Ministry guidelines, spatial distribution of chemical concentrations, concentration depth profiles, and statistical correlations between elements were discussed.

7.1.1 Outer Sudbury Communities

As discussed in 7.0, the Outer Sudbury Communities grouping consists of fourteen local communities including Blezard Valley, Capreol, Chelmsford, Dowling, Hanmer, Levack, Naughton, Onaping Falls, Skead, Val Caron, Val Therese, Wahnapitae, Wanup and Whitefish. This grouping was based on the concentrations of nickel, copper, cobalt, arsenic, selenium, lead, cadmium, chromium, iron, zinc, and barium in 0 - 5 cm surface soil layer. Concentrations of the eleven elements used in determining this grouping were relatively low at all three depths. Refer to Table 7.1.1.1 and Section 10.3.1.

Table 7.1.1.1: Summary Statistics for Metals and Arsenic in Urban Soil of the Outer Communities of the City of Greater Sudbury, 2001.

Summary Statistic	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
0 to 5 cm Urban Soil in the Outer Communities, n = 284																			
Minimum	4600	0.4	2.5	19	0.4	1600	18	3	9	8600	2	1200	100	0.75	17	0.5	13	8	13
10th percentile	7130	0.4	2.5	25	0.4	2700	22	4	21	11000	7	1800	140	0.75	32	0.5	23	23	19
1st quartile	8500	0.4	2.5	29	0.4	3200	24	5	26	12000	9	2100	160	0.75	39	0.5	28	26	22
Median	9700	0.4	2.5	35	0.4	4200	27	5	35	13000	11	2400	190	0.75	48	0.5	35	28	27
3rd quartile	11000	0.4	2.5	43	0.4	5950	33	7	44	15000	14	3600	240	0.75	57	0.5	41	31	36
95th percentile	14000	0.4	7	68	0.4	11000	46	12	59	19850	35	5400	379	0.75	79	1.0	49	40	56
Maximum	27000	1.6	16	150	3.8	33000	67	22	97	33000	170	10000	650	1.7	151	1.2	76	78	78
Mean	9999	0.4	3.6	39	0.4	5133	30	6	36	13711	15	2943	210	0.76	50	0.5	35	29	31
CV (std. dev./mean)	28%	22%	70%	44%	57%	68%	28%	43%	38%	25%	95%	46%	40%	12%	35%	24%	27%	23%	39%
Skewness	2.4	9.6	3.2	3.1	12.1	12.1	3.8	1.8	2.3	1.1	2.2	6.0	2.0	2.3	8.5	1.7	3.8	0.4	2.2
5 to 10 cm Urban Soil in the Outer Communities, n = 228																			
Minimum	4900	0.4	2.5	17	0.4	1200	17	3	7	7700	4	1100	99	0.75	18	0.5	13	21	12
10th percentile	7170	0.4	3	24	0.4	2270	22	4	16	11000	6	1700	130	0.8	28	0.5	21	24	17
1st quartile	8400	0.4	2.5	28	0.4	2800	24	4	22	12000	8	1900	150	0.75	33	0.5	27	26	19
Median	9950	0.4	2.5	35	0.4	3700	27	5	29	13000	9	2200	180	0.75	40	0.5	34	28	25
3rd quartile	11000	0.4	2.5	43	0.4	5100	32	6	35	15000	12	3400	230	0.75	51	0.5	40	32	31
95th percentile	15000	0.4	7.6	74	0.4	9455	46	12	53	20000	22	5565	317	0.75	70	0.5	49	40	62
Maximum	37000	1.8	23	210	0.4	38000	77	19	71	36000	91	12000	590	1.7	134	2.0	58	74	97
Mean	10428	0.4	3.4	40	0.4	4505	29	6	30	13850	11	2809	202	0.76	43	0.5	34	30	28
CV (std. dev./mean)	36%	37%	86%	58%	0%	77%	31%	44%	39%	28%	80%	57%	39%	11%	37%	27%	29%	26%	49%
Skewness	3.5	6.2	4.2	3.9		5.4	2.6	2.5	0.8	2.6	5.2	2.8	2.3	10.8	1.9	6	0.0	2.8	2.3
10 to 20 cm Urban Soil in the Outer Communities, n = 213																			
Minimum	4900	0.4	2.5	14	0.4	1400	15	3	4	7000	3	1400	85	0.75	13	0.5	12	17	9
10th percentile	6520	0.4	3	22	0.4	2100	21	4	11	10000	5	1700	130	0.8	22	0.5	20	22	15
1st quartile	8200	0.4	2.5	28	0.4	2800	23	4	17	11000	6	1900	160	0.75	27	0.5	26	25	19
Median	9500	0.4	2.5	35	0.4	3500	27	5	25	13000	9	2200	190	0.75	38	0.5	33	28	24
3rd quartile	11000	0.4	2.5	43	0.4	4500	32	6	33	16000	11	3300	235	0.75	48	0.5	41	33	31
95th percentile	16400	0.4	7	76	0.4	8180	47	11	47	23000	21	5900	384	0.75	68	0.5	50	45	58
Maximum	31000	4.0	44	210	0.9	20000	78	29	100	35000	214	11000	600	2.7	124	1	68	66	230
Mean	10174	0.4	3.4	40	0.4	4185	29	6	27	13935	11	2836	206	0.77	40	0.5	33	30	27
CV (std. dev./mean)	36%	73%	112%	63%	9%	68%	33%	50%	54%	31%	144	59%	40%	21%	42%	17%	31%	28%	68%
Skewness	2.5	9.2	7.4	3.6	14.6	3.4	2.0	3.7	1.7	2.0	10	2.6	1.9	10.2	1.5	5.3	0.2	2	6.7

All results are in µg/g dry weight.

In the Outer Sudbury Communities, the concentrations of nickel, copper, cobalt, arsenic and lead were similar in the school, park and residential properties, with only marginal differences. Due to the low n-values for residential properties at all depths, comparisons with this group are very general. It should be noted that in the Outer Sudbury Communities all of the urban soil sampling sites were school or park properties except for 5 residential properties in Skead. Refer to Table 7.1.1.2.

Table 7.1.1.2: Summary Statistics for Metals and Arsenic in All 0-5 cm Soil Samples in the Outer Sudbury Communities by Land Use

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Residential 0 to 5 cm				n = 12															
Minimum	7500	0.4	2.5	24	0.4	1700	19	5	20	11000	7	1800	130	0.75	32	0.5	22	23	18
10th percentile	7910	0.4	2.5	26	0.4	1820	20	5	22	12000	7	1830	143	0.75	34	0.5	22	24	23
1st quartile	8200	0.4	2.5	34	0.4	2250	23	5	28	12000	8	2150	170	0.75	36	0.5	23	25	26
Median	8900	0.4	2.5	41	0.4	2850	23	6	39	13000	10	2300	200	0.75	45	0.5	29	28	27
3rd quartile	11500	0.4	5.0	61	0.4	3250	29	7	46	14500	33	2650	220	0.75	50	0.5	30	30	40
95th percentile	12000	0.4	6.5	69	0.4	3535	43	8	56	16000	37	2890	258	0.75	58	0.5	31	33	47
Maximum	12000	0.4	7.0	71	0.4	3700	47	8	57	16000	40	3000	280	0.75	59	0.5	33	35	49
Mean	9517	0.4	3.6	46	0.4	2758	27	6	38	13417	18	2342	197	0.75	44	0.5	27	28	31
CV (std. dev./mean)	18%	0%	47%	36%	0%	23%	31%	19%	32%	12%	75%	16%	21%	0%	20%	0%	14%	12%	32%
Skewness	0.6		1.1	0.4		-0.5	1.7	0.4	0.0	0.4	0.9	0.2	0.3		0.3		-0.4	0.7	0.8
Schools and Daycares 0 to 5 cm				n = 95															
Minimum	5100	0.4	2.5	19	0.4	1700	18	3	12	8600	2	1200	100	0.75	17	0.5	16	20	13
10th percentile	7740	0.4	2.5	27	0.4	2440	23	4	21	11000	6	1900	134	0.75	32	0.5	22	23	21
1st quartile	8600	0.4	2.5	30	0.4	3200	25	5	26	11000	10	2100	150	0.75	38	0.5	27	26	23
Median	9600	0.4	2.5	35	0.4	4200	28	5	38	13000	12	2600	200	0.75	50	0.5	33	28	27
3rd quartile	11000	0.4	5.5	44	0.4	6400	34	7	48	15000	16	3650	250	0.75	65	0.5	39	32	37
95th percentile	13000	0.4	7.0	54	0.4	14300	46	10	69	17600	52	5460	330	0.75	83	1.0	48	37	52
Maximum	17000	0.8	8.0	81	0.8	33000	66	12	97	33000	170	8200	440	1.50	120	1.2	76	78	62
Mean	9769	0.4	3.6	37	0.4	5828	31	6	40	13587	18	3043	208	0.77	52	0.6	34	29	30
CV (std. dev./mean)	19%	17%	49%	28%	17%	84%	28%	34%	42%	24%	119	42%	32%	17%	37%	29%	30%	23%	34%
Skewness	0.5	5.4	1.1	1.4	5.4	3.3	1.8	1.1	1.1	2.7	4.5	1.3	0.8	5.4	1.2	3.0	1.0	4.1	1.0
Parks 0 to 5 cm				n = 177															
Minimum	4600	0.4	2.5	19	0.4	1600	18	4	9	9300	4	1600	110	0.75	19	0.5	13	8	13
10th percentile	6960	0.4	2.5	25	0.4	2860	22	4	20	11000	8	1800	140	0.75	33	0.5	24	23	19
1st quartile	8500	0.4	2.5	28	0.4	3300	24	5	26	12000	9	2100	160	0.75	39	0.5	31	26	22
Median	9700	0.4	2.5	34	0.4	4300	27	5	33	13000	11	2400	180	0.75	47	0.5	36	28	27
3rd quartile	11000	0.4	2.5	43	0.4	5850	32	7	42	15000	14	3600	230	0.75	56	0.5	42	31	36
95th percentile	15200	0.4	9.4	71	0.4	9520	45	12	55	21000	27	5440	420	0.75	78	0.5	49	41	59
Maximum	27000	1.6	16	150	3.8	19000	67	22	74	29000	66	10000	650	1.70	151	1.0	61	55	78
Mean	10155	0.4	3.6	39	0.4	4921	29	6	34	13797	13	2931	212	0.76	50	0.5	36	29	31
CV (std. dev./mean)	32%	25%	80%	51%	70%	50%	28%	47%	34%	26%	57%	48%	44%	9%	35%	20%	24%	24%	42%
Skewness	2.3	9.7	3.3	3.1	9.9	2.4	1.9	2.4	0.6	1.9	3.2	2.2	2.4	13.3	2.0	4.4	0.0	1.3	1.6

All results are in µg/g dry weight.

At 0 - 5 cm the concentrations of nickel, copper and lead were marginally higher in school properties than park and residential properties, while the concentrations of cobalt and arsenic were marginally higher in parks. Concentrations in the schools were marginally higher than the residences from the 25th percentile for nickel, the 75th percentile for copper, and the 95th percentile for cobalt and lead. Generally, concentrations in the schools were marginally higher than the parks from the median to 95th percentile for nickel, copper and lead, and concentrations of cobalt and arsenic were lower from the 95th percentile.

In the parks, concentrations were marginally higher then residences from the 25th percentile for nickel, and from the 95th percentile for cobalt and arsenic. Concentrations in the residences were higher than the parks from the minimum value for copper, and from the 75th percentile for lead. The maximum concentrations for lead was approximately twice as high in school properties compared with park and residential properties, but still relatively low. The maximum concentrations for nickel, cobalt and arsenic were observed in park properties, and were approximately twice as high for cobalt and arsenic compared to school and residential properties but still relatively low.

At 5 - 10 cm and 10 - 20 cm, concentrations were marginally higher in the park properties then the school and residential properties. The concentration in the schools were marginally higher than the residences for nickel, and similar for copper, cobalt, arsenic and lead.

Table 7.1.1.3 summarizes the number of urban soil samples that exceed the Table F and Table A criteria at all depths in the Outer Sudbury Communities. Only nickel, arsenic and lead concentrations exceeded Table A at any depth in the Outer Sudbury Communities. Nickel only exceeded Table A in one surface soil sample replicate. When averaged with the second replicate, however, the average concentration for this sample location was below Table A. Lead also exceeded Table A in only one sample replicate, however, no second replicate was available. All four of the arsenic Table A exceedences occurred at station 5030910 in Whitefish. No other elements exceeded Table A at any depths in the Outer Sudbury Communities.

Table 7.1.1.3: Summary of MOE Table F and Table A Exceedences for All Depths of Urban Soil Samples in the Outer Sudbury Communities of the City of Greater Sudbury

Element	Table F			Table A		
	0 to 5 cm	5 to 10 cm	10 to 20 cm	0 to 5 cm	5 to 10 cm	10 to 20 cm
Antimony	1	5 (2%)	4 (2%)	0	0	0
Arsenic	0	2 (1%)	2 (1%)	0	2 (1%)	2 (1%)
Cadmium	2 (1%)	0	0	0	0	0
Chromium	0	3 (1%)	1	0	0	0
Cobalt	1	0	1	0	0	0
Copper	3 (1%)	0	2 (1%)	0	0	0
Lead	1	0	1	0	0	1
Molybdenum	0	0	1	0	0	0
Nickel	176 (62%)	94 (41%)	79 (37%)	1	0	0
Selenium	0	1	0	0	0	0
Zinc	0	0	1	0	0	0
No. of Samples	284	228	213	284	228	213

Eleven elements exceed Table F criteria in the Outer Sudbury Communities. With the exception of nickel, the numbers of Table F exceedences per element were small. At 0 - 5 cm, 62% of the urban soil samples exceeded Table F for nickel while at 10 - 20 cm, only 37% of the urban soil samples exceeded Table F for nickel.

Due to low concentrations, sampling and analytical error, and the inherent variability in urban soils, no concentration gradient with respect to the three main smelting locations for any of the elements in the Outer Sudbury Communities was observed. Figure 7.1.1.1 depicts the lack of concentration gradient in the Outer Sudbury Communities for nickel in the 0 - 5 cm soil. Refer to Sections 10.2.7 through 10.2.9 for concentration dot maps of nickel, copper, cobalt, arsenic and lead in the Outer Sudbury Communities. Due to the large area covered by the Outer Sudbury Communities the area is represented by three maps, Valley East, Valley West, and Sudbury West. The Valley East maps includes Capreol, Hanmer, Val Therese, Blezard Valley, Val Caron and Skead. The Valley West maps include Levack, Onaping Falls, Dowling, Chelmsford, and Azilda. The Sudbury West maps include Whitefish, Naughton and Lively.

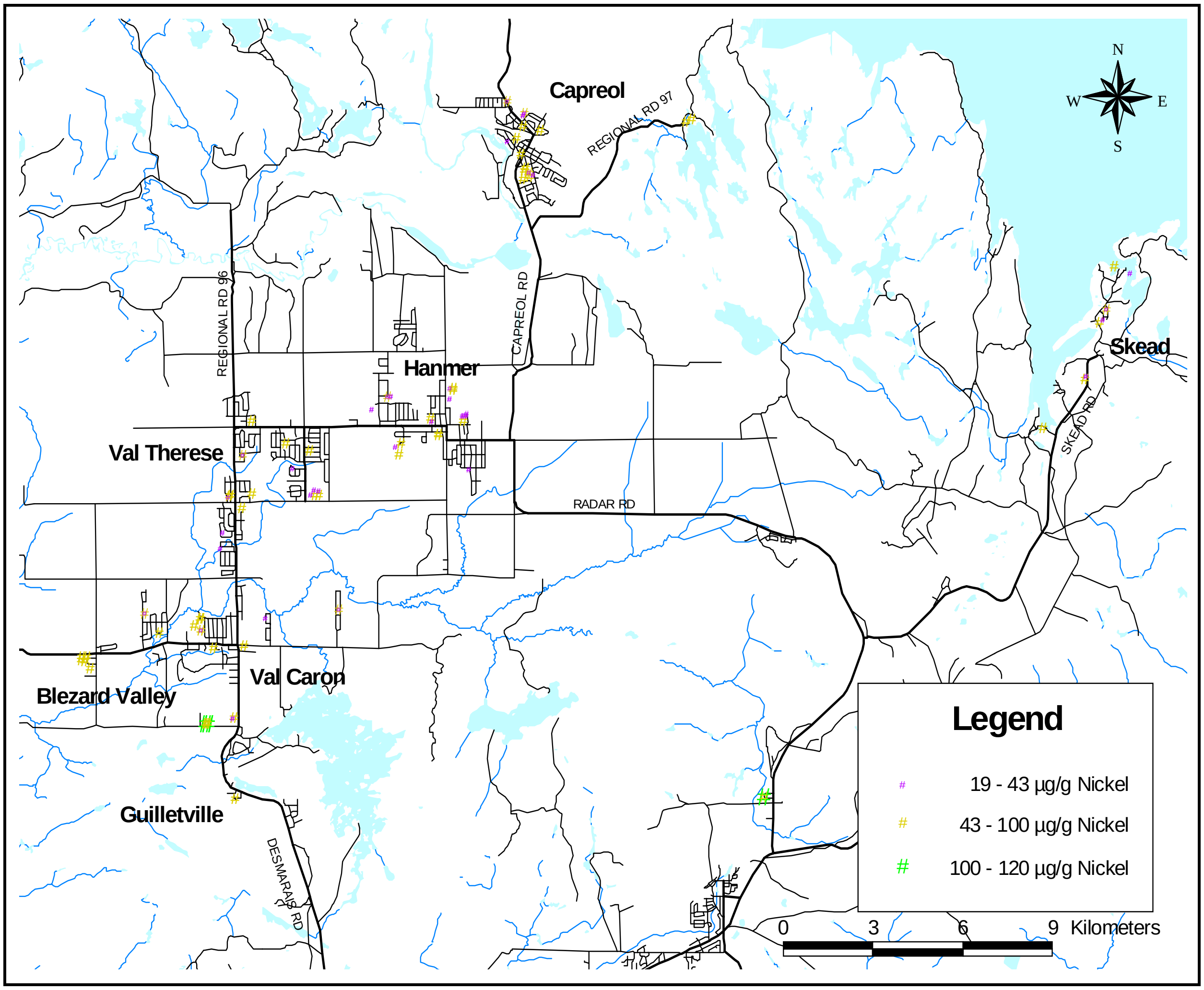


Figure 7.1.1.1: Ni concentrations in urban 0 - 5 cm soil in Valley East

As discussed in Section 5.3, the data was sorted by nickel concentrations to differentiate between the Group A, B and C trends. All three trends were observed in the Outer Sudbury Communities. In some cases, other elements did not show the same trend as nickel when the sorting was completed. This may be a reflection of average concentrations that are close or at the analytical method detection limit (MDL), as was the case for cadmium and selenium in the Outer Sudbury Communities. This may also be the result of poor correlation between other elements and nickel.

In the Outer Sudbury Communities, 49% of the sample locations exhibited a trend of decreasing concentrations with increasing depth, consistent with Group A. Nickel and copper concentrations, in Group A, showed a visual trend of decreasing concentration with depth in all quarters. Average concentrations at surface were 1.1 to 1.8 times the average concentrations at 10 - 20 cm for nickel and copper, for all quarters. Figure 7.1.1.2 depicts the depth profile of nickel in Group A for the Outer Sudbury communities.

Cobalt, lead, barium, iron and zinc showed a visual trend of aerial deposition in the third and fourth quarters. Average concentrations of these elements at surface were 1.1 to 1.4 times the average concentrations at 10 - 20 cm with the exception of lead. Average lead concentrations were 1.3 to

2.3 times at the surface than at 10 - 20 cm. A visual trend of aerial deposition was also observed in the first and second quarters for lead and zinc. Concentrations for selenium and cadmium in all quarters were at or near analytical MDLs, therefore no concentration trends were observed. The first through third quarters for arsenic in Group A were also at or near analytical MDLs, however, the average concentrations in the fourth quarter showed a slight increasing trend (1.1 times) with depth. This trend in the fourth quarter for arsenic may be an artifact of the sorting process.

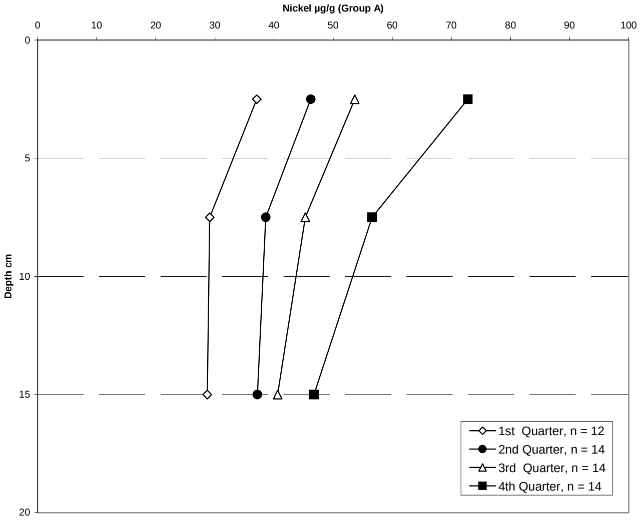


Figure 7.1.1.2: Outer Communities, Ni depth profiles, Group A**.**

Average aluminum, chromium and vanadium concentrations in Group A showed no observable change with depth in all four quarters. The wide range in concentrations between the quarters of these elements may indicate differences in soil type.

Refer to Section 10.5.1 for graphs of the depth profiles for the elements discussed above in the Outer Sudbury Communities.

In the Outer Sudbury Communities, 21% of the sample locations exhibited a trend of maximum concentrations at 5 - 10 cm, while lower concentrations were observed at both 0 - 5 and 10 - 20 cm. This trend is consistent with Group B. Nickel, copper, lead and zinc concentrations, in Group B, showed a strong, visual trend of maximum concentration occurring at 5 - 10 cm in the second half (1.5 to 1.8 times the average surface concentrations). This trend was weak in the first half for these elements (1.1 to 1.3 times). Figure 7.1.1.3 depicts the depth profile of nickel in Group B for the Outer Sudbury Communities.

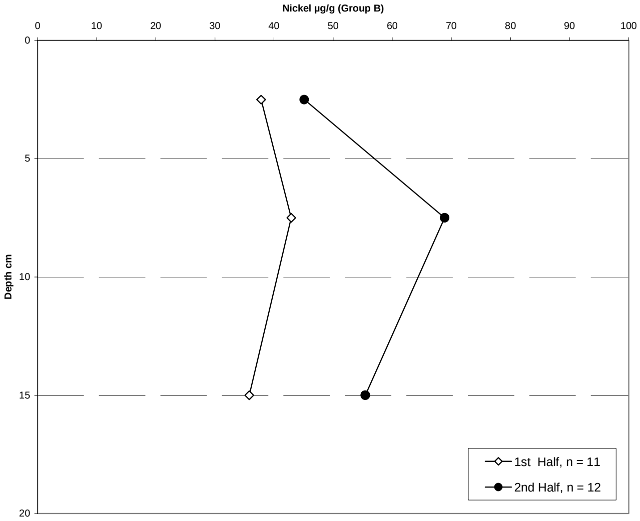


Figure 7.1.1.3: Outer Communities, Ni depth profiles, Group B.

Cobalt, aluminum, barium and chromium showed a weak Group B trend in the second half (1.1 to 1.2 times) and a weak or no observable change with depth in the first half. Concentrations for arsenic, selenium and cadmium in both halves were at or near analytical MDLs, therefore no concentration trends were observed. Average iron and vanadium concentrations in Group B showed no observable change with depth in both halves. Refer to Section 10.5.1 for graphs of the depth profiles for the elements discussed above.

In the Outer Sudbury Communities, 30% of the sample locations exhibited a trend of increasing concentration with increasing depth, consistent with Group C. Nickel and copper concentrations, in Group C, showed a weak, visual trend of increasing concentrations in the first and second thirds (1.2 to 1.3 times the surface concentrations) and a strong, visual trend in the last third (1.4 to 1.6 times). Figure 7.1.1.4 depicts the depth profile of nickel in Group C for the Outer Sudbury Communities.

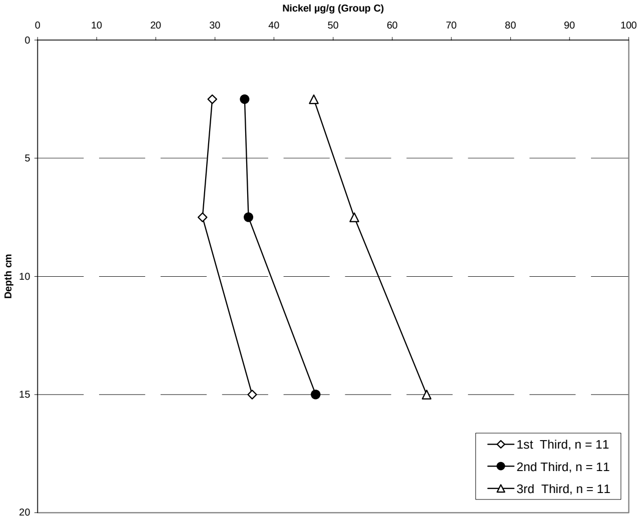


Figure 7.1.1.4: Outer Communities, Ni depth profiles, Group C.

Lead, aluminum and zinc showed a weak trend of increasing concentrations with depth in the last third (1.1 to 1.4 times). Lead also showed this weak trend in the second third (1.3 times). Aluminum and zinc showed a weak trend of decreasing concentration with depth in both the first and second thirds while lead showed this trend only in the first third. Barium showed no observable change in concentration with depth in the first and second thirds and showed a weak trend of decreasing concentration with depth in the last third.

Cobalt, chromium, iron and vanadium concentrations in Group C showed no observable change with depth for all thirds. Concentrations for arsenic, selenium and cadmium in all thirds were at or near analytical MDLs and generally no concentration trends were observed. Refer to Section 10.5.1 for graphs of the depth profiles for the elements discussed above.

Overall, nickel, copper, lead and zinc concentrations in 49% of the sample locations in the Outer Sudbury Communities showed an aerial deposition trend from surface (Group A). These sample locations appeared to be unaffected by landscaping practices. The remaining 51% of the sample locations appeared to be affected by some degree of landscaping practices as nickel, copper, lead and zinc concentrations showed strong to weak trends of maximum concentrations below surface (Groups B & C). These elevated concentrations may still be attributed to aerial deposition, however, have been buried by landscaping practices at individual properties over time. Addition, grading, removal and / or mixing of urban soils may alter the vertical distribution of chemical concentrations in the soil. Cobalt, barium and iron also showed a weak aerial deposition trend from surface in 49% of the sample locations.

There is some question as to whether the Table F upper limit for background concentrations should be used for the City of Greater Sudbury due to the local geology. The Outer Sudbury Communities appear to be minimally impacted by aerial deposition and could be used to determine an upper limit of local background. For most elements there is evidence of at least a small amount of aerial deposition or evidence that landscaping practices have buried elevated concentrations resulting from aerial deposition. Given these restrictions, the local background was determined using only the 10 - 20 cm soil results.

Table 7.1.1.4: Comparison of the 98th Percentiles*, MOE Table F Values, and Table F Site Exceedences for All Samples from the Outer Sudbury Communities

Element	98th Percentile (µg/g)	Table F Value (µg/g)	Table F Site Exceedences
Antimony	<0.8	1	0
Arsenic	14	17	1 (1%)
Barium	133	210	0
Beryllium	<0.5	1.2	0
Cadmium	<0.8	1	0
Chromium	55	71	1 (1%)
Cobalt	12	21	0
Copper	77	85	0
Lead	31	120	1 (1%)
Molybdenum	1.1	2.5	0
Nickel	83 / 57*	43	43 (39%)
Selenium	1	1.9	0
Vanadium	59	91	0
Zinc	70	160	1 (1%)

* 98th percentile calculated for Ni, using only 10 to 20 cm, Group A results

The 10 - 20 cm replicates for each sampling location were averaged and 98th percentile values determined for each of the elements where Table F values exist, similar to the procedure used to create the Table F values. These values were calculated using the entire Outer Sudbury Community data set. The data was not segregated by depth trends (i.e. Group A, B and C). For antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, molybdenum, selenium, vanadium and zinc the 98th percentile calculated for the Outer Sudbury Communities based on the 10 - 20 cm soil samples were all well below the Table F values. Using the Table F values for these elements is therefore justified. Refer to Table 7.1.1.4 for 98th percentiles calculated for the Outer Sudbury Communities, the corresponding Table F values and number of locations that exceeded Table F values for each element.

The 98th percentile calculated for nickel, using the entire Outer Sudbury Communities data set, was 83 µg/g which exceeded the Table F value of 43 µg/g. Forty three of the 110 sampling locations exceed the Table F value for nickel. The nickel concentrations in Group A decrease with depth and the 98th percentile of the 10 - 20 cm sample results in Group A was calculated to be 57 µg/g. Fifteen of 54 Group A sampling locations exceeded the Table F value for nickel. It should be noted that the Group A fourth quarter data for nickel did not appear to approach the background concentrations at 10 - 20 cm. If the data from this quarter was removed, the Group A 98th percentile value would likely be closer to the Table F nickel value of 43 µg/g. The 98th percentiles determined here will not be used in this report to replace the Table F for nickel because of the limited number of sampling points and the depths collected may not have been deep enough. Laurentian University was responsible for conducting extensive sampling in undisturbed areas in 2001 for the purpose of determining an accurate background concentration for the City of Greater Sudbury.

Table 7.1.1.5: Pearson's and Spearman's Correlations for 0 - 5 cm Urban Soil in the Outer Sudbury Communities

	Al	**As**	**Ba**	**Cd**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Ni**	**Se**	**Sr**	**V**	**Zn**
Al	1	*0.1*	*0.7*	*0.1*	*0.7*	*0.3*	*0.2*	*0.7*	*0.2*	*0.3*	*0.5*	*0.3*	*0.0*	*0.6*	*0.7*	*0.5*
As	0.1	1	*0.1*	*0.1*	*0.0*	*0.1*	*0.3*	*0.1*	*0.3*	*-0.1*	*0.0*	*0.2*	*0.1*	*-0.2*	*0.0*	*0.2*
Ba	**0.9**	0.1	1	*0.2*	*0.7*	*0.6*	*0.3*	*0.7*	*0.3*	*0.6*	***0.8***	*0.4*	*0.0*	*0.6*	*0.7*	*0.7*
Cd	0.2	0.0	0.2	1	*0.1*	*0.2*	*0.1*	*0.2*	*0.1*	*0.1*	*0.2*	*0.0*	*0.3*	*0.1*	*0.2*	*0.2*
Cr	0.7	0.0	0.7	0.2	1	*0.6*	*0.2*	***0.8***	*0.3*	*0.7*	*0.6*	*0.2*	*0.0*	*0.6*	***0.8***	*0.6*
Co	0.5	0.1	0.7	0.2	0.6	1	*0.3*	***0.8***	*0.3*	*0.7*	***0.8***	*0.4*	*0.0*	*0.3*	*0.7*	*0.6*
Cu	0.2	0.3	0.2	0.0	0.2	0.4	1	*0.3*	*0.6*	*0.1*	*0.3*	***0.9***	*0.1*	*0.0*	*0.2*	*0.4*
Fe	**0.8**	0.1	**0.8**	0.2	**0.8**	**0.8**	0.3	1	*0.2*	*0.7*	***0.8***	*0.2*	*0.0*	*0.4*	***0.9***	*0.7*
Pb	0.1	0.1	0.2	0.0	0.3	0.1	0.2	0.0	1	*0.1*	*0.2*	*0.5*	*0.1*	*0.0*	*0.2*	*0.6*
Mg	0.5	0.0	0.6	0.1	0.6	0.7	0.1	0.7	0.0	1	*0.7*	*0.1*	*0.0*	*0.4*	*0.6*	*0.5*
Mn	0.6	0.2	0.7	0.1	0.6	**0.8**	0.3	**0.8**	0.1	0.6	1	*0.3*	*0.0*	*0.4*	***0.8***	*0.7*
Ni	0.2	0.2	0.2	0.0	0.2	0.3	**0.8**	0.2	0.2	0.1	0.3	1	*0.1*	*0.2*	*0.2*	*0.4*
Se	0.0	0.1	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.2	1	*-0.1*	*0.0*	*0.1*
Sr	0.5	-0.1	0.4	0.1	0.5	0.3	0.0	0.4	0.0	0.4	0.4	0.1	0.0	1	*0.5*	*0.2*
V	0.7	0.1	0.7	0.1	**0.8**	0.7	0.2	**0.9**	0.0	0.6	0.7	0.2	0.0	0.4	1	*0.6*
Zn	0.6	0.3	0.7	0.2	0.6	0.7	0.5	0.7	0.3	0.5	**0.8**	0.4	0.1	0.2	0.6	1

Spearman's correlations in upper right in italics. Pearson's correlations in lower left in normal font.

Pearson's and Spearman's statistical correlation analysis was performed on all of the elements except beryllium at each of the three depths. Refer to Table 7.1.1.5 for an abbreviated version of the results of the Pearson's and Spearman's analysis for the 0 - 5 cm depth and Tables 10.4.1.1 through 10.4.1.3 for the full results of the analysis at all three depths. In Table 7.1.1.5 the results have been rounded to one decimal place and values that were 0.75 or greater are considered strong and are indicated in bold type.

Of the major elements emitted by the mining and smelting processes in the Sudbury area only nickel and copper were strongly correlated with each other in the Outer Sudbury Communities at the 0 - 5 cm depth using Pearson's and Spearman's; 0.8 and 0.9, respectively. The correlation between nickel and copper remained strong and constant, with depth, using Spearman's and strong, although slightly decreasing with depth, using Pearson's. Arsenic did not correlate with any element at any depth using either Pearson's or Spearman's. Refer to Figures 7.1.1.5 and 7.1.1.6 for graphs of the

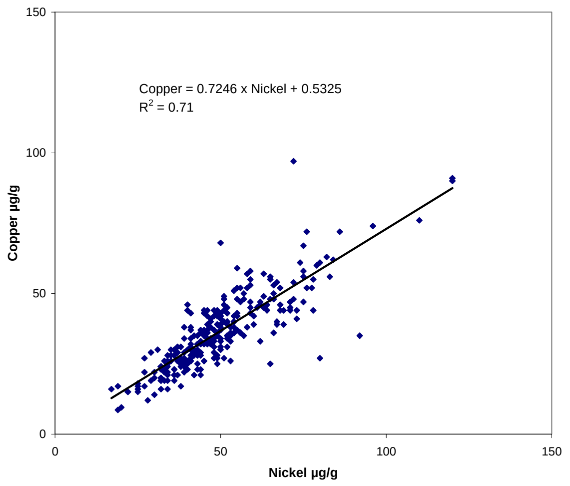


Figure 7.1.1.5: Cu vs. Ni, 0-5 cm, Outer Communities

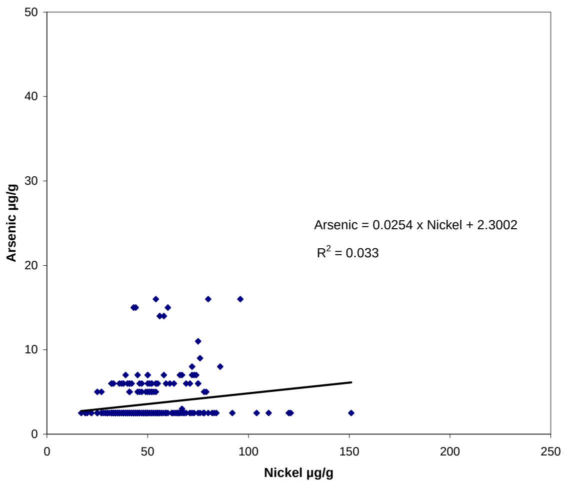


Figure 7.1.1.6: As vs Ni, 0-5 cm, Outer Communities

Ni/Cu and Ni/As correlations.

Using Pearson's and Spearman's, lead did not correlate with any elements at either the 0 - 5 or 5 - 10 cm depth intervals with the exception of a moderate correlation with zinc at 5 - 10 cm. At 10 - 20 cm, lead strongly correlated with cadmium and zinc in Pearson's but these correlations were largely driven by station 5030770 in McNicol Playground, Capreol. A moderate correlation between lead and copper was observed with Spearman's at this depth.

Strong or moderate correlations of cadmium with lead, molybdenum and/or zinc at 0 - 5 cm and 10 - 20 cm were largely driven by station 5030817, Douglas St playground in Dowling, at the 0 - 5 cm depth and by station 5030770 at the 10 - 20 cm depth. Cadmium was not detected above the analytical detection limit in any of the 5 - 10 cm samples and therefore did not correlate with any elements at this depth.

Pearson's and Spearman's showed both strong and moderate correlations between aluminum, barium, chromium, cobalt, iron, magnesium, manganese, vanadium and zinc at all depths. Overall the number and strength of these correlations generally increased with depth with little difference between Pearson's and Spearman's. Strontium and calcium became correlated to these elements in the 5 - 10 cm and 10 - 20 cm depths. Refer to Tables 10.4.1.1 through 10.4.1.3.

The correlations of aluminum, barium, iron, manganese, and vanadium are consistently strong in the Outer Sudbury Communities especially at depth. The increase in the number and strength of these correlations with depth is indicative of less disturbed soil at depth. Refer to Figures 7.1.1.7 and 7.1.1.8. This along with the soil profiles for these elements show that these elements appear to be indicative of the natural chemistry of the soil in the City of Greater Sudbury. Cobalt and chromium concentrations in the Outer Sudbury Communities tended to correlate with these naturally occurring elements indicating that cobalt and chromium concentrations also appear to be attributed to natural background concentrations rather than emissions from smelting activities. Cobalt and chromium concentrations in the Outer Sudbury Communities did not correlate with nickel and copper concentrations at any depth.

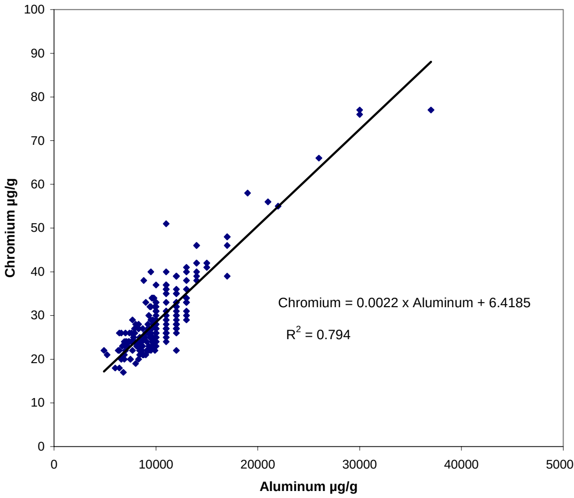


Fig. 7.1.1.7: Cr vs. Al, 5-10 cm, Outer Communities

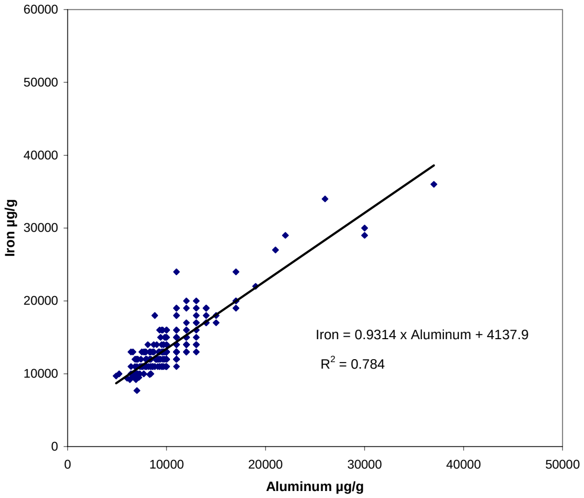


Fig. 7.1.1.8: Fe vs. Al, 5-10 cm, Outer Communities

Nickel and copper concentrations, in the Outer Sudbury Communities, strongly correlated only with each other and not with any other element at any depth. In the Ontario Typical Range (OTR) data that was used to create the Table F criteria, there were strong Spearman's correlations between cobalt and aluminum, barium, chromium, iron and nickel and a moderate correlation with vanadium. Nickel showed strong correlations with copper, cobalt, chromium and aluminum. The number and strength of the OTR correlations indicates that Ontario background concentrations of nickel, cobalt and copper generally correlate with elements such as aluminum, barium, chromium, iron and vanadium. Since, nickel and copper concentrations were not strongly correlated with any other elements in the Outer Sudbury Communities, nickel and copper appear to be slightly elevated due to emissions from the mining and smelting operations. OTR data was collected throughout Ontario including one third of the data from Northern Ontario. Refer to Figures 7.1.1.9 and 7.1.1.10. Refer to Figures 10.4.1.1 through 10.4.1.39 for a complete list of graphs showing selected element correlations at all three depths for the Outer Sudbury Communities.

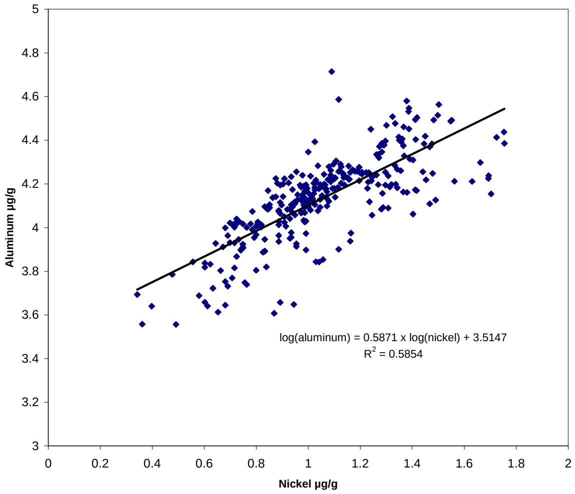


Figure 7.1.1.9: Ni vs Al in OTR rural data.

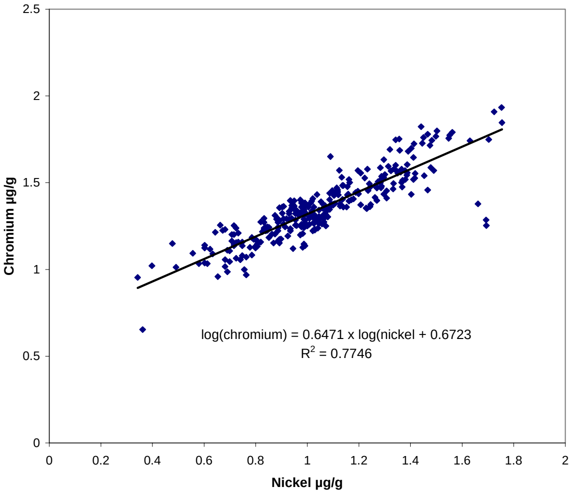


Figure 7.1.1.10: Ni vs Cr in OTR rural data.

In the Outer Sudbury Communities, only a small number of sample locations exceeded Table A for nickel, arsenic and lead at any depth. Eleven elements exceeded Table F criteria in the Outer Sudbury Communities. With the exception of nickel, the numbers of Table F exceedences per element were small. Nickel, copper, lead and zinc concentrations, in approximately half of the sample locations, showed a strong aerial deposition trend from surface. At the remaining sample locations, elevated concentrations of these elements occurred below surface. These elevated concentrations may still be attributed to aerial deposition, however, may have been buried by landscaping practices over time. Cobalt, barium and iron also showed a weak aerial deposition trend from surface in approximately half of the sample locations. Despite evidence of aerial deposition, no concentration gradient for nickel, copper, lead and zinc was observed in the Outer Sudbury Communities. No concentration gradients were observed for any elements.

Nickel and copper concentrations in the Outer Sudbury Communities only strongly correlated with each other and not with any other element at any depth. Aluminum, barium, iron, manganese, and vanadium appeared to be indicative of the natural chemistry of the soil in the City of Greater Sudbury. Cobalt and chromium concentrations in the Outer Sudbury Communities tended to correlate with these naturally occurring elements and not with nickel and copper. Using the data from the Outer Sudbury Communities, local Sudbury background concentrations were calculated. Only the local nickel background concentration exceeded the Table F criteria. This indicates that with the exception of nickel, the Table F criteria appear to be appropriate for use in the City of Greater Sudbury.

7.1.2 Inner Sudbury Communities

As discussed in 7.0, the Inner Sudbury Communities grouping consisted of three local communities and three geographic groupings including Azilda, Garson, Lively, Sudbury East, Sudbury New and Sudbury South. The grouping was based on the concentrations of nickel, copper, cobalt, arsenic, selenium, lead, cadmium, chromium, iron, zinc, and barium in 0 - 5 cm surface soil. Concentrations of the eleven elements used in determining this grouping are relatively low but higher than the Outer Sudbury Communities. Refer to Table 7.1.2.1.

Table 7.1.2.1: Summary Statistics for Metals and Arsenic in Urban Soil of the Inner Sudbury Communities of the City of Greater Sudbury.

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
0 to 5 cm Urban Soil in the Inner Communities, n = 675																			
Minimum	4100	0.4	2.5	15	0.2	1800	17	3	11	7500	2	1300	90	0.75	16	0.5	10	17	12
10th percentile	7400	0.4	2.5	29	0.4	3200	24	5	35	11000	8	2200	150	0.75	47	0.5	24	24	21
1st quartile	8500	0.4	2.5	34	0.4	3900	27	6	47	13000	10	2500	170	0.75	62	0.5	30	26	26
Median	9800	0.4	2.5	43	0.4	5000	31	7	67	14000	14	3100	200	0.75	84	0.5	36	29	32
3rd quartile	11000	0.4	6.0	53	0.4	6400	36	9	100	16000	22	3700	240	0.75	125	0.5	42	32	40
95th percentile	15000	0.8	11	82	0.8	10300	46	14	183	19000	49	5200	310	0.75	250	1.0	50	37	64
Maximum	19000	4.4	30	130	2.0	27000	70	42	1400	27000	220	13000	510	6.40	1400	6.0	170	47	150
Mean	10100	0.5	4.9	46	0.4	5475	32	8	88	14329	21	3306	210	0.79	109	0.6	36	30	35
CV (std. dev./mean)	24%	66%	72%	36%	37%	46%	23%	47%	105%	19%	114	36%	26%	35%	93%	65%	30%	16%	45%
Skewness	0.7	7.5	2.5	1.3	5.8	2.5	1.0	4.2	7.9	1.1	4.6	2.5	1.3	13.8	7	7.3	3.2	0.5	2.6
5 to 10 cm Urban Soil in the Inner Communities, n = 531																			
Minimum	5100	0.4	2.5	15	0.4	1400	17	3	8	7500	1	1300	92	0.75	17	0.5	13	13	9
10th percentile	6900	0.4	2.5	26	0.4	2600	23	5	27	11000	6	2000	140	0.75	37	0.5	23	24	18
1st quartile	8400	0.4	2.5	33	0.4	3200	25	6	38	12000	8	2300	160	0.75	50	0.5	28	26	22
Median	9900	0.4	2.5	42	0.4	4100	30	7	54	14000	11	2900	190	0.75	68	0.5	34	30	27
3rd quartile	12000	0.4	7	53	0.4	5300	34	8	75	16000	14	3600	230	0.75	96	0.5	40	33	35
95th percentile	15000	0.4	11	86	0.4	9150	46	11	120	20000	27	5400	315	0.75	150	1.0	49	40	58
Maximum	22000	6.5	34	150	1.2	22000	75	29	880	26000	310	10000	440	3.20	880	5.0	65	50	160
Mean	10269	0.4	4.9	46	0.4	4672	31	7	64	14251	14	3120	201	0.78	80	0.6	34	30	31
CV (std. dev./mean)	27%	74%	81%	43%	18%	51%	25%	35%	90%	21%	162%	38%	30%	25%	75%	54%	26%	18%	50%
Skewness	0.8	14.6	3.2	1.7	7.3	2.6	1.3	2.7	9.2	0.9	9.8	1.8	1.0	7.4	7.3	6.2	0.2	0.6	3.1
10 to 20 cm Urban Soil in the Inner Communities, n = 492																			
Minimum	4900	0.4	2.5	16	0.4	1500	17	4	9	8000	2	1400	93	0.75	18	0.5	12	10	9
10th percentile	6200	0.4	2.5	24	0.4	2310	21	4	23	10000	5	2000	130	0.75	32	0.5	20	23	15
1st quartile	8000	0.4	2.5	33	0.4	3000	25	5	31	12000	6	2300	160	0.75	43	0.5	27	25	19
Median	9900	0.4	2.5	44	0.4	4000	29	7	46	14000	9	2900	200	0.75	58	0.5	34	29	25
3rd quartile	12000	0.4	6.0	62	0.4	5300	36	9	68	17000	13	3900	250	0.75	86	0.5	41	34	34
95th percentile	17000	0.4	11	100	0.4	9435	49	12	130	22000	28	6045	330	0.75	160	1.0	53	43	53
Maximum	23000	3.9	40	160	1.2	24000	69	21	340	30000	150	11000	430	21.00	360	2.0	60	62	110
Mean	10419	0.4	4.8	50	0.4	4561	31	7	56	14553	12	3269	205	0.81	71	0.6	34	30	29
CV (std. dev./mean)	34%	56%	82%	50%	17%	56%	30%	34%	71%	26%	105%	42%	31%	114%	63%	31%	30%	22%	49%
Skewness	1.0	10.5	3.8	1.4	8.8	2.6	1.2	1.3	2.7	1.0	5.6	1.7	0.7	21.5	2.4	2.9	0.2	0.8	2.0

All results are in µg/g dry weight.

In the 0 - 5 cm soil samples, nickel and copper concentrations were approximately double the concentrations found in the Outer Sudbury Communities (Table 7.1.1.1). Lead had a slight increase from the 70th percentile up. Arsenic, barium, cobalt and selenium had only a small increase from the 95th percentile up as compared to the Outer Sudbury Communities. Aluminum, iron, vanadium and zinc were only higher at the maximum concentrations. In the 10 - 20 cm soil samples, nickel and copper were approximately double the concentrations found in the Outer Sudbury Communities from the 80th percentile up. All other elements were essentially the same between the Inner and Outer Sudbury Communities at the 10 - 20 cm depth.

It should be noted that in the Outer Sudbury Communities all of the urban soil sampling sites were school or park properties except for 5 residential properties in Skead. In the Inner Sudbury Communities half of the urban soil samples were from residential properties, with the other half from either school or park properties. Two residential properties, stations 5037916 and 5037939, were atypical in that they were considerably higher in concentration for most elements. At station 5037939 the owner informed the Ministry representative that the yard in question had been filled in and he did not know the origin of the fill. At station 5037916, the concentrations of one sample replicate was approximately an order of magnitude higher for most elements. As a result, these two properties elevated the maximum and 95th percent concentrations observed in the Inner Sudbury Communities. For the purposes of depth profile and correlation analysis the results from these two stations were removed from the data set.

In the Inner Sudbury Communities, the concentrations of nickel, copper, cobalt, arsenic and lead varied between residential, school and park properties and with depth. The sample size for the school properties decreased substantially at 5 - 10 and 10 - 20 cm. This reduction in sample size may affect the validity of comparisons between the school properties and the other land uses. Refer to Table 7.1.2.2.

Table 7.1.2.2: Summary Statistics for Metals and Arsenic for All 0- 5 cm Urban Soil Samples from the Inner Sudbury Communities by Land Use

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Residential 0 to 5 cm				n = 314															
Minimum	5300	0.4	2.5	26	0.2	2000	17	4	20	7500	4	1800	120	0.75	30	0.5	14	17	15
10th percentile	7600	0.4	2.5	33	0.4	3500	26	6	41	12000	9	2200	150	0.75	53	0.5	27	25	24
1st quartile	8900	0.4	2.5	39	0.4	4000	28	6	56	13000	12	2500	180	0.75	70	0.5	32	27	29
Median	10000	0.4	5.0	49	0.4	4900	32	8	79	14000	17	3000	205	0.75	90	0.5	38	30	36
3rd quartile	12000	0.4	7.0	62	0.4	5900	38	10	120	16000	25	3600	240	0.75	140	0.5	42	33	47
95th percentile	15350	0.8	12	88	0.8	8135	47	15	217	20000	46	4700	310	1.50	270	1.0	50	38	71
Maximum	19000	2.5	30	130	2.0	18000	70	41	1400	27000	220	9200	450	6.40	1400	6.0	63	47	150
Mean	10687	0.5	5.5	53	0.4	5256	33	9	106	14803	23	3161	214	0.83	124	0.7	37	30	41
CV (std. dev./mean)	23%	56%	70%	35%	43%	39%	22%	49	116	20%	104%	31%	25%	49%	105%	75%	22%	16%	46%
Skewness	0.6	5.8	2.2	1.1	4.9	2.7	0.9	4.2	6.6	1.2	5.0	2.4	1.1	9.6	6.5	6.8	-0.1	0.5	2.4
Schools and Daycares 0 to 5 cm				n = 175															
Minimum	4100	0.4	2.5	15	0.4	2000	20	3	11	8500	2	1600	110	0.75	16	0.5	14	20	12
10th percentile	7340	0.4	2.5	28	0.4	2900	24	5	26	11000	6	2300	150	0.75	38	0.5	23	24	20
1st quartile	8200	0.4	2.5	32	0.4	3600	28	6	39	12500	9	2600	170	0.75	57	0.5	28	26	25
Median	9200	0.4	2.5	40	0.4	5100	31	7	56	14000	12	3100	200	0.75	73	0.5	33	29	29
3rd quartile	10300	0.4	6.0	45	0.4	6900	35	9	100	15000	21	4000	230	0.75	120	0.5	41	32	35
95th percentile	12000	0.5	8.0	53	0.5	11000	43	13	160	17300	113	5460	270	0.75	205	1.2	48	34	52
Maximum	14000	4.4	9.0	70	1.6	18000	67	42	370	24000	200	9200	380	1.60	630	4.0	170	39	75
Mean	9249	0.5	3.8	39	0.4	5584	32	8	73	13809	24	3426	202	0.75	95	0.6	35	29	31
CV (std. dev./mean)	18%	89%	51%	23%	36%	46%	22%	54	68%	17%	136%	35%	21%	9%	76%	64%	41%	12%	35%
Skewness	-0.3	7.0	1.0	0.4	5.3	1.3	1.6	4.9	2.3	1.1	3.0	1.7	0.5	13.2	3.5	5.1	5.2	0.0	1.6
Parks 0 to 5 cm				n = 186															
Minimum	4900	0.4	2.5	18	0.4	1800	17	4	13	9100	3	1300	90	0.75	25	0.5	10	17	13
10th percentile	6900	0.4	2.5	26	0.4	2900	22	5	32	11000	7	2200	140	0.75	45	0.5	23	22	19
1st quartile	8200	0.4	2.5	31	0.4	4000	24	6	45	12000	10	2400	160	0.75	62	0.5	29	25	25
Median	9600	0.4	2.5	40	0.4	5000	28	8	60	14000	13	3200	200	0.75	82	0.5	36	28	30
3rd quartile	11000	0.4	6.0	49	0.4	6600	34	9	79	15000	17	3800	240	0.75	110	0.5	44	32	36
95th percentile	15000	0.4	12	74	0.4	12000	45	14	168	19000	26	6250	318	0.75	247	1.0	56	37	51
Maximum	17000	2.6	27	95	1.0	27000	57	20	230	22000	50	13000	510	0.75	304	1.0	80	42	77
Mean	9911	0.4	4.7	42	0.4	5741	30	8	70	14018	14	3438	211	0.75	96	0.6	37	29	31
CV (std. dev./mean)	25%	51%	81%	36%	15%	54%	25%	35	58%	20%	50%	43%	32%	0%	59%	29%	30%	17%	34%
Skewness	0.7	7.4	2.4	1.1	9.6	2.8	1.1	1.0	1.7	0.7	2.0	2.6	1.5		1.8	2.4	0.6	0.5	1.4

All results are in µg/g dry weight.

Cobalt concentrations were generally similar in all three land uses at all depths. Concentrations of nickel and copper were generally higher in residential properties than in school and park properties, except at 10 - 20 cm where these elements were similar in both residential and park properties . Nickel and copper concentrations in the residential properties were higher than school and park properties from the 10th percentile to the median and onwards, dependant on the depth and element. Nickel concentrations between residential and park properties at 5 - 10 cm were very similar except for a higher maximum value for the residential properties. Arsenic concentrations were higher in the residential and park properties than in the schools at surface from the median to the 90th percentile and onwards and marginally higher in the 5 - 10 cm soi layer. At 10 - 20 cm, arsenic concentrations in the park properties were higher than in the residential and school properties from the 95th percentile and onwards. Except for the surface, lead concentrations were higher in the residential properties than in the park and school properties from the 30th to 80th percentiles and onwards, respectively. At the surface, lead concentrations were generally higher in the school properties, from the 80th to 90th percentile and onwards, with the exception of the maximum value which was highest in residential properties.

Selenium concentrations were marginally higher in the residential and school properties at the surface and in the residential properties at 5 - 10 cm. Selenium concentrations were similar at depth between all land uses. Zinc concentrations were higher in the residential properties at all depths. Chromium and iron concentrations were also generally higher in the residential and park properties below surface. This trend may be the result of the small number of samples for the school properties below surface. Cadmium concentrations were similar at all depths between all land uses.

Generally, concentrations of nickel, copper, and to a lesser extent cobalt, were substantially higher in school and park properties at the surface compared to the Outer Sudbury Communities. Concentrations remained higher than the Outer Sudbury Communities for nickel and copper with depth.

Table 7.1.2.3: Summary of MOE Table F and Table A Exceedences for Metals and Arsenic in All Urban Soil Samples from the Inner Communities of the City of Greater Sudbury

Element	Table F			Table A		
	0 to 5 cm	5 to 10 cm	10 to 20 cm	0 to 5 cm	5 to 10 cm	10 to 20 cm
Antimony	21 (3%)	5 (1%)	8 (2%)	0	0	0
Arsenic	7 (1%)	7 (1%)	6 (1%)	4 (1%)	7 (1%)	3 (1%)
Cadmium	7 (1%)	2	3 (1%)	0	0	0
Chromium	0	1	0	0	0	0
Cobalt	8 (1%)	2	0	2	0	0
Copper	240 (36%)	102 (19%)	74 (15%)	19 (3%)	3 (1%)	4 (1%)
Lead	16 (2%)	4 (1%)	1	1	4 (1%)	0
Molybdenum	2	1	1	0	0	0
Nickel	622 (92%)	442 (83%)	362 (74%)	115 (17%)	25 (5%)	28 (6%)
Selenium	12 (2%)	8 (2%)	1	0	0	0
No. of Samples	675	531	492	675	531	492

Table 7.1.2.3 summarizes the number of urban soil samples that exceed the Table F and Table A criteria in the Inner Sudbury Communities. Concentrations of nickel, copper, cobalt, arsenic and lead exceeded Table A at one or more depth intervals in the Inner Sudbury Communities. Only nickel,

copper and arsenic concentrations exceeded Table A at all depths. No other elements exceeded Table A at any depths in the Inner Sudbury Communities. Ten elements exceed Table F criteria in the Inner Sudbury Communities. With the exception of nickel and copper, the numbers of Table F exceedences per element were small. At 0 - 5 cm, 92% of the urban soil samples exceeded Table F for nickel, and 36% exceeded for copper. At 10 - 20 cm, only 74% of the urban soil samples exceeded Table F for nickel, and 15% exceeded for copper.

Concentration dot maps were created for nickel, copper, cobalt, arsenic and lead at the 0 - 5 cm soil depth for the Inner Sudbury Communities. Concentration gradient trends in this community group were observed for nickel and copper for the 0 - 5 cm soil. Nickel concentrations generally decreased slightly to the south and northwest with respect to Copper Cliff. The number of Table A exceedences decreased with increasing distance from the smelter. There was also a small trend of decreasing copper concentrations in all directions with respect to increasing distance from Copper Cliff. This trend continues into the Outer Sudbury Communities. For an example of the spacial distribution trend in the Inner Sudbury Communities for nickel in the 0 - 5 cm soil, refer to Figure 7.1.2.1.
No concentration gradient trend was observed for cobalt, arsenic or lead in the Inner Sudbury Communities. Refer to Sections 10.2.5 through 10.2.7 and 10.2.9 for concentration dot maps of

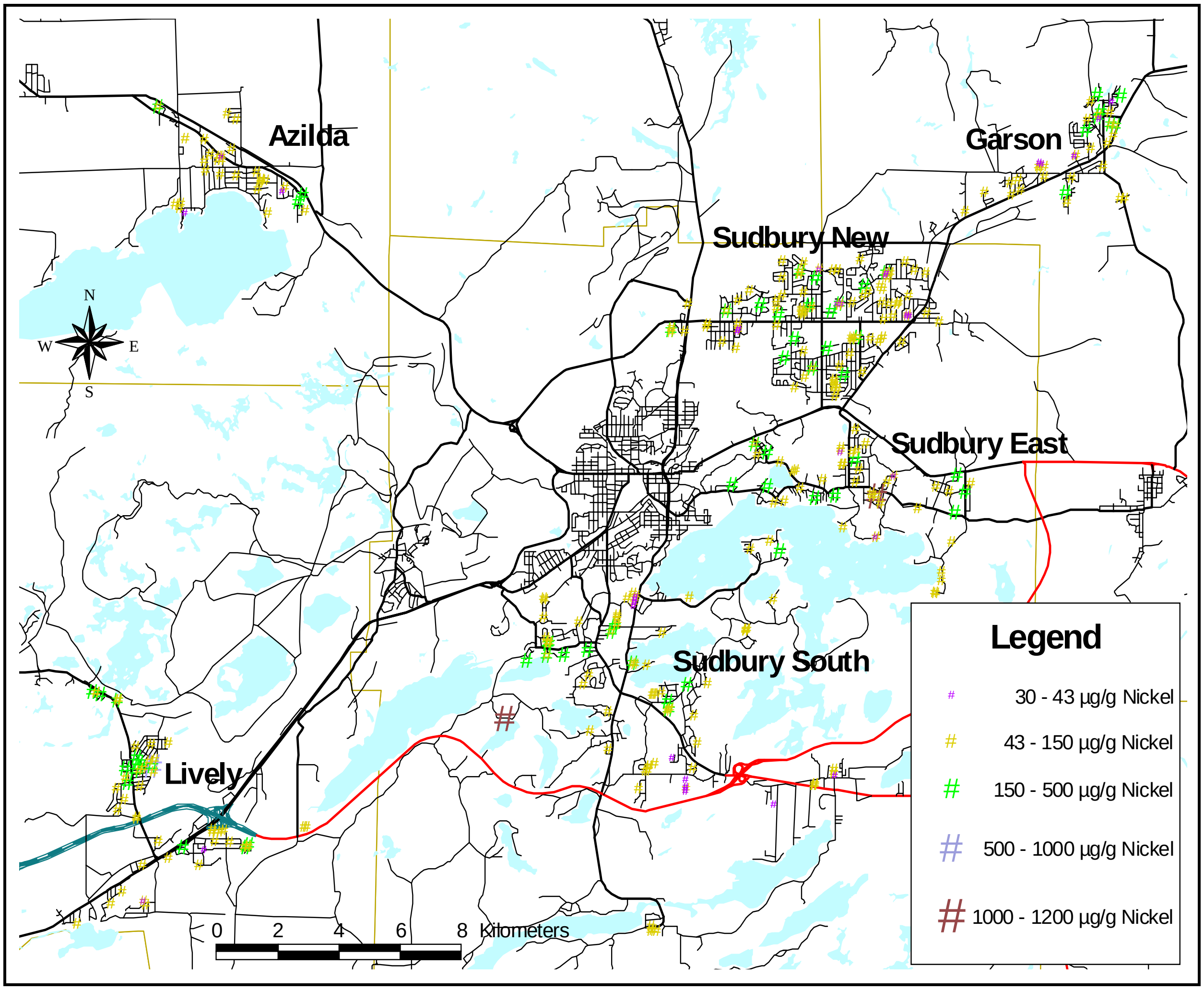


Figure 7.1.2.1: Nickel concentrations in 0 to 5 cm soil in the Inner Sudbury Communities

nickel, copper, cobalt, arsenic and lead at 0 - 5 cm in these communities. Due to the large area covered by the Inner Sudbury Communities, the area is represented by four maps: Sudbury New/East/Garson, Sudbury South, Valley West, and Sudbury West.

In the Inner Sudbury Communities, all three depth trends (Group A, B and C) were observed at varying numbers of sample locations. Seventy-eight percent of the sample locations exhibited a trend of decreasing concentrations with increasing depth, consistent with Group A. Nickel, copper, lead and zinc, and to a lesser extent cobalt, concentrations in Group A showed a visual trend of decreasing concentration with depth in all quarters. Average concentrations at the surface were 1.1 to 1.5 times the concentration at 10 - 20 cm for cobalt and zinc while average concentrations at the surface were 1.3 to 2.8 times those at depth for nickel, copper and lead. Figure 7.1.2.2 depicts the depth profile of lead in Group A for the Inner Sudbury Communities.

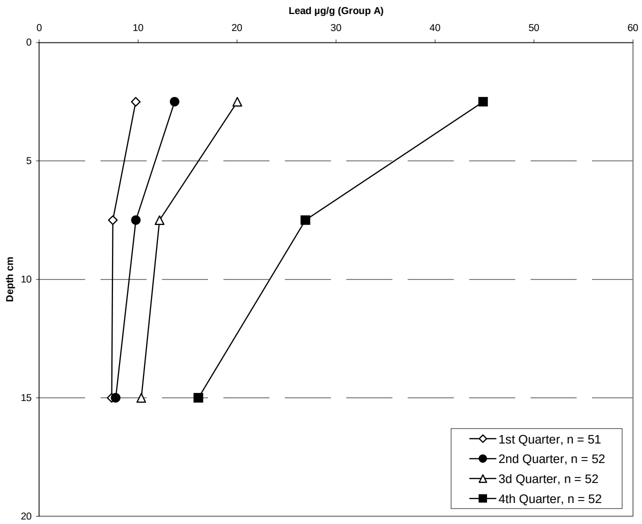


Figure 7.1.2.2: Inner Communities, Pb depth profiles, Group A.

Chromium also showed a visual trend of decreasing concentrations with depth in the second and fourth quarters (1.1 times). The average concentrations in the first and third quarters for chromium showed no observable change with depth.

Concentrations for both selenium and cadmium showed a visual trend of decreasing concentration with depth in the fourth quarter (1.3 to 1.4 times). In the third quarter for selenium, the maximum concentration was observed at the 5 - 10 cm depth. All quarters for both cadmium and selenium were at or near analytical MDLs, therefore these trends should be interpreted with caution. The first and second quarters for arsenic in Group A were also at or near analytical MDLs while the third and fourth quarters showed a visual trend of decreasing concentration with depth (1.4 times).

Average aluminum, iron and vanadium concentrations in Group A showed no observable change with depth in all four quarters. The wide range in concentrations between the quarters of these elements may indicate differences in soil type. Refer to Section 10.5.2 for graphs of the depth profiles for the elements discussed above.

In the Inner Sudbury Communities, 6% of the sample locations exhibited a trend of maximum concentrations at 5 - 10 cm, while lower concentrations were observed at both 0 - 5 and 10 - 20 cm. This trend is consistent with Group B. Nickel, cobalt and lead concentrations, in Group B, showed a strong, visual trend of maximum concentration occurring at 5 - 10 cm in the second half. Average concentrations at 5 - 10 cm were 1.2 to 1.7 times the average concentrations at surface for these elements. This trend was weak in the first half for these elements. Figure 7.1.2.3 depicts the depth profile of lead in Group B for the Inner Sudbury Communities.

Copper, in Group B, showed a strong, visual trend of maximum concentrations (1.6 times) at 5 - 10 cm in the second half and a weak trend of decreasing concentration with depth in the first half. Concentration trends of iron, chromium, zinc, aluminum and vanadium were similar to copper but weaker (1.1 to 1.2 times). Concentrations for selenium and cadmium in both halves, and arsenic concentrations in the first half, were at or near analytical MDLs, therefore no concentration trends were observed. Arsenic concentrations in the second half showed no observable change with depth.

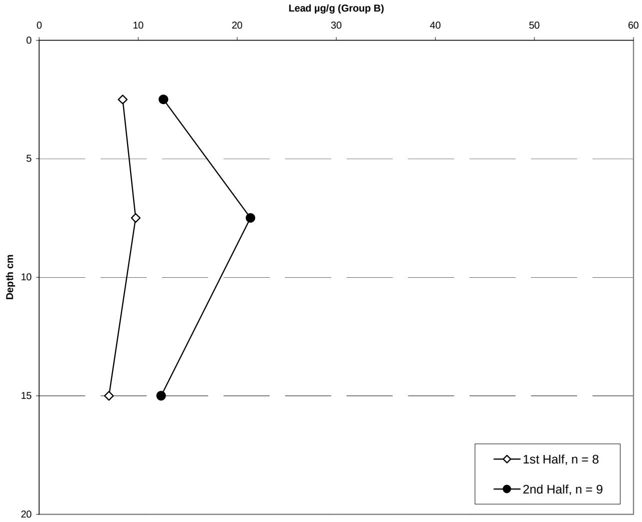


Figure 7.1.2.3: Inner Communities, Pb depth profiles, Group B.

In the Inner Sudbury Communities, 16% of the sample locations exhibited a trend of increasing concentration with increasing depth, consistent with Group C. Nickel, copper, cobalt and lead concentrations, in Group C, showed a strong to weak, visual trend of increasing concentrations with depth in all quarters. Average concentrations at 10 - 20 cm were 1.1 to 2.1 times the average concentrations at surface for these elements. Figure 7.1.2.4 depicts the depth profile of lead in Group C for the Inner Sudbury Communities.

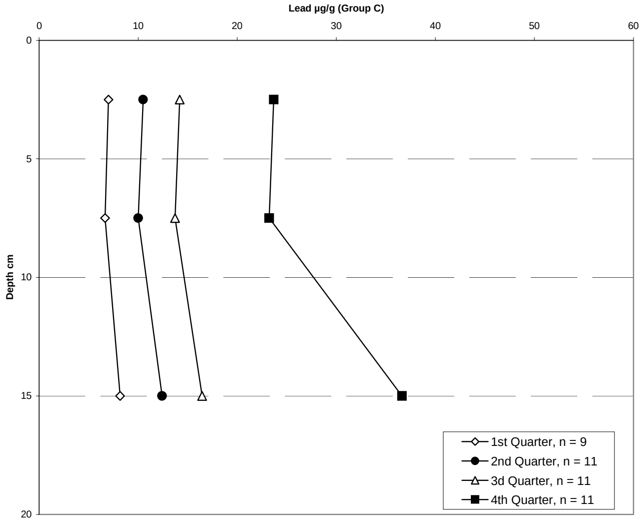


Figure 7.1.2.4: Inner Communities, Pb depth profiles, Group C.

Arsenic showed a similar trend in the second to fourth quarters (1.5 to 2.2 times), however, average concentrations were at or near the analytical MDL in the first quarter.

Chromium, iron, zinc, aluminum and vanadium showed no observable change in average concentrations with depth in the first and second quarter and a weak trend of increasing concentrations with depth in the third and fourth quarters (1.1 to 1.4 times). Concentrations for selenium and cadmium in all quarters were at or near analytical MDLs.

In the Inner Sudbury Communities, 78% of the sampling locations showed a pattern of aerial deposition from surface, compared with only 49% in the Outer Sudbury Communities. Generally, the trend of decreasing concentration with increasing depth was stronger for nickel, copper, lead, and to a lesser degree selenium, cadmium and chromium in the Inner Sudbury Communities. Only 22% of the sampling locations in the Inner Sudbury Communities showed a pattern of maximum concentration occurring below the surface, compared to over 50% of the locations in the Outer Sudbury Communities. This trend was stronger in the Outer Sudbury Communities for barium and zinc, and stronger in the Inner Sudbury Communities for cobalt and arsenic. Refer to Section 10.5.2 for graphs of the depth profiles for the elements discussed above.

Overall, concentrations of nickel, copper, lead, zinc, and to a lesser extent cobalt, in 78% of the sample locations in the Inner Sudbury Communities, showed a strong aerial deposition trend from surface. These sample locations appeared to be unaffected by landscaping practices. The remaining sample locations appeared to be affected by some degree of landscaping practices, although nickel, copper, cobalt and lead concentrations showed strong to weak trends of maximum concentrations below surface. These elevated concentrations may still be attributed to aerial deposition, however, have been buried by landscaping practices at individual properties over time. Addition, grading, removal and / or mixing of urban soils may alter the vertical distribution of chemical concentrations in the soil. Chromium also showed a weak aerial deposition trend from surface in 78% of the sample locations.

Pearson's and Spearman's statistical correlation analysis was performed on all of the elements except beryllium at each of the three depths. As discussed above, stations 5037916, a residential backyard in Sudbury East, and 5037939, a residential front yard in Sudbury South, were atypical in that they were higher in concentration for most elements than other properties in the Inner Sudbury Communities. They were therefore not included in the correlations analysis and discussion. Refer to Tables 7.1.2.4 to 7.1.2.6 below for an abbreviated version of the results of the Pearson's and Spearman's analysis for all three depths, and Tables 10.4.2.1 through 10.4.2.3 for the full results of the analysis. In Tables 7.1.2.4 to 7.1.2.6 the results have been rounded to one decimal place and values that were 0.75 or greater are considered strong and are indicated in bold type.

Table 7.1.2.4: Pearson's and Spearman's Correlations for 0 - 5 cm Soil in Inner Sudbury Communities

	Al	Ba	Cr	Co	Cu	Fe	Pb	Mg	Mn	Ni	Sr	V	Zn
Al	1	*0.7*	***0.8***	*0.3*	*0.2*	*0.7*	*0.1*	*0.5*	*0.6*	*0.2*	***0.8***	***0.8***	*0.4*
Ba	**0.8**	1	*0.7*	*0.6*	*0.5*	*0.7*	*0.4*	*0.5*	*0.7*	*0.5*	*0.6*	*0.7*	*0.7*
Cr	**0.8**	0.7	1	*0.5*	*0.3*	***0.8***	*0.3*	*0.6*	*0.7*	*0.4*	*0.6*	***0.8***	*0.5*
Co	0.3	0.5	0.4	1	***0.8***	*0.6*	*0.7*	*0.4*	*0.4*	***0.8***	*0.2*	*0.4*	*0.7*
Cu	0.2	0.5	0.3	**0.8**	1	*0.4*	***0.8***	*0.2*	*0.3*	***1.0***	*0.1*	*0.2*	*0.7*
Fe	0.7	0.7	0.7	0.7	0.5	1	*0.3*	*0.7*	*0.7*	*0.4*	*0.5*	***0.9***	*0.6*
Pb	0.1	0.2	0.4	0.4	0.5	0.2	1	*0.1*	*0.2*	***0.8***	*0.1*	*0.1*	*0.6*
Mg	0.4	0.3	0.4	0.3	0.1	0.5	0.0	1	*0.7*	*0.2*	*0.5*	*0.6*	*0.4*
Mn	0.6	0.6	0.6	0.3	0.2	0.7	0.1	0.5	1	*0.3*	*0.6*	*0.7*	*0.5*
Ni	0.2	0.5	0.4	**0.8**	**0.9**	0.5	0.4	0.2	0.2	1	*0.1*	*0.2*	*0.7*
Sr	0.6	0.5	0.5	0.1	0.1	0.4	0.0	0.6	0.4	0.1	1	*0.7*	*0.3*
V	**0.8**	0.7	**0.8**	0.4	0.2	**0.9**	0.1	0.5	0.7	0.3	0.5	1	*0.5*
Zn	0.4	0.7	0.5	0.6	0.6	0.6	0.4	0.3	0.5	0.6	0.2	0.5	1

Spearman's correlations in upper right in italics. Pearson's correlations in lower left in normal font.
Bold indicates strong correlations.

Table 7.1.2.5: Pearson’s and Spearman’s Correlations for 5 - 10 cm Soil in Inner Sudbury Communities

	Al	Ba	Cr	Co	Cu	Fe	Pb	Mg	Mn	Ni	Sr	V	Zn
Al	1	***0.8***	***0.8***	*0.5*	*0.4*	***0.8***	*0.3*	*0.6*	*0.7*	*0.3*	***0.8***	***0.9***	*0.5*
Ba	**0.9**	1	***0.8***	*0.7*	*0.6*	***0.8***	*0.5*	*0.6*	*0.7*	*0.6*	*0.7*	***0.8***	*0.7*
Cr	**0.9**	**0.8**	1	*0.6*	*0.3*	***0.9***	*0.3*	***0.8***	***0.8***	*0.4*	***0.8***	***0.9***	*0.6*
Co	0.6	0.7	0.7	1	*0.7*	*0.7*	*0.6*	*0.6*	*0.6*	*0.7*	*0.4*	*0.6*	*0.7*
Cu	0.5	0.6	0.5	0.7	1	*0.4*	***0.8***	*0.2*	*0.3*	***0.9***	*0.2*	*0.3*	*0.7*
Fe	**0.9**	**0.8**	**0.8**	0.7	0.5	1	*0.3*	*0.7*	***0.8***	*0.4*	*0.7*	***0.9***	*0.7*
Pb	0.1	0.2	0.2	0.2	0.3	0.1	1	*0.2*	*0.3*	***0.8***	*0.2*	*0.3*	*0.7*
Mg	0.5	0.5	0.7	0.5	0.2	0.6	0.1	1	***0.8***	*0.2*	*0.6*	*0.7*	*0.5*
Mn	0.7	0.7	**0.8**	0.6	0.4	**0.8**	0.1	0.6	1	*0.3*	*0.7*	***0.8***	*0.6*
Ni	0.4	0.6	0.4	**0.8**	**0.9**	0.5	0.3	0.2	0.4	1	*0.2*	*0.3*	*0.7*
Sr	**0.8**	0.6	0.7	0.4	0.2	0.6	0.0	0.5	0.7	0.3	1	***0.8***	*0.4*
V	**0.9**	**0.8**	**0.9**	0.6	0.4	**0.9**	0.1	0.6	**0.8**	0.4	0.7	1	*0.6*
Zn	0.5	0.7	0.6	0.6	0.6	0.6	0.3	0.4	0.6	0.6	0.4	0.5	1

Spearman’s correlations in upper right in italics. Pearson’s correlations in lower left in normal font.
Bold indicates strong correlations.

Table 7.1.2.6: Pearson’s and Spearman’s Correlations for 10 - 20 cm Soil in the Inner Communities

	Al	Ba	Cr	Co	Cu	Fe	Pb	Mg	Mn	Ni	Sr	V	Zn
Al	1	***0.9***	***0.9***	*0.7*	*0.5*	***0.9***	*0.5*	*0.6*	***0.8***	*0.5*	***0.8***	***0.9***	*0.7*
Ba	**0.9**	1	***0.9***	*0.7*	*0.6*	***0.9***	*0.5*	*0.7*	***0.8***	*0.6*	***0.8***	***0.8***	***0.8***
Cr	**0.9**	**0.9**	1	*0.7*	*0.4*	***0.9***	*0.4*	***0.8***	***0.9***	*0.4*	***0.8***	***0.9***	*0.7*
Co	0.6	0.7	0.6	1	*0.7*	***0.8***	*0.7*	*0.6*	*0.7*	*0.7*	*0.5*	*0.7*	***0.8***
Cu	0.4	0.5	0.4	**0.8**	1	*0.5*	***0.8***	*0.3*	*0.4*	***0.9***	*0.3*	*0.4*	***0.8***
Fe	**0.9**	**0.9**	**0.9**	0.7	0.5	1	*0.5*	***0.8***	***0.8***	*0.5*	*0.7*	***0.9***	***0.8***
Pb	0.2	0.3	0.2	0.4	0.5	0.2	1	*0.2*	*0.4*	***0.8***	*0.4*	*0.4*	***0.8***
Mg	0.7	0.6	**0.8**	0.5	0.2	**0.8**	0.1	1	***0.8***	*0.2*	*0.7*	***0.8***	*0.6*
Mn	**0.8**	**0.8**	**0.8**	0.6	0.3	**0.8**	0.2	**0.8**	1	*0.4*	***0.8***	***0.8***	*0.7*
Ni	0.4	0.5	0.3	**0.8**	**0.9**	0.4	0.4	0.2	0.3	1	*0.3*	*0.4*	*0.7*
Sr	**0.8**	0.7	**0.8**	0.4	0.3	0.7	0.2	0.7	**0.8**	0.3	1	***0.8***	*0.6*
V	**0.9**	**0.8**	**0.9**	0.6	0.3	**0.9**	0.2	0.7	**0.8**	0.3	**0.8**	1	*0.7*
Zn	0.6	0.7	0.6	0.7	0.6	0.7	0.5	0.5	0.7	0.6	0.5	0.6	1

Spearman’s correlations in upper right in italics. Pearson’s correlations in lower left in normal font.
Bold indicates strong correlations.

Of the major elements emitted by the mining and smelting processes in the Sudbury area, in the Inner Sudbury Communities, nickel, copper and cobalt were strongly correlated with each other at the 0 to 5 cm depth using Pearson’s and Spearman’s. An example of these correlations are presented in Figures 7.1.2.5 and 7.1.2.6 below. Refer to Section 10.4.2 for additional correlation figures. These elements were moderately correlated with zinc in Spearman’s. The correlation between nickel, copper and cobalt remained similar at all depth intervals with minor fluctuations in the level of significance for cobalt in both Pearson’s and Spearman’s.

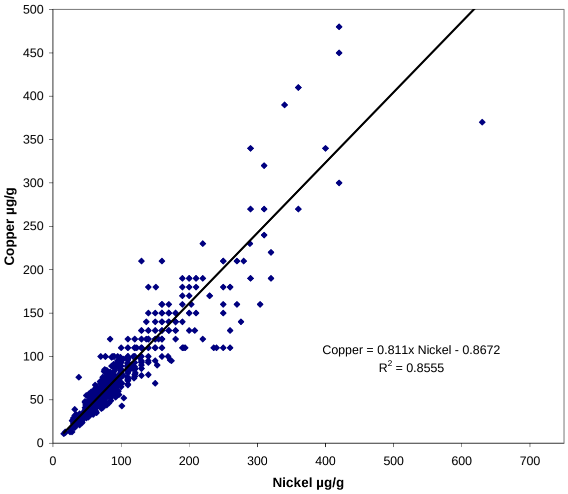


Figure 7.1.2.5: Cu vs. Ni in 0 to 5 cm soil.

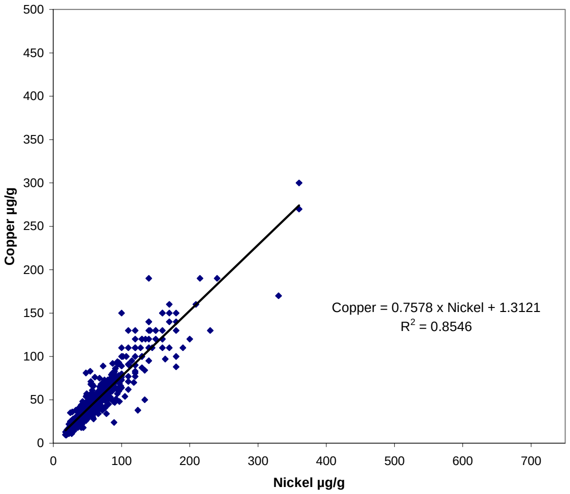


Figure 7.1.2.6: Cu vs Ni in 10 to 20 cm soil.

Unlike in the Outer Sudbury Communities, cobalt was not strongly correlated with the naturally occurring elements (i.e. aluminum, barium etc.) at the surface, while it was strongly correlated with nickel and copper. As the depth increased, the correlations between cobalt and aluminum, barium, chromium, iron, manganese, vanadium and zinc became stronger while the correlations between cobalt, nickel and copper decreased slightly. This indicates that elevated cobalt concentrations at surface in the Inner Sudbury Communities may be attributed to smelter emissions and not to background concentrations.

Lead did not correlate with any elements at any depth using Pearson's. Using Spearman's, however, lead was strongly correlated with nickel and copper, and to a lesser extent cobalt at 0 - 5 cm. The lead correlations with nickel and copper remained strong and constant at all depth intervals. At 5 - 10 cm, lead moderately correlated to zinc, and at 10 - 20 cm, was strongly correlated to zinc and moderately correlated to cobalt.

The difference between the Pearson's and Spearman's correlations can be illustrated using the lead/zinc relationship. As discussed in Section 7.2, Pearson's correlation is used as an indicator of the strength of a linear relationship between two variables. This relationship may be strongly affected by the presence of non normal data or outliers. Spearman's correlation is used as an indicator of the strength of non-linear relationships and reduces the effect of outliers on the relationship. Similar to Spearman's, log - log transformations also reduce the effect of outliers and highly skewed, non normal data on correlations.

At 5 - 10 cm, the presence of two outliers, with high lead concentrations at station 5037913 strongly affected the Pearson's correlation values (R = 0.3) with nickel, copper and zinc while it only marginally affected the Spearman's correlation values (R = 0.7 to 0.8). Arbitrarily removing these outliers would increase the Pearson's correlation value to R = 0.64 for lead and zinc. Refer to Table 7.1.2.5. As shown in Figure 7.1.2.7, the lead and zinc correlation at 5 - 10 cm in the Inner Sudbury Communities using Pearson's appeared to be unduly influenced by the two outliers. The R^2 value was low (R^2 = 0.09). Figure 7.1.2.8 depicts the same lead and zinc correlation using Pearson's, however, the data has been log - log transformed. The log - log transformation reduced the effect of the outliers, strengthening the correlation. This is indicated by the increased R^2 value of 0.5 and R value of 0.7.

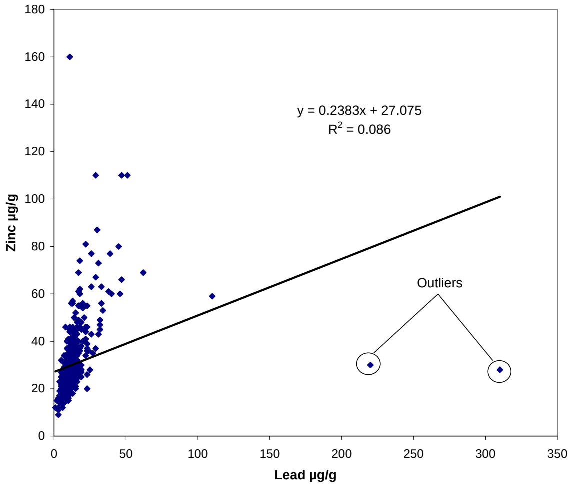


Figure 7.1.2.7: Zn vs Pb, 5 to 10 cm

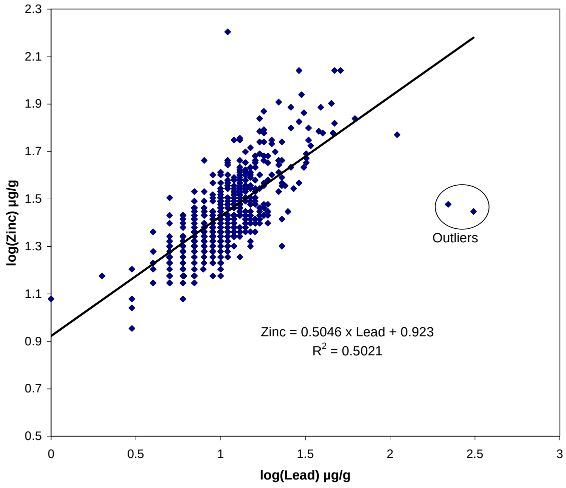


Figure 7.1.2.8: log[Zn] vs log[Pb], 5 to 10 cm

Arsenic was not correlated with any elements at the 0 - 5 or 5 - 10 cm depth intervals using Pearson's or at any depth using Spearman's. Arsenic was moderately correlated in Pearson's with copper and nickel at 10 - 20 cm. These correlations, however, were largely driven by station 5030636. Figures 7.1.2.9 and 7.1.2.10 clearly show the effect of this station on the arsenic and copper correlation.

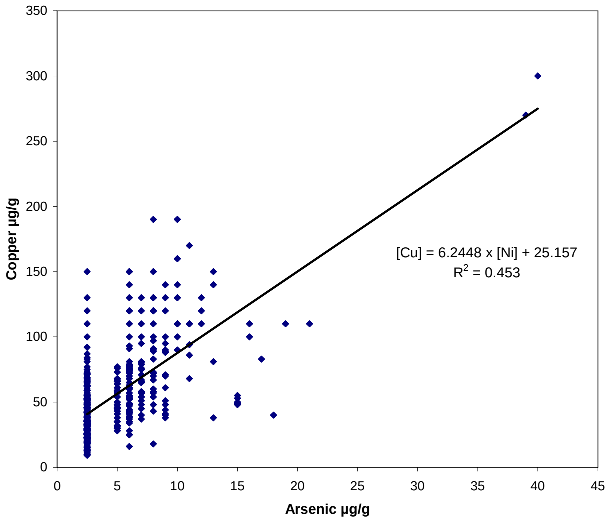


Fig. 7.1.2.9: Cu vs. As, 10-20 cm, Inner Communities

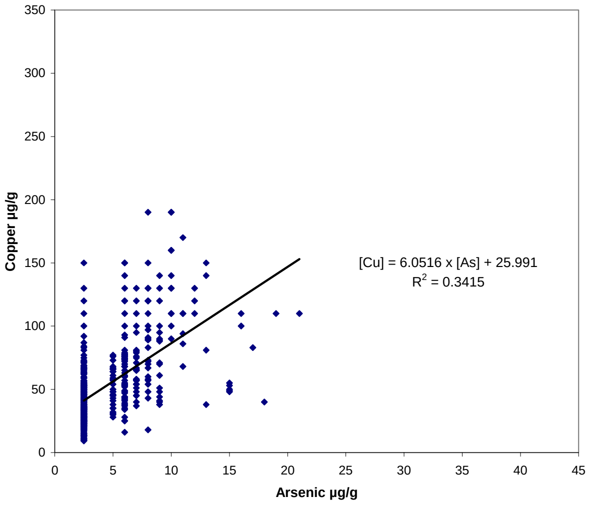


Fig. 7.1.2.10: Cu vs. As, 10-20 cm, Inner Communities without outliers.

Pearson's and Spearman's showed both strong and moderate correlations between aluminum, barium, chromium, iron, magnesium, manganese, strontium, vanadium and zinc at all depths. Overall the number and strength of these correlations increased with depth and were more prevalent using Spearman's. These elements are indicative of the naturally occurring geology in the City of Greater Sudbury and are expected to correlate with one another. The increase in the number and strength of these correlations with depth is indicative of less disturbed soil at depth. Correlations with the naturally occurring elements generally increased with Spearman's at depth and decreased with Pearson's, while the correlations with the elements associated with smelter emissions generally stay constant with Pearson's at depth and decreased with Spearman's. Refer to Tables 7.1.2.4 to 7.1.2.6.

Of the major elements emitted by the mining and smelting processes in the Sudbury area only nickel and copper were strongly correlated at all depths in the Outer Sudbury Communities. Cobalt concentrations appeared to be naturally occurring and not related to the smelter emissions. In the Inner Sudbury Communities, at all depths, nickel, copper and cobalt remain strongly correlated while lead also becomes strongly correlated with nickel and copper. The correlations between cobalt with nickel and copper became weaker and the correlations between cobalt and the naturally occurring elements became stronger with depth. This indicates that although cobalt concentrations at the surface may be attributed to smelter emissions, concentrations at depth may be also attributed to natural background concentrations. Refer to Figures 10.4.2.1 through 10.4.2.42 for a complete list of graphs showing selected element correlations at all three depths for the Inner Sudbury Communities.

In summary, element concentrations were relatively low in the Inner Sudbury Communities, but higher than the Outer Sudbury Communities. At all depths, nickel and copper concentrations were approximately double the concentrations found in the Outer Sudbury Communities from the median to 80th percentile up. Cobalt, arsenic, lead, barium and selenium concentrations were only slightly higher. Concentrations of nickel, copper, cobalt, arsenic and lead exceeded Table A at one or more depth intervals in the Inner Sudbury Communities. Only nickel, copper and arsenic concentrations exceeded Table A at all depths. Ten elements exceed Table F criteria in the Inner Sudbury Communities.

In the Outer Sudbury Communities the majority of the urban soil sampling locations were school or park properties. In the Inner Sudbury Communities half of the urban soil samples were from residential properties and half were from school or park properties. A concentration gradient was observed for nickel and copper for the 0 - 5 cm soil. Nickel concentrations generally decreased to the south and northwest, and copper concentrations decrease in all directions with respect to Copper Cliff. This trend continues into the Outer Sudbury Communities.

Overall, concentrations of nickel, copper, lead, zinc, and to a lesser extent cobalt and chromium, showed a strong aerial deposition trend from surface in 78% of the sample locations in the Inner Sudbury Communities. The remaining sample locations appeared to be affected to some degree by landscaping practices, although nickel, copper, cobalt and lead concentrations showed strong to weak trends of maximum concentrations below surface. These elevated concentrations may still be attributed to aerial deposition, however, have been buried by landscaping practices at individual properties over time.

In the Inner Sudbury Communities, nickel, copper, and cobalt were strongly correlated with each other at all depths using Pearson's and Spearman's. These elements were moderately correlated with zinc at the surface, and strongly correlated with lead at all depths using Spearman's. Unlike in the Outer Sudbury Communities, cobalt was not strongly correlated with the naturally occurring elements (i.e. aluminum, barium etc.) at the surface, while it was strongly correlated with nickel and copper. With depth, the correlations between cobalt with nickel and copper became weaker and the correlations between cobalt and the naturally occurring elements became stronger. This indicates that although cobalt concentrations at the surface may be attributed to smelter emissions, concentrations at depth may also be due to natural background concentrations.

7.1.3 Sudbury Core

In the Sudbury Core, defined as being west of Notre Dame and north of Lorne and York Streets and included the neighbourhoods of Flour Mill, Gatchell, Little Britain and Northern Heights, the concentrations of the eleven elements, at 0 - 5 cm, used in determining this grouping were substantially higher than in both Outer and Inner Sudbury Communities, but were similar to Coniston. The similarities and differences between the Sudbury Core and Coniston will be discussed in the next section.

At 0 - 5 cm in the Sudbury Core, nickel, copper, cobalt, arsenic, barium, lead, cadmium, selenium, and zinc concentrations were substantially higher than in the Outer and Inner Sudbury Communities from the median to the 95th percentile. Chromium and iron were similar to marginally higher at the 75th percentile at 0 - 5 cm and 5 - 10 cm, and similar at 10 - 20 cm. Refer to Table 7.1.3.1.

Table 7.1.3.1: Summary Statistics for Metals and Arsenic in Urban Soil of the Sudbury Core of the City of Greater Sudbury.

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
0 to 5 cm Urban Soil in the Sudbury Core, n = 324																			
Minimum	4000	0.4	2.5	17	0.4	1500	19	4	17	9000	1	1500	110	0.75	20	0.5	13	20	13
10th percentile	7500	0.4	2.5	31	0.4	3230	25	6	56	12000	9	2200	150	0.75	69	0.5	23	24	24
1st quartile	8400	0.4	2.5	37	0.4	4000	28	8	99	13000	17	2600	170	0.75	111	0.5	29	26	33
Median	9900	0.4	6.0	49	0.4	5100	32	11	190	15000	29	3000	200	0.75	200	1.0	37	29	47
3rd quartile	12000	0.4	10	72	1.0	6950	39	17	365	18000	65	3600	230	0.75	350	2.0	43	32	86
95th percentile	14000	1.0	20	119	1.9	11000	53	35	84	24850	140	5285	300	0.75	935	4.0	51	37	159
Maximum	20000	2.7	34	210	4.1	16000	110	75	16	36000	320	9800	1200	3.2	2000	9.0	84	42	230
Mean	10095	0.5	8.0	58	0.7	5753	35	15	28	16240	47	3223	210	0.77	294	1.4	36	30	64
CV (std. dev./mean)	23%	52%	75%	49%	81%	44%	31%	70%	95	26%	99%	32%	40%	22%	99%	90%	28%	15%	67%
Skewness	0.5	5.1	1.9	1.5	2.3	1.2	2.5	2.3	2.1	1.5	2.2	2.1	7.0	11.6	2.5	2.3	0.4	0.4	1.3
5 to 10 cm Urban Soil in the Sudbury Core, n = 273																			
Minimum	4400	0.4	2.5	17	0.4	1500	17	3	12	9400	2	1400	110	0.75	18	0.5	10	20	12
10th percentile	7600	0.4	2.5	28	0.4	2600	23	6	45	12000	9	2020	140	0.75	58	0.5	22	24	21
1st quartile	8800	0.4	5.0	37	0.4	3300	27	7	75	13000	13	2300	160	0.75	90	0.5	28	27	29
Median	10000	0.4	7.0	54	0.4	4300	31	10	130	15000	21	2700	200	0.75	170	1.0	35	30	41
3rd quartile	12000	0.4	11	70	0.4	5800	37	13	245	18000	45	3250	230	0.75	280	1.0	42	34	74
95th percentile	15000	0.9	18	110	1.0	8490	50	19	425	21000	110	4345	300	0.75	480	2.0	49	40	120
Maximum	20000	1.5	24	160	1.5	14000	59	36	830	26000	310	7200	480	2.40	970	5.0	71	46	210
Mean	10587	0.4	8	58	0.5	4761	32	11	174	15633	37	2915	202	0.77	202	1.1	35	30	55
CV (std. dev./mean)	26%	41%	59%	48%	46%	45%	26%	45%	77%	20%	106	32%	27%	20%	75%	67%	28%	16%	68%
Skewness	0.9	3.9	0.9	1.2	3.1	1.5	0.9	1.5	1.7	0.6	2.7	1.7	1.2	8.2	1.7	1.7	0.2	0.6	1.6
10 to 20 cm Urban Soil in the Sudbury Core, n = 271																			
Minimum	4700	0.4	2.5	17	0.4	1400	18	3	11	9000	2	1300	110	0.75	15	0.5	11	19	10
10th percentile	6900	0.4	2.5	32	0.4	2300	21	6	42	12000	8	2000	140	0.75	57	0.5	20	24	21
1st quartile	8050	0.4	5	39	0.4	2900	25	7	58	13000	11	2300	160	0.75	77	0.5	27	26	28
Median	10000	0.4	6.0	51	0.4	3900	29	9	100	15000	21	2700	190	0.75	130	1.0	34	29	39
3rd quartile	12000	0.4	9.0	71	0.4	5500	36	11	170	17000	38	3400	230	0.75	210	1.0	42	33	61
95th percentile	17000	1.0	15	130	0.4	8500	50	16	350	22000	120	5700	320	0.75	405	2.0	52	41	125
Maximum	22000	2.8	22	240	1.3	13000	64	28	530	28000	470	8300	390	2.90	820	4.0	66	50	340
Mean	10465	0.5	7.1	61	0.4	4451	31	9	132	15397	34	3013	201	0.77	163	0.9	34	30	51
CV (std. dev./mean)	32%	53%	57%	57%	31%	48%	29%	40%	77%	23%	132	38%	29%	21%	75%	68%	31%	20%	75%
Skewness	1.2	5.4	1.3	1.9	4.6	1.4	1.2	1.6	1.8	1.0	4.7	1.9	1.1	10.3	2.2	2.4	0.2	1.0	2.9

All results are in µg/g dry weight.

At 10 - 20 cm, nickel, copper, lead and zinc concentrations remained higher in the Sudbury Core than in the Outer and Inner Sudbury Communities. Arsenic and barium concentrations were also higher in the Sudbury Core compared to the Outer Sudbury Communities, but only marginally higher compared to the Inner Sudbury Communities. At this depth, cobalt and selenium concentrations were only marginally higher than both the Outer and Inner Sudbury Communities. Cadmium, chromium and iron concentrations were similar in all three communities at the 10 - 20 cm depth. All other elements in the Sudbury Core were essentially the same as the Outer and Inner Sudbury Communities at all depths.

In the Sudbury Core, concentrations of nickel, copper, cobalt, arsenic and lead were higher in the residential properties than in the park and school properties. Due to the low n-values for school properties at all depths, comparisons with this group are very general. The n-value for schools was 45 out of a total of 324 urban soil samples at 0 - 5 cm, and 11 out of 271 samples at depth. At all depth intervals, concentrations of nickel, copper and lead were generally two to three times higher in the residences from the minimum to 20th percentile. Cobalt and arsenic were up to twice as high in residential properties from the 20th to 90th percentile. Refer to Table 7.1.3.2.

Table 7.1.3.2: Summary Statistics for Metals and Arsenic in All 0 to 5 cm Urban Soil Samples from the Sudbury Core by Land Use

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Residential 0 to 5 cm				n = 184															
Minimum	5900	0.4	2.5	25	0.4	1500	20	4	28	11000	7	1500	120	0.75	33	0.5	15	20	17
10th percentile	7730	0.4	5.0	34	0.4	3330	26	8	113	13000	18	2200	150	0.75	123	0.5	23	24	34
1st quartile	8600	0.4	6.0	46	0.4	4000	29	11	200	14000	31	2500	170	0.75	195	1.0	28	27	46
Median	10000	0.4	9.0	60	0.9	5150	34	15	315	17000	50	2900	200	0.75	300	1.5	37	29	74
3rd quartile	12000	0.4	13	86	1.3	6750	42	21	475	19000	86	3500	230	0.75	465	2.0	43	33	110
95th percentile	14000	1.1	21	120	2.2	10850	56	44	920	27000	160	4400	300	0.75	1043	4.8	49	38	179
Maximum	17000	2.7	34	210	4.1	15000	110	75	1600	36000	320	6000	1200	3.20	2000	9.0	84	42	230
Mean	10316	0.5	10	68	1.0	5730	37	18	392	17386	67	3039	216	0.78	400	1.9	37	30	84
CV (std. dev./mean)	21%	60%	58%	44%	74%	42%	34%	63%	75%	26%	78%	25%	48%	28%	81%	76%	29%	15%	55%
Skewness	0.4	4.2	1.6	1.1	1.6	1.1	2.2	1.9	1.7	1.3	1.8	0.9	6.4	8.7	2.0	2.0	0.5	0.3	0.8
Schools and Daycares 0 to 5 cm					n = 45														
Minimum	5800	0.4	2.5	21	0.4	2400	21	4	19	9000	3	1900	110	0.75	20	0.5	20	21	17
10th percentile	7020	0.4	2.5	28	0.4	3080	25	5	27	11000	6	2100	150	0.75	38	0.5	23	25	18
1st quartile	7950	0.4	2.5	32	0.4	3500	26	7	50	12000	8	2300	170	0.75	63	0.5	27	27	22
Median	8700	0.4	2.5	37	0.4	4000	29	8	92	13000	16	3000	180	0.75	110	0.5	32	28	31
3rd quartile	9600	0.4	6.0	43	0.4	5650	32	9	150	14000	22	3400	200	0.75	160	0.5	35	29	39
95th percentile	11000	0.4	8.8	52	0.7	8720	39	21	496	18800	69	4480	228	0.75	376	3.0	41	33	91
Maximum	12000	0.4	14	53	1.3	11000	51	28	530	21000	75	5800	270	0.75	660	4.0	52	37	130
Mean	8691	0.4	4.5	37	0.4	4707	30	9	129	13373	20	3007	184	0.75	140	0.9	32	28	37
CV (std. dev./mean)	16%	0%	65%	20%	43%	41%	19%	55%	101%	18%	92%	29%	16%	0%	91%	97%	21%	10%	62%
Skewness	0.1		1.6	0.2	4.1	1.6	1.8	2.4	2.2	1.3	2.1	1.2	0.3		2.4	2.5	0.6	0.5	2.4
Parks 0 to 5 cm				n = 95															
Minimum	4000	0.4	2.5	17	0.4	2100	19	5	17	9900	1	2000	110	0.75	24	0.5	13	21	13
10th percentile	7580	0.4	2.5	27	0.4	3040	24	6	48	12000	8	2380	150	0.75	60	0.5	27	24	21
1st quartile	8600	0.4	2.5	35	0.4	4500	27	7	70	13000	12	2900	170	0.75	83	0.5	31	26	26
Median	10000	0.4	2.5	44	0.4	5600	31	10	110	15000	20	3200	210	0.75	130	0.5	37	29	37
3rd quartile	12000	0.4	6.0	55	0.4	7850	36	12	160	17000	26	3950	250	0.75	195	1.0	46	34	46
95th percentile	15000	0.4	8.0	74	0.9	11000	45	17	240	20000	41	6230	293	0.75	290	2.0	52	37	67
Maximum	20000	1.5	32	120	1.7	16000	50	55	950	30000	101	9800	310	0.75	1528	3.5	60	40	140
Mean	10334	0.4	4.7	46	0.5	6293	32	11	134	15378	21	3683	210	0.75	162	0.8	38	30	38
CV (std. dev./mean)	27%	35%	89%	39%	46%	44%	22%	60%	85%	20%	65%	38%	24%	0%	106%	70%	25%	15%	47%
Skewness	0.3	6.0	4.6	1.5	3.4	1.1	0.4	4.4	4.6	1.6	2.5	1.9	0.2		5.9	2.9	-0.2	0.3	2.4

All results are in µg/g dry weight.

Generally, the concentrations in the parks were similar for cobalt and arsenic, and only marginally higher for nickel, copper and lead compared to the schools starting from the 10th to 80th percentile at 0 - 5 cm and 5 - 10 cm. The maximum concentrations in the parks at 0 - 5 cm were approximately twice the concentrations in the schools for all 5 elements. At 10 - 20 cm, concentrations in the parks were only marginally higher than the schools for nickel, cobalt, arsenic and lead from the 20th to 95th percentile.

Concentrations of barium, selenium and zinc in the residential properties at all depths were marginally higher than in the parks from the minimum to median percentile, and marginally higher for cadmium from the 60th to 95th percentile.

Generally, surface soil park concentrations for nickel, copper, cobalt, and lead were substantially to marginally higher in the Sudbury Core compared to the Inner Sudbury Communities, while arsenic concentrations were similar. With depth, however, park concentrations were marginally higher or lower for all 5 elements compared to the Inner Sudbury Communities. At surface, school concentrations for nickel and copper were marginally higher compared to the Inner Sudbury Communities, while cobalt and lead concentrations were generally similar with lower maximum values. With depth, nickel, copper and lead were marginally higher compared to the Inner Sudbury Communities.

There were considerably more exceedences of Table F and A in the Sudbury Core than the Outer and Inner Sudbury Communities. Table 7.1.3.3 summarizes the number of urban soil samples that exceed the Table F and Table A criteria in the Sudbury Core. Nickel, copper, arsenic and lead concentrations exceeded Table A at all depths. Cobalt concentrations exceeded Table A only at 0 - 5 cm. No other elements exceeded Table A at any depths in the Sudbury Core. At 0 - 5 cm, 43% of the urban soil samples exceeded Table A and 80% exceeded Table F for copper. At the same depth 63% of the samples exceeded Table A and 96% exceed Table F for nickel. Generally, the number of exceedences of Table F and A decreased with depth. The number of nickel, copper and selenium exceedences, however, did not decrease as quickly.

Table 7.1.3.3: Summary of MOE Table F and Table A Exceedences for Metals and Arsenic in Urban Soil Samples in the Sudbury Core of the City of Greater Sudbury.

Element	Table F			Table A		
	0 to 5 cm	5 to 10 cm	10 to 20 cm	0 to 5 cm	5 to 10 cm	10 to 20 cm
Antimony	13 (4%)	10 (4%)	10 (4%)	0	0	0
Arsenic	24 (7%)	16 (6%)	9 (3%)	12 (4%)	3 (1%)	3 (1%)
Barium	0	0	2 (1%)	0	0	0
Cadmium	71 (22%)	14 (5%)	3 (1%)	0	0	0
Chromium	4 (1%)	0	0	0	0	0
Cobalt	48 (15%)	9 (3%)	5 (2%)	14 (4%)	0	0
Copper	260 (80%)	189 (69%)	163 (60%)	139 (43%)	79 (29%)	37 (14%)
Lead	25 (8%)	15 (5%)	11 (4%)	4 (1%)	2 (1%)	4 (1%)
Molybdenum	1	0	1	0	0	0
Nickel	310 (96%)	258 (95%)	260 (96%)	205 (63%)	146 (53%)	112 (41%)
Selenium	102 (31%)	64 (23%)	33 (12%)	0	0	0
Zinc	12 (4%)	6 (2%)	6 (2%)	0	0	0
No. of Samples	324	273	271	324	273	271

Spatial distribution of the chemical concentrations in the Sudbury Core were assessed using concentration dot maps. Concentration dot maps were created for nickel, copper, cobalt, arsenic, lead, cadmium, selenium, zinc, chromium and iron at the 0 - 5 cm and 10 - 20 cm soil depths. The highest concentrations of nickel, copper, cobalt, lead and arsenic in 0 - 5 cm urban soil occurred in the neighbourhoods of Gatchell and Little Britain and to a lesser degree at the northwest corner of Ramsey Lake. Gatchell and Little Britain are located directly east of the Inco slag disposal area. The concentrations of these elements generally decreased to the northeast and east. Concentrations of cadmium, selenium, zinc, chromium and iron were only slightly higher in Gatchell and / or Little Britain.

At 10 - 20 cm nickel and copper concentrations decreased but generally remained above Table A in Gatchell and Little Britain and to a lesser degree at the northwest corner of Ramsey Lake. The decrease in nickel and copper concentrations with depth was more pronounced in Little Britain than the other two areas. Concentrations of the other eight elements decreased with depth, however, maintained a spatial distribution similar to the surface, with the exception of cadmium which showed no concentration gradient at depth. For an example of the spatial distributions for nickel in the 0 - 5 and 10 - 20 cm soil depths, refer to Figures 7.1.3.1 and 7.1.3.2. Refer to Section 10.2.4 for concentration dot maps of these ten elements at 0 to 5 cm and 10 - 20 cm in the Sudbury Core.

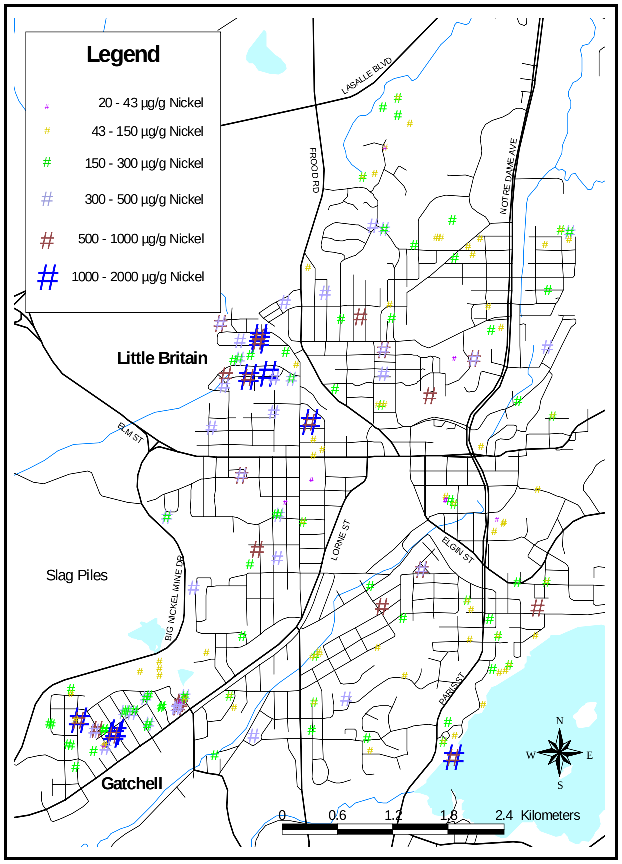


Figure 7.1.3.1: Ni concentrations in urban 0 - 5 cm soil in Sudbury Core

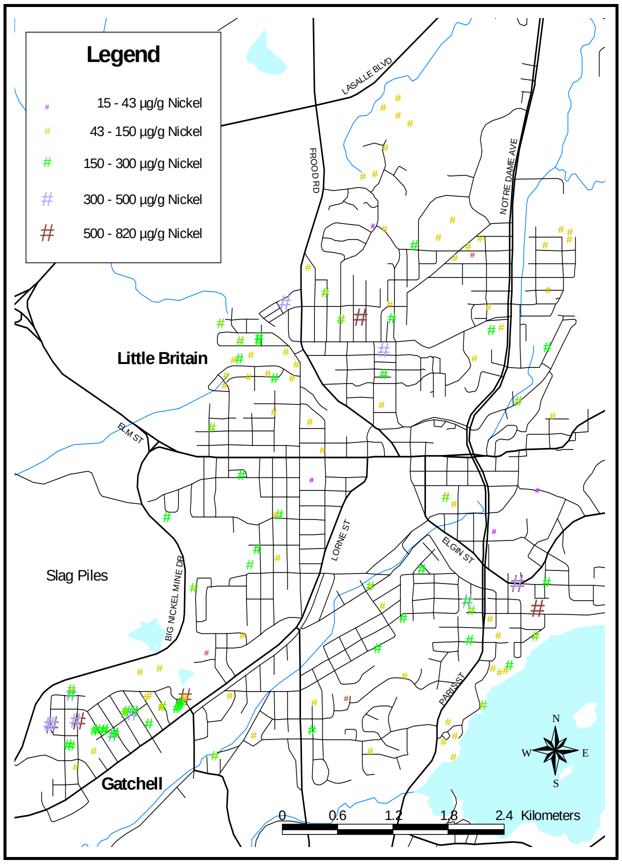


Figure 7.1.3.2: Ni concentrations in urban 10 - 20 cm soil in Sudbury Core

In the Sudbury Core, all three depth trends (Group A, B and C) were observed at varying numbers of sample locations. Seventy-two percent of the sample locations exhibited a trend of decreasing concentrations with increasing depth, consistent with Group A. Nickel, copper and cobalt concentrations, in Group A, showed a strong visual trend of decreasing concentration with depth in the third and fourth quarters. These elements also showed a weaker visual trend in the first and second quarters. Average concentrations for these elements at the surface were 1.2 to 2.0 times greater than the concentrations at 10 - 20 cm in the first and second quarters, and 1.8 to 4.3 times greater in the third and fourth quarters. Concentrations of lead, chromium and zinc also showed a weak visual trend of decreasing concentrations with depth in all quarters (1.1 to 2.0 times). Generally the trends for these elements were weaker in the first quarters and strongest in the last. Figure 7.1.3.3 depicts the depth profile of cobalt in Group A for the Sudbury Core.

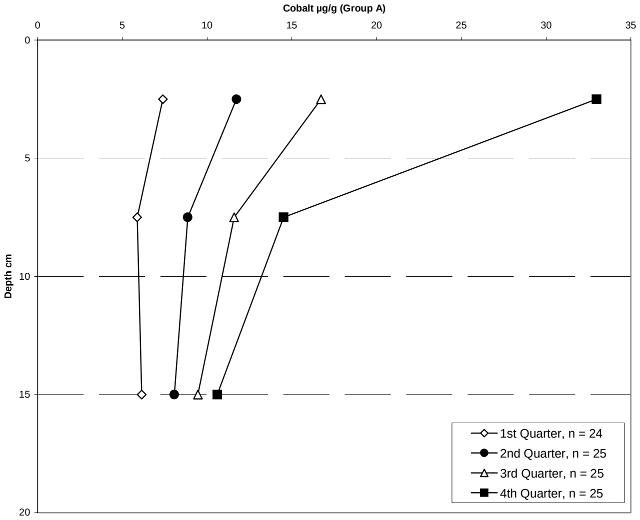


Figure 7.1.3.3: Sudbury Core, Co depth profiles, Group A

Arsenic and iron concentrations showed a weak visual trend of aerial deposition in the third and fourth quarters (1.1 to 1.9 times). The average concentrations of these elements in the first and second quarters showed no observable change with depth. Concentrations for both selenium and cadmium showed a visual trend of decreasing concentration with depth in the fourth quarters (2.5 to 3.8 times), and a weaker trend (1.9 to 2.2 times) in the third quarter. The concentrations in the first through third quarters for cadmium and selenium, and the first quarter for arsenic, were at or near analytical MDLs. As a result, the concentration trends observed in these quarters should be interpreted with caution.

Average aluminum and vanadium concentrations in Group A showed no observable change with depth in all four quarters. The wide range in concentrations between the quarters of these elements may indicate differences in soil type. Refer to Section 10.5.3 for graphs of the depth profiles for the elements discussed above.

In the Sudbury Core, 12% of the sample locations exhibited a trend of maximum concentrations at 5 - 10 cm, while lower concentrations were observed at both 0 - 5 and 10 - 20 cm. This trend is consistent with Group B. Nickel, copper, cobalt, lead, selenium, zinc, iron and vanadium concentrations, in Group B, showed a visual trend of maximum concentration occurring at 5 - 10 cm in the second half. Average concentrations at 5 - 10 cm were 1.1 to 1.3 times the average concentrations at surface for these elements. This trend was also observed in the first half for nickel and cobalt, but concentrations were only 1.1 times greater at 5 - 10 cm than the surface. Generally, a weak trend of decreasing concentration with depth was observed in the first half for copper, lead, selenium, zinc and iron. No observable change in concentration with depth was observed in the first half for vanadium. Selenium concentrations in the first half were at or near analytical MDLs, and should be interpreted with caution. Figure 7.1.3.4 depicts the depth profile of cobalt in Group B for the Sudbury Core.

Concentrations for cadmium in both halves, and arsenic concentrations in the first half, were at or near analytical MDLs, and no concentration trends were observed. Arsenic concentrations in the second half showed a pattern of maximum concentrations occurring at 5 - 10 cm with slightly lower concentrations at surface, and much lower concentrations at 10 - 20 cm. For chromium, in both halves, maximum concentrations were observed at 5 - 10 cm, with only slightly lower concentrations at surface, but much lower concentrations at 10 - 20 cm. In both halves for aluminum, no concentration change with depth was observed.

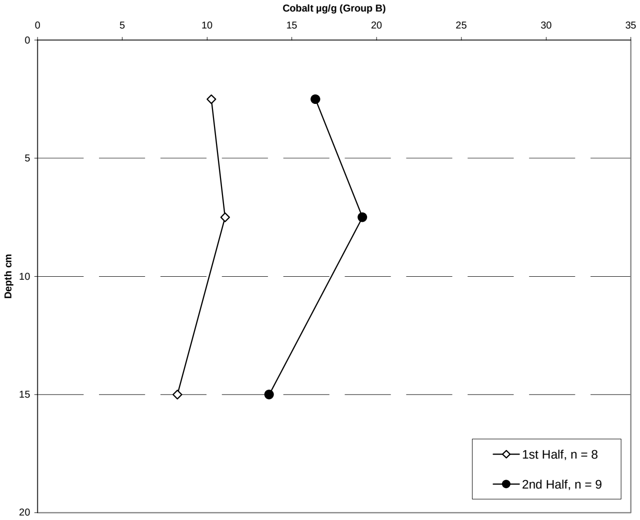


Figure 7.1.3.4: Sudbury Core, Co depth profiles, Group B

In the Sudbury Core, 16% of the sample locations exhibited a trend of increasing concentration with increasing depth, consistent with Group C. Concentrations of nickel, copper, cobalt, lead, and to a lesser degree iron showed a strong visual trend of increasing concentrations with depth in the second half, and a similar but weaker trend in the first half. Average concentrations of nickel, copper, cobalt and lead at the 10 - 20 cm soil depth were 1.5 to 2.0 times the average concentrations observed at surface in the second half, and only 1.2 to 1.3 times greater in the first half. Iron concentrations in both halves showed a similar but weak trend, and were 1.1 to 1.2 times greater at 10 - 20 cm than at surface. Figure 7.1.3.5 depicts the depth profile of cobalt in Group C for the Sudbury Core.

Chromium, zinc, aluminum and vanadium concentrations showed a weak pattern of decreasing concentration with increasing depth in the first half, typical of Group A. In the second half, however, these elements showed a trend of increasing concentration with increasing depth, consistent with Group C. The concentrations at 10 - 20 cm, in the second half for these elements was 1.1 to 1.5 times the concentration at the surface.

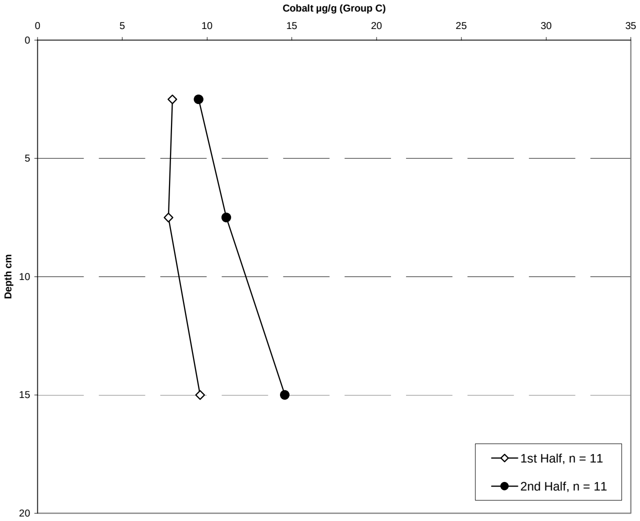


Figure 7.1.3.5: Sudbury Core, Co depth profiles, Group C

Concentrations for cadmium in both halves, and arsenic and selenium in the second halves only were at or near analytical MDLs, and there was no observable change with depth. In the second half, arsenic concentrations showed a pattern of increasing concentration with depth (1.2 times), and selenium showed no concentration change with depth. Refer to Section 10.5.3 for graphs of the depth profiles for the elements discussed above.

Overall, nickel, copper, cobalt, lead, chromium and zinc concentrations in 72% of the sample locations in the Sudbury Core showed a strong aerial deposition trend from the surface. Arsenic, selenium, cadmium and iron also showed a weaker aerial deposition trend from surface in these sample locations. These locations appeared to be unaffected by landscaping practices. The remaining sample locations appeared to be affected to some degree by landscaping practices, and nickel, copper, cobalt, lead, selenium, zinc, iron and vanadium concentrations showed strong to weak trends of maximum concentrations below surface. These elevated concentrations may still be attributed to aerial deposition, however, have been buried by landscaping practices at individual properties over time. Addition, grading, removal and / or mixing of urban soils may alter the vertical distribution of chemical concentrations in the soil.

In the Outer and Inner Sudbury Communities, only nickel, copper, and lead showed a strong trend of aerial deposition in all quarters, while in the Sudbury Core a strong aerial deposition trend was observed for cobalt as well. Weak trends of aerial deposition were observed in the third and/or fourth quarters for zinc, iron, chromium, selenium and cadmium in the Outer and Inner Sudbury Communities. The trends for chromium, selenium and cadmium were approximately twice as strong in the Sudbury Core, and the trends for iron and zinc were only slightly stronger. In the Sudbury Core, arsenic concentrations also showed a weak to strong trend of aerial deposition in the third and fourth quarters.

Pearson's and Spearman's statistical correlation analysis was performed on all of the elements except beryllium at each of the three depths. Refer to Tables 7.1.3.4 to 7.1.3.6 below for an abbreviated version of the results of the Pearson's and Spearman's analysis for all three depths, and Tables 10.4.3.1 through 10.4.3.3 for the full results of the analysis. In Tables 7.1.3.4 to 7.1.3.6 the results have been rounded to one decimal place and values that were 0.75 or greater are considered strong and are indicated in bold type.

Table 7.1.3.4: Pearson's and Spearman's Correlations for 0 to 5 cm Urban Soil in the Sudbury Core

	Al	**As**	**Ba**	**Cd**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Ni**	**Se**	**Sr**	**V**	**Zn**
Al	1	*0.3*	*0.7*	*0.3*	*0.7*	*0.3*	*0.3*	*0.6*	*0.3*	*0.5*	*0.7*	*0.3*	*0.2*	***0.9***	***0.8***	*0.4*
As	0.3	1	*0.6*	*0.7*	*0.4*	***0.8***	***0.8***	*0.7*	***0.8***	*0.1*	*0.3*	***0.9***	*0.7*	*0.2*	*0.3*	***0.8***
Ba	0.6	0.6	1	*0.7*	***0.8***	*0.7*	*0.7*	***0.8***	***0.8***	*0.5*	*0.7*	*0.7*	*0.5*	*0.6*	*0.6*	***0.8***
Cd	0.3	**0.8**	0.7	1	*0.5*	***0.8***	*0.7*	*0.6*	*0.7*	*0.2*	*0.4*	***0.8***	*0.6*	*0.3*	*0.3*	*0.7*
Cr	0.5	0.5	0.6	0.6	1	*0.6*	*0.5*	***0.8***	*0.5*	*0.6*	*0.7*	*0.5*	*0.4*	*0.6*	*0.7*	*0.6*
Co	0.3	**0.9**	0.7	**0.9**	0.5	1	***0.9***	***0.8***	***0.9***	*0.3*	*0.4*	***1.0***	*0.7*	*0.2*	*0.3*	***0.8***
Cu	0.3	**0.8**	0.7	**0.8**	0.5	**0.9**	1	*0.7*	***0.9***	*0.1*	*0.3*	***1.0***	*0.7*	*0.1*	*0.2*	***0.8***
Fe	0.6	**0.8**	**0.8**	0.7	0.6	**0.9**	**0.8**	1	*0.7*	*0.5*	*0.6*	*0.7*	*0.5*	*0.5*	*0.7*	*0.7*
Pb	0.2	0.7	0.7	0.7	0.4	0.7	**0.8**	0.6	1	*0.1*	*0.3*	***0.9***	*0.7*	*0.2*	*0.2*	***0.9***
Mg	0.5	0.0	0.3	0.1	0.3	0.1	0.1	0.3	0.0	1	*0.6*	*0.2*	*0.0*	*0.6*	*0.6*	*0.3*
Mn	0.4	0.2	0.6	0.3	0.3	0.2	0.2	0.4	0.2	0.3	1	*0.3*	*0.2*	*0.7*	***0.8***	*0.4*
Ni	0.3	**0.9**	0.7	**0.9**	0.5	**1.0**	**1.0**	**0.8**	0.7	0.1	0.2	1	*0.7*	*0.2*	*0.2*	***0.8***
Se	0.2	0.6	0.5	0.6	0.4	0.6	0.7	0.6	0.6	0.0	0.1	0.6	1	*0.1*	*0.2*	*0.7*
Sr	**0.8**	0.2	0.6	0.2	0.4	0.2	0.1	0.4	0.2	0.5	0.6	0.2	0.1	1	***0.8***	*0.3*
V	**0.8**	0.3	0.6	0.3	0.5	0.3	0.3	0.6	0.2	0.5	0.5	0.3	0.2	0.7	1	*0.4*
Zn	0.3	0.6	**0.8**	0.7	0.5	0.7	0.7	0.6	**0.8**	0.1	0.4	0.7	0.6	0.3	0.3	1

Spearman's correlations in upper right in italics. Pearson's correlations in lower left in normal font.
Bold indicates strong correlations.

Table 7.1.3.5: Pearson's and Spearman's Correlations for 5 to 10 cm Urban Soil in the Sudbury Core

	Al	As	Ba	Cd	Cr	Co	Cu	Fe	Pb	Mg	Mn	Ni	Se	Sr	V	Zn
Al	1	*0.2*	*0.6*	*0.1*	***0.8***	*0.3*	*0.1*	*0.7*	*0.1*	*0.6*	*0.7*	*0.2*	*0.0*	***0.8***	***0.9***	*0.3*
As	0.2	1	*0.6*	*0.4*	*0.3*	***0.8***	***0.9***	*0.5*	***0.8***	*0.1*	*0.3*	***0.9***	*0.6*	*0.1*	*0.2*	***0.7***
Ba	0.6	0.6	1	*0.4*	*0.7*	***0.8***	*0.7*	***0.8***	*0.7*	*0.5*	*0.7*	*0.7*	*0.5*	*0.5*	*0.6*	***0.8***
Cd	0.1	0.5	0.4	1	*0.3*	*0.4*	*0.4*	*0.3*	*0.4*	*0.1*	*0.2*	*0.4*	*0.4*	*0.2*	*0.1*	*0.4*
Cr	0.7	0.3	0.6	0.3	1	*0.5*	*0.4*	***0.8***	*0.3*	***0.8***	***0.8***	*0.4*	*0.2*	*0.7*	***0.8***	*0.5*
Co	0.3	**0.8**	0.7	0.5	0.4	1	***0.9***	*0.7*	***0.8***	*0.5*	*0.5*	***0.9***	*0.5*	*0.2*	*0.4*	***0.8***
Cu	0.2	**0.8**	0.7	0.5	0.3	**0.9**	1	*0.6*	***0.8***	*0.2*	*0.3*	***1.0***	*0.6*	*0.1*	*0.2*	***0.8***
Fe	**0.8**	0.5	0.7	0.3	**0.8**	0.7	0.6	1	*0.5*	*0.7*	*0.7*	*0.6*	*0.4*	*0.6*	***0.8***	*0.6*
Pb	0.1	0.6	0.7	0.5	0.2	0.6	0.7	0.4	1	*0.2*	*0.3*	***0.8***	*0.6*	*0.1*	*0.1*	***0.9***
Mg	0.7	0.0	0.4	0.0	0.7	0.3	0.1	0.7	0.0	1	***0.8***	*0.2*	*0.0*	*0.6*	*0.7*	*0.3*
Mn	0.7	0.2	0.6	0.2	0.7	0.4	0.2	0.7	0.2	0.7	1	*0.3*	*0.2*	*0.7*	***0.8***	*0.5*
Ni	0.2	**0.8**	0.7	0.5	0.3	**0.9**	**1.0**	0.6	0.6	0.1	0.2	1	*0.6*	*0.1*	*0.2*	***0.8***
Se	0.1	0.7	0.5	0.5	0.3	0.6	0.7	0.4	0.6	0.0	0.2	0.7	1	*0.1*	*0.1*	*0.5*
Sr	**0.8**	0.1	0.6	0.2	0.7	0.2	0.1	0.6	0.2	0.6	0.7	0.2	0.1	1	***0.8***	*0.3*
V	**0.9**	0.2	0.5	0.1	**0.8**	0.3	0.1	**0.8**	0.0	0.7	0.7	0.2	0.1	**0.8**	1	*0.3*
Zn	0.2	0.7	**0.8**	0.5	0.3	0.7	0.7	0.5	**0.8**	0.1	0.4	0.7	0.5	0.3	0.2	1

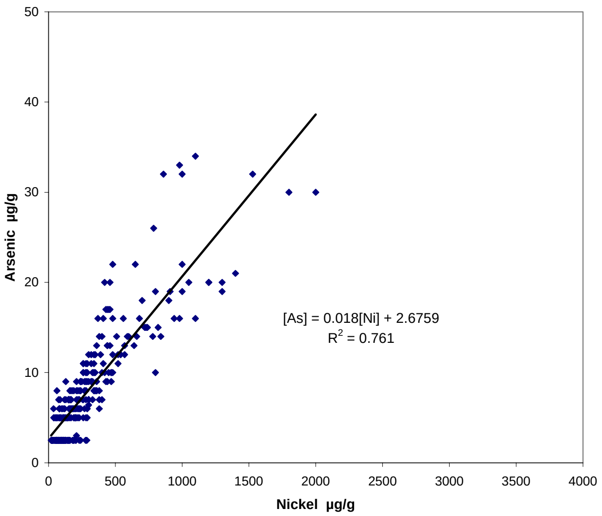
Spearman's correlations in upper right in italics. Pearson's correlations in lower left in normal font.
Bold indicates strong correlations.

Table 7.1.3.6: Pearson's and Spearman's Correlations for 10 to 20 cm Urban Soil in the Sudbury Core

	Al	As	Ba	Cd	Cr	Co	Cu	Fe	Pb	Mg	Mn	Ni	Se	Sr	V	Zn
Al	1	*0.3*	*0.7*	*0.1*	***0.9***	*0.4*	*0.2*	***0.9***	*0.2*	*0.6*	***0.8***	*0.2*	*0.2*	***0.8***	***0.9***	*0.3*
As	0.2	1	*0.6*	*0.3*	*0.3*	*0.6*	***0.9***	*0.4*	*0.7*	*0.0*	*0.3*	***0.8***	*0.5*	*0.2*	*0.2*	***0.8***
Ba	0.6	0.6	1	*0.3*	*0.7*	*0.7*	*0.6*	***0.8***	*0.6*	*0.5*	*0.7*	*0.6*	*0.3*	*0.7*	*0.7*	*0.7*
Cd	0.1	0.4	0.4	1	*0.2*	*0.3*	*0.3*	*0.2*	*0.3*	*0.0*	*0.2*	*0.3*	*0.3*	*0.2*	*0.1*	*0.3*
Cr	**0.9**	0.3	0.6	0.2	1	*0.5*	*0.3*	***0.9***	*0.2*	***0.8***	***0.8***	*0.3*	*0.2*	***0.8***	***0.9***	*0.4*
Co	0.3	0.7	0.7	0.6	0.5	1	***0.8***	*0.7*	*0.7*	*0.5*	*0.6*	***0.8***	*0.3*	*0.4*	*0.5*	*0.7*
Cu	0.2	**0.8**	0.6	0.5	0.3	**0.8**	1	*0.5*	***0.8***	*0.1*	*0.4*	***1.0***	*0.4*	*0.2*	*0.2*	***0.9***
Fe	**0.9**	0.5	0.7	0.3	**0.9**	0.6	0.4	1	*0.3*	*0.7*	***0.8***	*0.4*	*0.3*	*0.7*	***0.9***	*0.5*
Pb	0.1	0.6	0.7	0.5	0.2	0.5	0.5	0.2	1	*0.0*	*0.3*	***0.8***	*0.3*	*0.2*	*0.1*	***0.9***
Mg	0.7	0.0	0.4	0.0	**0.8**	0.3	0.0	0.7	0.0	1	*0.7*	*0.1*	*0.1*	*0.6*	*0.7*	*0.2*
Mn	**0.8**	0.3	0.7	0.3	**0.9**	0.5	0.3	**0.8**	0.3	0.7	1	*0.4*	*0.2*	***0.8***	***0.8***	*0.5*
Ni	0.2	**0.8**	0.6	0.6	0.3	**0.9**	**1.0**	0.4	0.5	0.0	0.3	1	*0.4*	*0.2*	*0.2*	***0.8***
Se	0.2	0.6	0.3	0.4	0.2	0.5	0.7	0.4	0.4	0.1	0.2	0.6	1	*0.1*	*0.2*	*0.4*
Sr	**0.8**	0.2	0.7	0.2	**0.8**	0.4	0.2	0.7	0.3	0.6	0.7	0.3	0.1	1	***0.8***	*0.3*
V	**0.9**	0.2	0.6	0.1	**0.9**	0.4	0.2	**0.9**	0.1	**0.8**	**0.8**	0.2	0.2	**0.8**	1	*0.3*
Zn	0.2	0.7	**0.8**	0.6	0.3	0.6	0.7	0.3	**0.9**	0.0	0.4	0.7	0.4	0.4	0.2	1

Spearman's correlations in upper right in italics. Pearson's correlations in lower left in normal font.
Bold indicates strong correlations.

In the Sudbury Core, at 0 - 5 cm, nickel, copper, cobalt, arsenic, cadmium and iron are strongly correlated with each other using Pearson's, and strongly or moderately using Spearman's. Lead and zinc moderately correlate with these elements using Pearson's, however, were strongly correlated with these elements using Spearman's. An example of the nickel vs arsenic and nickel vs cadmium correlations are presented in Figures 7.1.3.6 and 7.1.3.7 below. Refer to Section 10.4.3 for additional correlation figures.



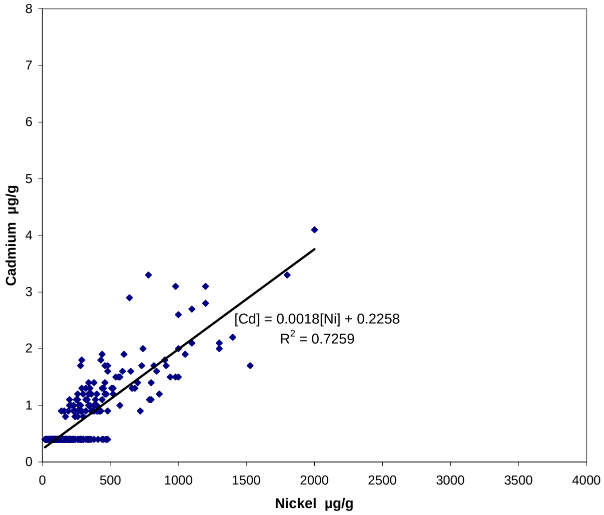


Fig 7.1.3.6: As vs. Ni, 0 - 5 cm, Sudbury Core

Fig 7.1.3.7: Cd vs. Ni, 0 - 5 cm, Sudbury Core

The correlation between nickel, copper, cobalt and arsenic remained similar at all depth intervals in Pearson's and Spearman's with minor fluctuations in the level of significance between cobalt and arsenic. Iron and cadmium, however, were not correlated with these elements below 0 - 5 cm. With depth, zinc remained moderately correlated with nickel, copper, cobalt and arsenic using Pearson's and strongly correlated using Spearman's. Using Spearman's, lead remained strongly correlated with all four elements at 5 - 10 cm and only strongly correlated with nickel and copper at 10 - 20 cm. The moderate correlations between lead and nickel, copper, cobalt and arsenic disappear with depth using Pearson's. A strong correlation between lead and zinc was also present, at all three depths, using Pearson's and Spearman's. As discussed in Section 7.1.2, the correlation between lead and zinc tended to be stronger using log transformation and/or Spearman's. Overall, the number of correlations occurring with nickel, copper, cobalt and arsenic decrease with depth.

The correlations of nickel, copper, cobalt, arsenic, lead and zinc at all depths indicate that concentrations of these elements in the Sudbury Core appear to be attributed to smelter emissions. The concentrations of cadmium and iron, at surface, also appear to be attributed to smelter emissions. Arsenic, cadmium and iron did not appear to be attributed to smelter emissions in either the Outer or Inner Sudbury Communities.

For the naturally occurring elements, the overall number of correlations increase with depth. This pattern was the inverse of the pattern observed for nickel, copper, cobalt and arsenic. Aluminum, strontium and vanadium were strongly correlated with each other at all depths using both Pearson's and Spearman's. Chromium, iron, magnesium, and manganese become strongly correlated with each other and with aluminum, strontium and vanadium as depth increased using both Pearson's and Spearman's. As these elements are indicative of the naturally occurring geology in the City of Greater Sudbury, the increase in the number and strength of these correlations was representative of less disturbed soil at depth. Unlike the Outer and Inner Sudbury Communities, only aluminum and vanadium were strongly correlated at all depths. As discussed previously in this section and Sections 7.1.1 and 7.1.2, aluminum and vanadium have consistently been present as indicators of the naturally occurring geology in the Outer and Inner Sudbury Communities and the Sudbury Core. Natural elements such as chromium and iron have shown evidence of aerial deposition in either the Outer or Inner Sudbury Communities.

As was also shown in the soil depth profiles, both chromium and iron showed evidence of aerial deposition in the Sudbury Core. Figures 7.1.3.8 and 7.1.3.9 illustrate the correlations between aluminum and iron at surface and at 10 - 20 cm. The increase in the strength of this correlation is evident and is indicative of aerial deposition of iron at the surface and less disturbed soil at depth. The correlations of barium to other elements fluctuates with depth and between Pearson's and Spearman's. Barium strongly and moderately correlates more with elements associated with smelter emissions such as nickel, copper, cobalt, lead, cadmium and zinc at 0 - 5 cm. The strength and number of these correlations, however, decrease with depth and correlations of barium with naturally occurring elements such as aluminum, manganese, strontium and vanadium increase. Barium was strongly correlated to iron at all depths, using Spearman's. The correlation of barium with aluminum, chromium and vanadium only occurred using Spearman's. The pattern and strength of barium correlations appear to be indicative of aerial deposition at the surface and natural background concentrations at depth. Refer to Section 10.4.3 for a complete list of graphs showing selected element correlations at all three depths for the Inner Sudbury Communities.

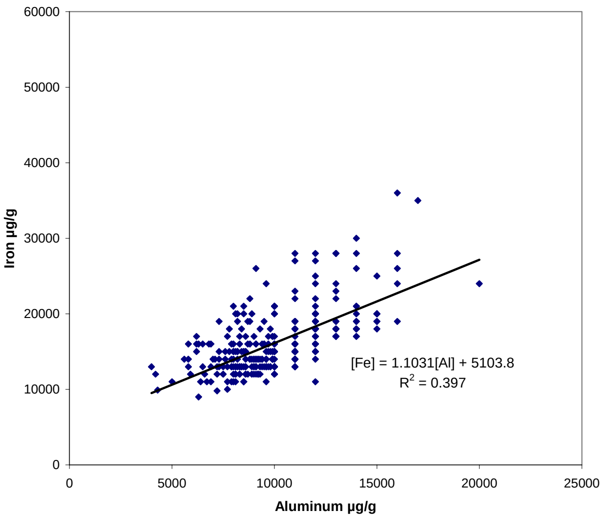


Fig 7.1.3.8: Fe vs. Al, 0 - 5 cm, Sudbury Core

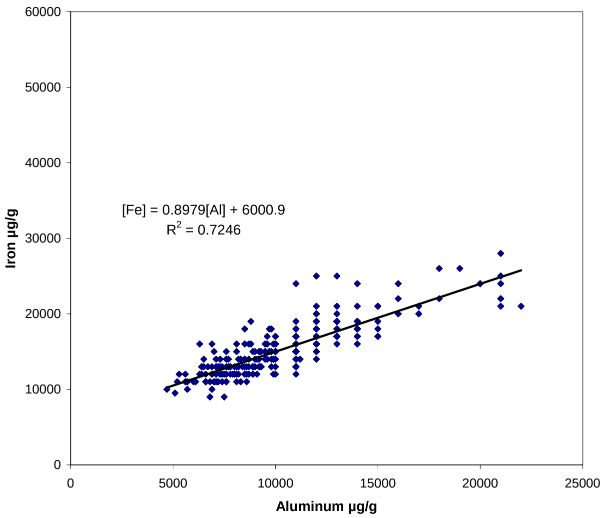


Fig 7.1.3.9: Fe vs. Al, 10 - 20 cm, Sudbury Core

In summary, element concentrations in the Sudbury Core were considerably higher and had more exceedences of MOE criteria than in the Outer and Inner Sudbury Communities. A large number of nickel and copper concentrations and a smaller number of arsenic and lead concentrations exceeded Table A at all depths. A small number of cobalt concentrations exceeded Table A only at surface. No other elements exceeded Table A criteria in the Sudbury Core. Twelve elements, at varying depths, exceeded Table F including nickel, copper, cobalt, arsenic, lead, cadmium, selenium, chromium, zinc, antimony, barium and molybdenum. The number of exceedences for all elements decreased with depth.

Overall, concentrations of nickel, copper, cobalt, lead, chromium, zinc, and to a lesser extent arsenic, barium, selenium, cadmium and iron showed a strong aerial deposition trend from surface in the majority of the sample locations in the Sudbury Core. A spatial concentration gradient was observed for nickel, copper, cobalt, lead and arsenic, originating in the neighbourhoods of Gatchell and Little Britain, adjacent to Inco property and generally decreasing to the east and northeast. Concentrations of cadmium, selenium, zinc, chromium and iron were only slightly higher in Gatchell and / or Little Britain. Concentrations of these ten elements decreased with depth, however, maintained a spatial distribution similar to the surface, with the exception of cadmium which showed no concentration gradient at depth.

In the Sudbury Core, approximately 30% of the sample locations appeared to be affected to some degree by landscaping practices, and nickel, copper, cobalt, lead, selenium, zinc, iron and vanadium concentrations at these locations showed trends of maximum concentrations below surface.

In the Outer and Inner Sudbury Communities, only nickel, copper, and lead showed a strong trend of aerial deposition, while in the Sudbury Core, a strong aerial deposition trend was observed for cobalt as well. Weak trends of aerial deposition were observed for zinc, iron, chromium, selenium and cadmium in the Outer and Inner Sudbury Communities. These trends were stronger in the Sudbury Core. In the Sudbury Core, arsenic concentrations also showed a weak to strong trend of aerial deposition.

The correlations of nickel, copper, cobalt, arsenic, lead and zinc at all depths indicate that concentrations of these elements in the Sudbury Core appear to be attributed to smelter emissions. The concentrations of cadmium, barium and iron, at surface, also appear to be attributed to smelter emissions. Arsenic, cadmium, barium and iron did not appear to be due to to smelter emissions in either the Outer or Inner Sudbury Communities.

7.1.4 Coniston

In Coniston, the surface soil concentrations of the eleven elements used in determining this grouping were considerably higher than the Outer and Inner Sudbury Communities, but were similar to the Sudbury Core. Refer to Table 7.1.4.1. At 0 - 5 cm in Coniston, nickel, copper, cobalt, arsenic, barium, lead, cadmium, selenium and zinc concentrations were considerably higher than in the Outer and Inner Sudbury Communities. Depending on the element the differences in concentrations started from the 25th to 75th percentile. Iron was marginally higher. At this depth, the only differences between Coniston and the Sudbury Core were that arsenic and cobalt were slightly higher in Coniston.

Table 7.1.4.1: Summary Statistics for Metals and Arsenic in Urban Soil in Coniston of the City of Greater Sudbury.

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
0 to 5 cm Urban Soil in Coniston, n = 301																			
Minimum	3900	0.4	2.5	20	0.4	1400	17	3	8	7400	2	1500	88	0.75	16	0.5	10	18	11
10th percentile	7000	0.4	2.5	33	0.4	2900	22	6	49	11000	12	2000	130	0.75	58	0.5	20	22	27
1st quartile	8050	0.4	2.5	42	0.4	3900	26	7	63	13000	17	2300	160	0.75	81	0.5	26	24	34
Median	9300	0.4	7.0	52	0.4	5400	29	12	150	15000	32	2700	180	0.75	200	0.5	33	27	51
3rd quartile	11000	0.4	13	67	0.9	7300	33	20	325	17000	62	3200	210	0.75	450	2.0	39	30	80
95th percentile	14000	1.0	33	90	1.8	11000	44	45	800	24000	150	4100	250	1.50	1200	3.0	47	35	140
Maximum	20000	3.0	47	180	2.7	33000	75	74	1200	33000	400	10000	320	2.90	1900	5.0	86	44	250
Mean	9622	0.5	10	55	0.7	6044	30	16	244	15379	50	2870	183	0.80	334	1.1	33	27	62
CV (std. dev./mean)	24%	63%	88%	38%	72%	57%	27%	82%	103%	25%	101%	32%	22%	26%	107%	84%	29%	16%	61%
Skewness	1.0	4.9	1.8	1.7	1.8	3.0	2.0	1.7	1.7	1.3	2.6	3.2	0.6	5.6	1.8	1.8	0.8	0.5	1.6
5 to 10 cm Urban Soil in Coniston, n = 297																			
Minimum	3900	0.4	2.5	20	0.4	1500	16	3	8	6500	2	1400	84	0.75	14	0.5	10	17	10
10th percentile	6960	0.4	2.5	31	0.4	2500	21	5	40	11000	9	1800	130	0.75	50	0.5	19	22	21
1st quartile	8100	0.4	2.5	37	0.4	3200	24	7	60	13000	13	2000	140	0.75	77	0.5	24	24	27
Median	9500	0.4	8.0	46	0.4	4000	27	10	120	14000	23	2300	170	0.75	170	0.5	32	27	39
3rd quartile	11000	0.4	15	64	0.4	5500	31	18	330	17000	49	2900	200	0.75	430	1.0	38	30	64
95th percentile	15000	1.2	29	96	0.9	7825	39	30	643	20250	133	3900	260	0.75	900	3.0	49	36	110
Maximum	21000	5.3	53	200	1.2	37000	57	46	920	23000	270	8100	310	2.10	1200	4.0	86	44	260
Mean	9777	0.5	11	53	0.5	4728	28	13	215	14827	41	2565	176	0.78	287	1.0	32	28	49
CV (std. dev./mean)	25%	80%	86%	45%	40%	67%	23%	64%	93%	21%	108	32%	25%	22%	94%	78%	33%	17%	65%
Skewness	0.9	6.5	1.5	2.0	2.6	5.6	1.2	1.4	1.3	0.2	2.2	2.4	0.7	5.1	1.3	1.6	0.8	0.5	2.2
10 to 20 cm Urban Soil in Coniston, n = 290																			
Minimum	4900	0.4	2.5	19	0.4	1400	16	4	17	8500	4	1200	79	0.75	22	0.5	10	17	10
10th percentile	6700	0.4	3	31	0.4	2400	20	6	41	11000	7	1700	120	0.8	54	0.5	18	22	19
1st quartile	7700	0	3	38	0	2800	23	7	77	12000	13	2000	140	1	96	1	24	24	26
Median	9150	0.4	8.0	49	0.4	3600	26	10	150	14000	28	2300	170	0.75	190	0.5	31	27	38
3rd quartile	11000	0.4	14	68	0.4	4900	31	16	330	16000	55	2900	200	0.75	390	1.0	39	30	58
95th percentile	15000	1.0	23	110	0.4	7855	39	22	506	20000	146	4200	276	0.75	651	3.0	50	37	120
Maximum	19000	2.7	55	200	1.0	30000	45	43	1100	28000	280	5300	360	1.60	1400	9.0	78	42	210
Mean	9557	0.5	10	57	0.4	4295	27	12	212	14606	43	2524	176	0.77	266	1.0	31	27	48
CV (std. dev./mean)	27%	65%	76%	51%	23%	70%	22%	54%	83%	23%	103%	31%	27%	17%	84%	93%	33%	17%	71%
Skewness	1.1	4.3	1.6	1.9	4.4	5.1	0.8	1.6	1.5	1	2.1	1.0	0.8	5.5	1.6	3.6	0.5	0.5	2.0

All results are in µg/g dry weight.

For 10 - 20 cm, nickel, copper, cobalt, arsenic, lead and zinc were substantially higher in Coniston compared to the Outer and Inner Sudbury Communities. Barium was also higher in Coniston compared to the Outer Sudbury Communities but was similar compared to the Inner Sudbury Communities. At this depth, selenium was marginally higher than both the Outer and Inner Sudbury Communities. Cadmium, chromium and iron concentrations were similar in all three communities at the 10 - 20 cm depth. All other elements in Coniston were essentially the same between the Outer and Inner Sudbury Communities. Nickel, copper, cobalt, arsenic and lead concentrations were higher at this depth in Coniston than in the Sudbury Core. All other elements in Coniston were the same as in the Sudbury Core.

The major land use in Coniston was residential. The two school properties only had gravel playgrounds and there were only a small number of park properties. As a result, the sample size for the park properties was very small and may affect the validity of comparisons between the park properties and residential properties. The concentrations of nickel, copper, cobalt, arsenic, lead, selenium, chromium, iron and zinc were higher in the residential properties than in the park properties at all depths. The differences in concentrations for nickel, copper, cobalt, arsenic, lead and zinc started from the 10th percentile to the median and onwards, dependant on the element and depth. The concentrations of selenium, chromium and iron started from the 10th to 90th percentile, dependant on the element and depth. Cadmium was substantially higher in the residential properties at surface but only marginally higher below surface. The small sample size for the park properties may have exaggerated the differences between land uses. Refer to Table 7.1.4.2

Table 7.1.4.2: Summary Statistics for All 0-5 cm Urban Soil Samples from Coniston by Land Use

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Residential 0 to 5 cm				n = 287															
Minimum	5400	0.4	2.5	20	0.4	1400	18	3	14	8500	6	1500	88	0.75	25	0.5	10	18	17
10th percentile	7060	0.4	2.5	35	0.4	2900	22	6	50	1200	13	2000	130	0.75	60	0.5	20	22	28
1st quartile	8150	0.4	2.5	42	0.4	3900	26	7	65	1300	18	2300	160	0.75	82	0.5	26	25	35
Median	9400	0.4	7.0	53	0.4	5300	29	11	150	1500	32	2700	180	0.75	200	0.5	33	27	53
3rd quartile	1100	0.4	13	67	0.9	7300	34	20	320	1700	68	3200	210	0.75	450	2.0	39	30	83
95th percentile	1400	1.0	33	90	1.8	1100	44	45	807	2470	150	4070	250	1.50	1200	3.0	47	35	140
Maximum	2000	3.0	47	180	2.7	3300	75	74	1200	3300	400	6900	320	2.90	1900	5.0	86	44	250
Mean	9709	0.5	10	56	0.7	5999	31	16	246	1548	52	2833	183	0.80	336	1.2	33	27	64
CV (std. dev./mean)	24%	64%	88%	37%	72%	57%	27%	82%	103	25%	99%	26%	22%	27%	107	84%	29%	16%	60%
Skewness	1.0	4.8	1.7	1.7	1.8	3.2	2.0	1.8	1.7	1.3	2.6	1.4	0.5	5.4	1.8	1.7	0.8	0.5	1.5
Parks 0 to 5 cm				n = 14															
Minimum	3900	0.4	2.5	20	0.4	2000	17	4	8	7400	2	1600	110	0.75	16	0.5	18	18	11
10th percentile	5800	0.4	2.5	28	0.4	2490	20	5	14	1100	3	1960	119	0.75	23	0.5	22	22	15
1st quartile	6900	0.4	2.5	32	0.4	3000	23	6	26	1100	6	2200	140	0.75	40	0.5	26	24	16
Median	7650	0.4	6.5	37	0.4	6300	26	12	99	1350	11	2900	175	0.75	195	0.5	32	25	30
3rd quartile	9300	0.4	13	46	0.4	9400	28	24	450	1500	20	3400	200	0.75	610	1.0	35	27	41
95th percentile	1100	0.4	17	60	1.1	1540	35	40	614	1735	41	9220	297	0.75	888	1.4	45	30	52
Maximum	1100	0.4	19	81	1.3	1800	36	43	620	1800	42	1000	310	0.75	940	2.0	45	31	58
Mean	7836	0.4	7.9	40	0.5	6979	26	16	211	1324	16	3636	184	0.75	300	0.7	32	25	30
CV (std. dev./mean)	25%	0%	74%	36%	54%	65%	20%	83%	109	20%	84%	69%	35%	0%	108	60%	26%	13%	50%
Skewness	0.0		0.6	1.9	2.0	1.3	0.4	1.2	0.9	-0.3	1.1	2.1	0.9		1.0	2.4	0.1	-0.1	0.4

All results are in µg/g dry weight.

Generally, surface soil park concentrations for nickel, cobalt and arsenic were similar when compared to the Sudbury Core, however, had lower maximum values. Concentrations of copper were marginally lower from the minimum value, and also had lower maximum values. Lead concentrations in Coniston were lower starting from the 25th percentile compared to the Sudbury Core. At depth, however, concentrations of nickel, copper and arsenic were marginally higher in Coniston compared to the Sudbury Core.

There were substantially more exceedences of Table A and F in Coniston than the Outer and Inner Sudbury Communities. Table 7.1.4.3 summarizes the number of urban soil samples that exceeded the Table F and Table A criteria in Coniston. Nickel, copper, cobalt, arsenic and lead concentrations exceeded Table A at all depths. No other elements exceeded Table A at any depths in Coniston. At 0 - 5 cm 39% of the urban soil samples exceeded Table A and 64% exceeded Table F for copper. At the same depth 55% exceeded Table A and 97% exceed Table F for nickel. Unlike the Sudbury Core, the number of Table A and F exceedences for nickel and copper remained constant with depth. The number of arsenic exceedences increased at 5 - 10 cm and then decreased at 10 - 20 cm.

Table 7.1.4.3: Summary of MOE Table F and Table A Exceedences for Metals and Arsenic in Urban Soil Samples from Coniston of the City of Greater Sudbury

Element	Table F			Table A		
	0 to 5 cm	5 to 10 cm	10 to 20 cm	0 to 5 cm	5 to 10 cm	10 to 20 cm
Antimony	14 (5%)	21 (7%)	11 (4%)	0	0	0
Arsenic	47 (16%)	61 (21%)	45 (16%)	35 (12%)	46 (15%)	22 (8%)
Cadmium	55 (18%)	6 (2%)	0	0	0	0
Chromium	2 (1%)	0	0	0	0	0
Cobalt	73 (24%)	46 (15%)	23 (8%)	23 (8%)	2 (1%)	2 (1%)
Copper	193 (64%)	186 (63%)	208 (72%)	116 (39%)	108 (36%)	110 (38%)
Lead	25 (8%)	20 (7%)	20 (7%)	6 (2%)	3 (1%)	3 (1%)
Molybdenum	1	0	0	0	0	0
Nickel	291 (97%)	279 (94%)	269 (93%)	166 (55%)	164 (55%)	167 (58%)
Selenium	83 (28%)	71 (24%)	56 (19%)	0	0	0
Zinc	4 (1%)	3 (1%)	5 (2%)	0	0	0
No. of Samples	301	297	290	301	297	290

Spatial distribution of the chemical concentrations in the Sudbury Core were assessed using concentration dot maps. Concentration dot maps were created for 10 elements at the 0 - 5 cm and 10 - 20 cm soil depths. Generally, the concentrations of nickel, copper, cobalt, arsenic and lead at 0 - 5 cm were elevated throughout Coniston. There was a trend of higher concentrations for these elements at 0 - 5 cm throughout the centre of the community with lower concentrations towards the east and west ends. The properties sampled in the east and west ends were generally newer than those sampled in the centre of town. At 0 - 5 cm, concentrations of cadmium, selenium, zinc, iron, and to a lesser extent chromium, were slightly higher in the centre of the community, but were relatively low.

In Coniston, the concentrations of nickel, copper, arsenic, and to a lesser extent lead and zinc, generally decrease slightly with depth, however, the spatial trend remains similar to the surface. Concentrations of cobalt, cadmium, selenium, chromium and iron also decreased with depth, but no concentration gradient was observed at 10 - 20 cm.

Concentrations in approximately half of the sample locations show the highest concentration at either 5 - 10 cm or 10 - 20 cm. This is different from the Sudbury Core where concentrations of these elements decreased rapidly with depth for the majority of sample locations. The largest increase in concentrations between surface and depth was observed for nickel, copper, cobalt, arsenic and iron at the south end of the community adjacent to the former smelter. For an example of the spatial distributions for nickel in the 0 - 5 and 10 - 20 cm soil depths, refer to Figures 7.1.4.1 and 7.1.4.2. Arrows have been inserted in Figure 7.1.4.2 highlighting the locations where concentrations increased with depth. Refer to Section 10.2.3 for concentration dot maps of these 10 elements at different depth intervals in Coniston.

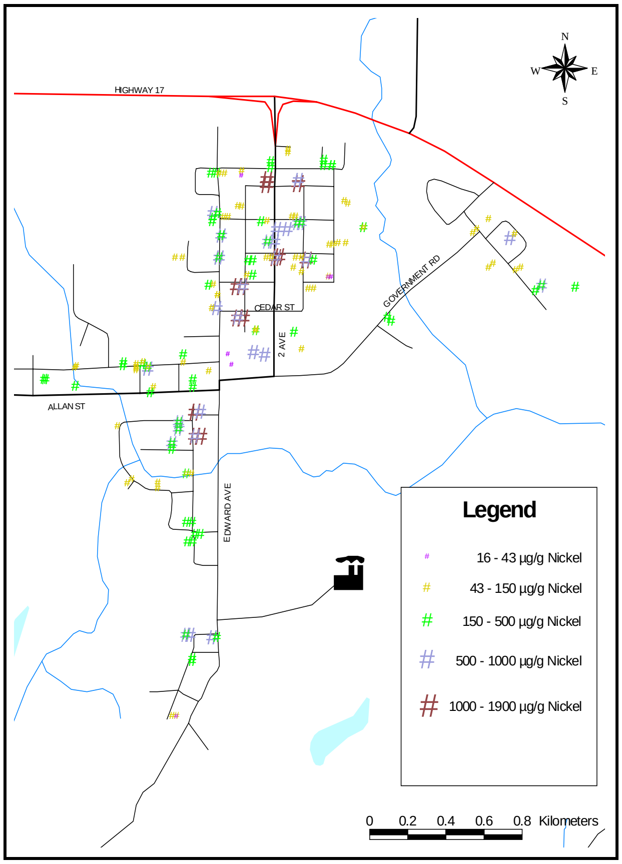


Figure 7.1.4.1: Ni concentrations in urban 0 - 5 cm soil in Coniston

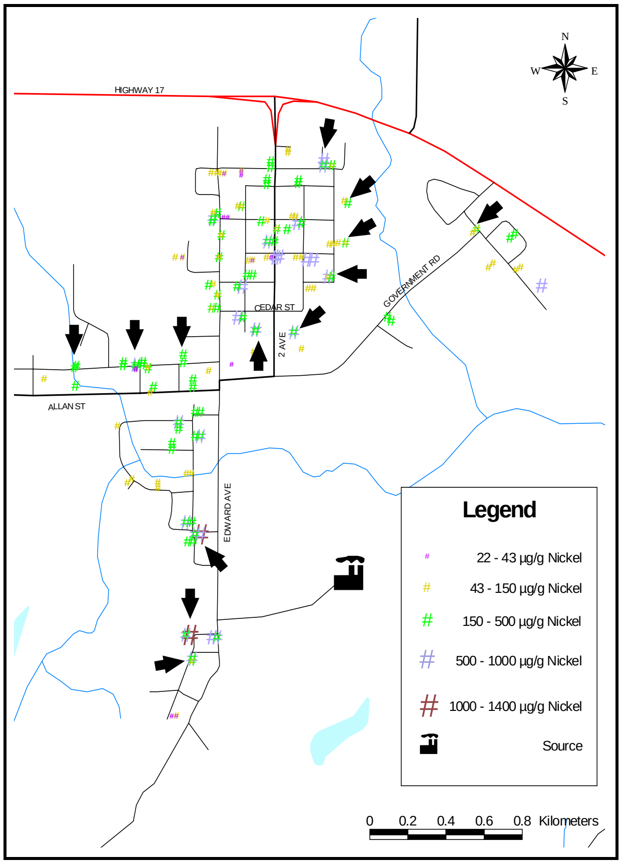


Figure 7.1.4.2: Ni concentrations in urban 10 - 20 cm soil in Coniston

In Coniston, all three depth trends (Group A, B and C) were observed at varying numbers of sample locations. Forty-four percent of the soil sampling locations showed a strong visual trend of decreasing concentration with depth for nickel, copper, cobalt, lead, iron and zinc in the second through fourth quarters, consistent with Group A. This trend was most pronounced between the 0 - 5 cm and the 5 - 10 cm depth. Average concentrations at surface for these elements were 1.1 to 3.0 times the average concentrations at the 10 - 20 cm depth, for the second through fourth quarters. Generally, the weakest trend was observed in the second quarters and the strongest was observed in the fourth.

Generally, the average concentrations for these elements decreased greatly between the surface and the 5 - 10 cm depth, but only marginally between the 5 - 10 cm and 10 - 20 cm depth. The exceptions were the fourth quarters for nickel, copper and cobalt which decreased in concentration at a relatively constant rate. Refer to Figure 7.1.4.3 for the depth profile of copper in Group A for Coniston.

Arsenic concentrations showed a weak visual trend of aerial deposition in the first and second quarters (1.1 to 1.4 times), and a stronger trend in the third and fourth quarters (1.5 to 2.0 times).

Selenium concentrations showed a weak to strong trend of aerial deposition in the third and fourth quarters (1.8 to 2.1 times). The first and second quarters for selenium showed no observable change in concentration with depth. Cadmium and chromium concentrations showed a similar trend of aerial deposition in the fourth quarter (3.0 times and 1.6 times respectively), while the first through third quarters showed no observable change with depth. The average concentrations in all quarters for cadmium, the first through third quarters for selenium, and the first and second quarters for arsenic were at or near analytical MDLs. As a result, the concentration trends observed in these quarters should be interpreted with caution.

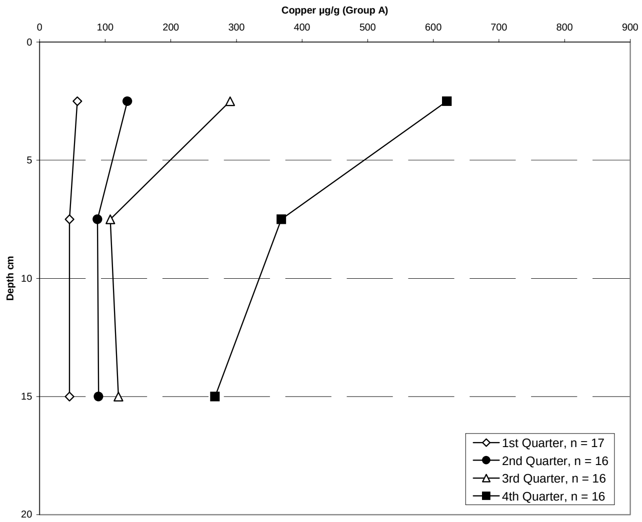


Figure 7.1.4.3: Coniston, Cu depth profile, Group A

A weak trend of aerial deposition was observed in the fourth quarters (1.1 to 1.3 times) for aluminum and vanadium. The depth trend observed for these two elements was likely an artifact of the sorting process. Aluminum and vanadium tend to be indicators of the naturally occurring geology of the City of Greater Sudbury and therefore would not be expected to show similar depth trends to nickel. The wide range in concentrations between the quarters of these elements may indicate differences in soil type. Refer to Section 10.5.4 for graphs of the depth profiles for the elements discussed above.

Only 44% of the sample locations in Coniston showed a strong trend of aerial deposition from surface, compared to approximately 75% of the locations in the Inner Sudbury Communities and the Sudbury Core, and 49% in the Outer Sudbury Communities. More than half of the sample locations in Coniston showed evidence of buried contamination, with maximum concentrations occurring at either 5 - 10 cm or 10 - 20 cm, the maximum depth of investigation. The smelter in Coniston ceased operation in 1972. The high occurrence of maximum concentrations below surface may be attributed to the absence of an ongoing emissions source in Coniston.

In Coniston, 28% of the sample locations exhibited a trend of maximum concentrations at 5 - 10 cm, while lower concentrations were observed at both 0 - 5 cm and 10 - 20 cm. This trend is consistent with Group B. Nickel, copper, cobalt, and to a lesser extent lead and zinc concentrations, showed a strong visual trend of maximum concentrations occurring at 5 - 10 cm in all quarters. For these elements, the average concentrations at 5 - 10 cm were 1.3 to 1.7 times the average concentrations at surface for the first through third quarters, and 1.7 to 3.4 times for the fourth quarters. Figure 7.1.4.4 depicts the depth profile of copper in Group B for Coniston.

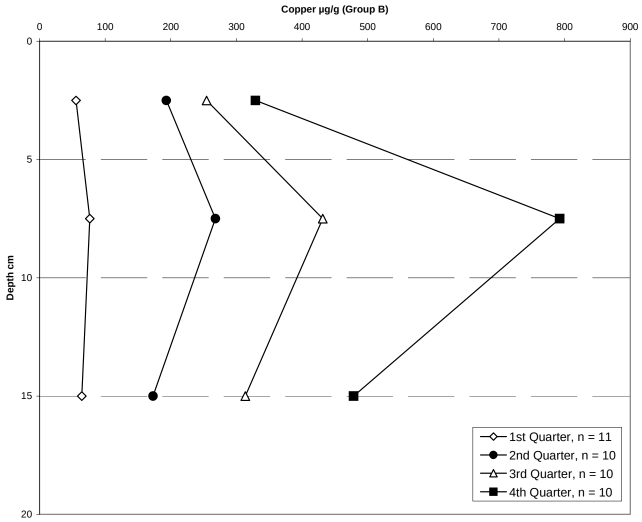


Figure 7.1.4.4: Coniston, Cu depth profile, Group B

A strong Group B trend (1.7 to 3.4 times) was observed in the fourth quarters for arsenic, cadmium and selenium. A similar but weaker trend was observed in the second and third quarters (1.2 to 1.5 times) for these elements, with the exception of the second quarter for cadmium which showed no change with depth. Arsenic and selenium concentrations in the first quarter, and cadmium concentrations in the first and second quarters were at or near analytical MDLs, and concentration trends in these quarters should be interpreted with caution. Chromium and iron concentrations showed a weak Group B trend (1.4 to 1.6 times) in the fourth quarters, and a very weak trend (1.1 to 1.2 times) in the second and third quarters.

A very weak Group B trend (1.1 to 1.2 times) was observed in the second through fourth quarters for aluminum, and third and fourth quarters for vanadium. The depth trend observed for these elements was likely an artifact of the sorting process. Aluminum and vanadium tend to be indicators of the naturally occurring geology of the City of Greater Sudbury and therefore would not be expected to show similar depth trends to nickel.

In Coniston, 29 % of the sample locations exhibited a trend of increasing concentration with increasing depth, consistent with Group C. Concentrations of nickel and copper showed a strong visual trend of increasing concentrations with depth in all quarters, while concentrations of cobalt and arsenic showed a strong visual trend in the second through fourth quarters. Average concentrations of nickel, copper, cobalt and arsenic at the 10 - 20 cm soil depth were 1.3 to 2.2 times the average concentrations observed at the surface in the second through fourth quarters. Figure 7.1.4.5 depicts the depth profile of copper in Group C for Coniston.

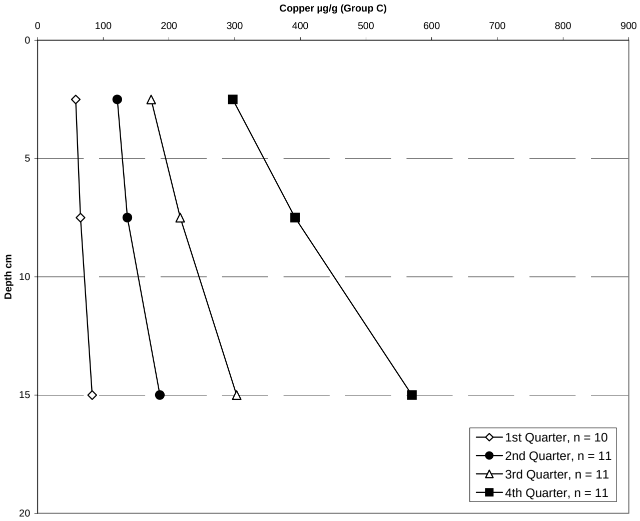


Figure 7.1.4.5: Coniston, Cu depth profile, Group C

Lead, selenium, zinc and to a lesser degree iron concentrations showed a strong pattern of decreasing concentration with increasing depth in the fourth quarters, consistent with Group C. Average concentrations observed at 10 - 20 cm, in the fourth quarter, was 1.2 to 1.8 times the concentrations observed at the surface. There was no observable concentration change with depth in the first through third quarters for these elements. Selenium concentrations in the first through third quarters were at or near analytical MDLs.

Aluminum, vanadium, cadmium and chromium showed a very weak to no change in concentration with depth. Average concentrations in all quarters for cadmium were at or near analytical MDLs and should be interpreted with caution. Refer to Section 10.5.4 for graphs of the depth profiles for the elements discussed above.

Overall, nickel, copper, cobalt, lead and zinc concentrations in 44% of the sample locations in Coniston showed a strong aerial deposition trend from surface. Arsenic, cadmium, selenium, chromium and iron also showed a weaker aerial deposition trend from surface in these sample locations. The remaining sample locations appeared to be affected by some degree of landscaping practices, and had maximum concentrations occurring below 0 - 5 cm. The same 10 elements showed a strong to weak trend of maximum concentrations occurring at 5 - 10 cm below surface. The concentration trends of these elements dropped off slightly at the 10 - 20 cm depth, and disappeared completely for cadmium and chromium. These elevated concentrations may still be attributed to aerial deposition, however, have been buried by landscaping practices at individual properties over time. Addition, grading, removal and / or mixing of urban soils may alter the vertical distribution of chemical concentrations in the soil.

The concentration trends observed in Coniston were similar to those observed in the Sudbury Core and the Inner Sudbury Communities for Groups A, B and C. In these communities, nickel, copper, cobalt and lead showed a strong trend of aerial deposition in all quarters. Weak to strong trends of aerial deposition were observed in the third and/or fourth quarters for arsenic, cadmium, selenium, chromium, zinc and iron in the Sudbury Core and Inner Sudbury Communities. In Coniston, however, only 44% of the sample locations showed a strong trend of aerial deposition from surface, compared to approximately 75% of the locations in the Inner Sudbury Communities and the Sudbury Core, and 49% in the Outer Sudbury Communities. More than half of the sample locations in Coniston showed evidence of buried contamination, with maximum concentrations occurring at either 5 - 10 cm or 10 - 20 cm.

Pearson's and Spearman's statistical correlation analysis was performed on all of the elements except beryllium at each of the three depths. Refer to Tables 7.1.4.4 to 7.1.4.6 below for an abbreviated version of the results of the Pearson's and Spearman's analysis for all three depths, and Tables 10.4.4.1 through 10.4.4.3 for the full results of the analysis. In Tables 7.1.4.4 to 7.1.4.6 the results have been rounded to one decimal place and values that were 0.75 or greater are considered strong and are indicated in bold type. Values that were between 0.70 and 0.75 were considered moderately correlated.

Table 7.1.4.4: Pearson's and Spearman's Correlations for 0 to 5 cm Urban Soil in Coniston

	Al	**As**	**Ba**	**Cd**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Ni**	**Se**	**Sr**	**V**	**Zn**
Al	1	*-0.2*	*0.5*	*-0.1*	*0.6*	*-0.1*	*-0.2*	*0.4*	*-0.2*	*0.5*	*0.6*	*-0.2*	*-0.2*	***0.8***	***0.9***	*-0.1*
As	-0.1	1	*0.5*	*0.7*	*0.2*	***0.9***	***0.9***	*0.6*	***0.8***	*-0.1*	*0.1*	***0.9***	*0.6*	*0.0*	*-0.1*	***0.8***
Ba	0.5	0.4	1	*0.4*	*0.6*	*0.6*	*0.5*	*0.7*	*0.5*	*0.3*	*0.6*	*0.5*	*0.3*	*0.6*	*0.4*	*0.6*
Cd	-0.1	**0.8**	0.4	1	*0.3*	*0.7*	*0.7*	*0.6*	*0.7*	*0.0*	*0.1*	*0.7*	*0.6*	*0.0*	*-0.1*	*0.7*
Cr	0.4	0.3	0.5	0.5	1	*0.3*	*0.2*	*0.6*	*0.1*	*0.6*	*0.6*	*0.2*	*0.2*	*0.5*	*0.6*	*0.3*
Co	-0.1	**0.9**	0.4	**0.9**	0.3	1	***1.0***	*0.7*	***0.8***	*0.1*	*0.2*	***1.0***	*0.6*	*0.1*	*0.0*	***0.8***
Cu	-0.1	**0.9**	0.5	**0.8**	0.3	**1.0**	1	*0.6*	***0.9***	*-0.1*	*0.1*	***1.0***	*0.6*	*0.0*	*-0.2*	***0.8***
Fe	0.3	**0.8**	0.6	0.7	0.5	**0.8**	**0.8**	1	*0.5*	*0.3*	*0.5*	*0.7*	*0.5*	*0.4*	*0.5*	*0.6*
Pb	-0.2	**0.8**	0.5	0.7	0.2	0.7	0.7	0.6	1	*-0.1*	*0.0*	***0.8***	*0.6*	*-0.1*	*-0.2*	***0.8***
Mg	0.4	-0.2	0.2	0.0	0.3	0.0	-0.1	0.1	-0.1	1	*0.6*	*-0.1*	*-0.1*	*0.5*	*0.6*	*0.1*
Mn	0.6	0.1	0.6	0.1	0.4	0.1	0.1	0.3	0.0	0.6	1	*0.1*	*0.0*	*0.7*	*0.7*	*0.3*
Ni	-0.1	**0.9**	0.4	**0.8**	0.3	**1.0**	**1.0**	**0.8**	0.7	-0.1	0.1	1	*0.6*	*0.0*	*-0.1*	***0.8***
Se	0.0	0.7	0.4	0.7	0.3	0.7	0.7	0.7	0.6	-0.1	0.1	0.7	1	*0.0*	*-0.1*	*0.6*
Sr	0.7	0.0	0.5	0.0	0.4	0.0	0.0	0.3	0.0	0.5	0.7	0.0	0.0	1	***0.8***	*0.1*
V	**0.9**	-0.1	0.4	-0.1	0.5	-0.1	-0.1	0.4	-0.1	0.5	0.6	-0.1	0.0	0.7	1	*-0.1*
Zn	-0.1	0.7	0.7	0.7	0.4	0.7	0.7	0.6	**0.8**	0.0	0.2	0.7	0.5	0.2	-0.1	1

Spearman's correlations in upper right in italics. Pearson's correlations in lower left in normal font.
Bold indicates strong correlations.

Table 7.1.4.5: Pearson's and Spearman's Correlations for 5 to 10 cm Urban Soil in Coniston

	Al	**As**	**Ba**	**Cd**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Ni**	**Se**	**Sr**	**V**	**Zn**
Al	1	*0.0*	*0.5*	*0.0*	***0.8***	*0.0*	*-0.1*	*0.6*	*-0.2*	*0.6*	*0.7*	*-0.1*	*-0.1*	***0.8***	***0.9***	*0.0*
As	-0.1	1	*0.5*	*0.3*	*0.1*	***0.9***	***0.9***	*0.6*	*0.7*	*-0.3*	*0.1*	***0.9***	*0.7*	*0.1*	*-0.1*	*0.7*
Ba	0.4	0.5	1	*0.2*	*0.5*	*0.6*	*0.5*	*0.7*	*0.5*	*0.2*	*0.7*	*0.5*	*0.4*	*0.6*	*0.4*	*0.7*
Cd	-0.1	0.4	0.3	1	*0.2*	*0.4*	*0.4*	*0.3*	*0.4*	*-0.1*	*0.1*	*0.4*	*0.4*	*0.1*	*0.0*	*0.4*
Cr	0.7	0.0	0.4	0.3	1	*0.2*	*0.1*	*0.6*	*0.0*	*0.6*	*0.7*	*0.1*	*0.0*	*0.7*	***0.8***	*0.2*
Co	0.0	**0.9**	0.5	0.5	0.1	1	***0.9***	*0.7*	*0.7*	*-0.2*	*0.2*	***1.0***	*0.7*	*0.2*	*0.0*	***0.8***
Cu	-0.1	**0.9**	0.6	0.5	0.1	**1.0**	1	*0.5*	***0.8***	*-0.3*	*0.1*	***1.0***	*0.6*	*0.1*	*-0.1*	***0.8***
Fe	0.6	0.6	0.7	0.3	0.5	0.7	0.6	1	*0.4*	*0.3*	*0.6*	*0.5*	*0.4*	*0.5*	*0.6*	*0.5*
Pb	-0.1	0.7	0.7	0.4	0.0	0.7	**0.8**	0.5	1	*-0.3*	*0.0*	***0.8***	*0.5*	*0.0*	*-0.2*	***0.8***
Mg	0.5	-0.3	0.1	-0.1	0.5	-0.2	-0.3	0.3	-0.3	1	*0.6*	*-0.3*	*-0.2*	*0.5*	*0.7*	*-0.1*
Mn	0.6	0.1	0.6	0.1	0.6	0.1	0.1	0.5	0.0	0.5	1	*0.1*	*0.0*	*0.7*	*0.7*	*0.3*
Ni	-0.1	**0.9**	0.5	0.5	0.1	**1.0**	**1.0**	0.6	0.7	-0.3	0.0	1	*0.6*	*0.1*	*-0.1*	***0.8***
Se	-0.1	0.7	0.4	0.4	0.0	**0.8**	**0.8**	0.5	0.6	-0.2	0.0	0.7	1	*0.0*	*-0.1*	*0.5*
Sr	0.7	0.0	0.5	0.1	0.6	0.1	0.1	0.4	0.0	0.5	0.7	0.1	0.0	1	*0.7*	*0.2*
V	**0.9**	-0.1	0.3	-0.1	0.7	-0.1	-0.1	0.6	-0.2	0.6	0.7	-0.2	-0.1	0.7	1	*0.0*
Zn	0.0	0.6	0.7	0.5	0.1	0.7	0.7	0.5	**0.8**	-0.1	0.3	0.7	0.5	0.3	-0.1	1

Spearman's correlations in upper right in italics. Pearson's correlations in lower left in normal font.
Bold indicates strong correlations.

Table 7.1.4.6: Pearson's and Spearman's Correlations for 10 to 20 cm Urban Soil in Coniston

	Al	**As**	**Ba**	**Cd**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Ni**	**Se**	**Sr**	**V**	**Zn**
Al	1	*0.1*	*0.5*	*0.0*	***0.8***	*0.2*	*0.1*	*0.7*	*-0.1*	*0.6*	*0.6*	*0.1*	*0.0*	***0.8***	***0.9***	*0.2*
As	0.0	1	*0.6*	*0.1*	*0.0*	***0.9***	***0.9***	*0.5*	*0.7*	*-0.3*	*0.1*	***0.9***	*0.5*	*0.2*	*0.0*	*0.7*
Ba	0.4	0.6	1	*0.16*	*0.5*	*0.7*	*0.6*	*0.7*	*0.5*	*0.2*	*0.7*	*0.6*	*0.3*	*0.6*	*0.5*	***0.8***
Cd	0.0	0.3	0.4	1	*0.0*	*0.2*	*0.2*	*0.2*	*0.2*	*0.0*	*0.1*	*0.2*	*0.2*	*0.1*	*0.0*	*0.2*
Cr	**0.8**	0.0	0.4	0.0	1	*0.2*	*0.0*	*0.7*	*-0.2*	***0.8***	*0.7*	*0.0*	*-0.1*	*0.7*	***0.9***	*0.2*
Co	0.2	**0.8**	0.7	0.3	0.1	1	***0.9***	*0.6*	*0.7*	*-0.1*	*0.3*	***1.0***	*0.5*	*0.3*	*0.1*	***0.8***
Cu	0.1	**0.9**	0.7	0.3	0.0	**0.9**	1	*0.4*	***0.8***	*-0.3*	*0.1*	***1.0***	*0.6*	*0.2*	*0.0*	***0.8***
Fe	0.7	0.5	0.7	0.2	0.6	0.6	0.5	1	*0.3*	*0.5*	*0.7*	*0.4*	*0.2*	*0.6*	*0.7*	*0.5*
Pb	-0.1	0.7	0.7	0.3	-0.2	0.6	0.7	0.3	1	*-0.3*	*0.1*	*0.7*	*0.4*	*0.1*	*-0.1*	***0.8***
Mg	0.6	-0.3	0.1	0.0	0.7	-0.1	-0.3	0.5	-0.3	1	*0.6*	*-0.3*	*-0.3*	*0.4*	*0.6*	*-0.1*
Mn	0.7	0.2	0.6	0.2	0.7	0.4	0.2	0.7	0.1	0.6	1	*0.1*	*0.1*	*0.7*	*0.7*	*0.4*
Ni	0.1	**0.9**	0.7	0.4	0.0	**1.0**	**1.0**	0.5	0.7	-0.3	0.3	1	*0.6*	*0.2*	*0.0*	***0.8***
Se	0.0	0.4	0.3	0.1	0.0	0.4	0.5	0.3	0.3	-0.2	0.1	0.5	1	*0.1*	*-0.1*	*0.5*
Sr	**0.8**	0.2	0.5	0.1	0.7	0.3	0.2	0.6	0.1	0.5	0.7	0.2	0.1	1	*0.7*	*0.4*
V	**0.9**	0.0	0.4	0.0	**0.9**	0.1	0.0	0.7	-0.1	0.7	0.7	-0.1	0.0	0.7	1	*0.1*
Zn	0.1	0.7	**0.8**	0.4	0.1	**0.8**	**0.8**	0.4	0.7	-0.1	0.4	**0.8**	0.3	0.3	0.0	1

Spearman's correlations in upper right in italics. Pearson's correlations in lower left in normal font.
Bold indicates strong correlations.

In Coniston, at 0 - 5 cm, nickel, copper, cobalt, arsenic, cadmium were strongly correlated with each other using Pearson's and Spearman's. Selenium, lead, zinc and iron moderately correlated with these elements using Pearson's. Using Spearman's, lead and zinc were strongly correlated with these elements. Lead and zinc, and lead and arsenic were also strongly correlated with each other at 0 - 5 cm using both Pearson's and Spearman's.

The correlation between nickel, copper, cobalt and arsenic remained similar at all depth intervals in Pearson’s and Spearman’s. Iron and selenium generally correlated with these elements at 5 - 10 cm but did not correlate with these elements at depth. Cadmium was not correlated with any elements below 0 - 5 cm. Generally with depth, zinc was strongly correlated with nickel, copper, cobalt and lead and moderately correlated with arsenic, using both Pearson’s and Spearman’s. Generally with depth, lead was strongly correlated with copper and zinc and moderately correlated with arsenic, cobalt and nickel using both Pearson’s and Spearman’s.

Overall, the number of correlations occurring with nickel, copper, cobalt, arsenic, lead and zinc decreased slightly with depth. The correlations of nickel, copper, cobalt, arsenic, lead and zinc at all depths were typically strong, indicating that concentrations of these elements in Coniston appear to be attributed to smelter emissions. Figures 7.1.4.6 and 7.1.4.7 show the correlations of nickel and cobalt at surface and at 10 - 20 cm in Coniston. Unlike in the Outer and Inner Sudbury Communities, cobalt remained strongly correlated to nickel with depth. The correlations of iron, cadmium and selenium at surface, also indicate that these concentrations may be due to smelter emissions. Refer to Section 10.4.4 for additional correlation figures.

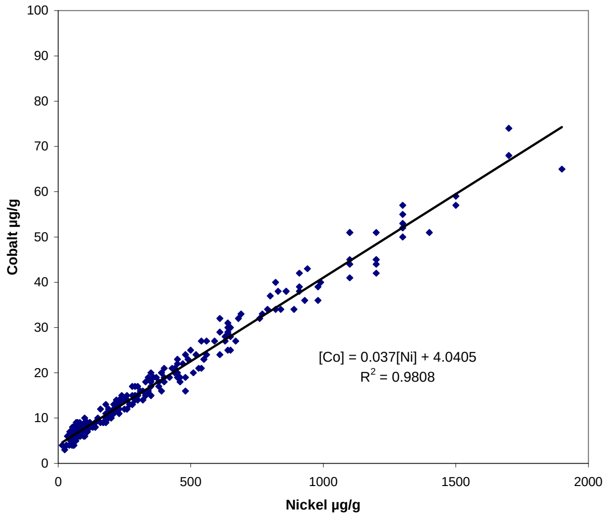


Fig 7.1.4.6: Co vs. Ni, 0 - 5 cm, Coniston

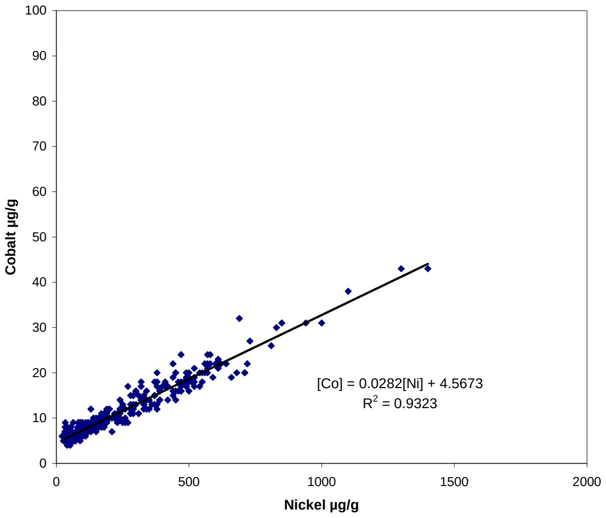


Fig 7.1.4.7: Co vs. Ni, 10 - 20 cm, Coniston

For the naturally occurring elements, the overall number of correlations increase with depth. Aluminum, strontium and vanadium were correlated with each other at all depths using both Pearson’s and Spearman’s. With depth, aluminum, strontium and vanadium developed strong correlations with chromium and moderate correlations with iron, magnesium, and manganese, using both Pearson’s and Spearman’s. These elements are indicative of the naturally occurring geology in the City of Greater Sudbury, the increase in the number and strength of these correlations was representative of less disturbed soil at depth. Similar to the Sudbury Core, only aluminum and vanadium were strongly correlated at all depths.

As observed in Figures 7.1.4.8 and 7.1.4.9, chromium and vanadium correlations strengthened with depth. This trend was also shown by the increase in Pearson’s and Spearman’s R-values, which ranged from R = 0.5 at 0 - 5 cm, to R = 0.9 at 10 - 20 cm, (Refer to Tables 7.1.4.4 and 7.1.4.6). At 0 - 5 cm, two patterns of chromium concentrations were observed. The first pattern consisted of high chromium concentrations while vanadium concentrations were relatively constant. Chromium and vanadium concentrations in the second pattern increased at a similar rate. The presence of two patterns suggested that there were two sources of chromium. The first pattern, which occurred at 0 - 5 cm, is indicative of aerial deposition, while the second pattern, which occurred at all depths, is indicative of the naturally occurring geology. Similar patterns were also observed with the aluminum/chromium and aluminum/iron correlations.

The number of correlations of barium to other elements increased with depth. At 0 - 5 cm, barium moderately correlated with zinc (using Pearson's) and iron (using Spearman's). At 5 - 10 cm, barium continued to be moderately correlated with zinc and iron using both Pearson's and Spearman's. Moderate correlations with lead (using Pearson's) and manganese (using Spearman's) were also present at this depth. At 10 - 20 cm, both Pearson's and Spearman's showed strong correlations between barium and zinc, and moderate barium correlations with cobalt and iron. Moderate correlations with nickel, copper, lead and manganese using Pearson's or Spearman's were also present at this depth. Unlike in the Sudbury Core, the barium correlations in Coniston were generally moderate, and increased in number with depth. Barium did not clearly correlate with either natural or elements associated with smelter emissions.

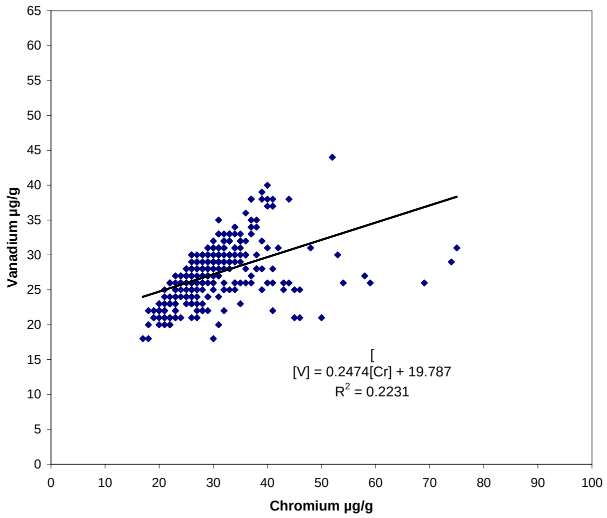


Fig 7.1.4.8: V vs. Cr, 0 - 5 cm, Coniston

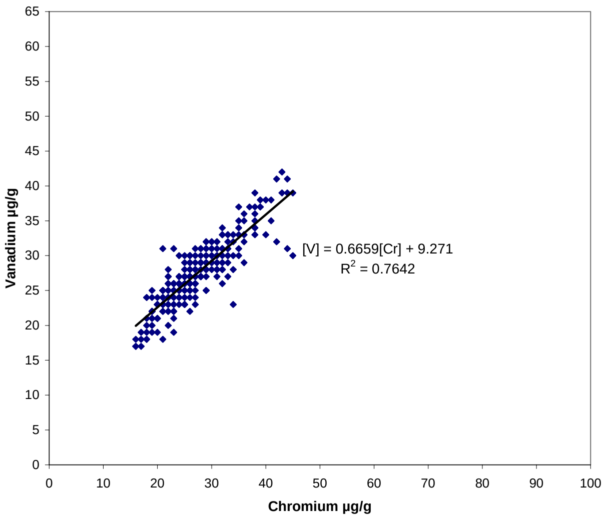


Fig 7.1.4.9: V vs. Cr, 10 - 20, Coniston

Refer to Section 10.4.4 for a complete list of graphs showing selected element correlations at all three depths for Coniston.

In summary, the element concentrations in Coniston were considerably higher and had more exceedences of MOE criteria than in the Outer and Inner Sudbury Communities. Element concentrations in Coniston were similar to the Sudbury Core at the 0 - 5 cm depth, with the exception of higher arsenic and cadmium concentrations in Coniston. Concentrations of nickel, copper, cobalt, arsenic and lead remained higher with depth in Coniston, compared to the Sudbury Core where they decreased more rapidly with depth. In Coniston, concentrations of these elements exceeded Table A at all depths. There were substantially more Table F and A exceedences of arsenic and cobalt at all depths in Coniston compared to the Sudbury Core. The number of arsenic exceedences increased at 5 - 10 cm, then decreased at 10 - 20 cm.

At 0 - 5 cm, a spatial concentration gradient was observed for nickel, copper, cobalt, arsenic and lead with the higher concentrations starting in the centre of the community and lower concentrations towards the east and west ends. Concentrations of cadmium, selenium, zinc, iron, and to a lesser extent chromium, were slightly higher in the centre of the community, but were all relatively low.

At depth, concentrations of nickel, copper, arsenic, and to a lesser extent lead and zinc, generally decrease slightly while maintaining a similar spatial trend to the surface. Concentrations of cobalt, cadmium, selenium, chromium and iron also decreased with depth, but a concentration gradient was not observed at 10 - 20 cm. Concentrations in more than half of the sample locations show the highest concentrations of nickel, copper, arsenic and lead at either 5 - 10 cm or 10 - 20 cm. For Coniston, the largest increase in concentrations between surface and depth was observed at the south end of the community adjacent to the former smelter.

In 44% of the sample locations in Coniston, nickel, copper, cobalt, lead, zinc, and to a lesser extent arsenic, cadmium, selenium, chromium and iron, concentrations showed a strong aerial deposition trend from surface. The remaining sample locations had maximum concentrations occurring below surface. A strong to weak trend of maximum concentrations occurring at 5 - 10 cm was observed for the same 10 elements. The concentration trends of these elements dropped off slightly at the 10 - 20 cm depth and disappeared completely for cadmium and chromium. These elevated concentrations may still be attributed to aerial deposition, however, overtime have been buried by landscaping practices at individual properties.

In Coniston, at 0 - 5 cm nickel, copper, cobalt, arsenic, cadmium, and to a lesser extent lead and zinc, were strongly correlated with each other using Pearson’s and Spearman’s. Selenium and iron moderately correlated with these elements using Pearson’s. Overall, the number of correlations occurring with nickel, copper, cobalt, arsenic, lead and zinc decreased slightly with depth. The correlations of these elements at all depths were typically strong, indicating that concentrations of these elements in Coniston appear to be attributed to smelter emissions. The correlations of iron, chromium, cadmium and selenium at surface also indicate that these concentrations may be due to smelter emissions. Correlations of naturally occurring elements increased in strength and number with depth, indicating the presence of less disturbed soil at depth. Similar to the Sudbury Core, only aluminum and vanadium were strongly correlated at all depths. Unlike the Sudbury Core, barium did not clearly correlate with either naturally occurring elements or those associated with smelter emissions.

7.1.5 Falconbridge

In Falconbridge, the concentrations of most of the eleven elements used in determining this grouping were considerably higher than in Coniston and the Sudbury Core at all depths. Refer to Table 7.1.5.1. At all three depth intervals in Falconbridge, nickel, copper, cobalt, arsenic, lead, selenium, cadmium, chromium and iron were generally higher than in both Coniston and the Sudbury Core. Differences in concentrations between the communities for these elements started from the 25th percentile, except for cadmium which started from the 25th to 75th percentile at all depths. At 10 - 20 cm, lead concentrations were marginally lower in Falconbridge than in Coniston from the 95th percentile.

Table 7.1.5.1: Summary Statistics for Metals and Arsenic in Urban Soil in Falconbridge of the City of Greater Sudbury

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
0 to 5 cm Urban Soil in Falconbridge, n = 220																			
Minimum	4900	0.4	2.5	15	0.4	1600	11	5	31	9200	6	1500	69	0.75	37	0.5	11	10	15
10th percentile	7090	0.4	9	31	0.4	3690	27	11	72	12900	14	2100	140	0.75	120	0.5	21	24	29
1st quartile	7900	0.4	29	39	1.1	5500	33	28	390	16000	35	2400	160	0.75	445	1.0	27	26	50
Median	9000	0.4	49	50	2.1	7300	40	49	780	21000	66	2800	180	2.2	820	2	33	30	66
3rd quartile	10000	0.4	100	56	3.0	9550	52	74	1200	27000	120	3250	210	3.7	1300	3	38	34	99
95th percentile	12000	1.2	181	69	4.3	13000	73	111	1900	38000	200	4105	240	7.6	2105	6	45	39	150
Maximum	17000	3.8	300	86	6.7	40000	100	190	3000	49000	370	6900	310	14.0	3700	12	51	56	240
Mean	9080	0.5	69	48	2.2	7885	44	54	828	21886	83	2902	182	2.8	915	2.6	32	30	76
CV (std. dev./mean)	19%	83%	84%	27%	59%	55%	34%	64%	72%	37%	80%	26%	20%	82%	71%	71%	24%	18%	54%
Skewness	0.5	4.9	1.3	0.1	0.4	3.9	0.9	0.8	0.8	0.9	1.5	1.6	0.4	1.7	1	1.6	-0.3	0.8	1.3
5 to 10 cm Urban Soil in Falconbridge, n = 217																			
Minimum	4700	0.4	2.5	22	0.4	2500	17	5	10	10000	4	1500	110	0.75	22	0.5	13	19	14
10th percentile	7800	0.4	18	31	0.4	3200	25	11	132	12600	15	1900	130	0.75	136	0.5	22	25	26
1st quartile	8800	0.4	34	38	0.4	4400	29	22	310	15000	26	2100	150	0.75	430	1.0	26	27	39
Median	9800	0.4	76	48	1.1	6500	36	37	580	20000	55	2400	180	0.75	740	3.0	31	31	57
3rd quartile	11000	0.4	140	58	1.7	9100	46	57	1000	26500	120	2700	230	0.75	1100	4.0	38	35	87
95th percentile	13000	1.2	323	74	3.4	13000	75	113	2025	40000	220	3300	300	2.23	2225	6.0	44	41	140
Maximum	23000	8.1	570	89	4.8	33000	140	150	3000	100000	340	13700	480	8.80	3100	11.0	50	110	210
Mean	10027	0.6	109	48	1.3	7123	41	43	754	22857	77	2627	196	1.02	849	2.8	32	33	65
CV (std. dev./mean)	23%	125%	96%	29%	73%	51%	49%	70%	80%	55%	86%	51%	31%	73%	74%	69%	25%	33%	56%
Skewness	2.1	7.1	1.7	0.2	1.2	2.2	2.3	1.2	1.3	2.9	1.3	5.8	1.5	6.1	1.3	1.1	-0.1	3.9	1.1
10 to 20 cm Urban Soil in Falconbridge, n = 217																			
Minimum	5200	0.4	2.5	24	0.4	2000	17	5	13	10000	4	1400	97	0.75	25	0.5	12	17	14
10th percentile	7800	0.4	17	32	0.4	3100	23	9	93	12000	11	1800	130	0.75	140	0.5	21	25	22
1st quartile	8700	0.4	29	39	0.4	3900	27	13	160	14000	18	2100	150	0.75	240	1.0	25	27	31
Median	10000	0.4	57	47	0.4	5100	32	21	310	16000	32	2300	170	0.75	410	2.0	31	31	43
3rd quartile	11000	0.4	120	59	1.0	6700	40	31	530	21000	64	2600	220	0.75	605	3.0	36	35	61
95th percentile	14000	1.0	242	78	1.8	9760	76	56	1000	37000	142	4800	340	1.70	1200	6.0	43	56	93
Maximum	25000	1.4	620	110	3.4	30000	160	110	2000	110000	230	15500	540	6.00	2500	8.0	55	130	140
Mean	10370	0.5	88	49	0.8	5737	37	25	398	19825	48	2694	193	0.88	488	2.1	31	33	49
CV (std. dev./mean)	27%	43%	101%	30%	71%	53%	56%	71%	83%	70%	89%	70%	37%	66%	78%	79%	26%	41%	49%
Skewness	2.4	3.4	2.4	0.9	2.0	3.4	3.5	2.3	1.7	4.5	1.5	4.8	1.9	6.4	2.2	1.6	0.1	4.1	0.9

All results are in µg/g dry weight.

Zinc concentrations were generally similar in the Sudbury Core, Coniston and Falconbridge for all three depths. Zinc concentrations were marginally higher in both the Sudbury Core and Coniston compared to Falconbridge at 10 - 20 cm for the 95th percentile and maximum values.

Generally, aluminum concentrations in Falconbridge were slightly higher at all depths from the 25th to 75th percentile and slightly lower from the median to 95th percentile in Coniston and the Sudbury

Core. Barium, magnesium, manganese, strontium and vanadium concentrations were either similar or marginally lower in Falconbridge compared to Coniston and the Sudbury Core at all depths.

In Falconbridge, concentrations of nickel, copper, cobalt, arsenic and lead were higher in the residential properties than in the park properties. Refer to Table 7.1.5.2. Due to the extremely low n-values for school properties at all depths, comparisons with this group were very general. The n-value was 3 out of a total of 220 urban soil samples at 0 - 5 cm, and zero out of 217 samples at depth.

Table 7.1.5.2: Summary Statistics for All 0-5 cm Urban Soil Samples from Falconbridge by Land Use

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Residential 0 to 5 cm	n = 199																		
Minimum	4900	0.4	2.5	15	0.4	1600	11	5	31	9200	6	1500	69	0.75	37	0.5	11	10	15
10th percentile	7080	0.4	11	32	0.4	4380	28	11	87	13000	17	2100	140	0.75	140	0.5	21	24	33
1st quartile	7900	0.4	31	41	1.5	5900	33	32	460	16000	42	2400	160	0.75	550	1.0	27	26	56
Median	9000	0.4	52	51	2.2	7500	41	51	810	21000	71	2700	180	2.4	850	2.0	34	29	71
3rd quartile	10000	0.4	110	58	3.0	9600	52	75	1200	27000	130	3200	200	3.9	1300	4.0	39	33	100
95th percentile	12000	1.2	190	71	4.5	13000	73	111	1910	38000	200	4010	240	8.1	2110	6.0	45	38	151
Maximum	17000	3.8	300	86	6.7	40000	100	190	3000	49000	370	5700	290	14	3700	12	51	44	240
Mean	9059	0.5	74	50	2.3	8167	45	56	874	22025	88	2864	182	2.9	956	2.7	33	30	80
CV (std. dev./mean)	19%	85%	81%	26%	53%	53%	34%	60%	68%	36%	76%	24%	19%	79%	67%	69%	25%	17%	51%
Skewness	0.5	4.7	1.2	0.0	0.4	4.0	0.8	0.8	0.8	0.9	1.4	1.1	0.2	1.6	1.0	1.5	-0.3	0.1	1.3
Schools and Daycares 0 to 5 cm					n = 3														
Minimum	6100	0.4	2.5	26	0.4	2500	31	11	46	12000	11	3400	190	0.75	61	0.5	19	26	27
Median	8700	0.4	2.5	43	0.4	6300	31	12	58	13000	20	3400	210	1.5	110	0.5	38	30	35
Maximum	9800	0.4	2.5	46	1.0	7000	35	13	66	16000	21	4200	220	1.8	120	0.5	42	32	36
Mean	8200	0.4	2.5	38	0.6	5267	32	12	57	13667	17	3667	207	1.4	97	0.5	33	29	33
Parks 0 to 5 cm				n = 18															
Minimum	6500	0.4	2.5	22	0.4	3100	24	8	44	12000	6	1800	130	0.75	68	0.5	22	25	17
10th percentile	8050	0.4	5.0	28	0.4	3400	26	10	54	12000	10	1940	140	0.75	87	0.5	25	26	20
1st quartile	8800	0.4	12	29	0.4	3500	26	15	88	13000	14	2500	150	0.75	120	1.0	27	26	25
Median	9300	0.4	34	36	0.4	3550	37	22	325	20500	22	2850	170	0.75	385	1.5	32	31	31
3rd quartile	9800	0.4	49	43	0.9	7600	39	34	480	27000	33	3400	230	1.60	690	2.0	34	35	47
95th percentile	11450	0.5	73	44	3.1	10450	61	93	1375	41600	73	5455	268	2.29	1905	3.2	35	52	82
Maximum	14000	1.2	84	45	4.2	13000	73	130	1800	45000	110	6900	310	2.80	2500	4.0	35	56	96
Mean	9456	0.4	34	35	1.0	5206	38	34	456	21722	31	3189	187	1.17	601	1.7	31	33	39
CV (std. dev./mean)	16%	42%	70%	20%	116	57%	34%	97%	110%	46%	86%	42%	27%	56%	116%	63%	14%	26%	57%
Skewness	1.2	4.2	0.4	-0.2	1.9	1.6	1.5	2.0	1.6	1.1	2.0	1.6	1.2	1.3	1.7	0.7	-1.0	1.6	1.4

All results are in µg/g dry weight.

At 0 - 5 cm, concentrations of nickel, copper, cobalt, arsenic and lead were generally up to two times higher in the residential area starting from the 20th to 60th percentile. At 5 - 10 cm, concentrations of these elements were up to two times higher in the residential area starting from the 70th to 90th percentile. Concentrations of these elements at 10 - 20 cm, however, were higher in park properties from the 10th to 60th percentile and higher in the residential properties from the 70th percentile.

Concentrations of barium, cadmium, chromium, selenium and zinc in the residential properties at 0 - 5 cm were marginally higher than in the parks starting from the 10th to 30th percentile. Concentrations of barium, cadmium and zinc in the residential properties at the lower two depth intervals were marginally higher than in the parks starting from the 10th to 95th percentile. At these two depths, chromium and iron concentrations were marginally higher in park properties starting from the 30th to 70th percentile.

Generally, park concentrations for nickel, copper, cobalt, arsenic, and to a lesser extent lead, were considerably higher in Falconbridge compared to the Sudbury Core and Outer and Inner Sudbury Communities at all depths. School concentrations were lower compared to the Sudbury Core and Coniston but were similar to marginally lower compared to the Outer Sudbury Communities at the surface.

There were substantially more exceedences of Table A and F in Falconbridge than in Coniston and the Sudbury Core. Table 7.1.5.3 summarizes the number of urban soil samples that exceeded the Table F and Table A criteria in Falconbridge.

Table 7.1.5.3: Summary of Table F and Table A Exceedences for Urban Soil Samples in Falconbridge

Element	Table F			Table A		
	0 to 5 cm	5 to 10 cm	10 to 20 cm	0 to 5 cm	5 to 10 cm	10 to 20 cm
Antimony	14 (6%)	13 (6%)	8 (4%)	0	0	0
Arsenic	187 (85%)	195 (90%)	192 (88%)	184 (84%)	193 (89%)	186 (86%)
Cadmium	167 (76%)	113 (52%)	50 (23%)	0	0	0
Chromium	15 (7%)	21 (10%)	12 (6%)	0	0	0
Cobalt	179 (81%)	163 (75%)	100 (46%)	135 (61%)	93 (43%)	29 (13%)
Copper	191 (87%)	204 (94%)	199 (92%)	178 (81%)	183 (84%)	138 (64%)
Lead	51 (23%)	49 (23%)	17 (8%)	9 (4%)	12 (6%)	1
Molybdenum	89 (40%)	5 (2%)	4 (2%)	0	0	0
Nickel	219 (100%)	210 (97%)	212 (98%)	191 (87%)	194 (89%)	187 (86%)
Selenium	150 (68%)	151 (70%)	117 (54%)	1	1	0
Vanadium	0	2 (1%)	4 (2%)	0	0	0
Zinc	7 (3%)	5 (2%)	0	0	0	0
No. of Samples	220	217	217	220	217	217

Nickel, copper, cobalt arsenic and lead concentrations exceeded Table A at all depths. Selenium concentrations exceeded Table A only at 0 - 5 cm and 5 - 10 cm depth intervals. No other elements exceeded Table A at any depths in Falconbridge. It should be noted that molybdenum concentrations were considerably higher in Falconbridge and had more Table F exceedences than any other community.

At 0 - 5 cm, 61% of the urban soil samples exceeded Table A for cobalt, 81% for copper, 84% for arsenic and 87% for nickel. At the same depth 76% exceeded Table F for cadmium, 81% for cobalt, 85% for arsenic, 87% for copper and over 99% for nickel. Generally the number of exceedences of Table F decrease with depth for antimony, cadmium, cobalt, lead, molybdenum and zinc. The number of Table F exceedences for arsenic, chromium, copper, nickel, selenium and vanadium remained high at all depths, increased slightly at 5 - 10 cm, and then decreased slightly at 10 - 20 cm. The number of Table A exceedences generally decreased with depth for cobalt and selenium. The number of Table A nickel, copper, arsenic and lead exceedences remained high at all depths, increased slightly at 5 - 10 cm, and then decreased slightly at 10 - 20 cm.

Concentration dot maps were created to illustrate the spatial distribution of chemical concentrations for 10 elements. The highest concentrations of nickel, copper, cobalt, arsenic, lead, cadmium, chromium, iron, selenium and zinc in the 0 - 5 cm urban soil occurred in the centre and east side of the community between Edison Road and Lakeshore Drive, directly west of the smelter.

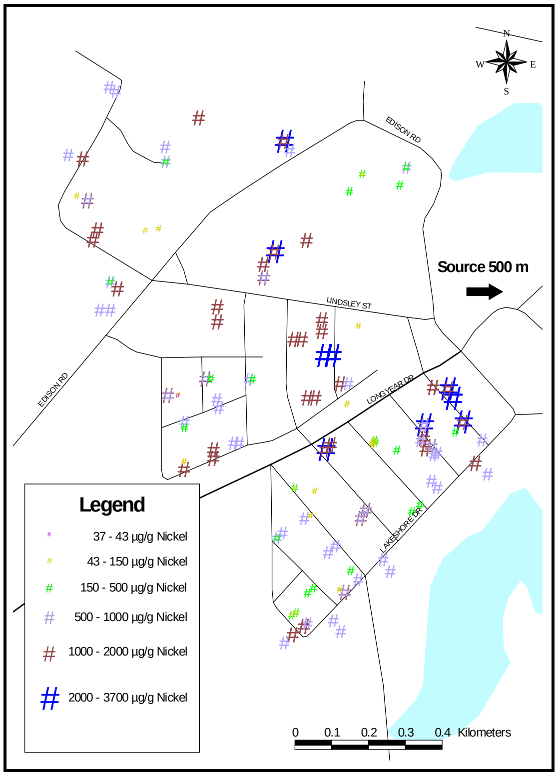


Figure 7.1.5.1: Ni concentrations in urban 0 - 5 cm soil in Falconbridge

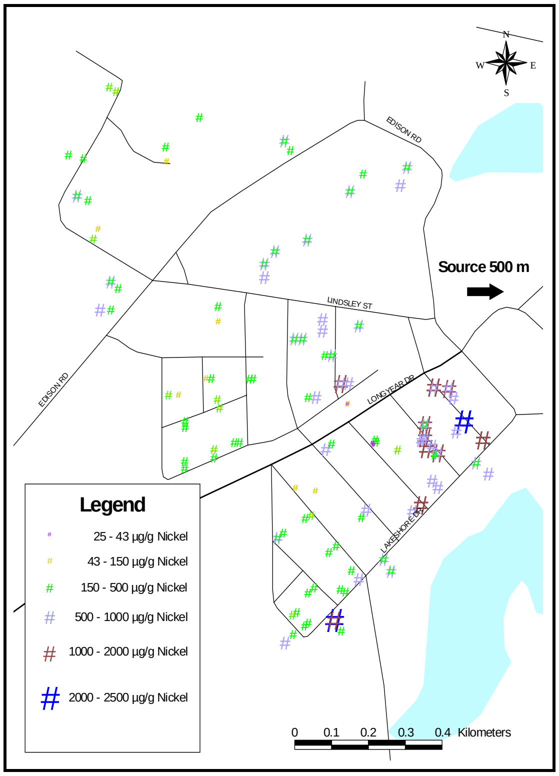


Figure 7.1.5.2: Ni concentrations in urban 10-20 cm soil in Falconbridge

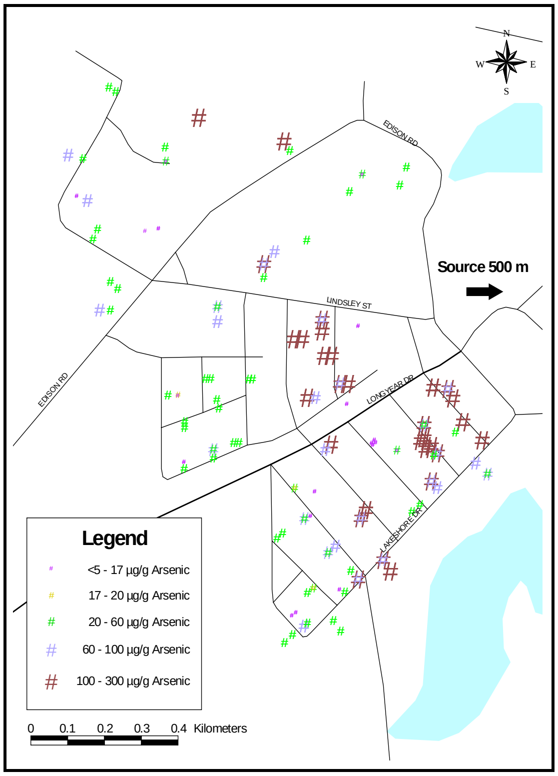


Figure 7.1.5.3: As concentrations in urban 0 - 5 cm soil in Falconbridge

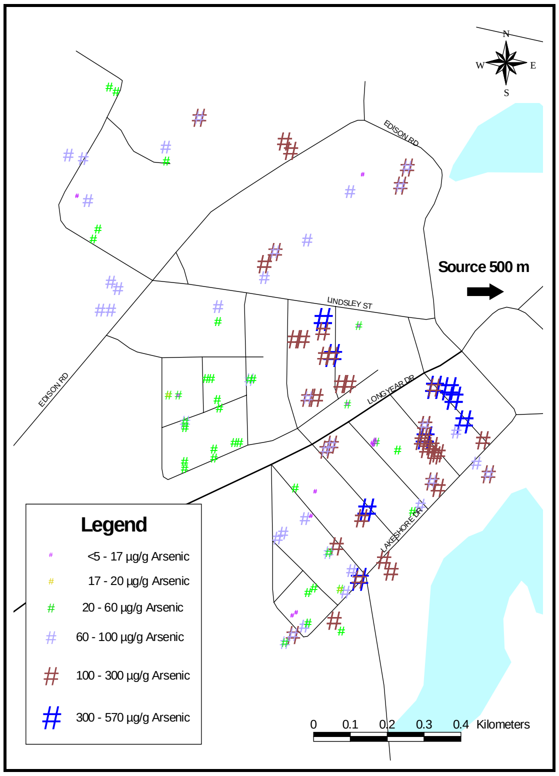


Figure 7.1.5.4: As concentrations in urban 5 - 10 cm soil in Falconbridge

At 10 - 20 cm, the concentrations of these elements appeared to decrease overall, although nickel, copper, cobalt and arsenic concentrations generally remained above Table A in this area. For an example of the spatial distributions for nickel in the 0 - 5 and 10 - 20 cm soil depths, refer to Figures 7.1.5.1 and 7.1.5.2.

Arsenic concentrations appeared to be the highest at 5 - 10 cm and were elevated in the centre and east side of the community from north of Edison Road to Lakeshore Drive. For an example of the spatial distributions for arsenic in the 0 - 5 and 5 - 10 cm soil depths, refer to Figure 7.1.5.3 and 7.1.5.4. While iron and chromium concentrations generally decreased with depth, the highest concentrations of these elements occurred at 10 - 20 cm in the ball diamonds in the northeast portion of the community. Refer to Section 10.2.2 for concentration dot maps of nickel, copper, cobalt, arsenic, lead, cadmium, chromium, iron, selenium and zinc at 0 - 5 and 10 - 20 cm in Falconbridge.

As discussed previously, the data was sorted by nickel concentrations to differentiate between the Group A, B and C depth trends. The assumption with this procedure was that the other elements shared similar proportions of sample locations exhibiting each depth trend as nickel. This assumption appeared to be accurate for the majority of the elements in Falconbridge. Arsenic, cadmium and chromium, however, had considerably different proportions of sample locations exhibiting each depth trend as compared to nickel. As a result, these three elements were sorted separately by their own concentrations to differentiate between depth trends.

In Falconbridge, all three depth trends (Groups A, B and C) were observed at varying numbers of sample locations. Nickel, copper, cobalt, lead and zinc concentrations, in 49% of the sample locations, showed a strong visual trend of decreasing concentration with depth (Group A) in all quarters. Average concentrations at surface were 1.6 to 4.4 times the average concentrations at 10 to 20 cm for these elements, for all quarters.

In 85% of the sample locations, cadmium exhibited a strong visual trend of decreasing concentrations with increasing depth (Group A) while chromium exhibited the same trend in 62% of sample locations. Both elements showed this trend in all quarters. The first quarter for cadmium showed a weaker Group A trend (1.8 times) than the other quarters. The average concentrations in the first quarter for cadmium were at or below the analytical method detection limit. Average surface cadmium concentrations were 3.0 to 3.8 times the average concentrations at 10 - 20 cm for the second through fourth quarters. Average concentrations for chromium were 1.3 to 1.8 times greater at surface than at 10 - 20 cm for all quarters. Figure 7.1.5.5 depicts the Group A depth profile for cadmium in Falconbridge.

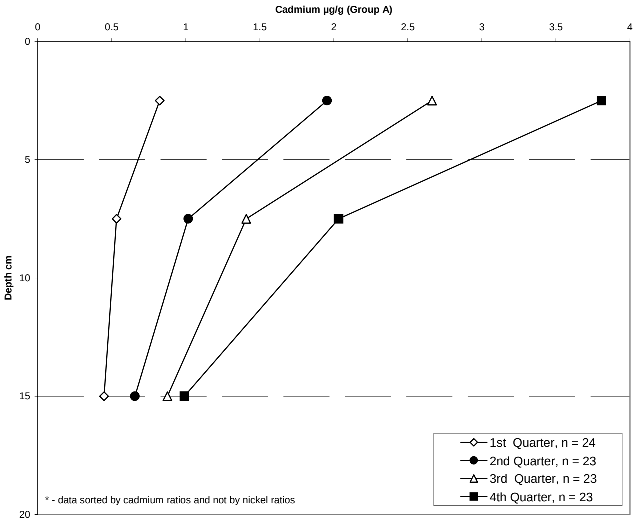


Figure 7.1.5.5: Falconbridge, Cd depth profiles, Group A.

Only 19% of the sample locations showed a Group A trend for arsenic. Arsenic showed a strong visual trend of decreasing concentrations with depth in both halves. The average concentrations at surface were 2.0 to

2.2 times the average concentrations at 10 - 20 cm in both halves. Figure 7.1.5.6 depicts the Group A depth profile for arsenic in Falconbridge.

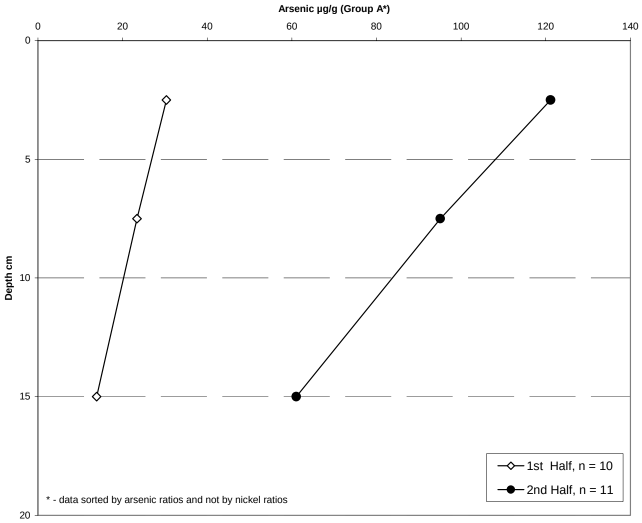


Figure 7.1.5.6: Falconbridge, As depth profiles, Group A.

In 49% of the sample locations, iron showed a strong visual trend of aerial deposition in the third and fourth quarters. A weak trend of aerial deposition was present in the first and second quarters. Average concentrations of iron at surface were 1.1 to 1.7 times the average concentrations at 10 - 20 cm. In the same percentage of sample locations, selenium had a strong visual trend of aerial deposition in the fourth quarter (2.3 times) and a weak trend in the second and third quarters (1.2 to 1.7 times). No observable change with depth was present in the first quarter for selenium.

Average aluminum and vanadium concentrations, in 49% of the sample locations, showed no observable change with depth or showed a visual trend of increasing concentration with depth (1.1 to 1.3 times). This trend was consistent with Group C rather than Group A. A weak trend of maximum concentration at 5 - 10 cm (Group B) was also observed in one quarter for vanadium (1.1 times). The multiple depth trends present for these elements was likely an artifact of the sorting process. Aluminum and vanadium tend to be indicators of the naturally occurring geology of the City of Greater Sudbury and therefore would not be expected to show similar depth trends to nickel. The wide range in concentrations between the quarters of these elements may indicate differences in soil type. Refer to Section 10.5.5 for graphs of the depth profiles for the elements discussed above.

In Falconbridge, nickel and copper concentrations in 39% of the sample locations showed a strong visual trend of maximum concentrations at 5 - 10 cm, while lower concentrations were observed at both 0 - 5 and 10 - 20 cm. This trend is consistent with Group B. Both elements showed this trend in all quarters. Average concentrations at 5 - 10 cm were 1.2 to 1.5 times the average concentrations at surface for these elements for all quarters.

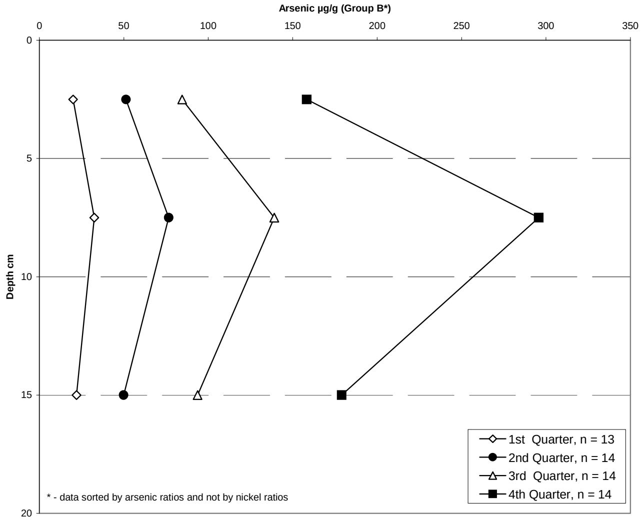


Figure 7.1.5.7: Falconbridge, As depth profiles, Group B.

In 52% of the sample locations, arsenic exhibited a strong visual trend of maximum concentrations at 5 - 10 cm (Group B) while chromium exhibited the same trend in 19% of sample locations. Both elements showed this trend in all quarters or halves. Average arsenic concentrations at 5 - 10 cm were 1.5 to 1.9 times the average concentrations at surface for all quarters. Average concentrations for chromium were 1.1 to 1.2 times greater at 5 - 10 cm than at surface for both halves. Figure 7.1.5.7 depicts the Group B depth profile for arsenic in Falconbridge.

Only 10% of the sample locations showed a Group B trend for cadmium. Cadmium showed a strong visual trend of decreasing concentrations with depth. The average concentration at 5 - 10 cm was 1.2 times the average concentration at surface. Due to the small proportion of sample locations exhibiting a Group B trend for cadmium, the data was not divided into halves, thirds or quarters for graphing purposes. Refer to Figure 7.1.5.8.

In 39% of the sample locations, cobalt, lead, selenium and iron showed a strong visual Group B trend in the third and fourth quarters. Zinc exhibited a similar trend only in the fourth quarter. Lead also exhibited a strong visual Group B trend in the second quarter while selenium and iron showed a weak Group B trend in the second quarter. The remaining quarters for cobalt, lead, selenium, iron and zinc exhibited either no observable change with depth or a weak trend of decreasing concentration with depth, consistent with Group A. Average concentrations of cobalt, lead, selenium and iron at 5 - 10 cm were 1.1 to 1.7 times the average concentrations at surface in the third and fourth quarters. Average zinc concentrations were approximately 1.1 times greater at 5 - 10 cm than at surface in the fourth quarter.

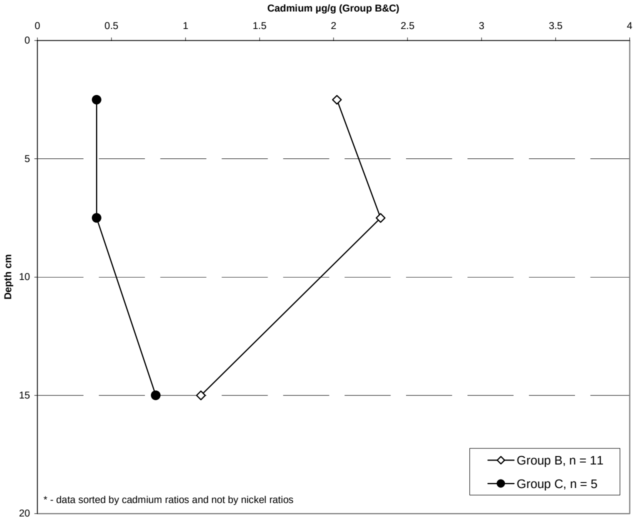


Figure 7.1.5.8: Falconbridge, Cd depth profiles, Group B & C.

Average aluminum and vanadium concentrations in 39% of the sample locations showed no observable change with depth in the first and second quarters. These elements showed a weak Group B trend (1.1 times) in the third quarter and a strong Group B trend in the fourth quarter (1.3 to 1.5 times).

In Falconbridge, nickel, copper, cobalt, lead and selenium concentrations in 13% of the sample locations showed a strong visual trend of increasing concentration with increasing depth, consistent with Group C. This trend was present in all halves for nickel, copper, cobalt and lead. This trend was also present in the second half for selenium with average concentrations in the first half showing no observable change with depth and concentrations were near the analytical MDL. Average concentrations at 10 - 20 cm were 1.5 to 1.9 times the average concentrations at surface for cobalt, lead and selenium while average concentrations were 2.0 to 2.7 times greater at 10 - 20 cm than surface for nickel and copper.

In 28% of the sample locations, arsenic exhibited a strong visual trend (2.0 to 2.5 times) of increasing concentration with increasing depth, consistent with Group C, while chromium exhibited a similar trend (2.2 times) in 18% of sample locations. Arsenic showed this trend in all thirds while chromium showed a weaker trend (1.2 times) in the first half. Figure 7.1.5.9 depicts the Group C depth profile for arsenic in Falconbridge.

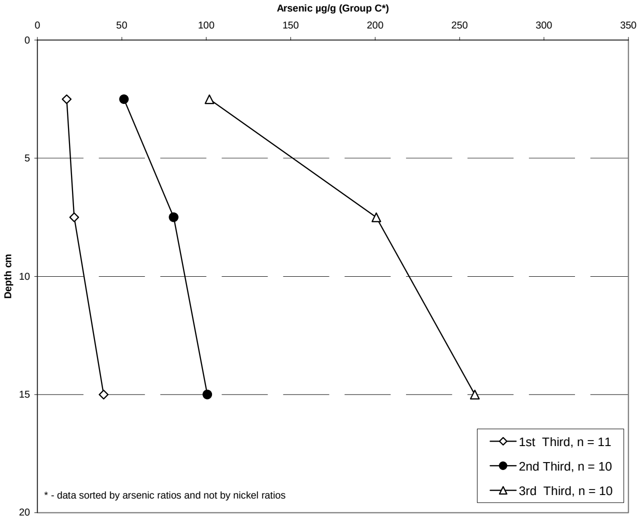


Figure 7.1.5.9: Falconbridge, As depth profiles, Group C.

Only 5% of the sample locations showed a Group C trend for cadmium. Cadmium showed a strong trend (2.0 times) of increasing concentrations with depth. However, the average concentrations were at or near the analytical MDL, with only 5% of the sample locations showing this trend, and the sample size was extremely small. Due to the small proportion of sample locations exhibiting a Group C trend for cadmium, the data was not divided into halves, thirds or quarters for graphing purposes.

In 13% of the sample locations, aluminum, vanadium, zinc and iron showed weak Group C trends (1.1 to 1.7 times). Zinc showed this trend in both halves while aluminum, vanadium and iron only showed this trend in the second half. The average concentrations in the first halves of aluminum, vanadium and iron showed no observable change with depth.

Overall, nickel, copper, cobalt, arsenic, lead, cadmium, selenium, iron, chromium and zinc exhibited a strong aerial deposition trend from surface. These sample locations appeared to be unaffected by landscaping practices. The percentage of sample locations that exhibited this trend, however, varied between elements. Only a small percentage of sample locations exhibited this trend for arsenic, while approximately 50% exhibited this trend for nickel, copper, cobalt, lead, selenium, iron and zinc, 62% for chromium and 85% for cadmium. These differences between elements may be attributed to numerous factors including element form, element mobility, smelter process changes and differing chemical composition of the ore over time. For example, cadmium may be a relatively recent emission while arsenic may have historically been emitted at greater volumes. A large number of sample locations (81%) for arsenic showed strong trends of maximum concentration below surface while only a small percentage of sample locations showed this trend for cadmium. Approximately 40 to 50% of sample locations showed this trend for the remaining elements. These elevated concentrations may still be attributed to aerial deposition, however, have also likely been buried by landscaping practices at individual properties over time. Addition, grading, removal and / or mixing of urban soils may alter the vertical distribution of chemical concentrations in the soil. As discussed above, other factors may also play a role in the distribution of the depth trends between elements.

In Falconbridge, ten elements including nickel, copper, cobalt, arsenic, lead, cadmium, selenium, chromium, iron and zinc, showed stronger indications of aerial deposition than in Coniston, the Sudbury Core or the Inner Sudbury Communities. In those communities, evidence of aerial deposition varied in strength, while in Falconbridge strong evidence was present for all ten elements.

Similar to Coniston, Falconbridge only had 49% of sample locations showing this trend for most elements. In Coniston, only 44% of the sample locations showed a strong trend of aerial deposition from surface, compared to approximately 75% of the locations in the Inner Sudbury Communities and the Sudbury Core. Unlike Coniston, chromium and cadmium in Falconbridge showed a strong trend of aerial deposition in 62% and 85% of sample locations, respectively. Similar to Coniston, more than half of the sample locations in Falconbridge showed evidence of buried contamination for most elements, with maximum concentrations occurring at either 5 - 10 cm or 10 - 20 cm. Arsenic showed evidence of buried contamination in approximately 80% of the sample locations.

Pearson’s and Spearman’s statistical correlation analysis was performed on all of the elements except beryllium at all three depths. It should be noted that 12 soil samples collected from baseball diamonds in the northeast portion of Falconbridge were removed from the data set and not included in the Pearson’s and Spearman’s statistical correlations. These baseball diamonds were built on slag material and had particularly high concentrations of iron and chromium below the surface. The samples were removed because they were outliers and were undoubtedly influencing the correlations. These samples were removed because they contained pieces of slag material at the 5 - 10 cm and 10 - 20 cm soil depth, and would have strongly influenced the correlations as outliers. Refer to Tables 7.1.5.4 to 7.1.5.6 below for an abbreviated version of the results of the Pearson’s and Spearman’s analysis for all three depths in Falconbridge, and Section 10.4.5 for the full results of the analysis. In Tables 7.1.5.4 to 7.1.5.6 the results have been rounded to one decimal place and values that were 0.75 or greater are considered strong and are indicated in bold type.

Table 7.1.5.4: Pearson’s and Spearman’s Correlations for 0 to 5 cm Urban Soil in Falconbridge

	Al	**As**	**Ba**	**Cd**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Ni**	**Se**	**Sr**	**V**	**Zn**
Al	1	*0.0*	*0.3*	*-0.2*	*0.2*	*-0.2*	*-0.2*	*0.0*	*-0.1*	*0.2*	*0.5*	*-0.2*	*-0.1*	***0.8***	*0.7*	*-0.1*
As	0.0	1	*0.7*	***0.8***	*0.7*	***0.8***	***0.9***	***0.9***	***0.9***	*0.3*	*0.1*	***0.8***	***0.8***	*0.0*	*0.3*	***0.8***
Ba	0.3	0.6	1	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.7*	*0.5*	*0.5*	*0.7*	*0.6*	*0.5*	*0.6*	***0.8***
Cd	-0.2	0.7	0.7	1	*0.7*	***0.9***	***0.9***	***0.8***	***0.9***	*0.4*	*0.1*	***0.9***	*0.7*	*0.0*	*0.2*	***0.9***
Cr	0.2	0.7	0.7	0.7	1	*0.7*	*0.7*	***0.8***	***0.8***	*0.5*	*0.2*	*0.6*	*0.7*	*0.3*	*0.5*	*0.7*
Co	-0.2	**0.8**	0.7	**0.9**	0.7	1	***1.0***	***0.9***	***0.9***	*0.4*	*0.1*	***1.0***	*0.7*	*0.0*	*0.2*	***0.9***
Cu	-0.2	**0.8**	0.7	**0.8**	0.6	**1.0**	1	***0.9***	***0.9***	*0.3*	*0.1*	***1.0***	*0.7*	*0.0*	*0.2*	***0.9***
Fe	0.1	**0.9**	0.7	**0.8**	**0.8**	**0.9**	**0.9**	1	***0.9***	*0.5*	*0.2*	***0.9***	*0.7*	*0.1*	*0.5*	***0.8***
Pb	0.0	**0.8**	0.7	**0.8**	0.7	**0.8**	**0.8**	**0.8**	1	*0.3*	*0.1*	***0.8***	***0.8***	*0.0*	*0.3*	***0.9***
Mg	0.2	0.2	0.5	0.4	0.5	0.4	0.3	0.4	0.3	1	*0.4*	*0.4*	*0.3*	*0.4*	*0.4*	*0.4*
Mn	0.5	0.0	0.5	0.1	0.2	0.1	0.1	0.2	0.1	0.4	1	*0.1*	*0.1*	*0.6*	*0.7*	*0.2*
Ni	-0.2	0.7	0.7	**0.8**	0.6	**1.0**	**1.0**	**0.9**	0.7	0.3	0.1	1	*0.7*	*0.0*	*0.2*	***0.8***
Se	0.0	0.7	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.3	0.1	0.7	1	*0.1*	*0.3*	*0.7*
Sr	0.7	0.0	0.5	0.1	0.3	0.1	0.0	0.2	0.1	0.4	0.6	0.1	0.1	1	*0.6*	*0.1*
V	0.7	0.4	0.6	0.2	0.6	0.3	0.3	0.5	0.4	0.4	0.7	0.2	0.4	0.6	1	*0.3*
Zn	-0.1	**0.8**	0.7	**0.8**	0.6	**0.8**	**0.8**	**0.8**	**0.8**	0.3	0.1	**0.8**	0.7	0.1	0.3	1

Spearman’s correlations in upper right in italics. Pearson’s correlations in lower left in normal font.
Bold indicates strong correlations.

Table 7.1.5.5: Pearson’s and Spearman’s Correlations for 5 to 10 cm Urban Soil in Falconbridge

	Al	**As**	**Ba**	**Cd**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Ni**	**Se**	**Sr**	**V**	**Zn**
Al	1	*0.2*	*0.5*	*0.1*	*0.3*	*0.1*	*0.1*	*0.3*	*0.2*	*0.5*	*0.5*	*0.1*	*0.1*	*0.7*	*0.7*	*0.2*
As	0.1	1	*0.7*	***0.8***	*0.7*	***0.9***	***0.9***	***0.9***	***0.9***	*0.2*	*0.0*	***0.8***	***0.8***	*0.1*	*0.3*	***0.8***
Ba	0.5	0.6	1	*0.7*	*0.7*	*0.7*	*0.7*	***0.8***	***0.7***	*0.6*	*0.4*	*0.7*	*0.6*	*0.5*	*0.6*	***0.8***
Cd	0.1	0.7	0.7	1	***0.8***	***0.9***	***0.9***	***0.8***	***0.8***	*0.4*	*0.1*	***0.9***	***0.8***	*0.2*	*0.3*	***0.8***
Cr	0.2	0.7	0.6	**0.8**	1	***0.8***	***0.8***	***0.8***	***0.8***	*0.5*	*0.1*	***0.8***	*0.7*	*0.4*	*0.4*	***0.8***
Co	0.1	**0.8**	0.7	**0.9**	0.7	1	***1.0***	***0.9***	***0.9***	*0.4*	*0.2*	***1.0***	***0.8***	*0.2*	*0.4*	***0.9***
Cu	0.1	**0.9**	0.7	**0.9**	0.7	**1.0**	1	***0.9***	***0.9***	*0.4*	*0.1*	***1.0***	***0.8***	*0.1*	*0.4*	***0.9***
Fe	0.3	**0.9**	0.7	**0.8**	0.7	**0.9**	**1.0**	1	***0.9***	*0.5*	*0.2*	***0.9***	*0.7*	*0.3*	*0.5*	***0.8***
Pb	0.1	**0.9**	0.7	**0.8**	0.6	0.7	**0.8**	**0.8**	1	*0.3*	*0.0*	***0.8***	***0.8***	*0.1*	*0.3*	***0.9***
Mg	0.5	0.2	0.5	0.4	0.3	0.4	0.4	0.5	0.3	1	*0.5*	*0.4*	*0.3*	*0.6*	*0.6*	*0.4*
Mn	0.5	-0.1	0.4	0.0	0.0	0.1	0.0	0.1	-0.1	0.4	1	*0.2*	*0.0*	*0.5*	*0.7*	*0.2*
Ni	0.1	**0.8**	0.7	**0.9**	0.7	**1.0**	**0.9**	**0.9**	0.7	0.4	0.1	1	***0.8***	*0.2*	*0.4*	***0.9***
Se	0.1	**0.8**	0.6	0.7	0.7	**0.8**	**0.8**	**0.8**	0.7	0.3	0.0	**0.8**	1	*0.1*	*0.3*	***0.8***
Sr	0.7	0.0	0.5	0.2	0.3	0.2	0.1	0.2	0.0	0.6	0.5	0.2	0.1	1	*0.6*	*0.2*
V	0.7	0.3	0.6	0.3	0.3	0.4	0.4	0.5	0.3	0.5	0.7	0.4	0.3	0.6	1	*0.4*
Zn	0.2	**0.8**	0.7	**0.8**	0.7	**0.8**	**0.8**	**0.8**	**0.8**	0.3	0.1	**0.8**	0.7	0.3	0.3	1

Spearman’s correlations in upper right in italics. Pearson’s correlations in lower left in normal font.
Bold indicates strong correlations.

Table 7.1.5.6: Pearson’s and Spearman’s Correlations for 10 to 20 cm Urban Soil in Falconbridge

	Al	**As**	**Ba**	**Cd**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Ni**	**Se**	**Sr**	**V**	**Zn**
Al	1	*0.2*	*0.5*	*0.1*	*0.4*	*0.2*	*0.2*	*0.5*	*0.2*	*0.3*	*0.4*	*0.2*	*0.1*	***0.8***	*0.6*	*0.3*
As	0.0	1	*0.7*	*0.6*	*0.6*	***0.9***	***0.9***	***0.8***	***0.9***	*-0.2*	*-0.2*	***0.9***	*0.7*	*0.1*	*0.1*	***0.8***
Ba	0.6	0.6	1	*0.6*	***0.8***	*0.7*	*0.7*	*0.7*	*0.7*	*0.3*	*0.3*	*0.7*	*0.6*	*0.4*	*0.5*	***0.8***
Cd	0.1	0.6	0.5	1	*0.6*	*0.7*	*0.7*	*0.6*	*0.7*	*0.1*	*0.1*	*0.7*	*0.6*	*0.1*	*0.2*	*0.7*
Cr	0.4	0.5	0.6	0.7	1	***0.8***	*0.7*	*0.7*	*0.7*	*0.3*	*0.2*	***0.7***	*0.6*	*0.4*	*0.4*	***0.8***
Co	0.1	0.7	0.5	**0.8**	0.7	1	***1.0***	***0.8***	***0.9***	*0.0*	*0.0*	***1.0***	***0.8***	*0.2*	*0.2*	***0.9***
Cu	0.1	**0.8**	0.5	**0.8**	0.7	**0.9**	1	***0.8***	***1.0***	*0.0*	*-0.1*	***0.9***	***0.8***	*0.1*	*0.2*	***0.9***
Fe	0.4	0.7	0.6	0.7	**0.8**	**0.9**	**0.9**	1	***0.8***	*0.3*	*0.2*	*0.7*	*0.6*	*0.4*	*0.5*	*0.7*
Pb	0.1	**0.9**	0.6	0.7	0.6	**0.8**	**0.9**	**0.8**	1	*0.0*	*-0.1*	***0.9***	*0.7*	*0.1*	*0.1*	***0.9***
Mg	0.5	-0.1	0.4	0.2	0.5	0.1	0.1	0.4	0.0	1	*0.5*	*0.0*	*0.1*	*0.4*	*0.4*	*0.1*
Mn	0.5	-0.2	0.4	0.0	0.2	-0.1	-0.1	0.2	-0.1	0.5	1	*0.0*	*-0.1*	*0.6*	*0.7*	*0.2*
Ni	0.1	**0.8**	0.5	**0.8**	0.7	**1.0**	**0.9**	**0.8**	**0.8**	0.1	-0.1	1	***0.8***	*0.2*	*0.2*	***0.9***
Se	0.1	**0.9**	0.6	0.7	0.6	**0.8**	**0.8**	0.7	**0.8**	0.1	-0.1	**0.8**	1	*0.1*	*0.1*	*0.7*
Sr	**0.8**	-0.1	0.5	0.0	0.3	0.1	0.0	0.2	0.0	0.4	0.5	0.1	0.0	1	*0.6*	*0.2*
V	0.7	0.0	0.5	0.2	0.4	0.1	0.1	0.4	0.1	0.6	0.7	0.1	0.1	0.5	1	*0.3*
Zn	0.3	0.6	0.7	0.7	0.6	0.7	**0.8**	0.7	**0.8**	0.2	0.2	0.7	0.7	0.2	0.2	1

Spearman’s correlations in upper right in italics. Pearson’s correlations in lower left in normal font.
Bold indicates strong correlations.

At 0 - 5 cm, using Pearson’s and Spearman’s, nickel, copper, cobalt, arsenic, lead, cadmium, iron and zinc concentrations were strongly correlated with each other. At this depth, barium, chromium and selenium were moderately correlated with each other and with all 8 of these elements using Pearson’s and Spearman‘s. As an exception, chromium was not strongly or moderately correlated with nickel, copper or zinc, and barium was not strongly or moderately correlated with arsenic or selenium using Pearson’s. At this depth, correlations were slightly stronger using Spearman’s than Pearson’s, especially for arsenic, lead and zinc. An example of the nickel vs arsenic and cadmium vs nickel correlations are presented in Figures 7.1.5.10 and 7.1.5.11 below. Refer to Section 10.4.5 for additional correlation figures.

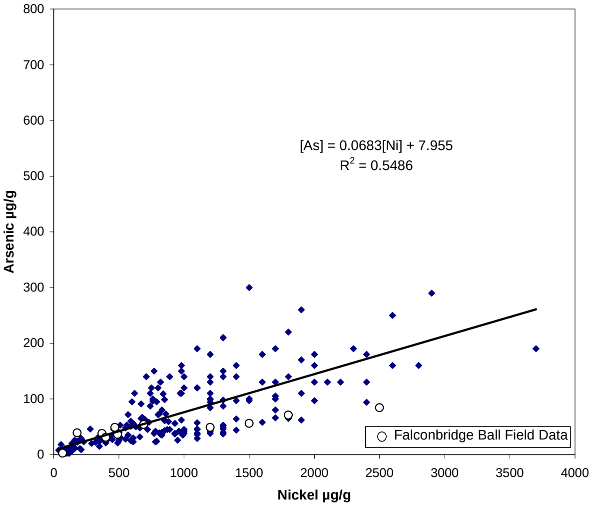


Fig 7.1.5.10: As vs. Ni, 0 - 5 cm, Falconbridge

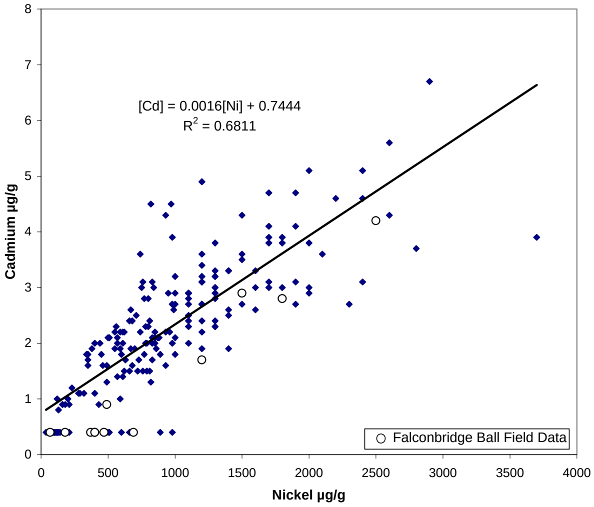


Fig 7.1.5.11: Cd vs. Ni, 0 - 5 cm, Falconbridge

Molybdenum concentrations were considerably higher in Falconbridge than in any other community at the surface. A moderate statistical correlation was observed between molybdenum and chromium (R= 0.7) at the 0 - 5 cm soil depth using Pearson's, and dropped off to R = 0.2 and R = 0.3 at 5 - 10 cm and 10 - 20 cm respectively. Refer to Section 10.4.5 for the full version of correlations in Falconbridge, which include molybdenum.

The correlation between nickel, copper, cobalt, arsenic and lead remained similar at all depth intervals in Pearson's and Spearman's with minor fluctuations in the level of significance with nickel, cobalt and arsenic using Pearson's.

Cadmium, iron and zinc concentrations remained strongly correlated with each other and with nickel, copper, cobalt, arsenic and lead using Pearson's and Spearman's at 5 - 10 cm. These three elements remained correlated with the 5 elements associated with smelter emissions at 10 - 20 cm, however, the level of significance varied between strong and moderate for both Pearson's and Spearman's. As an exception, cadmium was only moderately correlated with nickel, copper, cobalt, lead and zinc using Spearman's at this depth.

As mentioned earlier, 12 soil samples collected from baseball diamonds in the northeast portion of Falconbridge were removed from the data set and not included in the Pearson's and Spearman's correlations. These baseball diamonds were built on slag material and had particularly high concentrations of iron and chromium below the surface. Figure 7.1.5.12 illustrates the relatively high iron concentrations in the baseball diamond samples compared with the rest of Falconbridge.

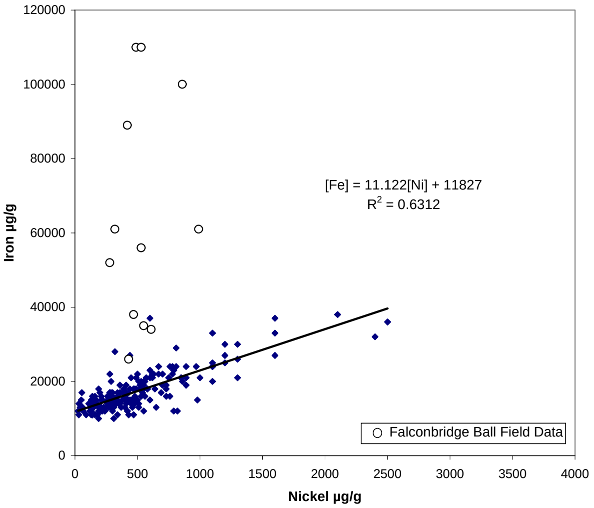


Fig 7.1.5.12: Fe vs. Ni, 10 - 20 cm, Falconbridge

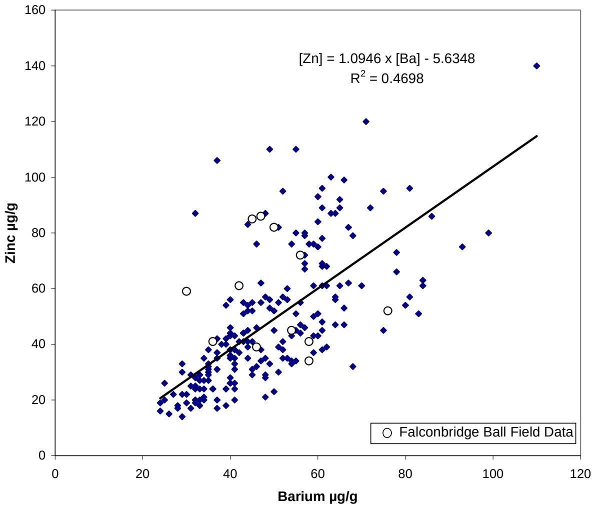


Fig 7.1.5.13: Zn vs. Ba, 10 - 20 cm, Falconbridge

Generally barium concentrations remained moderately correlated with nickel, copper, cobalt, arsenic, lead, cadmium, iron and zinc in 5 - 10 cm using Pearson's and Spearman's. At 10 - 20 cm, these correlations were strong and generally strong using Spearman's, however, dropped of to only one moderate correlation with zinc using Pearson's. Refer to Figure 7.1.5.13 for an example of the strong barium and zinc correlation at depth.

Chromium concentrations remained moderately correlated with nickel, copper, cobalt, arsenic, iron and zinc, became moderately correlated with selenium, and strongly correlated with cadmium using Pearson's at 5 - 10 cm. At this depth, chromium was strongly correlated with these 8 elements including lead using Spearman's, with the exception of arsenic and selenium which were only moderately correlated. The number of strong and moderate chromium correlations decreased at the 10 - 20 cm soil depth. Chromium was moderately correlated with nickel, copper, cobalt and cadmium, and became strongly correlated with iron using Pearson's. Chromium was also moderately correlated with nickel, copper, iron and lead, and strongly correlated with barium, cobalt and zinc using Spearman's. Refer to Figure 7.1.5.14 for an example of the strong nickel vs chromium correlation at 5 - 10 cm.

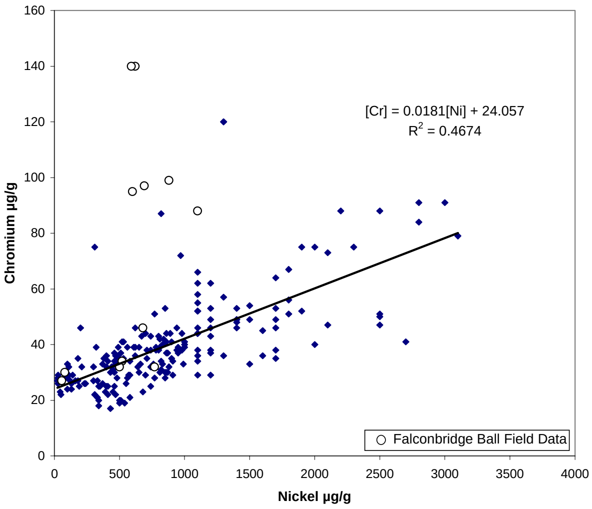


Fig 7.1.5.14: Cr vs. Ni, 5 - 10 cm, Falconbridge

Selenium correlations were the strongest below 0 - 5 cm. Selenium was generally strongly correlated with nickel, copper, cobalt, arsenic, lead, cadmium, iron and zinc, and moderately correlated with chromium at 5 - 10 cm using Pearson's and Spearman's. Selenium correlations varied between strong and moderate for these 9 elements at the 10 - 20 cm depth for Pearson's, however, dropped off for cadmium, chromium and iron using Spearman's. The selenium correlations with nickel, copper and cobalt were consistently strong using both Pearson's and Spearman's at 5 - 10 cm and 10 - 20 cm. A large number of selenium concentrations were at or near the laboratory MDL. Selenium correlations would likely be stronger if more sensitive laboratory equipment had been used.

Aluminum and vanadium were moderately correlated with each other at all depths using Pearson's, and only at 0 - 5 cm and 5 - 10 cm using Spearman's. At 10 - 20 cm, aluminum and vanadium were not strongly or moderately correlated using Spearman's. Aluminum and strontium correlations varied between moderate and strong for all depths using Pearson's and Spearman's. Vanadium and manganese were moderately correlated with each other at all three depths using both Pearson's and Spearman's. This is different than other communities, including Coniston, where aluminum and vanadium correlations with other elements usually got stronger with depth.

The strong correlations of nickel, copper, cobalt, arsenic, lead, cadmium, iron and zinc at all depths indicate that concentrations of these elements in Falconbridge appear to be attributed to smelter emissions. The correlations of selenium, chromium and barium with each other and the elements associated with smelter emissions were moderate at surface and increased slightly with depth. The concentrations of these elements at all depths also appeared to be attributed to smelter emissions.

For the naturally occurring elements, correlations between aluminum, vanadium, strontium and manganese remained moderate and relatively constant with depth using Pearson's and Spearman's. Aluminum correlations with barium, chromium, iron and zinc started to develop with depth using Pearson's and Spearman's, (Al/Ba correlations increased from approximately R=0.3 at surface to R=0.6 at depth, Al/Cr increased from R=0.2 to R=0.4, Al/Fe increased from R= 0 to 0.5, and Al/Zn increased from R=0.1 to R=0.3). As discussed previously in this section and Sections 7.1.1 and 7.1.2, no evidence of aerial deposition was observed for aluminum or vanadium. These elements have been consistently present as indicators of the naturally occurring geology in the Outer and Inner Sudbury Communities, Coniston and the Sudbury Core.

Refer to Section 10.4.5 for a complete list of graphs showing selected element correlations at all three depths for the Inner Sudbury Communities.

In summary, the element concentrations at all depth intervals in Falconbridge were considerably higher and had more exceedences of MOE criteria than in Coniston, the Sudbury Core, and the Outer and Inner Sudbury Communities. Nickel, copper, cobalt arsenic and lead concentrations exceeded Table A at all depths. Selenium concentrations exceeded Table A only at the 0 - 5 cm and 5 - 10 cm depth intervals. No other elements exceeded Table A at any depth in Falconbridge. Molybdenum concentrations were higher in Falconbridge and had more Table F exceedences than in any other community. Generally the number of exceedences of Table F decreased with depth for antimony, cadmium, cobalt, lead, molybdenum and zinc. The number of exceedences for arsenic, chromium, copper, nickel, selenium and vanadium remained high at all depths. The number of Table A exceedences generally decreased with depth for cobalt and selenium. The number of nickel, copper, arsenic and lead exceedences remained high at all depths, increased slightly at 5 - 10 cm, and then decreased slightly at 10 - 20 cm.

Generally, the highest concentrations of nickel, copper, cobalt, arsenic, lead, cadmium, chromium, iron, selenium and zinc in the 0 - 5 cm urban soil occurred in the centre and east side of the community, directly west of the smelter. At 10 - 20 cm, the concentrations of these elements decreased overall. Arsenic concentrations were the highest at 5 - 10 cm and were elevated in the centre and east side of the community. While iron and chromium concentrations generally decreased with depth, the highest concentrations of these elements occurred at 10 - 20 cm in the baseball diamonds in the northeast portion of the community.

In Falconbridge, ten elements including nickel, copper, cobalt, arsenic, lead, cadmium, selenium, chromium, iron and zinc showed a strong aerial deposition trend from surface. For most elements, however, only 49% of sample locations showed this trend while cadmium and chromium showed this trend in 62% and 85% of sample locations, respectively. In more than half of the sample locations, most elements also showed evidence of buried contamination with maximum concentrations occurring at either 5 - 10 cm or 10 - 20 cm. Arsenic showed evidence of buried contamination in approximately 80% of the sample locations.

The differing depth trends appeared to be the result of landscaping practices at individual properties over time. Addition, grading, removal and / or mixing of urban soils may alter the vertical distribution of chemical concentrations in the soil. The differences between elements in the percentage of sample locations showing these trends may be the result of numerous factors including: element form, element mobility, smelter process changes and differing chemical composition of the ore over time.

The strong correlations of nickel, copper, cobalt, arsenic, lead, cadmium, iron and zinc at all depths indicate that concentrations of these elements in Falconbridge appear to be attributed to smelter emissions. The correlations of selenium, chromium and barium with each other and the elements associated with smelter emissions were weak at the surface and increased slightly with depth. The concentrations of these elements at all depths also appeared to be attributed to smelter emissions. For the naturally occurring elements, correlations between aluminum, vanadium, strontium and manganese remained moderate and relatively constant with depth using Pearson’s and Spearman’s. Aluminum correlations with barium, chromium, iron and zinc started to increase with depth using Pearson’s and Spearman’s, however, did not become strongly or moderately correlated. This indicated that the soil at depth was still relatively disturbed as these correlations in other communities, at depth, strengthened, representing relatively undisturbed soil. This was further supported by the large number of Table A and F exceedances at depth as well as the large percentage of sample locations that exhibited maximum concentrations below surface. Based on this evidence, soil sampling in Falconbridge did not fully delineate the vertical extent of elevated concentrations related to smelter emissions.

7.1.6 Copper Cliff

In Copper Cliff, the surface soil concentrations of nickel, copper, cobalt, arsenic, lead, cadmium, selenium, chromium, iron, zinc and barium were considerably higher than in Coniston, the Sudbury Core and the Outer and Inner Sudbury Communities. Depending on the element, the differences in concentrations began from the minimum value or 25th percentile. Refer to Table 7.1.6.1.

Table 7.1.6.1: Summary Statistics for Metals and Arsenic in Urban Soil in Copper Cliff of the City of Greater Sudbury.

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
0 to 5 cm Urban Soil in Copper Cliff, n = 290																			
Minimum	6200	0.4	2.5	28	0.4	2600	20	6	65	11000	10	2000	98	0.75	71	0.5	16	16	23
10th percentile	8590	0.4	6	45	0.4	4300	29	12	360	14000	25	2600	160	0.75	299	2.0	23	25	38
1st quartile	9500	0.4	9.0	52	0.8	5600	32	17	660	15000	41	3200	180	0.75	500	3.0	32	28	54
Median	11000	0.4	14	67	1.4	7500	38	27	1200	19000	69	3800	210	0.75	840	6.0	39	31	76
3rd quartile	13000	0.4	24	90	2.2	11000	46	43	2000	24000	110	4400	230	1.60	1300	11.0	44	34	120
95th percentile	15000	1.0	45	120	3.4	21550	60	79	3300	33000	220	7910	270	2.40	2455	16.0	52	38	180
Maximum	19000	2.2	72	180	5.2	82000	93	100	5600	49000	410	17000	450	3.80	3649	49.0	71	51	250
Mean	11124	0.5	18	73	1.6	9599	40	33	1433	20507	87	4250	207	1.14	1022	7.6	38	31	92
CV (std. dev./mean)	19%	54%	69%	38%	63%	84%	28%	63%	72%	31%	79%	48%	20%	56%	69%	80%	26%	16%	53%
Skewness	0.5	3.5	1.3	1.2	0.7	5.3	1.4	1.1	1.3	1.1	2.0	3.2	0.7	1.7	1.1	2.3	0.0	-0.1	0.9
5 to 10 cm Urban Soil in Copper Cliff, n = 286																			
Minimum	6900	0.4	2.5	28	0.4	2100	20	5	26	8100	7	1700	84	0.75	40	0.5	11	20	18
10th percentile	9000	0.4	6	43	0.4	3700	27	9	200	14000	13	2500	160	0.75	170	1.0	23	26	32
1st quartile	10000	0.4	11	55	0.4	4400	31	14	440	16000	34	2900	180	0.75	370	2.0	30	29	45
Median	12000	0.4	17	76	0.4	6100	37	21	700	19000	54	3400	210	0.75	610	4.0	37	33	66
3rd quartile	15000	0.8	29	100	1.1	7900	45	31	1100	23000	99	3900	250	0.75	950	5.0	45	37	90
95th percentile	19000	1.6	50	140	2.0	12000	56	46	1700	28800	190	5580	318	1.58	1780	8.0	55	42	148
Maximum	25000	4.9	101	290	3.7	37000	90	70	2800	41000	330	12000	350	2.00	3100	14.0	90	46	210
Mean	12578	0.6	22	84	0.8	6750	39	23	785	19981	73	3583	217	0.81	726	3.9	37	33	72
CV (std. dev./mean)	25%	82%	77%	48%	68%	54%	26%	53%	61%	25%	80%	33%	23%	28%	71%	63%	31%	17%	51%
Skewness	0.7	3.6	1.7	1.8	1.5	3.1	0.9	0.9	0.9	0.8	1.5	2.9	0.4	3.9	1.3	1.1	0.6	0.1	1.0
10 to 20 cm Urban Soil in Copper Cliff, n = 286																			
Minimum	5400	0.4	2.5	17	0.4	1700	15	5	25	9400	6	2000	110	0.75	37	0.5	11	19	16
10th percentile	8650	0.4	7	48	0.4	3400	26	9	170	14000	13	2450	150	0.75	195	0.5	24	26	30
1st quartile	10000	0.4	11	60	0.4	4200	30	13	310	16000	29	2800	180	0.75	320	2.0	29	29	41
Median	12000	0.4	19	83	0.4	5500	36	19	560	19000	61	3300	210	0.75	545	3.0	37	33	59
3rd quartile	15000	1.1	32	120	0.9	6900	44	26	820	22000	120	3900	260	0.75	770	4.0	46	37	89
95th percentile	18000	1.9	56	168	1.3	9950	51	37	1300	27000	240	5500	320	1.58	1200	6.0	59	43	150
Maximum	23000	5.8	99	720	1.9	14000	85	46	2000	59000	610	8800	560	2.80	1900	11	95	54	310
Mean	12403	0.8	24	94	0.6	5784	37	20	596	19529	87	3487	222	0.83	588	2.8	38	33	72
CV (std. dev./mean)	26%	85%	70%	58%	55%	39%	25%	45%	60%	26%	97%	29%	27%	37%	58%	61%	32%	17%	63%
Skewness	0.5	3.0	1.3	5.6	1.4	1.1	0.5	0.6	0.8	2.3	2.2	1.7	1.0	4.1	0.9	1.0	0.8	0.2	2.1

All results are in µg/g dry weight.

At 10 - 20 cm, the same eleven elements were still considerably elevated compared to Coniston, the Sudbury Core, and the Outer and Inner Sudbury Communities and differences in concentrations were observed from the minimum value to the 25th percentile with the exception of cadmium. The difference between cadmium in Copper Cliff and the other communities was not observed until the 75th percentile.

At surface, the concentrations of copper, selenium and barium were higher in Copper Cliff than in Falconbridge while the concentrations of cobalt, arsenic and cadmium were higher in Falconbridge than in Copper Cliff. Depending on the element, the differences began from the minimum value to 25th percentile. At this depth, nickel, lead, iron, chromium and zinc concentrations were similar in both communities. At 10 - 20 cm, however, concentrations of copper, lead, selenium, barium and zinc were higher in Copper Cliff than in Falconbridge starting from the minimum value to the 25th percentile. Concentrations of cobalt, arsenic, cadmium, iron and chromium were higher in Falconbridge than in Copper Cliff from the 25th percentile for arsenic and between the 75th percentile and maximum value for the other elements. At this depth, only nickel concentrations remained similar between Copper Cliff and Falconbridge. As discussed in Section 7.1.5, baseball diamonds in Falconbridge had high concentrations of iron and chromium that were atypical when compared to other sample locations in Falconbridge.

The major land use in Copper Cliff was residential, with only one school property present and a small number of park properties. As a result, the sample sizes for the school and park properties were very small and may affect the validity of comparisons between land uses.

At surface, the concentrations of nickel, copper, cobalt, arsenic and cadmium were similar between the residential properties and park properties. Concentrations of iron and chromium were also similar, however, the residential maximum concentrations were higher. Concentrations of lead, selenium and zinc were higher in the residential properties than in the park properties from the 10th

Table 7.1.6.2: Summary Statistics for Metals and Arsenic in All 0-5 cm Urban Soil Samples from Copper Cliff by Land Use

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Residential 0 to 5 cm				n = 266															
Minimum	6200	0.4	2.5	28	0.4	2600	20	6	65	11000	10	2000	110	0.7	71	0.5	16	17	23
10th percentile	8700	0.4	6.5	45	0.4	4450	29	13	395	14000	30	2600	160	0.8	320	2.0	23	25	44
1st quartile	9600	0.4	10	53	0.9	5700	33	18	690	16000	43	3200	180	0.8	530	4.0	31	28	56
Median	11000	0.4	15	68	1.4	7550	38	29	1200	19000	70	3800	210	0.8	885	6.0	39	31	80
3rd quartile	13000	0.4	23	91	2.2	11000	46	42	2000	23000	120	4400	230	1.6	1300	11	44	34	130
95th percentile	15000	1.0	44	128	3.4	21000	60	75	3075	32750	220	8000	270	2.4	2375	16	52	38	188
Maximum	19000	2.2	72	180	5.2	82000	93	100	5600	49000	410	17000	450	3.8	3200	49	71	51	250
Mean	11227	0.5	18	74	1.6	9629	40	33	1440	20515	91	4282	208	1.2	1017	7.8	38	31	95
CV (std. dev./mean)	19%	54%	67%	38%	61%	85%	28%	60%	69%	31%	77%	49%	20%	55%	65%	78%	26%	15%	51%
Skewness	0.5	3.6	1.3	1.2	0.7	5.5	1.5	1.1	1.3	1.1	2.0	3.1	0.8	1.6	1.0	2.4	0.0	0.1	0.9
Schools 0 to 5 cm				n = 6															
Minimum	7400	0.4	6	32	0.4	7000	20	11	250	13000	11	4100	98	0.8	250	1.0	20	16	26
Median	9550	0.4	26	79	2.6	11500	31	50	1800	24500	71	4750	180	0.8	1600	6.0	40	28	44
Maximum	11000	0.4	37	110	3.1	27000	54	80	2900	34000	100	5500	250	1.6	2500	12	60	33	110
Mean	9500	0.4	22	70	2.0	14167	35	47	1587	23167	60	4750	178	0.9	1452	5.7	41	25	60
CV (std. dev./mean)	15%	0%	60%	43%	63%	57%	39%	66%	70%	38%	69%	10%	33%	39%	70%	75%	39%	29%	66%
Skewness	-0.3		-0.5	-0.3	-0.8	0.9	0.6	-0.2	-0.3	-0.2	-0.4	0.3	-0.2	2.4	-0.3	0.3	0.1	-0.6	0.8
Parks 0 to 5 cm				n = 18															
Minimum	7300	0.4	2.5	34	0.4	2700	25	9	250	13000	13	2400	150	0.75	205	1.0	17	24	24
10th percentile	7960	0.4	6.0	38	0.4	4140	28	11	314	13000	16	2610	177	0.75	254	1.0	30	25	29
1st quartile	9100	0.4	7.0	40	0.4	4300	29	12	350	13000	17	3000	180	0.75	300	1.5	35	27	30
Median	9950	0.4	8.0	56	0.4	6050	37	17	610	17500	25	3600	195	0.75	455	2.5	39	30	43
3rd quartile	11000	0.4	14	70	1.4	8900	43	22	990	25000	37	4000	240	0.75	620	6.0	43	34	55
95th percentile	13000	1.0	55	81	3.7	18600	56	94	4260	31350	122	4625	265	2.4	3017	21	47	36	142
Maximum	13000	1.1	63	90	4.0	22000	64	100	4600	39000	130	5900	290	3.4	3649	22	49	36	150
Mean	10150	0.5	16	57	1.2	7622	38	32	1274	19500	45	3611	207	0.98	959	5.4	39	31	56
CV (std. dev./mean)	18%	48%	110%	29%	105	67%	27%	101	115%	39%	95%	24%	18%	71%	116%	121	20%	14%	69%
Skewness	0.2	2.0	2.1	0.3	1.4	1.9	0.9	1.5	1.5	1.2	1.4	0.8	0.7	3.1	1.6	1.9	-1.2	-0.1	1.6

All results are in µg/g dry weight.

percentile and onwards. Concentrations of nickel, copper, arsenic and selenium were higher in both the residential and park properties compared to the school property. Lead, iron, chromium and zinc concentrations were higher in the residential properties compared to the school property. Concentrations of these elements were similar between the school and park land uses. Cadmium and cobalt concentration were similar between all land uses. Refer to Table 7.1.6.2.

Generally, at 5 - 10 and 10 - 20 cm all elements were higher in the residential properties compared to the school and park properties. The differences in concentrations between residential and park properties started from the 10th percentile to the 70th percentile and onwards, dependant on the element and depth. The sample size for the school property was extremely small and therefore only general comparisons were made for this land use below surface. For arsenic, 5 - 10 cm concentrations at the school property were similar to the concentrations present in the residential properties. This was likely attributed to the small sample size present for the school properties. Additionally, the park properties were higher than the residential properties at the 95th percentile for arsenic at this depth. The residential properties, however, were higher from the 10th percentile to 90th percentile on and maximum values were similar between land uses. The small sample size present for the park properties may have exaggerated the differences between land uses.

Generally, park concentrations for nickel and copper were higher in Copper Cliff compared to Falconbridge, while concentrations of cobalt, arsenic and lead were similar to marginally lower compared to Falconbridge, at surface. With depth, park concentrations were higher in Falconbridge for all 5 elements. Generally, school concentrations for nickel, copper, cobalt and arsenic were higher in Copper Cliff compared to all other communities, at all depths.

There were substantially more exceedences of Table A and F in Copper Cliff than in the Sudbury Core or Coniston. Table 7.1.6.3 summarizes the number of urban soil samples that exceed the Table F and Table A criteria in Copper Cliff. Nickel, copper, cobalt, arsenic, lead and selenium concentrations exceeded Table A at all depths. No other elements exceeded Table A at any depth in Copper Cliff. In total, twelve elements exceeded Table F criteria in Copper Cliff and are listed in Table 7.1.6.3. At 0 - 5 cm, 97% of the urban soil samples exceeded Table A and 99 to 100% exceeded Table F for nickel and copper. Generally, the number of exceedences of Table F and A were constant or decreased slightly for nickel and copper with depth. For cobalt and selenium, the number of exceedances of Table A decreased rapidly while Table F exceedances decreased gradually with depth. The number of Table F and A exceedances for arsenic and lead increased with depth. The number of antimony Table F exceedances increased with depth, while Table F exceedances of cadmium, chromium and molybdenum decreased with depth. Table F exceedances for barium and zinc remained relatively constant with depth.

Table 7.1.6.3: Summary of MOE Table F and Table A Exceedences for Metals and Arsenic in Urban Soil Samples in Copper Cliff of the City of Greater Sudbury.

Element	Table F			Table A		
	0 to 5 cm	5 to 10 cm	10 to 20 cm	0 to 5 cm	5 to 10 cm	10 to 20 cm
Antimony	14 (5%)	41 (14%)	73 (26%)	0	0	0
Arsenic	123 (42%)	141 (49%)	151 (53%)	90 (31%)	123 (43%)	138 (48%)
Barium	0	6 (2%)	4 (1%)	0	0	0
Cadmium	188 (65%)	85 (30%)	37 (13%)	0	0	0
Chromium	4 (1%)	2 (1%)	1	0	0	0
Cobalt	190 (66%)	134 (47%)	113 (40%)	81 (28%)	33 (12%)	5 (2%)
Copper	288 (99%)	281 (98%)	281 (98%)	280 (97%)	253 (88%)	242 (85%)
Lead	58 (20%)	49 (17%)	65 (23%)	19 (7%)	10 (3%)	24 (8%)
Molybdenum	9 (3%)	0	1	0	0	0
Nickel	290 (100%)	285 (100%)	284 (99%)	280 (97%)	265 (93%)	266 (93%)
Selenium	266 (92%)	243 (85%)	226 (79%)	73 (25%)	5 (2%)	1
Zinc	26 (9%)	7 (2%)	14 (5%)	0	0	0
No. of Samples	290	286	286	290	286	286

High concentrations of nickel and copper were present uniformly throughout the 0 - 5 cm interval in Copper Cliff, although some of the highest concentrations were present immediately adjacent to the INCO smokestacks. Nickel and copper concentrations generally decreased towards the southern end of the community. Concentrations of these elements decreased with depth but remained elevated, with the spatial pattern at 10 - 20 cm similar to the surface. Figures 7.1.6.1 and 7.1.6.2 depict the copper concentrations at the surface and depth in Copper Cliff.

At 0-5 cm, cobalt, arsenic, cadmium, selenium and iron concentrations were elevated throughout the community and decreased gradually towards the south. High concentrations of selenium were present in the surface soil adjacent to the INCO smokestacks. Concentrations of cobalt, cadmium and selenium decreased with depth and maintained a similar spatial pattern to the surface. Iron concentrations remained constant and increased with depth at some sample locations. At 10 - 20 cm, the highest concentrations of iron were present in the southern portion of the community. Slag material was present at some of the properties with high iron concentrations. As shown in Figures 7.1.6.3 and 7.1.6.4, arsenic concentrations increased with depth and were uniformly elevated throughout the community.

High lead concentrations were randomly present throughout the community at surface. At depth, however, lead concentrations generally increased and high concentrations were clustered in the southern portion of the community. Lead concentrations were generally not elevated adjacent to the INCO smokestacks. Slag material was present at some properties with high lead concentrations.

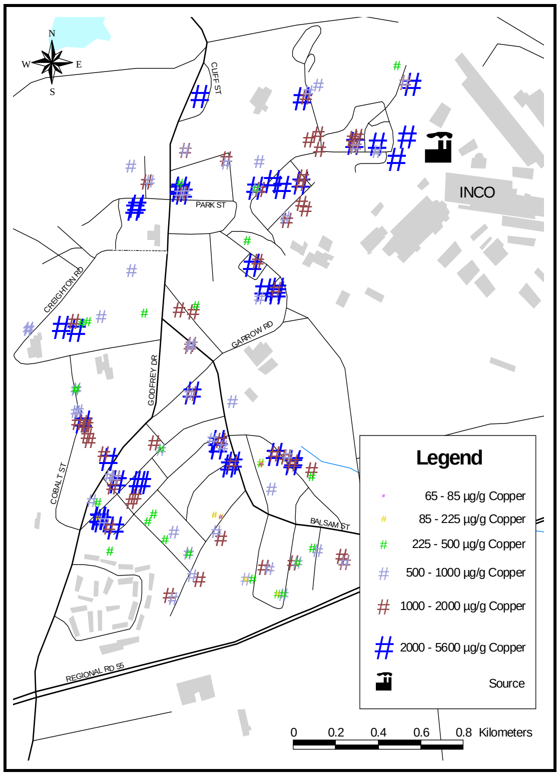


Figure 7.1.6.1: Cu concentrations in urban 0 - 5 cm soil in Copper Cliff

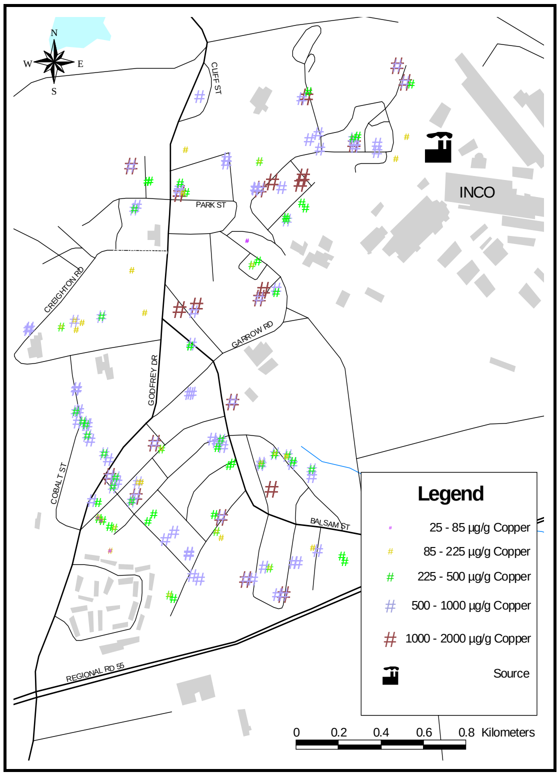


Figure 7.1.6.2: Cu concentrations in urban 10 - 20 cm soil in Copper Cliff

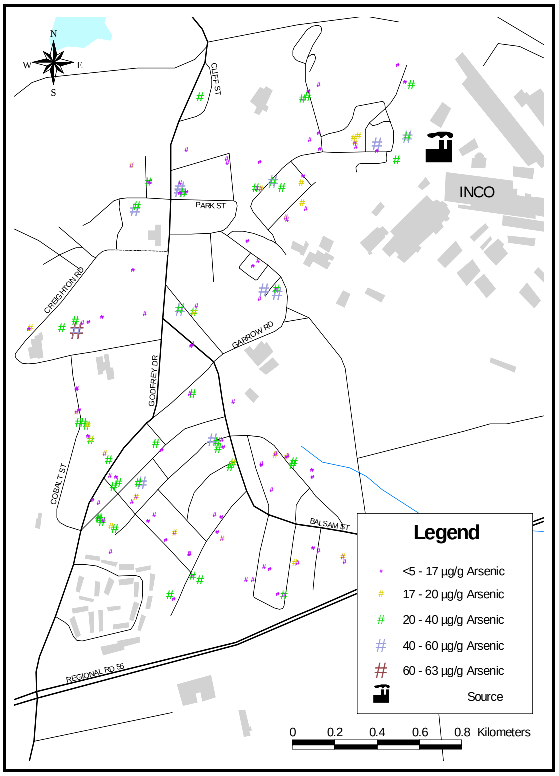


Figure 7.1.6.3: As concentrations in urban 0 - 5 cm soil in Copper Cliff

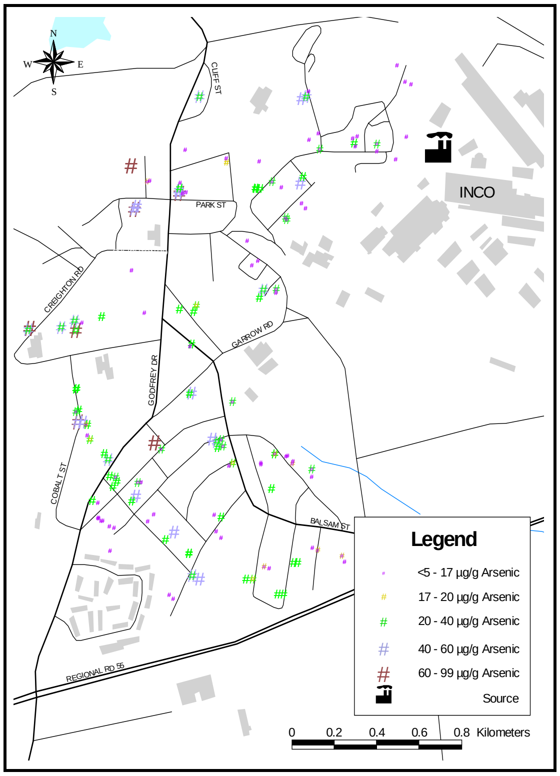


Figure 7.1.6.4: As concentrations in urban 10 - 20 cm soil in Copper Cliff

Chromium and zinc concentrations were rarely elevated above Table F background criteria in Copper Cliff. Elevated zinc concentrations were present in the southern portion of the community at surface, however, concentrations decreased and appeared to be randomly distributed at depth. No pattern of chromium concentrations was noted at surface or at depth in Copper Cliff. Refer to Section 10.2.1 for concentration dot maps of nickel, copper, cobalt, arsenic, lead, cadmium, selenium, zinc, chromium and iron at 0 - 5 and 10 - 20 cm in Copper Cliff.

As discussed previously, the data was sorted by nickel concentrations to differentiate between the Group A, B and C trends. The assumption with this procedure was that the other elements shared similar proportions of the sample locations exhibiting each depth trend as nickel. This assumption appeared to be accurate for the majority of the elements in Copper Cliff. Selenium, however, had substantially different proportions of sample locations exhibiting each depth trend as compared to nickel. As a result, the selenium was sorted separately to differentiate between depth trends for this element.

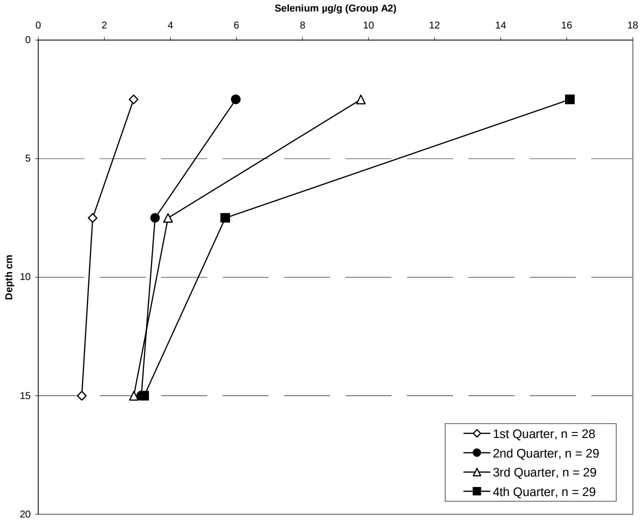


Figure 7.1.6.5: Copper Cliff, Se depth profiles, Group A.

In Copper Cliff, all three depth trends (Group A, B and C) were observed at varying numbers of sample locations. Nickel, copper, cobalt, cadmium, and to a lesser extent lead and zinc concentrations in 62% of the sample locations, showed a strong visual trend of decreasing concentration with depth in all quarters (Group A). Average concentrations at surface for copper and cadmium were 1.7 to 5.8 times the average concentrations at 10 - 20 cm for all quarters. The average concentrations in the first quarter for cadmium, however, were at or below the analytical MDL. Average concentrations at surface for nickel and cobalt were 1.4 to 3.7 times the average concentrations at 10 - 20 cm for all quarters. For lead and zinc, average concentrations were 1.4 to 2.1 times greater at surface than at 10 - 20 cm for the second through fourth quarters. In 80% of the sample locations, selenium exhibited a strong visual trend of decreasing concentrations with increasing depth in all quarters (Group A). Average selenium concentrations at surface were 1.9 to 5.0 times the average concentrations at 10 - 20 cm for all quarters. Figure 7.1.6.5 depicts the Group A depth profile for selenium in Copper Cliff.

In 62% of the sample locations, iron and chromium showed a strong visual trend of aerial deposition in the third and fourth quarters. No observable change in concentration with depth was noted in the second quarter for iron and in the first and second quarters for chromium. A weak trend of increasing concentration with depth, consistent with Group C (1.2 times), was noted in the first quarter for iron. Average concentrations of these elements at surface were 1.1 to 1.6 times the average concentrations at 10 - 20 cm in the third and fourth quarters.

Average arsenic, aluminum and vanadium concentrations, in 62% of the sample locations, showed no observable change with depth or showed a trend of increasing concentration with depth (1.1 to 1.3 times). This trend was consistent with Group B or C, rather than Group A. A weak visual

Group A trend (1.3 times) was observed for arsenic in the fourth quarter. The multiple depth trends present for aluminum and vanadium was likely an artifact of the sorting process. Aluminum and vanadium tended to be indicators of the naturally occurring geology of the City of Greater Sudbury and therefore were not expected to show similar depth trends to nickel. The wide range in concentrations between the quarters of these elements may indicate differences in soil type. Refer to Section 10.5.6 for graphs of the depth profiles for the elements discussed above.

In Copper Cliff, nickel, copper, cobalt, arsenic and iron concentrations, in 15% of the sample locations and selenium concentrations in 13% of the sample locations, showed a strong visual trend of maximum concentrations at 5 - 10 cm, while lower concentrations were observed at both 0 - 5 and 10 - 20 cm. This trend is consistent with Group B. All elements showed this trend in both halves. Average concentrations at 5 - 10 cm were 1.1 to 1.7 times the average concentrations at surface for these elements, for all quarters. Figure 7.1.6.6 depicts the Group B depth profile for selenium in Copper Cliff.

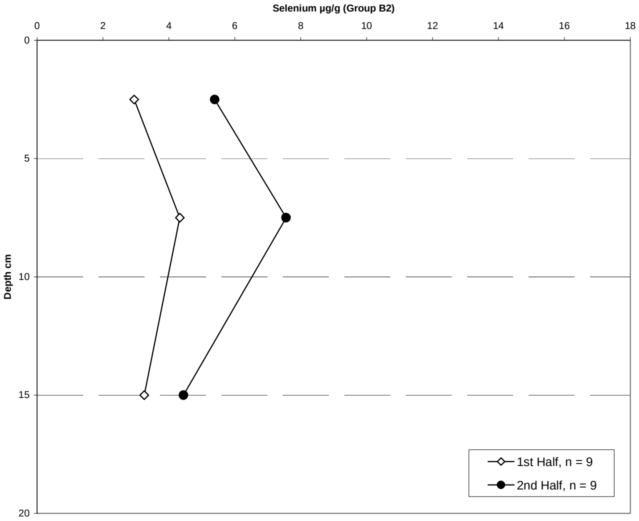


Figure 7.1.6.6: Copper Cliff, Se depth profiles, Group B.

In 15% of the sample locations, aluminum showed a strong visual Group B trend in the second half (1.2 times) and a weak Group B trend in the first half (1.1 times). Cadmium showed weak Group B trends in both halves (1.1 times) while chromium and vanadium showed no observable changes in the first half and a weak Group B trend in the second half (1.1 times). The average concentrations in the first half for cadmium were near the analytical MDL. Lead showed a strong Group B trend in the first half (1.2 times) and a weak Group C trend in the second half (1.1 times). Zinc showed a weak Group B trend in the first half (1.1 times) and a strong Group A trend in the second half (1.3 times). Refer to Section 10.5.6 for graphs of the depth profiles for the elements discussed above.

In Copper Cliff, nickel and arsenic concentrations in 22% of the sample locations showed a strong visual trend of increasing concentration with increasing depth (1.6 to 2.9 times) consistent with Group C. This trend was present in all thirds for these elements. Selenium concentrations in 8% of the sample locations showed a strong Group C trend. Average concentrations at depth were 2.1 times greater than those at surface for selenium. Cobalt, lead and zinc showed strong to weak trends of increasing concentration with depth (1.1 to 2.6 times) in all thirds. Copper, iron and aluminum also showed a strong Group C trend in the second and last third (1.2 to 1.5 times). Both copper and lead also showed weak Group A trends (1.3 times) from surface to 5 - 10 cm in the first third. No observable change or a weak Group C trend (1.2 to 1.3 times) was noted in average concentrations for chromium and vanadium in all thirds. No observable change was noted in average concentrations for cadmium in any third. Both the first and second thirds for cadmium were at or near the analytical MDL.

Figure 7.1.6.7 depicts the Group C depth profile for selenium in Copper Cliff. Refer to Section 10.5 for graphs of the depth profiles for the elements discussed above.

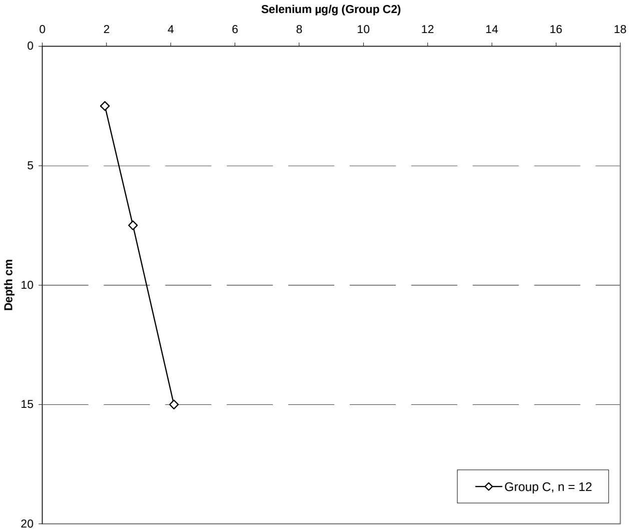


Figure 7.1.6.7: Copper Cliff, Se depth profiles, Group C.

Overall, nickel, copper, cobalt, lead, cadmium, selenium, iron, chromium and zinc exhibited a strong aerial deposition trend from surface. This trend was present in 80% of the sample locations for selenium and 62% of sample locations for the other elements. These sample locations appeared to be unaffected by landscaping practices. The remaining sample locations appeared to be affected to some degree by landscaping practices as nickel, copper, cobalt, arsenic, lead, selenium, iron, zinc and aluminum concentrations showed strong trends of maximum concentrations at 5 - 10 or 10 - 20 cm below surface. These elevated concentrations may still be attributed to aerial deposition, however, over time have been buried by landscaping practices at individual properties. Addition, grading, removal and / or mixing of urban soils may alter the vertical distribution of chemical concentrations in the soil.

In Copper Cliff, nine elements including nickel, copper, cobalt, lead, cadmium, selenium, chromium, iron and zinc showed strong indications of aerial deposition. The elements, with the exception of arsenic, were similar to Falconbridge although the trend was stronger in Copper Cliff for certain elements. Additionally, there was strong evidence of aerial deposition for arsenic in Falconbridge although at a limited number of sample locations this evidence was not present for arsenic in Copper Cliff. In Coniston, the Sudbury Core or the Inner Sudbury Communities, evidence of aerial deposition varied in strength, while in Copper Cliff strong evidence was present. Similar to the Inner Sudbury Communities and the Sudbury Core, Copper Cliff had 62% of sample locations that showed an aerial deposition trend for most elements. Selenium showed a strong trend of aerial deposition in 80% of the sample locations. Also similar to the Inner Sudbury Communities and the Sudbury Core, less than half of the sample locations for most elements in Copper Cliff showed evidence of buried contamination, with maximum concentrations occurring at either 5 - 10 cm or 10 - 20 cm. This is different from Falconbridge and Coniston where over half of the sample locations showed evidence of buried contamination.

Pearson’s and Spearman’s statistical correlation analysis was performed on all of the elements except beryllium at each of the three depths. Refer to Tables 7.1.6.4 to 7.1.6.6 below for an abbreviated version of the results of the Pearson’s and Spearman’s analysis for all three depths and Tables 10.4.6.1 through 10.4.6.3 for the full results of the analysis. In Tables 7.1.6.4 to 7.1.6.6 the results have been rounded to one decimal place and values that were 0.75 or greater are considered strong and are indicated in bold type. Values that were between 0.70 and 0.75 were considered moderately correlated.

Table 7.1.6.4: Pearson’s and Spearman’s Correlations for 0 to 5 cm Urban Soil in Copper Cliff

	Al	**As**	**Ba**	**Cd**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Ni**	**Se**	**Sr**	**V**	**Zn**
Al	1	*0.3*	*0.6*	*0.4*	*0.7*	*0.3*	*0.3*	*0.6*	*0.3*	*0.4*	*0.6*	*0.3*	*0.3*	*0.7*	***0.8***	*0.3*
As	0.3	1	*0.7*	***0.8***	*0.6*	***0.9***	***0.8***	***0.8***	***0.8***	*0.3*	*0.2*	***0.9***	*0.7*	*0.1*	*0.4*	***0.8***
Ba	0.6	0.7	1	*0.7*	***0.8***	*0.7*	*0.7*	***0.8***	*0.7*	*0.5*	*0.6*	*0.7*	*0.6*	*0.5*	*0.6*	***0.8***
Cd	0.4	0.7	0.7	1	*0.7*	***0.9***	***0.9***	***0.8***	***0.8***	*0.5*	*0.3*	***0.9***	***0.8***	*0.2*	*0.3*	***0.9***
Cr	0.6	0.6	0.7	0.7	1	*0.7*	*0.7*	***0.8***	*0.6*	*0.5*	*0.6*	*0.7*	*0.7*	*0.6*	***0.8***	*0.7*
Co	0.3	**0.8**	0.6	**0.9**	0.7	1	***1.0***	***0.8***	***0.8***	*0.5*	*0.3*	***1.0***	***0.9***	*0.2*	*0.4*	***0.9***
Cu	0.3	**0.8**	0.5	**0.9**	0.6	**0.9**	1	***0.8***	***0.8***	*0.4*	*0.2*	***1.0***	***0.9***	*0.2*	*0.3*	***0.8***
Fe	0.6	**0.8**	0.7	**0.8**	**0.8**	**0.9**	**0.8**	1	***0.8***	*0.5*	*0.5*	***0.8***	*0.7*	*0.4*	*0.6*	***0.8***
Pb	0.3	0.7	0.7	0.6	0.5	0.7	0.6	0.6	1	*0.3*	*0.3*	***0.8***	*0.7*	*0.2*	*0.4*	***0.9***
Mg	0.2	0.1	0.2	0.4	0.2	0.3	0.3	0.3	0.1	1	*0.5*	*0.4*	*0.4*	*0.4*	*0.4*	*0.5*
Mn	0.6	0.3	0.6	0.3	0.5	0.3	0.2	0.4	0.3	0.2	1	*0.3*	*0.2*	*0.7*	*0.7*	*0.4*
Ni	0.3	**0.9**	0.6	**0.9**	0.7	**1.0**	**0.9**	**0.9**	0.6	0.3	0.2	1	***0.9***	*0.2*	*0.3*	***0.8***
Se	0.3	0.7	0.4	0.7	0.6	**0.8**	**0.8**	0.6	0.5	0.2	0.1	**0.8**	1	*0.2*	*0.4*	*0.7*
Sr	0.7	0.2	0.5	0.3	0.5	0.2	0.2	0.3	0.2	0.2	0.7	0.2	0.2	1	*0.7*	*0.3*
V	**0.8**	0.4	0.6	0.3	0.7	0.4	0.3	0.6	0.3	0.1	0.7	0.3	0.3	0.7	1	*0.4*
Zn	0.4	0.7	**0.8**	**0.8**	0.6	**0.8**	0.7	0.7	**0.8**	0.4	0.4	**0.8**	0.5	0.3	0.4	1

Spearman’s correlations in upper right in italics. Pearson’s correlations in lower left in normal font.
Bold indicates strong correlations.

Table 7.1.6.5: Pearson’s and Spearman’s Correlations for 5 to 10 cm Urban Soil in Copper Cliff

	Al	**As**	**Ba**	**Cd**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Ni**	**Se**	**Sr**	**V**	**Zn**
Al	1	*0.4*	***0.8***	*0.4*	***0.8***	*0.5*	*0.4*	***0.8***	*0.3*	*0.7*	*0.7*	*0.4*	*0.3*	***0.8***	***0.9***	*0.5*
As	0.3	1	*0.7*	*0.7*	*0.6*	***0.9***	***0.8***	*0.7*	*0.7*	*0.2*	*0.4*	***0.9***	*0.6*	*0.3*	*0.4*	***0.8***
Ba	0.6	0.5	1	*0.6*	***0.8***	*0.7*	*0.6*	***0.9***	*0.7*	*0.6*	*0.7*	*0.7*	*0.5*	*0.6*	*0.7*	***0.8***
Cd	0.4	0.7	0.5	1	*0.6*	***0.8***	***0.8***	*0.7*	*0.6*	*0.3*	*0.4*	***0.8***	*0.6*	*0.3*	*0.4*	***0.8***
Cr	**0.8**	0.5	0.7	0.7	1	*0.6*	*0.5*	***0.9***	*0.5*	*0.7*	*0.7*	*0.6*	*0.5*	*0.7*	***0.9***	*0.7*
Co	0.4	**0.8**	0.6	**0.8**	0.6	1	***0.9***	***0.8***	*0.7*	*0.3*	*0.4*	***1.0***	*0.7*	*0.3*	*0.4*	***0.8***
Cu	0.3	0.7	0.5	**0.8**	0.5	**0.9**	1	*0.7*	*0.7*	*0.3*	*0.3*	***0.9***	***0.8***	*0.2*	*0.3*	***0.8***
Fe	0.7	0.6	0.7	0.6	**0.8**	0.7	0.7	1	*0.6*	*0.6*	*0.7*	*0.7*	*0.5*	*0.6*	***0.8***	***0.8***
Pb	0.2	0.5	0.6	0.5	0.4	0.6	0.6	0.5	1	*0.2*	*0.4*	*0.6*	*0.5*	*0.3*	*0.3*	***0.8***
Mg	0.5	0.0	0.4	0.2	0.5	0.1	0.1	0.5	0.0	1	*0.6*	*0.3*	*0.2*	*0.5*	*0.7*	*0.4*
Mn	0.6	0.3	0.6	0.3	0.7	0.4	0.3	0.6	0.4	0.5	1	*0.3*	*0.2*	*0.7*	***0.8***	*0.5*
Ni	0.4	**0.8**	0.5	**0.8**	0.6	**1.0**	**0.9**	0.7	0.5	0.1	0.3	1	*0.7*	*0.3*	*0.3*	***0.8***
Se	0.2	0.6	0.4	0.6	0.4	0.7	**0.8**	0.6	0.4	0.1	0.2	0.7	1	*0.1*	*0.3*	*0.6*
Sr	0.7	0.2	0.6	0.3	0.6	0.3	0.2	0.6	0.3	0.4	0.7	0.3	0.1	1	***0.8***	*0.4*
V	**0.9**	0.3	0.6	0.3	**0.8**	0.4	0.3	**0.8**	0.3	0.5	**0.8**	0.4	0.3	**0.8**	1	*0.5*
Zn	0.4	0.6	0.7	0.7	0.6	0.7	0.7	0.7	**0.8**	0.1	0.6	0.7	0.5	0.5	0.4	1

Spearman’s correlations in upper right in italics. Pearson’s correlations in lower left in normal font.
Bold indicates strong correlations.

Table 7.1.6.6: Pearson's and Spearman's Correlations for 10 to 20 cm Urban Soil in Copper Cliff

	Al	**As**	**Ba**	**Cd**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Ni**	**Se**	**Sr**	**V**	**Zn**
Al	1	*0.3*	*0.7*	*0.2*	***0.9***	*0.4*	*0.3*	***0.8***	*0.3*	*0.7*	*0.7*	*0.3*	*0.2*	***0.8***	***0.9***	*0.4*
As	0.2	1	*0.6*	*0.5*	*0.4*	***0.8***	*0.7*	*0.5*	*0.6*	*0.1*	*0.4*	*0.7*	*0.5*	*0.3*	*0.2*	*0.7*
Ba	0.5	0.4	1	*0.4*	***0.8***	*0.7*	*0.6*	***0.8***	*0.7*	*0.6*	***0.8***	*0.6*	*0.4*	*0.7*	*0.7*	***0.8***
Cd	0.2	0.4	0.4	1	*0.4*	*0.7*	*0.7*	*0.5*	*0.5*	*0.2*	*0.3*	*0.7*	*0.5*	*0.3*	*0.2*	*0.6*
Cr	**0.8**	0.3	0.6	0.3	1	*0.6*	*0.5*	***0.8***	*0.4*	***0.8***	***0.8***	*0.5*	*0.4*	***0.8***	***0.9***	*0.6*
Co	0.4	0.7	0.5	0.7	0.6	1	***0.9***	*0.7*	*0.7*	*0.3*	*0.5*	***0.9***	*0.7*	*0.4*	*0.4*	***0.8***
Cu	0.3	0.5	0.4	**0.8**	0.5	**0.9**	1	*0.6*	*0.7*	*0.2*	*0.4*	***0.9***	*0.7*	*0.3*	*0.3*	***0.8***
Fe	0.6	0.4	0.5	0.4	**0.8**	0.6	0.6	1	*0.6*	*0.7*	*0.7*	*0.6*	*0.4*	*0.7*	***0.8***	*0.7*
Pb	0.2	0.6	0.6	0.5	0.3	0.6	0.5	0.4	1	*0.2*	*0.5*	*0.6*	*0.5*	*0.4*	*0.3*	***0.8***
Mg	0.7	0.0	0.4	0.1	0.7	0.2	0.1	0.5	0.1	1	*0.7*	*0.1*	*0.1*	*0.6*	***0.8***	*0.3*
Mn	0.6	0.4	0.7	0.3	0.7	0.5	0.3	0.6	0.5	0.6	1	*0.4*	*0.2*	***0.8***	***0.8***	*0.6*
Ni	0.3	0.6	0.4	0.7	0.4	**0.9**	**0.9**	0.5	0.5	0.1	0.3	1	*0.7*	*0.3*	*0.3*	***0.8***
Se	0.2	0.4	0.3	0.6	0.4	0.7	0.7	0.4	0.4	0.0	0.1	0.6	1	*0.2*	*0.2*	*0.5*
Sr	0.7	0.3	0.6	0.4	0.7	0.4	0.3	0.5	0.3	0.6	**0.8**	0.3	0.2	1	***0.8***	*0.5*
V	**0.8**	0.2	0.5	0.2	**0.9**	0.4	0.3	0.7	0.2	0.7	0.7	0.3	0.2	**0.8**	1	*0.4*
Zn	0.3	0.6	0.7	0.7	0.4	0.7	0.6	0.5	**0.8**	0.2	0.6	0.6	0.4	0.4	0.3	1

Spearman's correlations in upper right in italics. Pearson's correlations in lower left in normal font.
Bold indicates strong correlations.

Generally, in Copper Cliff at 0 - 5 cm nickel, copper, cobalt, arsenic, cadmium, selenium, iron and zinc strongly or moderately correlated with each other using Pearson's and Spearman's. Using Spearman's, lead also strongly correlated with the above referenced elements while using Pearson's lead only strongly correlated with zinc. Barium and chromium are also strongly or moderately correlated with a number of these elements at this depth using Pearson's and Spearman's.

With depth, nickel, copper and cobalt remained strongly correlated with each other using both Pearson's or Spearman's. Cadmium and selenium was strongly or moderately correlated with nickel, copper and cobalt with depth using Pearson's and Spearman's. Cadmium and selenium correlations would likely be stronger if more sensitive laboratory equipment had been used. Arsenic was strongly or moderately correlated with nickel, copper, cobalt and zinc with depth using Spearman's. The number and strength of the arsenic correlations were fewer and weaker using Pearson's and decreased with depth. Lead was strongly correlated with zinc only using both Pearson's and Spearman's with increasing depth. Using Spearman's, lead also moderately correlated with arsenic, barium, copper and cobalt at 5 - 10 cm and only barium, copper and cobalt at 10 - 20 cm. Zinc remained strongly or moderately correlated with nickel, copper, cobalt, arsenic, lead, iron and barium using Spearman's with depth. At 5 - 10 cm, zinc also strongly correlated with cadmium and managanese using Spearman's. With depth, zinc correlations were fewer and weaker using Pearson's. Barium, iron and chromium correlations with elements associated with smelter emissions generally decreased with depth while correlations with naturally occurring elements increased with depth. There were generally more barium, iron and chromium correlations with Spearman's than Pearson's.

Overall, correlations were strong and numerous between nickel, copper, cobalt, arsenic, lead, cadmium, selenium, iron and zinc at surface in Copper Cliff. Generally, the number of correlations between these elements decreased with depth. Correlations of nickel, copper and cobalt, however, remained strong with each other and with arsenic, cadmium, selenium and zinc with depth. This

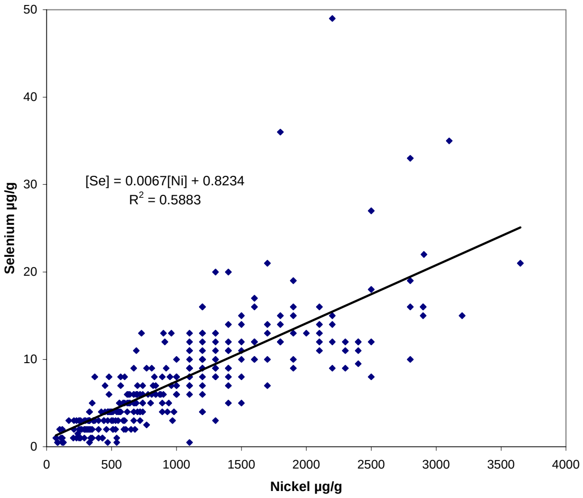


Fig 7.1.6.8: Se vs. Ni, 0 - 5 cm, Copper Cliff

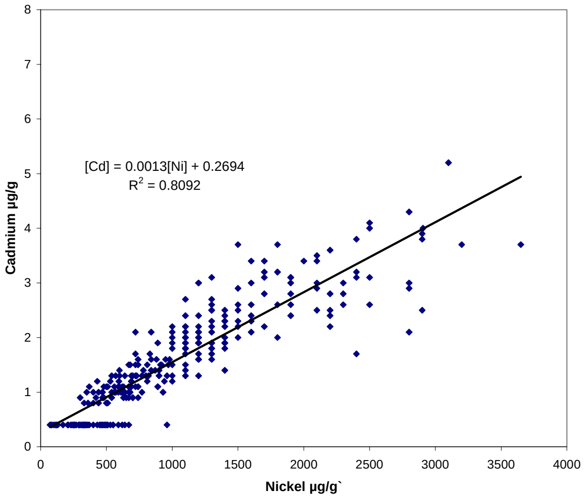


Fig 7.1.6.9: Cd vs. Ni, 0 - 5 cm, Copper Cliff

is an indication that concentrations, at all depths, of these elements in Copper Cliff appear to be attributed to smelter emissions. Figures 7.1.6.8 and 7.1.6.9 show the correlations of nickel and selenium and nickel and cadmium at surface in Copper Cliff.

The correlations of lead, barium, iron and chromium at surface also indicate that these concentrations may be due to smelter emissions. Generally, nickel concentrations were similar to or greater then copper concentrations at all depths throughout the City of Greater Sudbury. As a result, the ratio of nickel to copper remained relatively constant, ranging between 0.7 to 0.9 copper to nickel. The only exception was at the surface in Copper Cliff where concentrations of copper were approximately 1.4 times the concentrations of nickel (ratio of 1.4 copper to nickel).

For the naturally occurring elements, the overall number of correlations increased with depth. Aluminum, strontium and vanadium were correlated with each other at all depths using both Pearson’s and Spearman’s. With depth, aluminum, strontium and vanadium developed strong or moderate correlations with barium, chromium, iron, magnesium, and manganese, using both Pearson’s and Spearman’s. These correlations tended to be more numerous and stronger using Spearman’s than Pearson’s. These elements are indicative of the naturally occurring geology in the City of Greater Sudbury. The increase in the number and strength of these correlations are representative of less disturbed soil at depth. Similar to the Sudbury Core and Coniston, only aluminum and vanadium were strongly correlated at all depths.

Refer to Section 10.4.6 for a complete list of graphs showing selected element correlations at all three depths for Copper Cliff.

In summary, the element concentrations, at all depth intervals in Copper Cliff, were considerably higher and had more exceedences of MOE criteria than in Coniston, the Sudbury Core, and the Outer and Inner Sudbury Communities. Generally, the concentrations of copper, lead, selenium, zinc and barium were higher in Copper Cliff than in Falconbridge while the concentrations of cobalt, arsenic, cadmium, iron and chromium were higher in Falconbridge. Only nickel concentrations generally remained similar between Copper Cliff and Falconbridge. The differences, however, between Copper Cliff and Falconbridge varied with depth.

In Copper Cliff, nickel, copper, cobalt, arsenic, lead and selenium concentrations exceeded Table A at all depths. No other elements exceeded Table A at any depth in Copper Cliff. In total, twelve elements exceeded Table F criteria in Copper Cliff. Generally, the number of exceedences of Table F and A were constant or decreased slightly for nickel and copper with depth. For cobalt and selenium, the number of exceedances of Table A decreased rapidly while Table F exceedances decreased gradually with depth. The number of Table F and A exceedances for arsenic and lead increased with depth.

High concentrations of nickel and copper, cobalt, arsenic, cadmium, selenium and iron, at surface were present uniformly throughout Copper Cliff, although some of the highest nickel, copper and selenium concentrations were present immediately adjacent to the INCO smokestacks. Concentrations of these elements generally decreased towards the southern end of the community. Nickel and copper concentrations remained elevated with depth while concentrations of cobalt, cadmium and selenium decreased. Iron concentrations generally remained constant with depth, however, at some sample locations slag material was present and iron concentrations increased with depth. Arsenic concentrations increased with depth and no gradient was observable as concentrations were elevated and uniform throughout the community. High lead concentrations were randomly present throughout the community at surface, however, concentrations generally increased with depth and high concentrations were clustered in the southern portion of the community. Slag material was also present at some of the properties with high lead concentrations. Elevated zinc concentrations were present in the southern portion of the community at surface, however, concentrations decreased and appeared to be randomly distributed at depth. No pattern of chromium concentrations was noted at surface or at depth in Copper Cliff.

In Copper Cliff, nine elements including nickel, copper, cobalt, lead, cadmium, selenium, chromium, iron and zinc showed strong indications of aerial deposition. The elements, with the exception of arsenic, were similar to Falconbridge, although the trend was stronger in Copper Cliff with over 60% of sample locations showing this trend. Selenium, however, showed this trend in 80% of the sample locations. In less than half of the sample locations most elements also showed evidence of buried contamination, with maximum concentrations occurring at either 5 - 10 cm or 10 - 20 cm.

The differing depth trends appeared to be the result of landscaping practices at individual properties over time. Addition, grading, removal and / or mixing of urban soils may alter the vertical distribution of chemical concentrations in the soil. The differences between elements in the percentage of sample locations showing these trends may be the result of numerous factors including: element form, element mobility, smelter process changes and differing chemical composition of the ore over time.

Overall, correlations were strong and numerous between nickel, copper, cobalt, arsenic, lead, cadmium, selenium, iron and zinc at surface in Copper Cliff. Generally, the number of correlations between these elements decreased with depth. Correlations of nickel, copper and cobalt, however, remained strong with each other and with arsenic, cadmium, selenium and zinc with depth. This is an indication that concentrations of these elements in Copper Cliff, at all depths, appear to be attributed to smelter emissions. The correlations of lead, barium, iron and chromium at surface, also indicate that these concentrations may be due to smelter emissions. Concentrations of copper were approximately 1.4 times the concentrations of nickel in Copper Cliff. Generally, nickel concentrations were similar to or greater than copper concentrations at all depths throughout the City of Greater Sudbury.

For the naturally occurring elements, the overall number of correlations increased with depth. Aluminum, strontium and vanadium were correlated with each other at all depths. With depth, aluminum, strontium and vanadium developed strong or moderate correlations with barium, chromium, iron, magnesium, and manganese. These elements are indicative of the naturally occurring geology in the City of Greater Sudbury, with the increased number and strength of these correlations representative of less disturbed soil at depth.

7.2 Sand and Gravel

This section will discuss the analytical results of the sand and gravel sample types that were collected by the Ministry in the City of Greater Sudbury in 2001. The sand and gravel sample types were collected in addition to the soil sample type as these materials were observed extensively throughout the City of Greater Sudbury in the school and park land uses. Sand and gravel, unlike grass covered urban soil, can come into direct contact with skin, thereby increasing the risk of exposure. Sand samples were generally collected in 0 - 15 cm intervals while gravel samples were generally collected at surface only.

The sand sample type was subdivided into Play Sand and Beach Sand while the gravel sample type was subdivided into Crushed Stone and Playground Gravel. Play Sand, Crushed Stone and Playground Gravel generally originated off-property and were brought in for landscaping purposes while Beach Sand was naturally occurring. The sand and gravel results were discussed based on sample type (i.e. Play Sand, Beach Sand, Playground Gravel and Crushed Stone) across the City of Greater Sudbury rather than community groupings. Concentrations were compared between the different types of sand and gravel and the 0 - 5 cm soil results for all parks, schools and daycares. These soil results were used for comparison as they represent the soil adjacent to the sand and gravel sample locations. Descriptive statistics, exceedences of applicable Ministry guidelines, spatial distribution of chemical concentrations and statistical correlations between elements were discussed.

For sand, pH analysis was completed on 45 samples and pH ranged from 4.95 to 8.1. The Ministry *Guideline for Use at Contaminated Sites in Ontario* (MOE 1997) states that Table A soil criteria for inorganics apply only when the soil pH is between 5.0 and 9.0. No sand samples analyzed had a pH value that exceeded 9.0, however one sand sample had a pH value below 5.0. This sample had a pH value of 4.95 and was located at one school in the Outer Sudbury Communities. The pH values for all other sand samples analyzed were within the range of 5.0 to 9.0. Refer to Section 10.3.6 for descriptive statistics and box and whisker plots.

For gravel, pH analysis was completed on 18 samples and pH ranged from 4.7 to 7.9. The Ministry *Guideline for Use at Contaminated Sites in Ontario* (MOE 1997) states that Table A soil criteria for inorganics apply only when the soil pH is between 5.0 and 9.0. No gravel samples analyzed had a pH value that exceeded 9.0, however one gravel sample had a pH value below 5.0. This sample had a pH value of 4.7 and was located at one school in the Inner Sudbury Communities. The pH values for all other gravel samples analyzed were within the range of 5.0 to 9.0. Refer to Section 10.3.6 for descriptive statistics and box and whisker plots.

7.2.1 Play Sand

There were 550 Play Sand samples collected from 324 sampling locations. Sixty five percent of the samples were from parks and the remainder were from schools and daycares. Thirty four percent of the samples were from the Outer Sudbury Communities, 42% were from the Inner Sudbury Communities, 16% were from the Sudbury Core and the remainder were from Coniston, Copper Cliff and Falconbridge.

The concentrations of nickel, copper, cobalt, arsenic, selenium and lead in the Play Sand samples were relatively low and were generally lower than the 0 - 5 cm soil samples collected from the same schools, daycares and parks. The concentrations of antimony, beryllium, chromium, iron, magnesium, manganese, molybdenum, strontium, vanadium and zinc in the play sand were similar to 0 - 5 cm soil from the schools and parks. Aluminum, barium and calcium were slightly lower in the play sand than the soil but this would be expected when comparing sand versus soil that ranges from sands to silty clays. Cadmium and selenium in the play sand were lower at the 95th percentile and the maximum values than the soil, but all the results were near the method detection limits.

The large differences between the play sand and soil results occurred with nickel, copper and cobalt, and to a lesser extent arsenic. The concentrations of these elements in the play sand were considerably lower that the concentrations in soil. At the 90th percentile the play sand nickel concentrations were one quarter the concentrations in soil and at the maximum the play sand was one sixth the soil concentrations. From the minimum to the 80th percentile the difference between the play sand concentrations and the soil were not as large. For arsenic the difference occurred only at the 90th, 95th percentile and maximum. Below the 90th percentile arsenic was generally at the detection limit for both sample types.

It was anticipated that the concentrations of nickel, copper, cobalt, arsenic and lead would be lower in the play sand than the surrounding soil as this material had been brought in and would only have accumulated recent aerial deposition of these elements. It should be noted that play sand samples were generally collected at 0 - 15 cm intervals while the soil samples were collected at 0 - 5 cm intervals. Play sand was collected at larger intervals because of the homogeneous nature of the sand and the mixing action that normally occurs in play areas. Due to these factors, the differences in sample volume between sample types should not affect the validity of the comparison.

Abbreviated summary statistics for the Play Sand results were given in Table 7.2.1.1 with the full summary statistics in Section 10.3.3.1. Table 7.2.1.2 gives the summary statistics for 0 - 5 cm soil samples from all of the schools, daycares and parks for comparison purposes.

Table 7.2.1.1: Summary Statistics for Metals and Arsenic in Play Sand in the City of Greater Sudbury.

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	2700	0.4	2.5	10	0.4	1500	11	3	6	6200	2	1400	70	0.75	11	0.5	10	7	9
10th percentile	4600	0.4	2.5	17	0.4	2190	22	5	14	11000	2	2700	150	0.75	19	0.5	16	24	16
1st quartile	5300	0.4	2.5	20	0.4	2500	25	6	18	13000	3	3000	160	0.75	22	0.5	18	27	18
Median	6350	0.4	2.5	24	0.4	2900	28	8	26	15000	4	3700	180	0.75	27	0.5	23	32	23
3rd quartile	7700	0.4	2.5	31	0.4	3400	33	9	38	17000	6	4200	220	0.75	35	0.5	27	36	28
95th percentile	10000	0.4	6.0	43	0.4	4400	46	11	58	23000	8	5345	290	0.75	58	1.0	37	51	38
Maximum	13000	2.3	34	67	0.8	12000	59	22	210	27000	82	7200	370	4.10	680	2.0	47	62	110
Mean	6613	0.4	3.1	26	0.4	3003	30	8	32	15380	5	3693	194	0.77	36	0.5	23	33	24
CV (std. dev./mean)	26%	28%	86%	34%	4%	30%	26%	31%	78%	24%	91%	24%	24%	24%	123%	29%	29%	27%	37%
Skewness	0.7	12.7	7.9	1.2	23.5	3.5	1.1	1.4	3.7	0.6	10.0	0.7	1.0	13.4	8.8	4.8	0.8	0.8	2.8

All results are in µg/g dry weight. n = 550

Table 7.2.1.2: Summary Statistics for 0 to 5 cm Soil from All Parks, Schools, and Daycares in the City of Greater Sudbury

	Al	Sb	As	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	3900	0.4	2.5	0.3	0.4	1600	17	3	8	7400	1	1200	90	0.8	16	0.5	10	8	11
10th percentile	7100	0.4	2.5	0.3	0.4	2900	23	4	25	11000	7	2000	140	0.8	36	0.5	23	24	20
1st quartile	8300	0.4	2.5	0.3	0.4	3500	25	5	35	12000	10	2300	160	0.8	48	0.5	29	26	24
Median	9500	0.4	2.5	0.3	0.4	4800	29	7	52	13000	13	3000	200	0.8	69	0.5	35	28	30
3rd quartile	11000	0.4	6.0	0.3	0.4	6800	35	10	93	15000	20	3800	240	0.8	120	0.5	42	32	38
95th percentile	14000	0.4	14	0.3	0.8	11000	45	18	300	21000	51	5800	310	0.8	320	2.0	51	37	61
Maximum	27000	4.4	84	0.5	4.2	33000	73	130	4600	45000	200	13000	650	3.4	3649	22	170	78	150
Mean	9744	0.4	5.2	0.3	0.5	5661	31	9	118	14337	19	3299	206	0.8	134	0.8	36	29	33
CV (std. dev./mean)	25%	55%	138%	6%	79%	58%	26%	110%	284%	27%	112%	42%	32%	22%	217%	175%	31%	19%	47%
Skewness	1.5	10.2	5.9	16.6	6.8	2.9	1.5	6.7	9.1	2.8	4.1	2.0	2.1	9.6	7.6	11.0	2.7	1.8	2.9

All results are in µg/g dry weight. n = 833

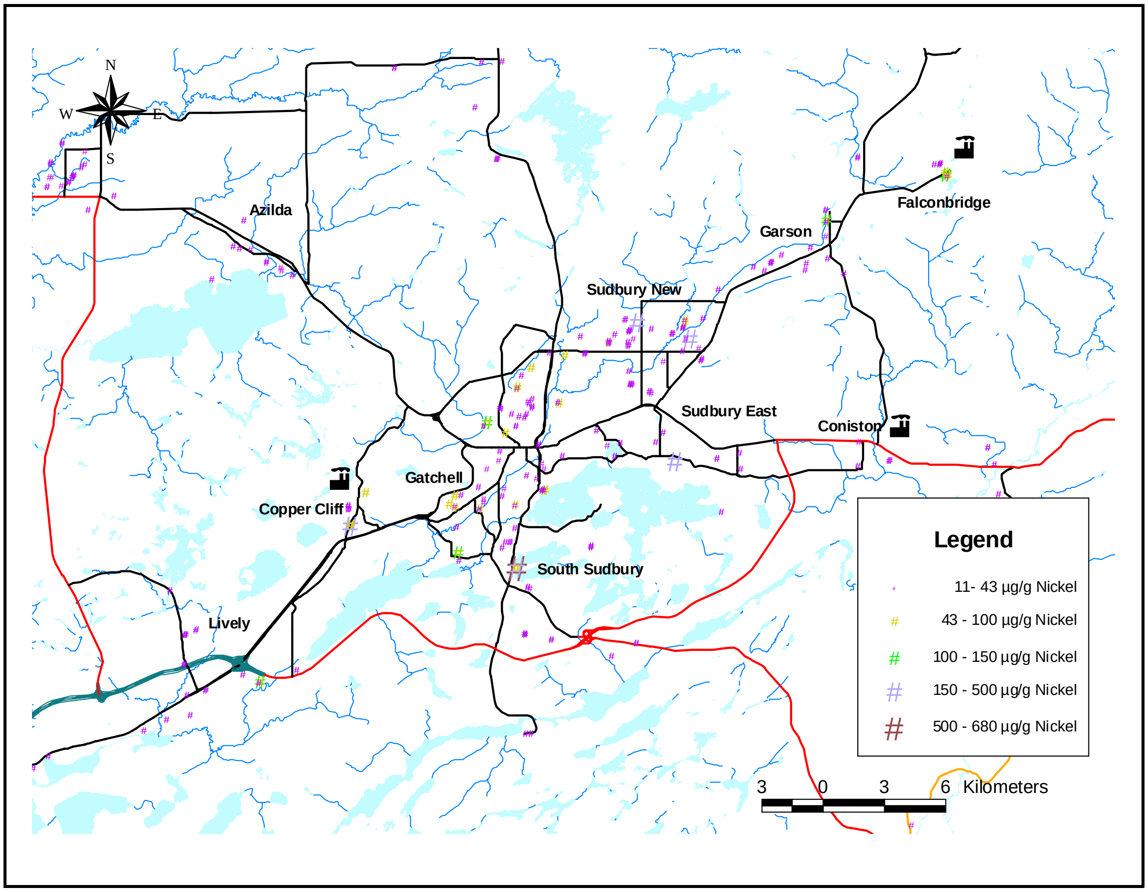


Figure 7.2.1.1: Nickel concentrations in play sand

There were only a few exceedences of the Ministry Table A guidelines in the Play Sand. There were nine exceedences of the nickel Table A value of 150 µg/g and one exceedence of the arsenic Table A value of 20 µg/g. Most of the Table F exceedences occurred for nickel and copper with 68 and 12 respectively. Arsenic exceeded Table F four times. Refer to Table 7.2.2.2 for a full listing of the Table A and F exceedences in Play Sand and Beach Sand. As was expected, two thirds of the Table F exceedences for nickel occurred in Copper Cliff , Falconbridge and the Sudbury Core. There were no Table F exceedences for nickel in Coniston but there has not been an active smelter there since the early 1970's. Most of the rest of the exceedences were in the Inner Sudbury Communities. There were four locations in the Inner Sudbury Communities with high nickel concentrations in Play Sand. In all four locations the nickel in the sand is as high or higher than the surrounding soil. The concentration of copper in these play sand locations was much lower than would normally be expected. There was no relationship between these locations and the three smelter communities. Refer to Figure 7.2.1.1 for a concentration dot map of nickel in Play Sand.

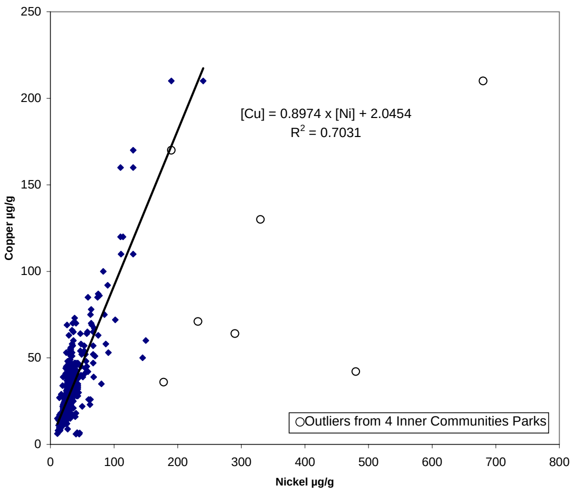


Fig. 7.2.1.2: Cu vs Ni, 0-5 cm, Play Sand

Nickel and copper were the only two elements related with smelter emissions that were strongly correlated with each other. The correlation was only moderate due to a number of high nickel outliers from the four locations mentioned above. The correlation was improved with the removal of these outliers from the data set. Refer to Figure 7.2.1.2 for the copper to nickel correlation in which the outliers were removed. All other strong correlations were related to the naturally occurring elements of aluminum, iron, magnesium and vanadium, refer to Section 10.4.7.

7.2.2 Beach Sand

There were only 42 beach sand samples from 22 beaches sampled in the City of Greater Sudbury. Fifteen of the beaches were located on Ramsey Lake with the rest scattered throughout the city. None of them were in the smelter communities of Coniston, Copper Cliff or Falconbridge.

While the maximum concentrations of nickel, copper, cobalt, arsenic and lead were higher in the play sand than the beach sand, generally the concentrations in the beach sand were similar to the play sand results up to the 95th percentile. Nickel and lead were marginally higher in the beach sand while copper, cobalt and arsenic were the same. Due to the small sample size and the concentration of the beach sites in one area more detailed comparisons will not be made. Refer to Table 7.2.2.1 for the abbreviated summary statistics and Section 10.3.3.1 for the detailed summary.

Table 7.2.2.1: Summary Statistics for Metals and Arsenic in Beach Sand in the City of Greater Sudbury.

	Al	**Sb**	**As**	**Ba**	**Cd**	**Ca**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Mo**	**Ni**	**Se**	**Sr**	**V**	**Zn**
Minimum	4100	0.4	2.5	14	0.4	1300	18	4	7	1000	3	2200	140	0.75	14	0.5	10	18	10
10th percentile	4920	0.4	2.5	17	0.4	2210	23	7	21	1200	4	2720	170	0.75	29	0.5	17	23	16
1st quartile	5200	0.4	2.5	19	0.4	2600	24	8	23	1300	4	3100	180	0.75	32	0.5	19	28	18
Median	6050	0.4	2.5	24	0.4	3000	30	9	29	1500	5	3550	190	0.75	38	0.5	24	31	23
3rd quartile	7300	0.4	2.5	27	0.4	3600	32	9	36	1700	6	4000	210	0.75	63	0.5	29	34	26
95th percentile	8980	0.4	2.5	35	0.4	4255	35	9	31	1800	6	4185	250	0.75	40	1.0	38	40	29
Maximum	1200	2.2	10	74	0.4	4600	39	12	130	1900	21	4500	250	0.75	170	1.0	39	40	39
Mean	6674	0.4	3.1	27	0.4	3093	29	9	36	1504	6	3517	197	0.75	49	0.6	25	31	23
CV (std. dev./mean)	28%	63%	54%	51%	0%	23%	17%	21%	69%	16%	64%	17%	14%	0%	58%	31%	29%	16%	29%
Skewness	1.3	6.5	2.7	2.3		0.0	0.1	-1.0	2.4	-0.2	2.4	-0.4	0.3		2.1	2.1	0.2	-0.4	0.4

All results are in µg/g dry weight. n = 42

As shown in Table 7.2.2.2, there was only one exceedence of Table A and that was for nickel. There were eighteen nickel, two copper and one antimony exceedences of Table F in the beach sand. Proportionally this was similar to the play sand samples.

Table 7.2.2.2: Summary of MOE Table F and Table A Exceedences for Sand Samples in the City of Greater Sudbury

Element	**Play Sand**		**Beach Sand**	
	Table F	**Table A**	**Table F**	**Table A**
Antimony	3 (1%)	0	1 (2%)	0
Arsenic	4 (1%)	1	0	0
Cadmium	0	0	0	0
Chromium	0	0	0	0
Cobalt	2	0	0	0
Copper	16 (3%)	0	2 (5%)	0
Lead	0	0	0	0
Molybdenum	1	0	0	0
Nickel	68 (12%)	9 (2%)	18 (43%)	1 (2%)
Selenium	2	0	0	0
Vanadium	0	0	0	0
Zinc	0	0	0	0
No. of Samples	550		42	

There was a strong correlation of nickel to copper in the beach sand, refer to Figure 7.2.2.1. There was also a moderate correlation with nickel and copper to lead in the beach sand. All other strong correlations were related to the naturally occurring elements of aluminum, iron, magnesium and vanadium. Refer to Section 10.4.8.

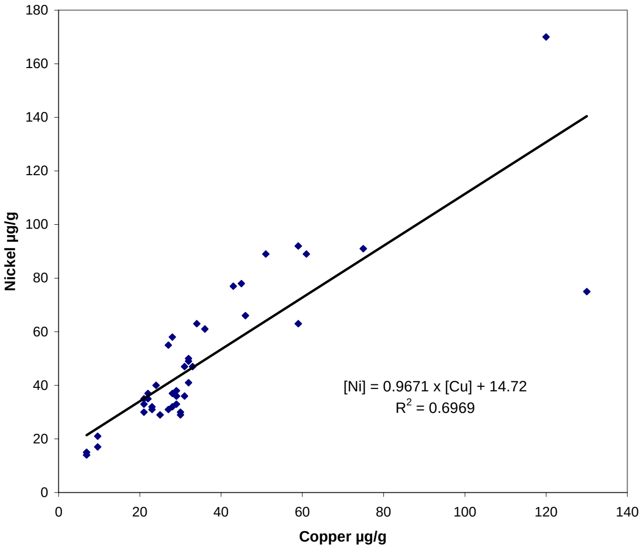


Figure 7.2.2.1: Cu vs Ni in Beach Sand

7.2.3 Playground Gravel

There were 107 playground gravel samples collected from 54 sampling locations. Ninety four percent of the samples were from schools and the remainder were from parks. Thirty two percent of the samples were from the Outer Sudbury Communities, 40% were from the Inner Sudbury Communities, 24% were from the Sudbury Core and the remaining 4% were from Coniston. Abbreviated summary statistics for the playground gravel results are given in Table 7.2.3.1 with the full summary statistics in Section 10.3.3.2.

Table 7.2.3.1: Summary Statistics for Metals and Arsenic in Playground Gravel in the City of Greater Sudbury.

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	4100	0.4	2.5	17	0.4	2000	17	3	11	8200	2	2100	120	0.75	17	0.5	10	11	10
10th percentile	5800	0.4	2.5	25	0.4	2700	22	5	17	11000	4	3200	160	0.75	25	0.5	20	23	17
1st quartile	6600	0.4	2.5	28	0.4	3400	25	6	26	13000	6	3800	170	0.75	34	0.5	26	26	22
Median	7800	0.4	2.5	34	0.4	4400	29	9	45	15000	8	4800	200	0.75	55	0.5	34	29	29
3rd quartile	9200	0.4	5.0	43	0.4	11000	34	12	83	18000	12	6100	230	0.75	93	0.5	69	33	37
95th percentile	12000	0.4	8.0	68	0.4	69000	43	22	197	23000	20	15000	280	1.97	190	1.0	240	42	58
Maximum	26000	1.5	17	200	1.0	250000	90	33	670	43000	32	26000	510	4.30	370	2.0	340	73	200
Mean	8171	0.4	3.7	39	0.4	14363	30	10	67	15688	10	6005	204	0.87	75	0.6	63	30	32
CV (std. dev./mean)	31%	33%	68%	52%	11%	231%	27%	55%	102	28%	54%	67%	24%	51%	82%	36%	106	27%	59%
Skewness	2.9	5.8	2.7	4.7	12.1	4.9	2.9	1.8	3.7	2.0	1.4	2.8	2.1	4.2	2.2	4.4	2.3	2.0	4.5

All results are in µg/g dry weight. n = 265

The concentration ranges of aluminum, chromium, iron, magnesium, manganese, vanadium and zinc in the playground gravel were similar to the concentration ranges found in the 0 - 5 cm parks, schools and daycare soil samples. Arsenic showed a similar pattern except for the maximum value in the soil being higher than the playground gravel. The concentrations ranges of barium, cadmium, selenium and strontium for the playground gravel were all lower. Most were below the detection limit for cadmium and selenium. Cobalt concentrations in the playground gravel were approximately two times higher than the soil from the minimum to the 95th percentile with the soil being higher above the 95th percentile. Nickel and copper concentrations in the playground gravel were slightly higher from the minimum to the median with the soil being slightly higher from the 75th percentile to the maximum concentrations. Generally, unlike the play and beach sand, there was little difference between the playground gravel and the park, school and daycare surface soil samples.

As with the play and beach sand the majority of the Table A and F exceedences occurred with nickel and copper, refer to Table 7.2.4.2. There were also a substantial number of cobalt Table F exceedences. There were 16 nickel and 3 copper Table A exceedences, and 93 nickel, 41 copper and

13 cobalt Table F exceedences out of 107 samples. There were no arsenic exceedences. The number of exceedences for playground gravel were higher than the play and beach sand and similar to the school soil samples.

The nickel and copper Table A and F exceedences in playground gravel were concentrated in the Sudbury Core, New and East Sudbury, and Coniston. Refer to Figure 7.2.3.1 for the nickel concentration dot map.

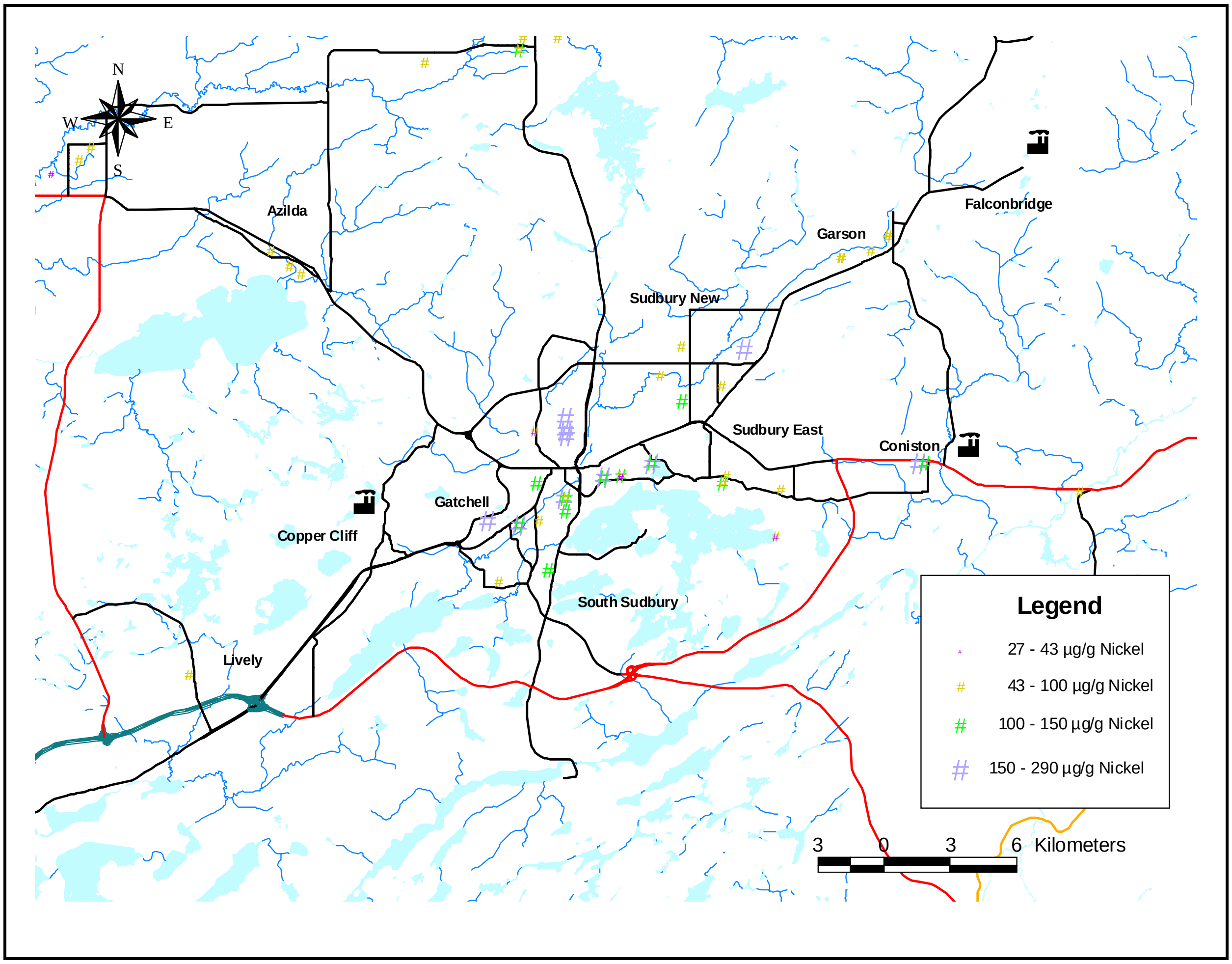


Figure 7.2.3.1: Nickel concentrations in playground gravel

As with the play sand, nickel and copper in playground gravel were the only two elements associated with smelter emissions that were strongly correlated with each other. All other strong correlations were related to the naturally occurring elements of aluminum, barium, chromium, iron, magnesium, manganese and vanadium. Refer to Section 10.4.10.

7.2.4 Crushed Stone

There were 158 ballfield crushed stone samples collected from 83 sampling locations. Seventy three percent of the samples were from parks and the remainder were from schools. Thirty one percent of the samples were from the Outer Sudbury Communities, 47% were from the Inner Sudbury Communities, 18% were from the Sudbury Core and the remaining 4% were from Coniston and Copper Cliff. Abbreviated summary statistics for the ballfield crushed stone results are given in Table 7.2.4.1 with the full summary statistics in Section 10.3.3.2.

Table 7.2.4.1: Summary Statistics for Metals and Arsenic in Baseball Infield Crushed Stone in the City of Greater Sudbury.

	Al	**Sb**	**As**	**Ba**	**Cd**	**Ca**	**Cr**	**Co**	**Cu**	**Fe**	**Pb**	**Mg**	**Mn**	**Mo**	**Ni**	**Se**	**Sr**	**V**	**Zn**
Minimum	4100	0.4	2.5	17	0.4	2000	17	3	11	8200	2	2100	120	0.75	17	0.5	15	11	10
10th percentile	5770	0.4	2.5	25	0.4	3270	21	5	15	10000	4	3100	150	0.75	23	0.5	26	20	15
1st quartile	6800	0.4	2.5	29	0.4	4600	24	5	20	12000	5	3700	160	0.75	28	0.5	37	24	19
Median	8000	0.4	2.5	36	0.4	8700	27	6	28	13500	6	5400	190	0.75	38	0.5	56	27	25
3rd quartile	9400	0.4	2.5	47	0.4	15000	30	9	51	15000	9	7500	220	0.75	64	0.5	110	30	30
95th percentile	12000	0.4	8.0	68	0.4	131450	36	11	101	19000	13	18150	270	2.11	140	1.0	270	36	34
Maximum	26000	1.5	17	200	1.0	250000	43	20	300	27000	32	26000	510	3.20	370	2.0	340	68	200
Mean	8366	0.4	3.5	42	0.4	21618	28	7	48	13932	8	6861	199	0.92	59	0.6	88	27	28
CV (std. dev./mean)	32%	36%	78%	55%	12%	192%	20%	41%	111%	23%	59%	72%	25%	53%	97%	33%	87%	26%	73%
Skewness	2.9	4.9	3.3	4.4	12.6	3.8	0.6	1.5	3.0	1.1	2.3	2.1	2.6	2.85	3.1	4.4	1.6	2.0	5.6

All results are in µg/g dry weight.   n = 157

The concentration ranges of calcium, magnesium and strontium are much higher in the ballfield crushed stone then in the park, school and daycare 0 - 5 cm soil results. This was expected as this crushed stone material is mostly limestone which is high in these elements. Aluminum, barium, iron, manganese, vanadium and zinc concentrations ranges were similar to the parks and school soil concentration ranges. The concentration range for chromium was slightly lower and arsenic, cadmium, cobalt, copper, lead and nickel were considerably lower for the crushed stone compared to the parks and school 0 - 5 cm soil. The difference was not as large as for the play sand but larger than the playground gravel.

There were fewer exceedences of the Ministry Table A and F criteria in the ballfield crushed stone than for the playground gravel. There were 9 nickel and 3 copper Table A exceedences and 63 nickel and 20 copper Table F exceedences out of 158 samples. There were no cobalt or arsenic exceedences. Refer to Table 7.2.4.2.

The largest number of exceedences of nickel and copper in the ballfield crushed stone occurred in Copper Cliff, Coniston and the Sudbury Core. There were still a number of exceedences in Lively, East Sudbury and New Sudbury but the concentrations were lower. Refer to Figure 7.2.4.1 for the concentrations of nickel in ballfield crushed stone.

Table 7.2.4.2: Summary of MOE Table F and Table A Exceedences for Gravel Samples in the City of Greater Sudbury

Element	Playground Gravel		Ballfield Crushed	
	Table F	Table A	Table F	Table A
Antimony	1 (1%)	0	4 (3%)	0
Arsenic	0	0	0	0
Cadmium	0	0	0	0
Chromium	2 (2%)	0	0	0
Cobalt	13 (12%)	0	0	0
Copper	41 (38%)	3 (3%)	20 (13%)	3 (2%)
Lead	0	0	0	0
Molybdenum	1 (1%)	0	3 (2%)	0
Nickel	93 (87%)	16 (15%)	63 (40%)	9 (6%)
Selenium	1 (1%)	0	1 (1%)	0
Vanadium	0	0	0	0
Zinc	0	0	1 (1%)	0
No. of Samples	107		158	

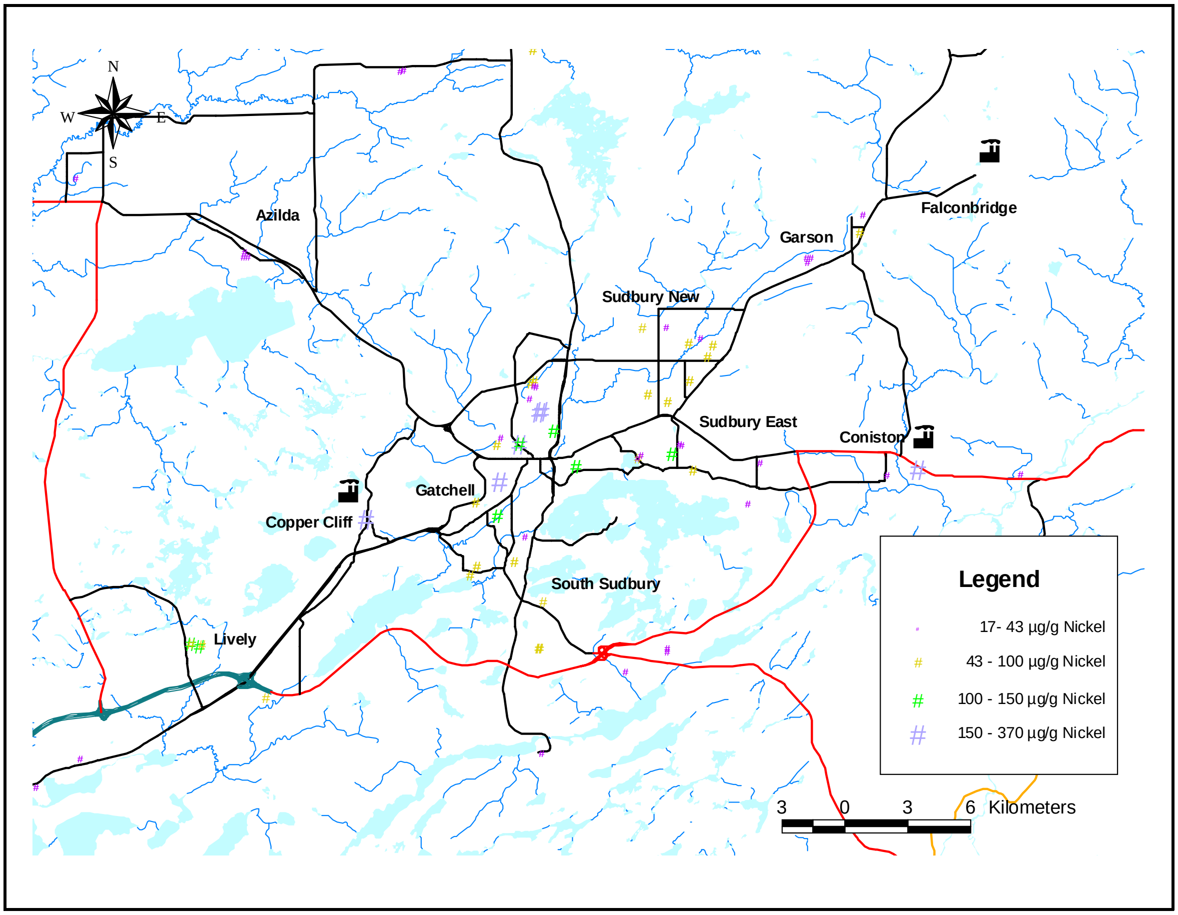


Figure 7.2.4.1: Nickel concentration in crushed stone.

Unlike play sand and playground gravel, nickel, copper, cobalt and lead were strongly correlated with each other in the ballfield crushed stone. Nickel and copper showed the strongest correlation, Refer to Figure 7.2.4.2. Also unlike the play sand and playground gravel there were fewer strong correlations between the naturally occurring elements. The strongest of these correlations were with calcium, magnesium and strontium as would be expected with crushed limestone. Refer to Section 10.4.9.

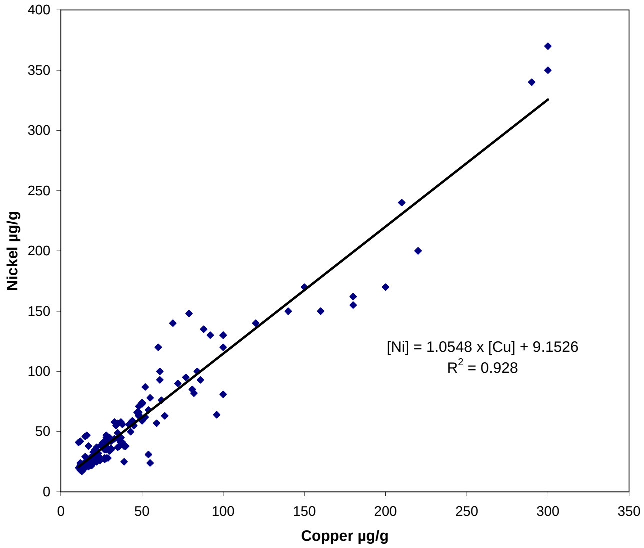


Figure 7.2.4.2: Cu vs Ni in Crushed Stone

7.2.5 Summary

In summary, the concentrations of elements associated with smelter emissions in the play and beach sand are quite low. Nickel and copper were the only elements that were consistently elevated in the sand type samples and occurred in the same ratios that have been observed in soil, see Section 7.2 for soil discussion. While nickel and copper were above Table F in many sand samples there were only a few above Table A criteria and all of the samples were below 1000 µg/g. There were four play sand samples from the park on Parkinson Street in Falconbridge that had substantially elevated arsenic but these were still well below the adjacent soil concentrations.

The playground gravel samples were essentially the same as the park, school and daycare 0 - 5 cm soil samples. They only differed at the high end where the park, school and daycare 0 - 5 cm soil samples were considerably higher than the playground gravel samples. The difference at the high end occurs because there were no gravel playgrounds in either Copper Cliff or Falconbridge where the highest soil levels are found. The ballfield crushed stone samples were in between the play sand and playground gravel concentrations. For play sand, beach sand, playground gravel and ballfield crushed stone the highest concentrations of nickel and copper were found in Copper Cliff, Coniston, Falconbridge and the Sudbury Core with the next highest concentrations in the Inner Sudbury Communities. The Outer Sudbury Communities had the lowest concentrations. The range of concentrations observed in the sand and gravel samples, for the elements associated with smelter emissions, was considerably less than the range of concentrations observed for urban soil.

7.3 Undisturbed Natural Soil

This discussion focuses on the undisturbed natural soil samples collected by the Ministry in the City of Greater Sudbury in 2001. Undisturbed natural soil samples were generally collected from undeveloped, naturally vegetated areas within the City of Greater Sudbury urban area. at up to three depth intervals, 0 - 5 cm, 5 - 10 cm and 10 - 20 cm. Vegetation cover was generally comprised of a naturally occurring mixture of woody shrubs and trees. Undisturbed natural soil samples consisted of all material less than 2 millimetres in diameter and ranged in texture from sand to silty clays.

There were 42 undisturbed natural soil samples collected from seven sampling locations in three parks in the City of Greater Sudbury: Bell Park, Moonlight Beach Park and Lake Laurentian Conservation Area. Bell Park was located in the community grouping of the Sudbury Core while the remaining two parks were located in the community grouping of Inner Sudbury Communities. The concentrations of the undisturbed soil samples were compared to urban soil collected from the Inner Sudbury Communities and the Sudbury Core. Due to the low sample size of the undisturbed natural soil, comparisons with urban soil are limited. Concentrations of the undisturbed natural soil samples were also compared to urban soil collected adjacent to the undisturbed natural soil sampling locations. Sample sizes of these groups of samples were similar.

In the undisturbed surface soil, concentrations of nickel, copper, cobalt, arsenic, lead, cadmium, selenium, and to a lesser extent zinc and iron, were substantially higher compared to the Inner Sudbury Communities and varied between higher and marginally higher than the Sudbury Core. Concentrations of nickel, copper, cobalt and arsenic were four to thirteen times higher starting from the minimum to median values compared to the Inner Sudbury Communities, while concentrations of lead, cadmium, and selenium were two to four times higher from the minimum to median values. Concentrations of iron and zinc were only marginally higher from the minimum value onwards.

At 10 - 20 cm, concentrations of zinc were marginally higher in the undisturbed soil from the minimum value with the exception of the maximum value. Concentrations of nickel, copper, arsenic and lead were similar until the 75th to 95th percentile where these elements were lower in the undisturbed soil. Concentrations of cobalt, selenium and iron were similar to the Inner Sudbury Communities. Concentrations of cadmium were below the analytical MDL in the undisturbed natural soil.

Compared to the Sudbury Core, surface concentrations of nickel, copper, cobalt and arsenic were two to four times higher starting from the minimum value, while concentrations of lead, cadmium, selenium and iron were only marginally higher from the minimum to median value, generally excluding the maximum values. At 10 - 20 cm, concentrations of nickel, copper, arsenic and lead were lower starting from the 25th percentile while cobalt, selenium and zinc were similar up until the 95th percentile and or maximum value where these elements were lower by half. Concentrations of iron were similar to the Sudbury Core while concentrations of cadmium were below the analytical MDL. Refer to Table 7.3.1.

Concentrations of nickel, copper, cobalt, arsenic, lead, selenium, cadmium, zinc and iron in the undisturbed natural soil were higher than urban soil samples collected from adjacent sampling locations. Concentrations of nickel, copper, cobalt, arsenic and lead were twice as high from the 25th percentile and up to five times higher from the 95th percentile. All other elements were marginally higher from the 25th to 75th percentile on. At 10 - 20 cm, concentrations of these nine elements were either similar or lower than concentrations found in adjacent urban soil.

Table 7.3.1: Summary Statistics for Metals and Arsenic in Undisturbed Natural Soil in the City of Greater Sudbury

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
0 to 5 cm Undisturbed Natural Soil,				n = 14															
Minimum	5200	0.4	6.0	67	0.4	1700	19	7	78	14000	8	1100	130	0.75	110	0.5	18	17	31
10th percentile	8160	0.4	7.2	70	0.4	2230	21	13	120	14600	17	1260	140	0.75	157	0.5	26	24	34
1st quartile	9100	0.4	21	71	0.4	2300	25	18	280	16000	30	1500	150	0.75	380	1.0	31	24	36
Median	11000	0.4	25	82	0.9	2850	33	26	545	19000	53	2350	265	0.75	638	1.8	33	31	56
3rd quartile	15000	1.1	41	100	1.4	7400	42	48	940	30000	94	3400	410	0.75	1215	2.0	47	34	64
95th percentile	15350	3.6	59	134	2.7	19200	50	100	1605	46000	147	3935	625	1.29	3249	4.5	50	36	134
Maximum	16000	4.3	60	140	3	27000	51	100	1800	46000	156	4000	690	2.30	3284	5.5	51	36	140
Mean	11407	1.1	29	89	1.1	5943	34	37	660	23286	63	2443	322	0.86	983	1.9	36	29	61
CV (std. dev./mean)	28%	114%	59%	26%	78%	119%	30%	82%	82%	47%	75%	40%	57%	48%	106%	74%	28%	19%	56%
Skewness	-0.2	2.2	0.5	1.2	1.3	2.5	0.3	1.5	1.0	1.4	0.9	0.3	0.9	3.7	1.7	1.5	0.3	-0.8	1.6
5 to 10 cm Undisturbed Natural Soil,				n = 14															
Minimum	6600	0.4	2.5	40	0.4	1200	20	5	41	10000	7	1500	110	0.75	68	0.5	16	20	21
10th percentile	8830	0.4	2.5	45	0.4	1830	24	7	61	13600	8	1690	123	0.75	76	0.5	26	24	31
1st quartile	13000	0.4	2.5	47	0.4	2100	28	8	64	15000	9	1900	160	0.75	81	0.5	28	28	38
Median	14500	0.4	7.0	79	0.4	2450	34	12	85	17000	12	2400	270	0.75	105	1.0	32	34	41
3rd quartile	17000	0.4	12	110	0.4	4400	48	15	240	19000	18	4100	340	0.75	145	1.0	49	40	48
95th percentile	21400	0.8	19	148	1.0	4835	59	27	484	23000	43	5255	504	0.75	588	2.0	56	43	96
Maximum	24000	1.6	23	180	1.0	4900	68	28	510	23000	47	6100	510	0.75	594	2.0	57	46	120
Mean	14750	0.5	8.9	85	0.5	2993	38	13	168	17286	18	3036	269	0.75	191	1.0	36	33	49
CV (std. dev./mean)	32%	66%	72%	49%	46%	41%	36%	53%	94%	21%	77%	47%	50%	0%	98%	52%	35%	23%	51%
Skewness	0.1	3.7	1.0	0.9	1.6	0.4	0.7	1.1	1.4	0.0	1.5	0.8	0.6		1.7	1.0	0.6	-0.2	2
10 to 20 cm Undisturbed Natural Soil,				n = 14															
Minimum	10000	0.4	2.5	46	0.4	1700	28	6	22	14000	5	2300	110	0.75	52	0.5	23	28	24
10th percentile	12300	0.4	2.5	47	0.4	1930	31	7	24	16000	6	2360	130	0.75	52	0.5	25	29	34
1st quartile	14000	0.4	2.5	49	0.4	2100	32	9	28	16000	7	2500	140	0.75	54	0.5	28	31	38
Median	17000	0.4	2.5	62	0.4	2650	40	10	52	18500	8	3150	190	0.75	61	0.5	34	36	43
3rd quartile	20000	0.4	2.5	110	0.4	4100	50	11	68	20000	8	5000	290	0.75	84	1.0	51	41	56
95th percentile	23700	1.1	7.1	134	0.4	4435	58	12	89	21700	10	5715	331	0.75	98	1.0	55	46	68
Maximum	25000	1.4	9.0	140	0.4	4500	61	13	110	23000	12	6300	370	0.75	104	1.0	56	49	71
Mean	17071	0.5	3.5	80	0.4	2993	42	10	52	18357	8	3750	218	0.75	69	0.7	37	36	47
CV (std. dev./mean)	25%	59%	59%	43%	0%	35%	25%	22%	48%	13%	21%	35%	39%	0%	27%	36%	32%	18%	29%
Skewness	0.3	2.6	2.1	0.6		0.3	0.5	-0.3	0.8	0.1	1.1	0.6	0.3		0.8	0.3	0.6	0.5	0.4

All results are in µg/g dry weight.

For undisturbed natural soil, pH analysis was completed on 3 samples and pH ranged from 4.47 to 5.1. The Ministry *Guideline for Use at Contaminated Sites in Ontario* (MOE 1997) states that Table A soil criteria for inorganics apply only when the soil pH is between 5.0 and 9.0. No undisturbed natural soil samples analyzed had a pH value that exceeded 9.0, however two undisturbed natural soil samples had pH values below 5.0. These two 0 - 5 cm samples had pH values of 4.47 and 4.86 and were located in Lake Laurentian Conservation Area and Bell Park, respectively. The third sample, collected at 10 - 20 cm, had a pH value of 5.1 and was located in Moonlight Beach Park. The pH values in all three undisturbed natural soil samples analyzed were lower than the pH values present in adjacent sand and urban soil samples. Refer to Section 10.3.6 for descriptive statistics and box and whisker plots.

Table 7.3.2 summarizes the number of undisturbed natural soil samples that exceed the Table F and Table A criteria. Nickel, copper and arsenic concentrations exceeded Table A at surface and 5 - 10 cm while cobalt exceeded Table A only at surface. No Table A exceedances for any element were noted at 10 - 20 cm. No other elements exceeded Table A at any depth. In total, nine elements exceeded Table F criteria and are listed in Table 7.3.2. At 0 - 5 cm, 93% of the undisturbed natural soil samples exceeded Table A and 100% exceeded Table F for nickel. The number of exceedences of Table A decreased substantially with depth while the number of Table F exceedances stayed constant. At 0 - 5 cm, 79% of the undisturbed natural soil samples exceeded Table A and 79 to 90% exceeded Table F for copper and arsenic, respectively. Nickel, copper, cobalt, arsenic, lead, selenium and iron concentrations, at surface, were considerably higher at stations 5030455 and 5030456 located in Bell Park compared to all other undisturbed natural soil sampling locations. Cadmium and zinc concentrations were also higher at station 5030455 in Bell Park compared to all other undisturbed soil sampling locations.

Table 7.3.2: Summary of MOE Table F and Table A Exceedences for Undisturbed Natural Soil Samples

Element	Table F			Table A		
	0 to 5 cm	5 to 10 cm	10 to 20 cm	0 to 5 cm	5 to 10 cm	10 to 20 cm
Antimony	4 (29%)	1 (7%)	1 (7%)	0	0	0
Arsenic	11 (79%)	1 (7%)	0	11 (79%)	1 (7%)	0
Cadmium	5 (36%)	0	0	0	0	0
Cobalt	8 (57%)	2 (14%)	0	4 (29%)	0	0
Copper	13 (93%)	7 (50%)	1 (7%)	11 (79%)	4 (29%)	0
Lead	2 (14%)	0	0	0	0	0
Molybdenum	1 (7%)	0	0	0	0	0
Nickel	14 (100%)	14 (100%)	14 (100%)	13 (93%)	3 (21%)	0
Selenium	7 (50%)	2 (14%)	0	0	0	0
No. of Samples	14	14	14	14	14	14

In the undisturbed natural soil, nickel, copper, cobalt, arsenic, lead, selenium, cadmium and iron showed a strong visual trend of decreasing concentration with depth, consistent with aerial deposition. Average concentrations at surface for nickel and copper were 12.7 to 14.3 times the average concentrations at 10 - 20 cm. Average concentrations at surface for arsenic and lead were 8.2 to 8.4 times the average concentrations at 10 - 20 cm. For cobalt, selenium, cadmium and iron, average concentrations were 1.3 to 3.8 times greater at surface than at 10 - 20 cm. The average concentrations for selenium and cadmium below surface, however, were at or below the analytical MDL. Figure 7.3.1 depicts the depth profile for nickel in undisturbed natural soil.

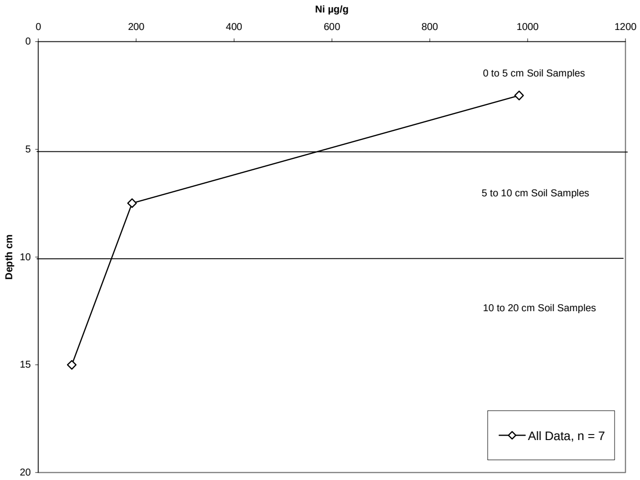


Figure 7.3.1: Undisturbed Natural Soil, Ni depth profiles, All Data

Unlike the urban soil samples, trends of maximum concentrations occurring below surface, at either 5 - 10 cm or 10 - 20 cm, were not generally observed for the undisturbed natural soil. This may be the result of minimal disturbance occurring at the undisturbed natural soil sample locations or the small sample size. These sample locations were located in undeveloped, naturally vegetated areas of parks within the City of Greater Sudbury. Disturbance of the soil at these sample locations by anthropogenic activities, such as landscaping, is unlikely to have occurred. A lack of anthropogenic disturbance may have resulted in metals and arsenic accumulation at surface in the undisturbed natural soil. Additionally, high organic content is often observed at the surface in undeveloped, naturally vegetated soil. Metals and arsenic will often bind with organic content in soil, resulting in accumulation of these elements. Total organic content (TOC) was only analyzed for two surface, undisturbed natural soil samples. The TOC results from these two samples were the highest for undisturbed natural soil, however, the small amount of data available precludes any meaningful interpretation.

Average aluminum, and to a lesser extent chromium and vanadium concentrations, showed a visual trend of increasing concentration with depth (1.2 to 1.5 times). Average zinc concentrations showed no observable change with depth.

Refer to Section 10.5.7 for graphs of the depth profiles for the elements discussed above.

In summary, undisturbed natural soil samples were collected from seven sampling locations in the Inner Sudbury Communities and the Sudbury Core. Generally, surface concentrations of nickel, copper, cobalt, arsenic, lead, cadmium, selenium, iron and zinc were higher in the undisturbed natural soil than in urban soil collected from adjacent sampling locations. These elements, with the exception of zinc, were also higher in the undisturbed natural soil compared to urban soil collected throughout both the Inner Sudbury Communities and the Sudbury Core. At depth, concentrations of these elements in undisturbed natural soil were generally similar or lower than concentrations in adjacent urban soil or in urban soil collected throughout the Inner Sudbury Communities and the Sudbury Core. The pH in undisturbed natural soil was lower than the pH in adjacent sand and urban soil samples.

In the undisturbed natural soil samples, nickel, copper and arsenic concentrations exceeded Table A at surface and 5 - 10 cm while cobalt exceeded Table A only at surface. No Table A exceedances for any element were noted at 10 - 20 cm. No other elements exceeded Table A at any depth while nine elements exceeded Table F. A strong trend of aerial deposition from surface was observed in all undisturbed natural soil sampling locations. Unlike in the urban soil samples, trends of maximum concentrations occurring below surface, at either 5 - 10 cm or 10 - 20 cm, were not generally observed for the undisturbed natural soil. This may be the result of minimal disturbance occurring at the undisturbed natural soil sample locations resulting in metals and arsenic accumulation at surface or the small sample size. In the undisturbed natural soil, nickel, copper, cobalt, arsenic, lead, selenium, cadmium and iron showed a strong visual trend of decreasing concentration with depth, consistent with aerial deposition. Average concentrations at surface for nickel and copper were 12.7 to 14.3 times the average concentrations at 10 - 20 cm. Average aluminum, and to a lesser extent chromium and vanadium concentrations, showed a trend of increasing concentration with depth (1.2 to 1.5 times). Average zinc concentrations showed no observable change with depth.

7.4 Commercial and Residential Produce

The Ministry and other institutions have collected garden produce and wild berries in the Sudbury area on a number of occasions. In most of these cases the collections were limited to specific areas and did not look at the community as a whole. In the Ministry's case, the two largest studies had been conducted in the community of Gatchell in 1971 and 1993 (MOE 1976 and MOE 1993b). As part of the 2001 soil survey, a preliminary sampling of residential garden vegetables and soil in five local communities and in commercial market gardens, berry farms and wild blueberries across the City of Greater Sudbury was conducted in the month of August for screening purposes only.

There were a number of areas where the 2001 produce sampling program was deficient. First, all of the produce was collected over a very narrow time span. This meant that certain produce, such as strawberries, were well past the normal harvest period and others were not fully developed or ripe. Second, for the residential garden samples, the volume of sample available was very small resulting in only small single samples being collected. Additionally, there was a wide range of vegetables grown in the residential gardens with no one vegetable grown at all locations. Arrangements had not been made in the spring to have the property owners plant sufficient or similar produce to meet the needs of the study. This was not an issue for the market garden vegetables and commercial berries where large duplicate samples were collected. Thirdly, no residential control properties were sampled for comparison purposes. Lastly, the sampling program did not sample enough properties to ensure an adequate representation of residential gardens within the City of Greater Sudbury. For example, Gatchell, which has a large number of residential gardens, only had three properties sampled while the Sudbury Core, Outer and Inner Sudbury Communities had no residential gardens sampled.

In addition to these deficiencies in the sampling program design, there were two laboratory quality control issues with the produce data. These two issues are dealt with in detail in Appendix G (MOE 2003). The first and most serious issue was the contamination of a small number of the samples with nickel, copper and lead during the preparation of the samples. It was determined that a small percentage of the residential produce samples were processed with a small seldomly used grinder that could result in metal particles wearing off the grinder and entering the samples. Although, it was possible to determine which samples were most likely impacted by the use of this grinder, it is possible that some samples were not identified. None of the commercial produce were processed using this equipment and were therefore not affected.

The second laboratory quality control issue dealt with the presence of magnetic particles in the produce samples. Due to the possible presence of metal particles from the small grinder or from staples used to seal the sample containers, all produce samples were examined for magnetic particles. Magnetic particles were found to be present in the produce samples and removed as outlined in Appendix G (MOE 2003). Further analysis showed that while some of the magnetic particles did originate from the small grinder or the staples, the majority of the particles were from environmental sources such as mineral soil and / or resulting from a high temperature furnace. Therefore, the removal of all magnetic particles artificially lowered the concentrations of certain elements in the samples. Refer to Appendix G for further discussion.

The two laboratory quality control issues, in addition to the deficiencies in the sampling program design, resulted in the residential produce data having limited usefulness. The residential produce data should only be used to indicate whether residential produce was accumulating metals and arsenic. It can not be used to determine the exposure risk for consumption of this produce or produce grown in the City of Greater Sudbury.

For commercial agricultural and urban garden soil, pH analysis was completed on 7 samples and pH ranged from 5.1 to 7.0. The Ministry *Guideline for Use at Contaminated Sites in Ontario* (MOE 1997) states that Table A soil criteria for inorganics apply only when the soil pH is between 5.0 and 9.0. The pH values for all commercial agricultural and urban garden soil analyzed were within this range. Refer to Section 10.3.6 for descriptive statistics and box and whisker plots.

7.4.1 Commercial Produce
7.4.1.1 Market Gardens

Nickel was the only element that was elevated above Ministry background criteria in just over half of the market garden soils collected. Nickel concentrations ranged from 27 to 62 µg/g, with a mean of 44 µg/g. The market garden control site had nickel concentrations ranging from 9 to 10 µg/g, with a mean of 9.5 µg/g. No other elements were elevated above background and the remaining elements were comparable to concentrations found at the control sites. Refer to Table 7.4.1.1.1 below for an abbreviated summary of the Market Garden soil results, and Section 10.3.2 and Appendix D for the detailed results.

Table 7.4.1.1.1: Summary Statistics for Metals and Arsenic in 0-15 cm Soil Samples from Market Gardens in the City of Greater Sudbury - 2001..

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5300	0.4	2.5	19	0.4	2600	16	3	26	8500	5	1700	100	0.75	27	0.5	13	18	19
10th percentile	6080	0.4	2.5	24	0.4	2690	17	4	28	9430	5	1700	110	0.75	35	0.5	16	20	20
1st quartile	6400	0.4	5.0	27	0.4	3000	19	4	31	10000	7	1800	120	0.75	38	0.5	17	22	22
Median	7750	0.4	6.0	29	0.4	3650	21	4	35	10000	8	1900	125	0.75	44	0.5	19	23	27
3rd quartile	9350	0.4	7.0	32	0.4	3950	23	4	42	11000	10	2100	150	0.75	50	0.5	28	25	30
95th percentile	11000	0.4	9.0	39	0.5	4820	25	5	44	12050	13	2310	201	0.75	59	0.5	34	28	34
Maximum	11000	0.4	9.0	44	1.9	5200	26	5	46	13000	17	2500	220	0.75	62	0.5	36	28	43
Mean	7830	0.4	5.7	29	0.5	3595	21	4	36	10390	9	1960	139	0.75	44	0.5	21	23	27
CV (std. dev./mean)	22%	0%	36%	20%	71%	20%	14%	11%	17%	10%	36%	12%	24%	0%	21%	0%	32%	11%	23%
Skewness	0.4		-0.2	0.6	4.5	0.5	0.0	0.0	0.1	0.7	1.1	0.8	1.4		0.2		0.9	0.1	0.9

There were 20 samples. Concentrations are in µg/g dry wt.

An abbreviated summary of the chemical analysis of the Market Garden produce collected in Sudbury are presented in Table 7.4.1.1.2 and are expressed as µg/g dry weight. Refer to Section 10.3.4 and Appendix D for the detailed results. Neither Provincial, Federal nor International guidelines are available for comparison. However, comparison can be made using the produce collected from the market garden control site located approximately 245 km west of Copper Cliff.

Table 7.4.1.1.2: Summary Statistics for All Market Garden Vegetables Collected in the City of Greater Sudbury - 2001.

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5.0	0.2	0.2	0.5	6.0	0.1	220	0.5	0.2	4.0	23	0.5	1100	3.7	0.2	0.5	0.2	0.5	0.5	12
10th percentile	5.0	0.2	0.2	0.6	7.6	0.1	319	0.5	0.2	6.1	36	0.5	1130	8.1	0.2	1.0	0.2	0.8	0.5	14
1st quartile	9.0	0.2	0.2	1.0	13	0.1	1050	0.5	0.2	7.8	58	0.5	1450	9.7	0.2	3.3	0.2	1.2	0.5	19
Median	40	0.2	0.2	4.8	16	0.2	2700	0.5	0.2	9.5	98	0.5	2550	22	0.3	6.0	0.2	6.8	0.5	30
3rd quartile	110	0.2	0.2	14	19	0.4	4650	0.7	0.5	11	185	0.5	3700	56	0.7	15	0.2	12	0.5	33
95th percentile	360	0.2	0.6	40	26	1.8	11000	1.1	1.1	16	378	0.9	6410	176	1.1	43	0.2	30	0.9	48
Maximum	1200	0.2	1.0	92	28	2.3	14000	3.4	1.1	17	1300	3.1	15000	230	2.6	45	0.2	43	2.9	61
Mean	112	0.2	0.3	12	16	0.4	3799	0.7	0.4	9.9	162	0.6	3107	45	0.5	11	0.2	9.0	0.6	28
CV (std. dev./mean)	192%	0%	63%	151%	36%	133%	98%	71%	75%	33%	138%	68%	86%	125%	104%	110%	0%	103%	70%	41%
Skewness	3.9		3.5	2.9	0.0	2.1	1.3	4.6	1.4	0.5	3.9	6.0	3.0	1.8	2.8	1.8		1.9	4.8	0.7

There were 44 samples collected from 6 market vegetable producers. Concentrations are in µg/g dry wt.

Unfortunately, control data is not available for all produce collected such as banana pepper, pumpkin, radish, yellow tomato, potato, and zucchini as these vegetables were not grown at the market garden control site.

The nickel content of vegetables collected from the City of Greater Sudbury was higher than what was determined from vegetables collected from the control sites. The nickel concentration for yellow beans grown in Sudbury ranged from 7.1 to 22 µg/g, with a mean of 14 µg/g, while the yellow bean control had a nickel concentration of 0.7 µg/g. The nickel range in carrots sampled in Sudbury was 3.2 to 43 µg/g, with a mean of 29 µg/g, while the carrot from the control area had a nickel concentration of 0.5 µg/g. Nickel concentration in lettuce ranged from 3.2 to 12 µg/g, for a mean of 8.0 µg/g, while the lettuce control had a nickel concentration of 3.7 µg/g. The nickel concentrations in tomatoes from the Sudbury area ranged from 0.5 to 45 µg/g, for a mean of 16 µg/g, while the tomato sampled in the control area had a nickel concentration of 1.1 µg/g. Nickel and copper content found in the control vegetables are within the international content ranges reported in plant foodstuffs of similar vegetable species from unpolluted regions (Kabata-Pendias 1994). Antimony (Sb), beryllium (Be), and selenium (Se) had values that were (0.2)<W, indicating they were less than the laboratory detection limit.

7.4.1.2 Commercial Berry Farms

Nickel and copper are the only elements that were found to be elevated above provincial background levels in soil at the commercial berry producer sites. Soil copper concentrations at the Sudbury sites ranged from 20 to 72 µg/g, for a mean of 31 µg/g, while the control site had soil copper concentrations of 1.0 to 5.0 µg/g, for a mean of 2.4 µg/g. Nickel concentrations at the Sudbury sites ranged from 29 to 52 µg/g, for a mean of 39 µg/g, while the control sites had nickel concentrations of 6 to 9 µg/g, for a mean of 7.2 µg/g. Refer to Table 7.4.1.2.1 for an abbreviated set of soil results and Section 10.3.2 and Appendix D for detailed results.

Table 7.4.1.2.1: Summary Statistics for Metals and Arsenic 0-15 cm Soil Samples from Commercial Berry Producers in the City of Greater Sudbury -

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5900	0.4	2.5	18	0.4	550	13	3	20	7100	7	790	35	0.75	29	0.5	10	14	11
10th percentile	6320	0.4	2.5	22	0.4	1420	14	3	22	7810	7	957	64	0.75	31	0.5	10	17	14
1st quartile	6650	0.4	2.5	24	0.4	1800	18	3	25	8400	7	1350	78	0.75	33	0.5	10	18	15
Median	7300	0.4	5.0	27	0.4	2100	19	4	29	9100	8	1600	110	0.75	39	0.5	10	19	18
3rd quartile	8200	0.4	7.0	33	0.4	2900	21	4	35	9950	10	1800	130	0.75	42	0.5	11	20	24
95th percentile	1280	0.4	9.5	36	0.4	4595	26	5	51	1570	17	2635	170	0.75	50	1	15	22	33
Maximum	1600	0.4	10	39	0.4	5800	27	5	72	2100	18	2900	180	0.75	52	1	17	23	39
Mean	7903	0.4	5.0	28	0.4	2411	19	4	31	9759	9	1660	106	0.75	39	0.5	11	19	20
CV (std. dev./mean)	28%	0%	49%	20%	0%	46%	19%	18%	36%	30%	35%	32%	35%	0%	17%	27%	17%	10%	34%
Skewness	2.7		0.4	0.1		1.3	0.6	0.3	2.4	3.0	1.8	0.7	0.1		0.5	2.9	2.1	-0.1	1.1

There were 32 samples. Concentrations are in µg/g dry wt.

An abbreviated summary of the chemical analysis of the Commercial Berry produce collected in Sudbury are presented in Table 7.4.1.2.2 and 7.4.1.2.3 and are expressed as µg/g dry weight. Refer to Section 10.3.4 and Appendix D for the detailed results. Currently, there are not any Provincial, Federal nor International human health guidelines available for comparison. However, comparison can be made using the berries collected from commercial berry control sites located approximately 125 and 245 km west of Copper Cliff.

Table 7.4.1.2.2: Summary Statistics for Metals and Arsenic for Commercial Raspberries Collected in the City of Greater Sudbury - 2001.

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5	0.2	0.2	1	5	0.1	930	0.5	0.2	4.1	23	0.5	900	11	0.2	4.6	0.2	0.9	0.5	9
10th percentile	5	0.2	0.2	1.4	6.0	0.1	1050	0.5	0.2	4.5	24	0.5	945	14	0.2	5.2	0.2	1.3	0.5	10
1st quartile	5	0.2	0.2	2.0	6.5	0.1	1250	0.5	0.2	4.6	28	0.5	970	15	0.2	5.7	0.2	1.8	0.5	11
Median	5	0.2	0.2	3.7	7.0	0.1	1500	0.5	0.2	5.1	32	0.5	1050	17	0.4	6.5	0.2	2.2	0.5	13
3rd quartile	6	0.2	0.2	5.7	9.0	0.1	1700	0.5	0.2	5.6	34	0.6	1450	37	0.5	7.7	0.2	2.9	0.5	13
95th percentile	11	0.2	0.2	7.9	11	0.3	1750	0.5	0.2	6.0	47	0.7	1525	65	1.0	9.1	0.2	6.1	0.5	18
Maximum	12	0.2	0.2	8.4	11	0.8	1900	0.5	0.3	6.2	68	1.1	1600	84	1.1	9.6	0.2	9.5	0.5	20
Mean	6	0.2	0.2	4.0	7.8	0.1	1452	0.5	0.2	5.1	33	0.6	1177	27	0.4	6.7	0.2	2.7	0.5	13
CV (std. dev./mean)	38%	0%	0%	61%	25%	122%	20%	0%	12%	11%	31%	27%	21%	79%	63%	22%	0%	75%	0%	21%
Skewness	1.8			0.4	0.6	4.0	-0.5		4.0	0.2	2.7	3.6	0.5	1.7	1.5	0.6		2.7		1.4

16 raspberry samples were collected. Concentrations are in µg/g dry wt.

Table 7.4.1.2.3: Summary Statistics for Metals and Arsenic for Commercial Strawberries Collected in the City of Greater Sudbury - 2001.

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5	0.2	0.2	3.9	6	0.1	920	0.5	0.2	2	13	0.5	510	4.6	0.2	1.4	0.2	1	0.5	4
10th percentile	5	0.2	0.2	4.3	6.0	0.1	936	0.5	0.2	2.6	19.3	0.5	561	9.6	0.2	1.5	0.2	1.2	0.5	4.3
1st quartile	5	0.2	0.2	5.7	6.0	0.1	1000	0.5	0.2	2.8	23.0	0.5	630	13.0	0.2	1.5	0.2	1.8	0.5	5.0
Median	5	0.2	0.2	8.7	7.0	0.1	1300	0.5	0.2	3.9	26.0	0.5	850	16.5	0.3	1.9	0.2	2.8	0.5	6.0
3rd quartile	7	0.2	0.2	12.0	8.0	0.1	1700	0.5	0.2	4.5	35.0	0.5	1000	21.0	0.4	2.1	0.2	4.2	0.5	7.0
95th percentile	9	0.2	0.2	13.4	8.4	0.2	1970	0.5	0.3	6.2	97.0	0.5	1070	27.1	0.7	2.2	0.2	4.4	0.5	7.4
Maximum	11	0.2	0.2	14.0	9.0	0.2	2100	0.5	0.4	6.5	160.0	0.5	1200	29.0	0.7	2.2	0.2	4.7	0.5	8.0
Mean	6	0.2	0.2	8.6	7.2	0.1	1336	0.5	0.2	3.9	37.8	0.5	838	16.8	0.3	1.8	0.2	2.8	0.5	6.0
CV (std. dev./mean)	30%	0%	0%	40%	14%	32%	29%	0%	26%	33%	98%	0%	25%	40%	51%	16%	0%	45%	0%	21%
Skewness	1.9			0.1	0.1	2.3	0.8		2.8	0.5	3.2		-0.2	0.2	1.3	-0.1		0.1		-0.3

14 strawberries samples were collected. Concentrations are in µg/g dry wt.

When strawberry and raspberry results are compared to the control site, the nickel content is found to be higher for all samples collected in the Sudbury area in comparison to the control areas. The Sudbury strawberry samples had a nickel concentration range of 1.4 to 2.2 µg/g with a mean of 1.8 µg/g while the strawberry control range was 0.5 to 0.6 µg/g with a mean of 0.6 µg/g.

The range of nickel concentrations for the commercial raspberries was 4.6 to 9.6 µg/g with a mean of 6.7 µg/g, while the raspberry control site nickel range was 0.5 to 1.1 µg/g with a mean of 0.9 µg/g.

No other elements analyzed indicate a similar pattern. Arsenic (As), beryllium (Be), and antimony (Sb) results do not appear in the table as all values were 0.2<W, while all vanadium (V) results were 0.5<W, all of which were less than laboratory detection limits.

7.4.1.3 Wild Blueberries

Arsenic, copper, nickel, and selenium values in soil for both wild blueberry sites exceeded the Table F background guideline and in most cases, were above the Table A criteria. Arsenic concentrations at the Sudbury sites ranged from 33 to 39 µg/g, for a mean of 37 µg/g while the control sites had arsenic concentrations of 5 to 6 µg/g. Copper concentrations at the Sudbury sites ranged from 120 to 400 µg/g, for a mean of 242.5 µg/g, while the control sites had copper concentrations of 14 to 15 µg/g. Nickel concentrations at the Sudbury sites ranged from 77 to 270 µg/g, for a mean of 180 µg/g, while the control sites had nickel concentrations of 19 to 20 µg/g. Other than these 4 elements, all other elements were comparable to the wild blueberry control site. Refer to Table 7.4.1.3.1 for an abbreviated set of wild blueberry soil results and Section 10.3.2 and Appendix D for the detailed results.

Table 7.4.1.3.1: Summary Statistics for Metals and Arsenic in 0-15 cm Soil Samples from Wild Blueberry Sites in the City of Greater Sudbury - 2001.

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	6400	0.4	33	24	0.4	610	16	6	120	10000	17	1100	110	0.75	77	0.5	10	18	16
Median	9250	0.7	36	39	0.4	905	25	11	225	16500	23	2300	180	0.75	179	2.0	12	31	33
Maximum	13000	1.0	39	51	0.4	1200	33	15	400	25000	32	3600	230	0.75	290	3.0	14	43	49
Mean	9475	0.7	36	38	0.4	905	25	11	243	17000	24	2325	175	0.75	181	1.9	12	31	33
CV (std. dev./mean)	37%	49%	8%	36%	0%	32%	40%	44%	53%	48%	27%	61%	34%	0%	60%	70%	18%	45%	59%

There were 4 samples. Concentrations are in µg/g dry wt.

Abbreviated results for chemical analysis of wild blueberries collected from wild blueberry patches in Sudbury are presented in Table 7.4.1.3.2 and are expressed as µg/g dry weight. Refer to Section 10.3.4 and Appendix D for the complete results. Currently, there are not any Provincial, Federal or International human health-based guidelines available for evaluation of metal content. As a result, the wild blueberries from the Sudbury area were compared against blueberries collected from a remote blueberry patch located approximately 70 km northwest of Copper Cliff where soil contamination was not a concern.

Table 7.4.1.3.2: Summary Statistics for Metals and Arsenic in Wild Blueberries Collected in the City of Greater Sudbury - 2001.

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	8	0.2	0.2	4.3	5.0	0.1	640	0.5	0.2	3.7	15	0.5	260	66	0.2	4.3	0.2	0.9	0.5	2.0
1st quartile	9	0.2	0.2	5.3	6.0	0.1	700	0.5	0.2	3.9	16	0.5	260	73	0.2	4.7	0.2	1.6	0.5	2.0
Median	10	0.2	0.2	8.2	8.0	0.1	910	0.5	0.2	4.6	30	0.5	325	98	0.2	5.4	0.2	2.0	0.5	4.0
3rd quartile	24	0.2	0.2	9.4	9.0	0.1	1300	0.5	0.2	6.4	35	0.5	370	110	0.2	6.8	0.2	2.2	0.5	5.0
Maximum	24	0.2	0.2	10.0	9.0	0.1	1500	0.5	0.2	6.7	53	0.5	390	110	0.2	7.1	0.3	2.3	0.5	6.0
Mean	14	0.2	0.2	7.6	7.5	0.1	993	0.5	0.2	5.0	30	0.5	322	92	0.2	5.6	0.2	1.8	0.5	3.8
CV (std. dev./mean)	56%	0%	0%	30%	22%	0%	34%	0%	0%	26%	48%	0%	17%	20%	0%	21%	19%	29%	0%	42%
Skewness	0.9			-0.6	-0.8		0.7			0.6	0.7		-0.1	-0.7		0.3	2.4	-1.3		0

6 wild blueberries samples were collected. Concentrations are in µg/g dry wt.

Comparison of the nickel content of the wild blueberries from the Sudbury area with those from the control area indicates that nickel and copper accumulation is higher in the Sudbury blueberries. The range of nickel for the Sudbury blueberries was 4.3 to 7.1 µg/g with a mean of 5.6 µg/g. These results are consistent with those found for the Sudbury area in a previous study (Bagatto 1990) where the results were based on washed samples whereas the MOE samples were unwashed. The wild blueberry control site had a nickel concentration range of 0.7 to 0.9 µg/g with a mean of 0.8 µg/g. This difference in means indicates a ratio of 7:1. The mean copper concentration for the Sudbury and control blueberries was 5.0 µg/g and 2.6 µg/g, respectively. This indicates a 2 fold increase in the copper content in the Sudbury berries in comparison to the control. The copper content measured in the Sudbury and control unwashed blueberry samples were lower than the mean concentration of 7.8 µg/g Cu previously reported for washed wild blueberries across Canada (Sheppard 1991).

7.4.2 Commercial Produce Summary

Market garden produce and commercial and wild blueberries were collected from the City of Greater Sudbury in July and August of 2001. Berry samples were collected late in the season which resulted in picking berries that were not optimal for consumption and more specifically, picking berries that were extremely over ripe. The extreme ripeness of the berry samples prohibited proper washing as would be expected prior to consumption. It is expected that the metal levels would be higher in unwashed samples compared to those that are washed. MOE has demonstrated that washing of vegetation samples collected in the Sudbury area before processing substantially reduces the metal content (Balsillie 1978 and MOE 1993b). The market garden produce was thoroughly washed prior to processing; however, due to the lateness of the growing season, a control sample for each vegetable sampled within the City of Greater Sudbury was not collected. Banana peppers, pumpkin, radish, yellow tomato, potato, and zucchini were not available at the control site and therefore, there is no way to compare the metal values obtained for these vegetables from the Sudbury area with an appropriate control.

A higher nickel content in the produce grown in the Sudbury area in comparison to the control areas was observed. This increase in nickel was clearly evident in carrots, tomatoes, wild blueberries, raspberries, and to a lesser extent, strawberries. Neither Provincial, Federal nor International guidelines are available for comparison of berries or market garden produce with respect to human health.

Soil samples were taken in close proximity to where the produce and berries were grown. At two of the Sudbury wild blueberry sites soil levels of arsenic, copper, nickel, and selenium were found to be above both the MOE Table F Soil Background Guidelines and the MOE Table A criteria. Nickel concentrations were above MOE Table F background concentrations at approximately half of the commercial market garden sites and at less than 20 per cent of the commercial berry sites. Soil metal results reported herein are similar to those reported historically (MOE 1990 and MOE 2001) despite the fact that historically data was reported for 0-5 cm undisturbed soil, whereas, data presented here was 0 -15 cm or 0 - 10 cm tilled soil.

7.4.3 Residential Produce

Residential garden sampling was limited to the communities of Coniston, Copper Cliff, Falconbridge, Gatchell and North Lively. The majority of the sampling was done in the first three communities as these communities either currently have smelting operations located in them or had historically and therefore would be the most impacted. The majority of the sampling was done between August 14 to 16, 2001 with samples collected at three additional sites on September 5 and 6, 2001. No residential control gardens were collected and currently there are not any Provincial, Federal or International guidelines available for evaluation of metal content in produce. The results of residential garden sampling will be limited to comparisons with the Sudbury market garden results and the market garden controls. These comparisons are done in Section 7.4.4. For all of the discussion and summary tables in Sections 7.4.3.1 to 7.4.3.5 all sample data was used. The results of the 12 samples suspected of being contaminated during sample processing were not removed.

7.4.3.1 Coniston

The concentrations of nickel, copper, cobalt, lead and arsenic in the residential garden soils in Coniston where similar to or lower than the concentrations in the adjacent yards. In the case of aerial depositon, garden soils would normally be lower than the adjacent yard soil as the soil in a garden is either mixed with the deeper soil or better soil is brought in for the garden area. In either case the result is dilution of the elements. There were 4 out of 15 properties with exceedences of Table A for copper and 7 for nickel with the highest copper concentration of 400 µg/g and nickel of 570 µg/g. No other elements exceeded Table A criteria. There were 2 arsenic, 4 zinc, 1 cobalt, 1 lead, 1 selenium, 4 copper and 7 nickel exceedences of the Table F criteria. Refer to Table 7.4.3.1.1 for an abbreviated summary of the Coniston garden soil results and Section 10.3.2 and Appendix A for the detailed summaries and results.

Table 7.4.3.1.1: Summary Statistics for Metals and Arsenic in Residential Garden Soil from Coniston in the City of Greater Sudbury.

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5500	0.4	2.5	33	0.4	2600	20	6	19	8900	4	1900	84	0.75	39	0.5	25	18	30
10th percentile	7400	0.4	2.5	53	0.4	6320	23	6	54	12000	11	2780	190	0.75	61	0.5	34	21	33
1st quartile	8700	0.4	2.5	56	0.4	7300	27	7	60	14000	13	3050	225	0.75	84	0.5	39	26	46
Median	11000	0.4	6.0	72	0.4	8900	31	9	100	15000	22	3700	250	0.75	130	0.5	42	30	64
3rd quartile	13000	0.4	12	88	0.4	12500	34	15	245	17000	36	4050	280	0.75	315	0.5	48	34	105
95th percentile	13000	0.4	18	110	0.4	19000	39	22	352	18000	108	5840	300	0.75	508	1.4	53	37	186
Maximum	14000	0.4	19	120	0.8	24000	40	24	400	20000	170	6600	320	0.75	570	2.0	54	38	210
Mean	10490	0.4	7.4	74	0.4	10134	30	11	142	15100	33	3693	244	0.75	190	0.6	42	29	83
CV (std. dev./mean)	21%	0%	70%	30%	18%	47%	18%	47%	77%	17%	111	28%	22%	0%	83%	64%	18%	18%	61%
Skewness	-0.4		0.8	0.3	5.4	1.2	-0.2	1.3	1.0	-0.7	2.9	1.2	-1.6		1.2	3.6	-0.5	-0.5	1.2

Number of samples n = 29 Concentrations are in µg/g dry wt.

There were 48 vegetable samples collected from 15 residential gardens in Coniston. Nickel concentrations ranged from less than the method detection limit (<MDL) to 49 µg/g with a mean of 8.8 µg/g. Copper ranged from 1.9 to 24 µg/g with a mean of 8.7 µg/g. Arsenic concentrations were <MDL for the majority of the samples with a maximum of 1.0 µg/g. The majority of the vegetable samples had lead concentrations <MDL with only two samples greater than 2 µg/g. Both of the samples with high lead are suspected of being contaminated during sample processing. Refer to Appendix G for details about lead contamination during sample processing. Refer to Table 7.4.3.1.2 for an abbreviated summary of the Coniston garden vegetable results and Section 10.3.4 and Appendix A for the complete summaries and detailed results.

Table 7.4.3.1.2: Summary of Metals and Arsenic in All Coniston Residential Garden Vegetables

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5	0.2	0.2	1	5	0.1	120	0.5	0.2	2	16	0.5	540	2	0.2	1	0.2	0.6	0.5	6
10th percentile	5	0	0.2	1	10	0.1	886	0.5	0.2	4	23	0.5	973	5	0.2	1	0.2	1.1	0.5	10
1st quartile	5	0.2	0.2	1	14	0.1	1400	0.5	0.2	5	35	0.5	1200	6	0.3	3	0.2	2.3	0.5	15
Median	14	0.2	0.2	3	18	0.1	2300	0.5	0.2	7	67	0.5	1800	11	0.5	7	0.2	7.2	0.5	22
3rd quartile	53	0.2	0.2	12	23	0.2	5450	0.7	0.3	11	110	0.5	3300	14	0.7	10	0.2	13	0.5	35
95th percentile	213	0.2	0.6	37	34	0.6	19000	1.3	0.4	19	287	1.8	7120	32	3.5	27	0.5	34	0.5	79
Maximum	1100	0.2	1.0	60	43	0.8	21000	3.8	1.4	24	1600	110	12000	59	17	49	1.2	41	2.8	300
Mean	63	0.2	0.3	9	19	0.2	5268	0.7	0.3	9	122	3.1	2573	13	1.3	9	0.2	10	0.6	33
CV (std. dev./mean)	262%	0%	63%	149%	41%	80%	120%	73%	82%	63%	194%	515%	86%	87%	220%	107%	67%	106%	61%	131%
Skewness	5.6		2.9	2.5	1.0	2.0	1.5	4.9	4.2	1.3	5.6	6.9	2.4	2.5	4.4	2.5	4.7	1.5	6.5	5.2

Number of samples n = 48 Concentrations are in µg/g dry wt.

7.4.3.2 Copper Cliff

In general, the concentrations of nickel, copper, cobalt, lead and arsenic in the residential garden soils in Copper Cliff were substantially lower than the concentrations in the adjacent yards. There was one property where the garden soil concentrations were marginally higher than the yard concentrations and two properties where the garden soil lead concentrations were substantially higher than the yard soil. Out of the 9 properties sampled there were 8 copper and nickel, 3 arsenic, 1 lead and 1 selenium exceedences of the Table A criteria. There were 3 cobalt, 1 nickel, 1 copper, 1 arsenic, 1 lead and 7 selenium exceedences of the Table F criteria. Garden soil concentrations of nickel ranged from 130 to 800 μ/g, copper from 140 to 820 μg/g, lead from 16 to 640 μg/g and arsenic from <MDL to 38 μg/g. These were considerably higher than the garden soils in Coniston. At the property with the highest lead concentrations, pieces of what appeared to be slag were observed in the samples. Similar material was observed in the 10 to 20 cm back yard samples which also had the highest lead concentrations in the yard soil. Refer to Table 7.4.3.2.1 for an abbreviated summary of the Copper Cliff garden soil results, Section 10.3.2 for the full summary, and Appendix A for the individual results.

Table 7.4.3.2.1: Summary Statistics for Metals and Arsenic in Residential Garden Soil from Copper Cliff in the City of Greater Sudbury

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	7700	0.4	2.5	38	0.4	5000	19	7	140	8600	16	2400	120	0.75	130	0.5	35	16	32
10th percentile	9200	0.4	7.0	43	0.4	6300	26	8	230	12000	19	3000	160	0.75	200	1.0	37	22	40
1st quartile	10000	0.4	8.0	63	0.4	6800	27	11	280	13000	20	3200	180	0.75	275	1.5	39	25	43
Median	11000	0.4	16	77	0.4	8600	31	18	470	17000	69	3800	220	0.75	430	2.0	43	28	84
3rd quartile	12000	0.9	28	100	1.0	16000	35	21	700	19000	145	6000	240	0.75	615	3.0	48	31	130
95th percentile	13000	1.4	38	270	1.9	34000	43	23	820	2100	530	7100	670	1.70	800	12	130	35	330
Maximum	13000	1.5	58	330	3.8	38000	64	110	5100	3300	640	7100	780	3.7	3700	36	160	38	380
Mean	11024	0.7	19	97	0.9	12681	32	20	682	1687	125	4462	264	0.94	578	5	53	28	114
CV (std. dev./mean)	14%	53%	74%	75%	91%	70%	29%	104	151%	30%	136	35%	62%	71%	128%	171	60%	20%	81%
Skewness	-0.7	0.9	1.3	2.5	2.6	1.9	1.9	4.1	4.3	1.2	2.3	0.5	2.5	4.0	4.1	3.6	3.0	-0.7	1.9

Number of samples n = 21 Concentrations are in μg/g dry wt.

There were 49 vegetable samples collected from 9 residential gardens in Copper Cliff. Nickel concentrations ranged from 0.7 to 180 μg/g with a mean of 25 μg/g. Copper ranged from 2.3 to 230 μg/g with a mean of 27 μg/g. Arsenic concentrations were <MDL for the majority of the samples with a maximum of 9 μg/g. Half of the vegetable samples had lead concentrations <MDL . One of the samples with lead greater than 2 μg/g was a root vegetable suspected of being contaminated during sample processing. The other samples with lead higher than 2.0 μg/g also had high nickel, copper, selenium and arsenic concentrations. These sample were all leafy vegetables that also had high concentrations of aluminum and vanadium. The ratios of aluminum to lead in the vegetables were similar to the ratios in the garden soil. The higher concentrations of these elements in the leafy vegetables are attributed to soil particles remaining on the samples after washing. It is more difficult to wash leafy vegetables than root or fruit type vegetables. Refer to Appendix G for a more detailed discussion of this process. An abbreviated summary of the Copper Cliff garden vegetable results is given in Table 7.4.3.2.2, refer to Section 10.3.4 and Appendix A for the detailed summaries and results.

Table 7.4.3.2.2: Summary of Metals and Arsenic in All Copper Cliff Residential Garden Vegetables

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5	0.2	0.2	1	5	0.1	490	0.5	0.2	2	15	0.5	290	4	0.2	0.7	0.2	0.7	0.5	2
10th percentile	5	0.2	0.2	1	5	0.1	842	0.5	0.2	5	26	0.5	418	6	0.2	1.5	0.2	1.1	0.5	5
1st quartile	7	0.2	0.2	3	7	0.1	1400	0.5	0.2	6	36	0.5	1100	13	0.2	5.3	0.2	2.2	0.5	12
Median	19	0.2	0.2	6	12	0.2	2300	0.5	0.2	8	73	0.5	1500	20	0.4	15	0.5	5.3	0.5	24
3rd quartile	135	0.2	0.6	13	20	0.3	5050	0.8	0.4	29	190	1.4	3300	39	1.1	33	1.5	17	0.5	45
95th percentile	620	0.2	2.1	29	33	1.2	20600	2.5	2.2	109	1060	17	5860	120	6.3	75	8.1	43	1.6	91
Maximum	1900	0.4	9.0	58	45	2.0	31000	6.4	4.9	230	2400	38	6400	380	9.4	180	22	52	5.1	120
Mean	177	0.2	0.7	10	15	0.3	5573	1.0	0.6	27	264	2.9	2383	45	1.2	25	2.0	11	0.8	32
CV (std. dev./mean)	212%	14%	197%	114%	63%	130%	125%	124%	159%	160%	194%	249%	75%	166%	173%	135%	209%	121%	110%	90%
Skewness	3.4	7.0	5.4	2.4	1.1	3.0	1.9	3.7	3.4	3.0	3.3	3.8	0.8	3.7	3	2.8	3.7	1.6	4.1	1.4

Number of samples n = 49 Concentrations are in µg/g dry wt.

7.4.3.3 Falconbridge

The concentrations of nickel, copper, cobalt, lead and arsenic in the residential garden soils in Falconbridge were substantially lower than the concentrations in the adjacent yards. Out of the six properties sampled there were 6 arsenic, 7 nickel, 5 copper, 1 lead and 3 cobalt exceedences of the Table A criteria. There were 6 arsenic, 4 cadmium, 1 chromium, 9 nickel, 5 cobalt, 7 copper, 1 lead and 4 selenium exceedences of the Table F criteria. Garden soil concentrations of nickel ranged from 60 to 1400 µ/g, copper from 45 to 1700 µg/g, lead from 7 to 240 µg/g and arsenic from 6 to 400 µg/g. The nickel, copper and arsenic concentrations in the Falconbridge garden soil were higher than the garden soils in Copper Cliff while lead concentrations were lower than Copper Cliff. Refer to Table 7.4.3.3.1 for an abbreviated summary of the Falconbride garden soil results, Section 10.3.2 for the full summary, and Appendix A for the individual results.

Table 7.4.3.3.1: Summary Statistics for Residential Garden Soil from Falconbridge

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	7300	0.4	6	32	0.4	2200	21	8	45	8700	7	1600	96	0.75	60	0.5	18	20	23
1st quartile	7600	0.4	11	35	0.4	3400	23	11	98	11300	13	1850	115	0.75	136	0.5	23	23	32
Median	8000	0.4	26	48	0.4	5600	28	22	360	14000	34	2400	160	0.75	360	0.5	30	25	45
3rd quartile	9600	0.4	115	63	1.7	9950	46	49	895	22500	108	2950	190	0.75	1030	2.0	36	29	112
95th percentile	10440	1.0	288	79	2.4	17400	66	65	1460	32600	192	4280	206	2.42	1280	5.4	42	33	146
Maximum	11000	1.2	400	88	2.8	21000	77	73	1700	37000	240	4800	210	2.50	1400	7.0	45	35	150
Mean	8600	0.5	88	51	1.1	7544	36	31	551	17367	70	2567	155	1.12	581	1.8	30	26	69
CV (std. dev./mean)	15%	53%	142%	35%	82%	78%	50%	74%	101%	52%	110	39%	27%	65%	85%	117	29%	18%	69%
Skewness	0.9	2.1	2.3	1.0	0.9	1.7	1.6	0.8	1.2	1.5	1.6	1.6	-0.2	1.64	0.5	2.1	0.2	0.9	0.9

Number of samples n = 9 Concentrations are in µg/g dry wt.

There were far fewer residential vegetable gardens and they tended to be much smaller than those in Coniston, Copper Cliff and Gatchell. All but two of the vegetable gardens in Falconbridge were sampled. There were only 12 vegetable samples collected from 6 residential gardens in Falconbridge. Nickel concentrations ranged from 9 to 51 µg/g with a mean of 31 µg/g. Copper ranged from 6 to 25 µg/g with a mean of 10 µg/g. Arsenic concentrations were <MDL for the majority of the samples with a maximum of 1.9 µg/g. The majority of the vegetables sampled had lead concentrations <MDL. The two samples with lead greater than 2 µg/g were suspected of being contaminated during sample processing. There were no leafy vegetables sampled in the Falconbridge gardens. Refer to Appendix G for a more detailed discussion of the lead contamination during sample processing. The concentrations of nickel and copper in the Falconbridge garden vegetables were similar to the Coniston garden vegetables and lower than the Copper Cliff garden vegetables.

An abbreviated summary of the Falconbridge garden vegetable results is given in Table 7.4.3.3.2, refer to Section 10.3.4 and Appendix A for the detailed summaries and results.

Table 7.4.3.3.2: Summary of Metals and Arsenic in All Falconbridge Residential Garden Vegetables

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5	0.2	0.2	0.5	6	0.1	290	0.5	0.4	6	35	0.5	1000	7	0.2	9	0.2	0.7	0.5	15
10th percentile	5	0.2	0.2	0.5	8	0.1	702	0.5	0.4	6	37	0.5	1110	8	0.3	17	0.2	1.0	0.5	17
1st quartile	5	0.2	0.2	0.8	11	0.2	1100	0.5	0.6	7	44	0.5	1200	9	0.4	19	0.2	1.6	0.5	20
Median	8	0.2	0.2	1.3	18	0.2	1900	0.5	1.1	8	65	0.5	2450	11	0.6	31	0.2	2.5	0.5	32
3rd quartile	20	0.2	0.6	5.4	19	0.3	3200	0.5	1.8	12	110	1.6	3200	20	0.7	44	0.2	9.1	0.5	48
95th percentile	69	0.2	1.5	14	21	0.5	5090	0.6	2.1	18	180	62	4005	23	0.9	49	0.2	14	0.5	72
Maximum	82	0.3	1.9	24	23	0.5	5200	0.8	2.2	25	180	130	4500	24	1.1	51	0.2	16	0.5	92
Mean	19	0.2	0.5	4.1	15	0.2	2339	0.5	1.2	10	85	12	2367	14	0.6	31	0.2	5.3	0.5	37
CV (std. dev./mean)	129%	14%	109%	162%	36%	54%	69%	16%	55%	55%	61%	311%	50%	45%	44%	44%	0%	100%	0%	60%
Skewness	2.0	3.5	2.1	2.9	-0.3	1.4	0.7	3.5	0.2	2.2	1.0	3.5	0.3	0.5	0.7	-0.1		1.2		1.5

Number of samples n = 12 Concentrations are in µg/g dry wt.

7.4.3.4 Gatchell

The concentrations of nickel, copper, cobalt, lead and arsenic in the residential garden soils in Gatchell were either similar or marginally lower than the concentrations in the adjacent yards. Out of the three properties sampled there were 2 nickel and copper exceedences of the Table A criteria and one 1 nickel and copper exceedence of the Table F criteria. Garden soil concentrations of nickel ranged from 120 to 390 µ/g, copper from 130 to 440 µg/g, lead from 21 to 120 µg/g and arsenic from 5 to 12 µg/g. The nickel, copper, lead and arsenic concentrations in the Gatchell garden soils were very similar to the garden soils in Coniston. Refer to Table 7.4.3.4.1 for an abbreviated summary of the Gatchell garden soil results, Section 10.3.2 for the full summary, and Appendix A for the individual results.

Table 7.4.3.4.1: Summary Statistics for Metals and Arsenic in Residential Garden Soil from Gatchell in the City of Greater Sudbury

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	7200	0.4	2.5	54	0.4	3500	28	8	130	14000	21	2700	170	0.8	120	0.5	22	25	58
1st quartile	8100	0.4	5.0	68	0.4	5100	28	9	140	14000	23	3600	260	0.8	120	0.5	29	25	65
Median	9050	0.4	6.0	78	0.4	6350	28	12	230	15000	69	3900	290	0.8	225	0.8	32	27	81
3rd quartile	10000	1.0	11	120	0.4	12000	35	12	260	16000	88	4300	400	0.8	270	1.0	52	28	170
95th percentile	10000	1.0	12	128	0.4	12750	51	14	395	16000	120	4375	415	0.8	293	1.0	52	28	178
Maximum	10000	1.0	12	130	0.4	13000	56	15	440	16000	130	4400	420	0.8	300	1.0	52	28	180
Mean	8900	0.6	7.1	88	0.4	7717	34	11	238	15000	67	3800	305	0.8	210	0.8	36	27	106
CV (std. dev./mean)	14%	52%	52%	35%	0%	50%	33%	22%	47%	7%	64%	16%	30%	0%	37%	37%	35%	6%	52%
Skewness	-0.3	1.0	0.4	0.6		0.6	2.1	0.3	1.3	0.0	0.4	-1.2	-0.1		-0.2	0.0	0.6	0.0	0.8

Number of samples n = 6 Concentrations are in µg/g dry wt.

While only the three smelter communities were supposed to have residential gardens sampled, the proximity of Gatchell to the Copper Cliff plants and the high number of large gardens in the community warranted some garden sampling. There were 21 vegetable samples collected from three residential gardens sampled in Gatchell. Nickel concentration ranged from 2 to 41 µg/g with a mean of 14 µg/g. Copper ranged from 3 to 64 µg/g with a mean of 20 µg/g. Arsenic concentrations were <MDL for the majority of the samples with a maximum of 2.3 µg/g. The majority of the vegetable samples had lead concentrations <MDL . None of the vegetable samples collected in Gatchell were suspected of being contaminated with lead during the sample processing. There were a number of samples with lead higher than 2.0 µg/g. These also had high nickel, copper, selenium and arsenic concentrations. These samples were all leafy vegetables that also had high concentrations of

aluminum and vanadium. The ratios of aluminum to lead in the vegetables were similar to the ratios in the garden soil. The higher concentrations of these elements in the leafy vegetables are attributed to soil particles remaining on the samples after washing. It is more difficult to wash leafy vegetables than root or fruit type vegetables. Refer to Appendix G for a more detailed discussion of this process. The concentrations of nickel and copper in the Gatchell garden vegetables were similar to the Coniston garden vegetables and lower than the Copper Cliff garden vegetables. An abbreviated summary of the Gatchell garden vegetable results is given in Table 7.4.3.4.2, refer to Section 10.3.4 and Appendix A for the detailed summaries and results.

Table 7.4.3.4.2: Summary Statistics for Metals and Arsenic in Gatchell Residential Garden Vegetables

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5	0.2	0.2	0.5	5	0.1	190	0.5	0.2	2.6	24	0.5	730	4	0.2	2.3	0.2	0.5	0.5	8
10th percentile	5	0.2	0.2	1.0	10	0.1	1300	0.5	0.2	4.8	53	0.5	900	5	0.2	2.9	0.2	2.0	0.5	13
1st quartile	6	0.2	0.2	2.0	12	0.1	1850	0.5	0.2	6.6	60	0.5	1300	8	0.3	4.4	0.2	5.2	0.5	16
Median	63	0.2	0.2	4.3	20	0.1	5000	0.7	0.2	13	120	0.5	3200	14	0.7	13	0.3	12	0.5	39
3rd quartile	230	0.2	0.8	15	27	0.3	9000	1.2	0.4	26	335	2.1	3800	26	2.0	23	0.4	23	0.5	46
95th percentile	810	0.2	1.5	31	31	0.6	19000	3.2	0.9	57	1100	4.9	6200	47	3.0	27	1.0	43	2.3	59
Maximum	1300	0.2	2.3	37	33	1.0	30000	4.7	2.2	64	1800	11	8400	91	3.5	41	1.6	49	3.3	78
Mean	194	0.2	0.6	10	19	0.2	6790	1.1	0.4	20	298	1.8	3167	20	1.1	14	0.4	15	0.8	35
CV (std. dev./mean)	170%	0%	103%	110%	42%	94%	105%	94%	105%	89%	147%	139%	63%	100%	95%	72%	79%	89%	91%	52%
Skewness	2.4		1.7	1.3	-0.1	2.2	2.1	2.5	2.9	1.4	2.5	2.7	1.0	2.4	1.0	0.9	2.2	1.2	2.8	0.3

Number of samples n = 21 Concentrations are in µg/g dry wt.

Six residential vegetable gardens were sampled by the Ministry in the Gatchell community in 1993. A total of 23 samples were collected, 4 root vegetables, 1 fruit vegetable and 13 leafy vegetables. While there were differences in the number of properties sampled, number of samples collected and the types of vegetables collected between the 1993 and 2001 studies, the concentrations of nickel, copper, cobalt, arsenic and lead were similar. There was also a difference between the leafy vegetables and the root and fruit vegetables in the 1993 study with concentrations higher in the leafy vegetables for most elements across the whole concentration ranges. Refer to Table 7.4.3.4.2 for a summary of the results presented in the 1993 report (MOE 1993b).

Table 7.4.3.4.2: Summary Statistics for Gatchell Residential Garden Vegetables collected in 1993

	As	Co	Cu	Fe	Pb	Mg	Ni	Se	Zn
Minimum	0.2	0.2	9	84	0.5	490	7	0.3	32
1st quartile	0.2	0.2	20	150	0.6	3100	14	0.3	33
Median	0.6	0.5	25	200	1	4300	21	0.5	45
3rd quartile	0.7	0.6	25	270	1.2	4900	25	0.7	67
Maximum	1.7	0.9	48	820	2.2	13000	31	1.8	94
Mean	0.6	0.5	25	270	1.1	5600	21	0.6	52

- there were 13 vegetables collected in Gatchell. Concentrations are in µg/g dry wt.

7.4.3.5 North Lively

The gardens in North Lively were not originally planned to be sampled. They were added at the request from the local Ministry office to investigate the potential of dust blowing off of tailings beside these residential properties. The concentrations of nickel, copper, cobalt and arsenic in the residential garden soils in North Lively where either similar or marginally lower than the concentrations in the adjacent yards. On two properties the lead concentrations were higher in the garden soil than the adjacent yards.Out of the three properties sampled there were no Table A criteria exceedences and only 4 nickel and two copper exceedences of the Table F criteria. Garden soil concentrations of nickel ranged from 73 to 150 µ/g, copper from 60 to 120 µg/g, lead from 28 to 110 µg/g and arsenic from 5 to 9 µg/g. The nickel, copper, lead and arsenic concentrations in the North Lively garden soils were the lowest of all the community garden soils sampled. The influence of dust blowing off of the tailings on the concentrations in the soil was smaller than the smelter emissions in the other four communities. Refer to Table 7.4.3.5.1 for an abbreviated summary of the North Lively garden soil results, Section 10.3.2 for the full summary, and Appendix A for the individual results.

Table 7.4.3.5.1: Summary Statistics for Metals and Arsenic in Residential Garden Soil from North Lively in the City of Greater Sudbury

	Al	Sb	As	Ba	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	11000	0.4	2.5	60	0.4	7700	28	8	60	17000	28	4200	270	0.75	73	0.5	28	33	76
1st quartile	13000	0.4	2.5	76	0.4	8850	29	8	70	19500	33	4950	285	0.75	77	0.5	43	36	95
Median	14500	0.4	4.8	92	0.4	9950	33	8	101	21000	45	5900	310	0.75	111	0.5	49	39	97
3rd quartile	19500	0.6	8.0	115	0.4	12000	43	10	115	22500	87	6650	330	0.75	135	0.5	57	42	105
95th percentile	21650	1.0	8.7	127	0.7	13950	50	11	120	24300	104	6895	347	1.24	147	0.5	70	45	110
Maximum	22000	1.1	9.0	130	0.8	15000	50	11	120	25000	110	7000	350	1.50	150	0.5	72	46	110
Mean	15875	0.5	5.3	94	0.5	10538	36	9	94	21000	58	5775	309	0.84	109	0.5	50	39	97
CV (std. dev./mean)	25%	50%	57%	26%	31%	22%	25%	13%	26%	12%	55%	18%	9%	31%	30%	0%	28%	11%	11%
Skewness	0.6	1.8	0.1	0.2	2.8	0.9	1.0	1.4	-0.4	0.0	0.7	-0.5	0.1	2.8	0.0		0.3	0.2	-1

Number of samples n = 8 Concentrations are in µg/g dry wt.

There were 18 vegetable samples collected from the three residential gardens sampled in North Lively. One property had two large separate gardens. Nickel concentrations ranged from 5 to 110 µg/g with a mean of 23 µg/g. Copper ranged from 4 to 98 µg/g with a mean of 21 µg/g. Arsenic concentrations were <MDL for the majority of the samples with a maximum of 1.1 µg/g. Seven of the 21 vegetable samples were suspected of being contaminated with lead and nickel during sample processing. In addition, there were two lettuce samples with lead higher than 2.0 µg/g. These samples also had high concentrations of aluminum and vanadium. As previously mentioned, the higher concentrations of lead in the leafy vegetables is attributed to soil particles remaining on the samples after washing. It is more difficult to wash leafy vegetables than root or fruit type vegetables. The concentrations of nickel and copper in the North Lively garden vegetables were similar to the Gatchell and Coniston garden vegetables and lower than the Copper Cliff garden vegetables. An abbreviated summary of the Gatchell garden vegetable results is given in Table 7.4.3.5.2, refer to Section 10.3.4 and Appendix A for the detailed summaries and results.

Table 7.4.3.5.2: Summary Statistics for Metals and Arsenic in Lively Residential Garden Vegetables

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5	0.2	0.2	1.3	10	0.1	680	0.5	0.2	3.6	23	0.5	990	5	0.2	2.1	0.2	2	0.5	10
10th percentile	5	0.2	0.2	1.9	16	0.1	1047	0.5	0.2	8.8	48	0.5	1347	6	0.2	3.0	0.2	3.3	0.5	19
1st quartile	11	0.2	0.2	2.7	20	0.1	1600	0.5	0.2	10	68	0.7	1800	10	0.2	4.5	0.2	6.7	0.5	27
Median	35	0.2	0.2	10	24	0.2	3050	0.5	0.2	15	90	2.4	2850	14	0.5	6.0	0.2	11	0.5	34
3rd quartile	150	0.2	0.2	25	27	0.2	7500	1.1	0.3	26	210	42	4000	19	1.5	19	0.2	24	0.5	41
95th percentile	1057	0.3	0.5	42	33	1.2	15450	2.8	1.0	44	1440	96	7560	56	4.7	83	0.2	49	2.7	110
Maximum	2000	0.3	1.1	50	37	1.6	18000	4.9	1.9	98	2800	260	13000	110	5.7	190	0.3	67	4.6	110
Mean	221	0.2	0.3	14	24	0.3	5554	1.0	0.4	21	335	32	3449	21	1.4	23	0.2	19	0.9	41
CV (std. dev./mean)	223%	15%	78%	99%	27%	139%	96%	108%	114%	100%	202%	193%	80%	118%	128%	193%	11%	95%	120%	68%
Skewness	3.2	2.7	3.6	1.3	0.0	2.8	1.3	3.1	3.5	3.2	3.3	3.3	2.6	3.1	1.6	3.3	4.2	1.5	3.3	1.8

Number of samples n = 18 Concentrations are in µg/g dry wt.

7.4.4 Market Garden and Residential Produce Comparisons

With the exception of lead, the removal of the data for the 12 residential garden vegetables suspected of being contaminated during sample processing have very little effect on the overall results. Summary statistics for all the residential garden vegetables, including the 12 samples in question, are given in Table 7.4.4.1. Table 7.4.4.2 consists of the same data with the 12 samples in question removed. There is little difference between the two summaries except for lead where there was a decrease from the 75th percentile and higher in the second set of results. For the rest of the discussion comparing the root, fruit and leafy vegetables and for comparing residential garden vegetables to the commercial market garden vegetables the results with the 12 samples removed will be used.

Table 7.4.4.1: Summary Statistics for Metals and Arsenic in All Residential Garden Vegetables Collected

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5	0.2	0.2	0.5	5	0.1	120	0.5	0.2	2	15	0.5	290	2	0.2	0.5	0.2	0.5	0.5	2
10th percentile	5	0.2	0.2	0.7	7.0	0.1	838	0.5	0.2	5	26	0.5	840	5	0.2	2.1	0.2	1.2	0.5	10
1st quartile	6	0.2	0.2	1.4	11	0.1	1400	0.5	0.2	6	40	0.5	1200	8	0.2	4.5	0.2	2.4	0.5	15
Median	18	0.2	0.2	5.1	18	0.2	2700	0.5	0.2	9	80	0.5	2150	13	0.5	8.8	0.2	7.4	0.5	27
3rd quartile	82	0.2	0.4	14	23	0.3	5450	0.8	0.4	18	145	1.5	3500	23	1.1	23	0.4	16	0.5	44
95th percentile	620	0.2	1.4	35	33	0.8	19000	2.4	1.9	64	1065	39	6265	88	4.4	54	3.0	43	1.6	89
Maximum	2000	0.4	9.0	60	45	2.0	31000	6.4	4.9	230	2800	260	13000	380	17.0	190	22	67	5.1	300
Mean	135	0.2	0.5	10	18	0.3	5382	0.9	0.5	18	217	7.1	2684	26	1.2	18	0.8	12	0.7	34
CV (std. dev./mean)	237%	11%	179%	125%	48%	116%	118%	107%	135%	157%	201%	383%	77%	183%	181%	146%	298%	111%	100%	95%
Skewness	3.9	7.1	7.8	2.1	0.6	3.4	1.9	4.0	3.7	4.6	3.9	6.9	2.0	5.8	4.5	3.9	6.5	1.7	4.5	4.3

Number of samples n = 148 Concentrations are in µg/g dry wt.

Table 7.4.4.2: Summary Statistics for Metals and Arsenic in All Garden Vegetables Collected minus Root and Shoot >2.5 µg/g Lead

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5	0.2	0.2	0.5	5	0.1	120	0.5	0.2	2	15	0.5	290	2.2	0.2	0.5	0.2	0.5	0.5	2
10th percentile	5	0.2	0.2	0.6	7	0.1	830	0.5	0.2	4	26	0.5	815	5.1	0.2	2	0.2	1.2	0.5	9
1st quartile	6	0.2	0.2	1.4	11	0.1	1400	0.5	0.2	6	40	0.5	1200	7.5	0.2	4.5	0.2	2.3	0.5	15
Median	18	0.2	0.2	5.1	18	0.2	2500	0.5	0.2	8	74	0.5	2250	13	0.5	8.2	0.2	7.1	0.5	26
3rd quartile	82	0.2	0.4	12	23	0.3	6350	0.8	0.4	18	145	1.1	3600	25	1.1	22	0.4	16	0.5	44
95th percentile	668	0.2	1.4	38	33	0.9	19250	2.4	1.9	63	1100	5.4	6325	96	4.8	52	3.3	42	1.8	87
Maximum	2000	0.4	9.0	60	45	2	31000	6.4	4.9	230	2800	38	13000	380	17	180	22	67	5.1	300
Mean	143	0.2	0.5	9.9	18	0.3	5561	0.9	0.5	18	227	1.8	2726	27	1.3	17	0.9	12	0.7	34
CV (std. dev./mean)	233%	9%	184%	128%	49%	116%	118%	109%	137%	161%	200%	269%	78%	182%	180%	136%	292%	114%	101%	98%
Skewness	3.8	11.7	7.8	2.2	0.6	3.3	1.8	3.8	3.7	4.7	3.8	5.5	1.9	5.6	4.3	3.9	6.2	1.7	4.3	4.3

Number of samples n = 136 Concentrations are in µg/g dry wt.

All of the residential garden vegetable data from the 5 communities was combined and then split into root, fruit (beans, tomatoes, etc.), and leafy vegetables in Tables 7.4.4.3 through 7.4.4.5. There was little difference between the root and fruit vegetables. Arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese and vanadium concentrations are the same over the whole concentration range. Magnesium, nickel, selenium and zinc are marginally higher in the fruit vegetables at the higher end of the concentration ranges.

There was a large difference between the root and fruit vegetables and the leafy vegetables. All elements in the leafy vegetables have substantially higher concentrations over the whole concentration range than the roots and fruits. For most elements it was only the minimum concentrations that were the same in all three types. While some of the differences can be due to the leafy parts of the plants taking up more metals then the reproducing fruit and root storage parts of the plants, a lot of it can be attributed to the difficulty in washing all of the soil off of leafy vegetables. The higher concentrations of aluminum and vanadium in the leafy vegetables and the correlation of the ratios of these two elements in the leaves with their ratios in the soil are highly indicative of soil particles not being removed in normal household type washing of leafy vegetables.

Table 7.4.4.3: Summary Statistics for Metals and Arsenic in All Residential Root Vegetables Collected minus >2.5 µg/g Lead

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5	0.2	0.2	0.5	5	0.1	120	0.5	0.2	2.6	21	0.5	290	3.4	0.2	0.8	0.2	0.5	0.5	2
10th percentile	8	0.2	0.2	0.7	5.0	0.1	270	0.5	0.2	4.4	29	0.5	870	4.9	0.2	1.7	0.2	0.8	0.5	10
1st quartile	13	0.2	0.2	2.4	8.0	0.1	1300	0.5	0.2	5.5	36	0.5	1150	5.9	0.2	2.5	0.2	1.8	0.5	14
Median	28	0.2	0.2	6.3	14	0.1	1700	0.5	0.2	6.8	69	0.5	1400	8.3	0.2	5.2	0.2	5.9	0.5	17
3rd quartile	59	0.2	0.2	17	18	0.2	2350	0.5	0.2	8.9	100	0.6	1750	17	0.4	8.2	0.2	9.3	0.5	28
95th percentile	87	0.2	0.5	32	23	0.3	3475	0.6	0.4	16	143	1.4	2700	110	0.6	18	0.5	12	0.5	42
Maximum	120	0.2	0.7	60	24	0.4	5600	0.9	0.5	27	160	1.6	3200	380	1.2	26	3.0	18	0.5	56
Mean	38	0.2	0.2	11	13	0.2	1788	0.5	0.2	8.0	73	0.7	1488	28	0.3	6.6	0.3	5.9	0.5	20
CV (std. dev./mean)	79%	0%	47%	121%	46%	51%	63%	13%	31%	57%	54%	48%	45%	236%	66%	85%	153%	72%	0%	58%
Skewness	0.9		3.6	2.3	0.1	1.3	1.0	5.1	3.1	2.4	0.5	2.1	0.6	4.7	2.8	1.9	5.8	0.6		1.3

Number of samples n = 36 Concentrations are in µg/g dry wt.

Table 7.4.4.4: Summary Statistics for Metals and Arsenic in All Residential Fruit Vegetables Collected minus >2.5 µg/g Lead

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5	0.2	0.2	0.5	5	0.1	490	0.5	0.2	1.9	15	0.5	310	2.2	0.2	0.5	0.2	0.7	0.5	4
10th percentile	5	0.2	0.2	0.6	8	0.1	949	0.5	0.2	4.5	25	0.5	788	5.7	0.2	2.4	0.2	1.3	0.5	9
1st quartile	5	0.2	0.2	1.1	12	0.1	1500	0.5	0.2	5.6	40	0.5	1200	9.4	0.4	5.4	0.2	2.3	0.5	17
Median	12	0.2	0.2	4.9	19	0.2	4300	0.5	0.2	10	81	0.5	3050	15	0.7	11	0.2	8.0	0.5	32
3rd quartile	160	0.2	0.6	12	26	0.3	12000	1.1	0.6	23	235	1.4	4250	30	1.6	26	0.6	22	0.5	47
95th percentile	900	0.2	1.6	37	34	1.1	20050	3.2	2.0	65	1220	8.0	6675	69	6.1	53	4.8	43	2.4	96
Maximum	2000	0.4	9.0	59	45	2.0	31000	6.4	4.9	230	2800	38	13000	370	17	180	22	67	5.1	300
Mean	181	0.2	0.5	9.6	19	0.3	6920	1.0	0.6	21	282	2.2	3171	27	1.6	20	1.1	14	0.8	39
CV (std. dev./mean)	211%	10%	179%	132%	46%	115%	103%	107%	130%	154%	184%	253%	73%	157%	160%	125%	272%	107%	105%	95%
Skewness	3.1	10.0	6.8	2.1	0.5	2.8	1.3	3.2	3.2	4.1	3.1	4.7	1.6	6.1	3.7	3.4	5.4	1.3	3.6	3.9

Number of samples n = 100 Concentrations are in µg/g dry wt.

Table 7.4.4.5: Summary Statistics for Metals and Arsenic in All Residential Leafy Vegetables Collected

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	18	0.2	0.2	1.2	5	0.1	1200	0.5	0.2	6	41	0.5	1200	4	0.2	3.4	0.2	1.2	0.5	17
10th percentile	49	0.2	0.2	7.5	17	0.2	4540	0.6	0.2	14	120	0.5	2880	14	0.3	7.2	0.2	14	0.5	26
1st quartile	84	0.2	0.3	10	20	0.3	9650	0.7	0.3	20	170	0.7	3400	17	0.4	10	0.2	20	0.5	40
Median	270	0.2	0.6	16	26	0.4	14000	1.3	0.5	26	370	1.7	4400	31	0.9	23	0.6	27	0.6	46
3rd quartile	600	0.2	1.3	30	31	0.7	19000	2.4	1.2	58	885	4.1	6150	48	1.7	50	1.3	41	1.5	78
95th percentile	1660	0.2	2.3	52	39	1.6	24400	5.1	2.6	136	2400	24	9200	73	3.4	93	4.2	50	4.2	110
Maximum	2000	0.4	9.0	59	45	2.0	31000	6.4	4.9	230	2800	38	13000	110	6.5	180	5.3	67	5.1	300
Mean	462	0.2	1.0	21	26	0.6	14230	1.8	0.9	45	665	5.0	5084	36	1.3	33	1.0	29	1.3	61
CV (std. dev./mean)	112%	16%	142%	71%	32%	81%	48%	87%	109%	100%	106%	172%	48%	63%	100%	106%	127%	47%	95%	79%
Skewness	1.7	6.1	4.5	1.2	0.0	1.6	0.2	1.7	2.4	2.7	1.7	2.7	1.6	1.3	2.4	2.6	2.2	0.5	1.9	3.7

Number of samples n = 37 Concentrations are in µg/g dry wt.

While there were considerably fewer commercial market garden samples collected compared to the residential samples, a similar pattern was observed between the root, fruit and leafy market garden vegetables. Refer to Tables 7.4.4.6 through 7.4.4.8. Arsenic, cadmium, chromium, cobalt copper, iron, lead, manganese, selenium, vanadium and zinc concentrations over the whole concentration range were very similar in both the market garden root and fruit vegetables. The concentrations of nickel in the fruit vegetables were approximately twice the concentration in the root vegetables. In the leafy market garden vegetables the concentrations of every element except for nickel, selenium and zinc where higher than either the root or fruit vegetables. The difference was not as great for cadmium, chromium, copper or lead as was observed in the residential garden vegetables but this would be expected as the concentrations of these elements in the market garden soils were lower than in the residential soils. The aluminum, barium, magnesium, manganese, and vanadium concentration ranges in the market garden leafy vegetables were similar to the residential leafy vegetable concentration ranges. This would be expected as these are not elements associated with smelter emissions and all the samples were washed the same way and therefore, all of the soil particles would not have been removed.

Table 7.4.4.6: Summary Statistics for Metals and Arsenic in Market Garden Root Vegetables Collected in the City of Greater Sudbury - 2001.

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	15	0.2	0.2	0.5	6.0	0.1	220	0.5	0.2	5.9	26	0.5	1100	3.7	0.2	0.5	0.2	0.6	0.5	12
10th percentile	21	0.2	0.2	0.5	6.0	0.1	256	0.5	0.2	6.8	46	0.5	1100	4.8	0.2	0.6	0.2	0.6	0.5	13
1st quartile	35	0.2	0.2	0.6	7.0	0.2	310	0.5	0.2	7.8	55	0.5	1100	7.9	0.2	1.0	0.2	0.9	0.5	16
Median	96	0.2	0.2	1.1	9.0	0.3	540	0.5	0.2	8.3	130	0.5	1250	9.7	0.2	3.7	0.2	1.4	0.5	20
3rd quartile	150	0.2	0.2	25	19	0.8	2400	0.7	0.3	10	210	0.5	1900	23	0.2	11	0.2	11	0.5	31
95th percentile	1053	0.2	0.9	80	24	2.2	1365	2.9	1.0	17	1143	2.4	1395	213	1.0	17	0.2	39.2	2.6	38
Maximum	370	0.2	0.3	41	28	1.0	2800	1.2	1.1	16	390	0.8	3200	110	1.1	21	0.2	15	0.9	35
Mean	110	0.2	0.2	12	13	0.4	1156	0.6	0.3	9.2	147	0.5	1671	24	0.3	6.0	0.2	5.2	0.5	22
CV (std. dev./mean)	86%	0%	17%	123%	58%	80%	89%	33%	80%	30%	69%	17%	44%	130%	95%	101%	0%	108%	20%	37%
Skewness	1.6		2.3	0.9	0.8	1.0	0.6	2.1	2.8	1.5	1.0	2.5	1.3	2.2	2.2	1.4		0.8	3.7	0.3

14 of the 44 vegetables samples collected were root vegetables. Concentrations are in µg/g dry wt.

Table 7.4.4.7: Summary Statistics for Metals and Arsenic in Market Garden Fruit Vegetables Collected in the City of Greater Sudbury - 2001.

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	5.0	0.2	0.2	0.5	11	0.1	380	0.5	0.2	4.0	23	0.5	1100	7.1	0.2	0.5	0.2	0.5	0.5	12
10th percentile	5.0	0.2	0.2	0.6	13	0.1	930	0.5	0.2	5.8	32	0.5	1410	9.0	0.2	1.6	0.2	1.0	0.5	14
1st quartile	5.0	0.2	0.2	1.5	14	0.1	1500	0.5	0.2	6.7	51	0.5	1700	13	0.3	3.3	0.2	3.6	0.5	19
Median	9.0	0.2	0.2	4.1	16	0.1	3150	0.5	0.2	8.8	67	0.5	2750	18	0.4	8.6	0.2	5.5	0.5	30
3rd quartile	35	0.2	0.2	7.4	19	0.1	4400	0.5	0.4	11	96	0.5	3400	25	0.7	18	0.2	9.2	0.5	40
95th percentile	58	0.2	0.2	14	26	0.4	4795	0.8	1.1	14	186	0.5	3795	85	2.2	45	0.2	13	0.5	56
Maximum	120	0.2	0.2	14	27	0.5	5100	0.8	1.1	14	200	0.5	3900	93	2.6	45	0.2	14	0.5	61
Mean	24	0.2	0.2	5.0	17	0.1	2912	0.6	0.4	8.9	78	0.5	2568	27	0.6	14	0.2	6.4	0.5	30
CV (std. dev./mean)	114%	0%	0%	83%	26%	73%	51%	19%	78%	30%	58%	0%	36%	91%	102%	107%	0%	67%	0%	46%
Skewness	2.2			0.9	0.9	2.7	-0.2	1.6	1.6	0.2	1.6		-0.1	1.9	2.5	1.2		0.2		0.7

22 of the 44 vegetable samples collected were fruit vegetables. Concentrations are in µg/g dry wt.

Table 7.4.4.8: Summary Statistics for Metals and Arsenic in Market Garden Leafy Vegetables Collected in the City of Greater Sudbury - 2001.

	Al	Sb	As	Ba	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Minimum	31	0.2	0.2	3.1	14	0.3	8300	0.5	0.2	11	92	0.5	3800	23	0.2	3.2	0.2	9.7	0.5	28
10th percentile	66	0.2	0.2	4.4	16	0.3	9280	0.5	0.2	11	119	0.5	4220	27	0.2	5.0	0.2	11	0.5	29
1st quartile	96	0.2	0.3	9.0	18	0.4	9800	0.6	0.3	12	155	0.5	4450	70	0.2	6.0	0.2	12	0.5	30
Median	170	0.2	0.4	19	19	1.6	1050	0.8	0.6	15	255	0.5	5300	150	0.2	8.6	0.2	22	0.5	33
3rd quartile	540	0.2	0.7	45	21	2.0	1200	1.4	0.9	16	580	1	9250	180	0.7	16	0.2	31	1.3	34
95th percentile	1053	0.2	0.9	80	24	2.2	1365	2.9	1.0	17	1143	2.4	1395	213	1.0	17	0.2	39	2.6	38
Maximum	1200	0.2	1.0	92	25	2.3	1400	3.4	1.1	17	1300	3.1	1500	230	1.1	17	0.2	43	2.9	40
Mean	355	0.2	0.5	30	19	1.3	1086	1.2	0.6	14	422	0.9	7100	132	0.4	10	0.2	23	1.0	33
CV (std. dev./mean)	117%	0%	59%	102%	17%	65%	17%	88%	56%	16%	101%	96%	58%	56%	82%	53%	0%	53%	91%	11%
Skewness	1.6		0.9	1.5	0.6	-0.3	0.6	2.0	0.3	-0.4	1.6	2.6	1.4	-0.6	1.4	0.3		0.5	1.8	1.1

8 of the 44 vegetable samples collected were leafy vegetables. Concentrations are in µg/g dry wt.

In general the concentrations of nickel, copper, cobalt, arsenic, lead, cadmium and zinc in the Commercial Market garden vegetables, Table 7.4.1.1.2, were lower than the concentrations of these elements in the residential garden vegetables, Table 7.4.4.1. The main difference is at the high end of the concentration ranges. There is an overlap of about seventy five percent in the ranges for nickel and copper between market gardens and residential gardens. Nickel in the market garden samples range from 0.5 to 45 μg/g while the residential vegetable range from 0.5 to 180 μ/g. At the 75th percentile the nickel concentration in residential vegetables is 22 μg/g which is lower than the maximum market garden concentration. Similar patterns are observed in the other elements. The maximum concentration for copper in the market garden vegetables is the same as the 75th percentile concentration in the residential garden samples.

7.4.4 Sudbury Produce Summary

The preliminary sampling of commercial and residential produce done in 2001 shows a pattern of elevated concentrations of nickel, copper, cobalt, arsenic, lead, cadmium and selenium in produce with the produce concentrations increasing as the concentration of these elements increase in the soil. While the concentration of these elements are relatively low in the commercial market garden vegetables they are still higher than the market garden controls. Approximately 25% of the residential garden vegetable samples are higher than the commercial market garden vegetables for these elements.

Leafy vegetables have higher a concentration of all elements compared to root and fruit vegetables mainly due to the inadequate removal of all soil from these vegetables during normal household washing practices. This is not a concern for the commercial market gardens sampled in this study as the concentrations of nickel, copper, cobalt, arsenic, lead, cadmium and selenium in their soil are low and the impact on vegetation is much less.

Generally, metals and arsenic concentrations in the commercial and wild blueberries were relatively low. However, concentrations of nickel in the commercial berry farm produce and concentrations of nickel and copper in the wild blueberry samples were elevated above the control samples.

The concentrations of nickel, copper, cobalt, arsenic, lead, cadmium and selenium in residential garden soils in the communities sampled are elevated but in general they are lower than the highest concentrations found in the adjacent yards. The highest garden soil concentrations were found in Falconbridge followed by Copper Cliff, Coniston, Gatchell and then Lively. Market garden soils were lower than all of five community residential garden soils.

This study shows that concentrations of nickel, copper, cobalt, arsenic, lead, cadmium and selenium are elevated in produce grown in the Sudbury area. Therefore a thorough sampling program needs to be carried out in the City of Greater Sudbury by the consultants doing the human health risk assessment. Sufficient samples, both number of samples and size of samples, need to be collected appropriately throughout the growing season from residential gardens, commercial market gardens, berry farms and wild blueberry patches to provide an accurate data base of information for inclusion in the human health risk assessment. The study should address the limitations of this study outlined above. The data collected in this preliminary study should not be used in the human health risk study due to the limitations outlined above.

7.5 Summary

In total, 6,734 soil samples were collected from 770 properties in the City of Greater Sudbury including: 16 commercial agriculture properties, 139 schools/daycares (104/35 respectively), 169 parks and 439 residential properties. Additionally, 245 produce samples were collected from 52 residential gardens and agricultural operations. Three main types of soil samples were collected: Soil, Sand and Gravel, and four types of produce samples: Root Vegetables, Fruit Vegetables, Leafy Vegetables and Berries.

For discussion purposes, sample locations were organized by local community or geographic location within the City of Greater Sudbury. Twenty four local communities or geographic groupings were ranked from highest to lowest using surface soil nickel concentrations. Six major groupings of communities were identified based on similar soil metal and arsenic concentrations. The six community groupings were Outer Sudbury Communities, Inner Sudbury Communities, Sudbury Core, Coniston, Falconbridge and Copper Cliff.

All laboratory analysis was completed at either Lakefield Research Laboratories or at Laboratory Services Branch of the MOE . Soil and produce samples were analyzed for the following elements: aluminum, antimony, arsenic, barium, beryllium, calcium, cadmium, cobalt, copper, chromium, iron, magnesium, manganese, molybdenum, nickel, lead, selenium, strontium, vanadium, and zinc. In addition, approximately 10% of the soil samples were analyzed for pH, electrical conductivity (EC) and total organic content (TOC). Produce samples were also analyzed for sulphur, boron, chlorine, and potassium.

Sample Type

The Soil sample type made up 88% of the soil (soil, sand, gravel) samples collected. This group was further subdivided into Urban Soil (developed, grassed areas, 85% of the total number of soil samples), Urban Garden Soil (residential vegetable gardens, 1% of the soil samples), Agricultural Soil (commercial market garden and berry farms, 1% of the soil samples) and Undisturbed Natural Soil (undeveloped, naturally vegetated areas, 1% of the soil samples).

The Sand sample type comprised 9% of the total number of soil samples collected and was subdivided into Play Sand (8% of the total number of soil samples) and Beach Sand (1 % of the total number of soil samples). The Gravel sample type comprised 4% of the total soil samples collected and was subdivided into Crushed Stone and Playground Gravel, each comprising 2% of the total number of soil samples collected.

Garden produce was sampled at residential properties and commercial operations. Residential gardens were sampled in Coniston, Falconbridge, Copper Cliff, Gatchell and Lively. Commercial operations sampled included commercial berry farms, wild blueberry patches and market garden produce growers. The Root Vegetable sample type comprised 24%, the Fruit Vegetable sample type 39%, Leafy Vegetable sample type 19% and the Berries sample type 18%, of the total number of produce samples collected.

Comparison to MOE Criteria

Soil results were compared to the MOE Table F and A criteria as referenced in the Ministry document *Guideline for Use at Contaminated Sites in Ontario* (MOE 1997). The Table F guidelines represent background soil concentrations obtained from a MOE province-wide parkland sampling program. The Table A soil guidelines are effects-based and were derived to protect both human health and the natural environment.

Overall, only nickel, copper, cobalt, arsenic, lead and selenium soil concentrations exceeded Table A in the City of Greater Sudbury. Concentrations of at least some of these elements were elevated above Table A in all community groupings, in all sample types, at all depths and in all land uses. The six elements noted above plus cadmium, chromium, iron, zinc, antimony, molybdenum, barium and vanadium also exceeded Table F in the City of Greater Sudbury. The number of Table A and F exceedances were highest in Falconbridge and Copper Cliff and decreased with increased distance from these communities. Ninety-nine percent of the soil, sand and gravel pH results were within the pH range prescribed in Table A.

Urban Soil

Generally in urban soil, metal and arsenic concentrations were higher in residential properties compared to park and school properties, at all depths. With one exception, this pattern was observed in Copper Cliff, Falconbridge, Coniston, the Sudbury Core and to a lesser extent, the Inner Sudbury Communities. In the Outer Sudbury Communities, concentrations were similar between all three land uses. The only exception was in Copper Cliff where concentrations were similar between residential and park properties at surface. Concentrations in all three land uses were highest in Falconbridge or Copper Cliff and decreased with distance from these communities. It should be noted that there were only a small number of school and park properties present within Coniston, Falconbridge and Copper Cliff and only a small number of residential properties sampled within the Outer Sudbury Communities. Comparisons, therefore, between land uses in these community groupings were limited.

Generally, metal and arsenic concentrations in urban soil were highest, at all depths, in Falconbridge or Copper Cliff. Copper, lead, selenium, zinc and barium concentrations were highest in Copper Cliff while cobalt, arsenic, cadmium, iron and chromium concentrations were highest in Falconbridge. Only nickel concentrations generally remained similar between these two communities. Elevated concentrations of cobalt, lead and zinc were also present in the Sudbury Core and / or Coniston. Urban soil metals and arsenic concentrations, at all depths, generally decreased towards the Outer Sudbury Communities Refer to Figures 7.5.1 through 7.5.4. Note that OC refers to Outer Communities, IC Inner Communities, SC Sudbury Core, CO Coniston, FA Falconbridge and CC Copper Cliff.

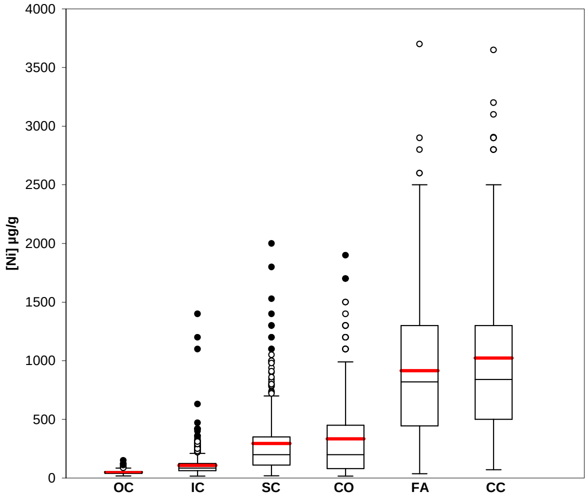


Figure 7.5.1 Nickel, 0 to 5 cm, in Urban Soil, by Communities

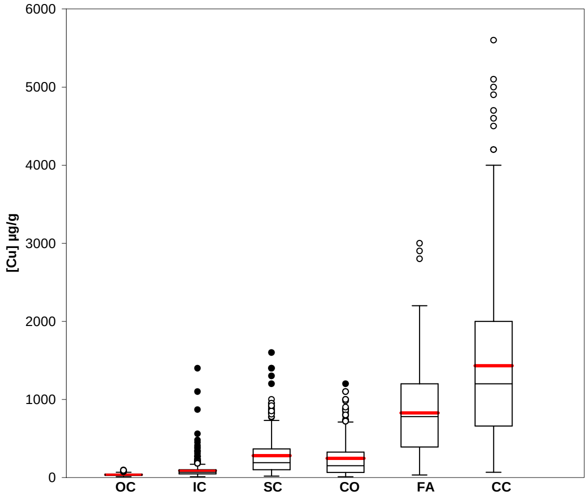


Figure 7.5.2: Copper, 0 to 5 cm, in Urban Soil, by Communities

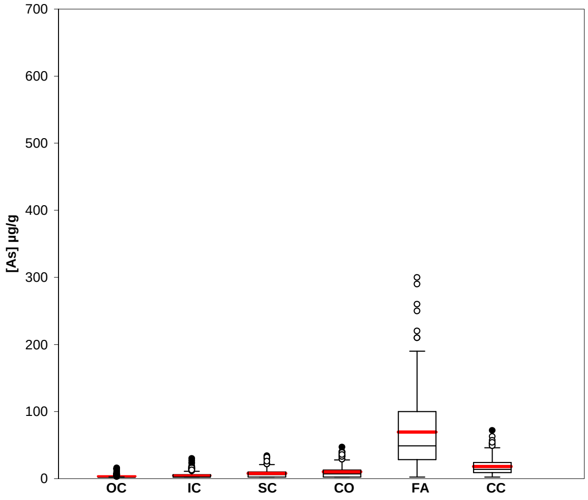


Figure 7.5.3: Arsenic, 0 to 5 cm, in Urban Soil, by Communities

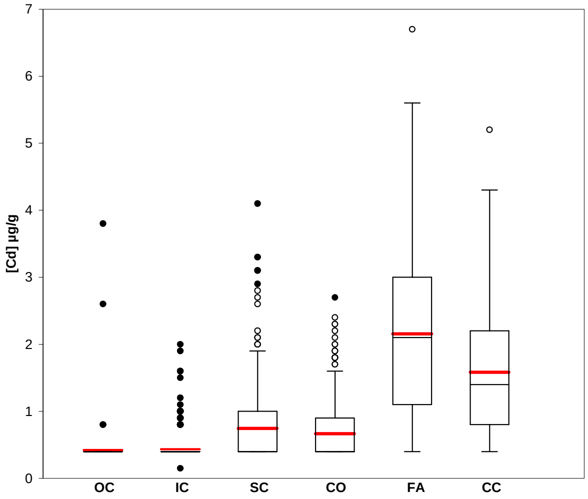


Figure 7.5.4: Cadmium, 0 to 5 cm, in Urban Soil, by Communities

With aerial deposition of metals and arsenic onto soil there should be a pattern of decreasing concentration with increasing soil depth. In urban soil, nickel, copper and lead showed strong trends of aerial deposition from surface in all community groupings but this trend weakened slightly with distance from Copper Cliff and Falconbridge. Aerial deposition trends for cobalt, arsenic, cadmium, selenium, chromium, iron and zinc were weak in the Outer and Inner Sudbury Communities, however, became stronger closer to Falconbridge and Copper Cliff. The percentage of sample locations that showed a trend of aerial deposition varied between community groupings from approximately fifty percent in the Outer Sudbury Communities, Coniston and Falconbridge to 62% in Copper Cliff and between 70 to 80% in the Sudbury Core and the Inner Sudbury Communities. In Falconbridge, only a small percentage of sample locations exhibited this trend for arsenic while 62% and 85% of sample locations exhibited this trend for chromium and cadmium, respectively. In Copper Cliff, 80% of sample locations exhibited this trend for selenium while arsenic did not show this trend at all. These differences between elements may be attributed to numerous factors including element form, element mobility, smelter process changes and differing chemical composition of the ore over time. The high percentage of elevated cadmium concentrations in Falconbridge and selenium concentrations in Copper Cliff, at surface, may be the result of a recent change in process or source of ore.

Depending on the community grouping, in the remaining 20 to 50% of the sample locations the maximum element concentrations were present below surface in urban soil. Elevated concentrations, at these sample locations, may still be attributed to aerial deposition, however, the aerial deposition may have been buried by landscaping practices at individual properties over time. Similar to aerial deposition from surface, trends of buried contamination were stronger closer to Falconbridge and Copper Cliff. More than half of the sample locations in the Outer Sudbury Communities, Coniston and Falconbridge showed evidence of buried contamination while smaller percentages of sample locations showed this trend in the Inner Sudbury Communities, the Sudbury Core or Copper Cliff. For arsenic in Falconbridge, 80% of the sample locations showed evidence of buried contamination. The high concentrations of arsenic below the surface in Falconbridge may be the result of high element mobility, differences in soil type, and/or higher historic arsenic emissions. In addition to the effect of landscaping practices in Coniston, a majority of sample locations may show evidence of buried contamination due to the absence of an ongoing emissions source. The smelter in Coniston ceased operation in 1972 while the smelters are still active in Falconbridge and Copper Cliff.

In urban soil, statistical correlations between nickel, copper, cobalt, arsenic, lead, cadmium, selenium, iron, chromium, zinc and barium were strongest and most numerous in Coniston, Falconbridge and Copper Cliff. The strength and number of these correlations decreased in all directions from the smelter communities. Generally, the strength and number of these correlations, with the exception of Falconbridge, decreased with depth. In the Outer Sudbury Communities, nickel and copper concentrations only correlated strongly with each other while in Coniston, Falconbridge and Copper Cliff, correlations were strong and numerous between the ten to eleven elements listed above. In contrast, Ontario background concentrations of nickel, cobalt and copper generally correlate with elements such as aluminum, barium, chromium, iron and vanadium. Since, nickel and copper concentrations were not strongly correlated with aluminum and vanadium in any of the community groupings and the overall strength and number of the correlations increased with proximity to the smelter operations, nickel, copper, cobalt, arsenic, lead, cadmium, selenium, iron, chromium, zinc and barium appear to be elevated due to emissions from the mining and smelting operations.

Aluminum, barium, iron, manganese, and vanadium appeared to be indicative of the natural chemistry of the soil in the City of Greater Sudbury. In all of the community groupings, except Falconbridge, correlations of naturally occurring elements increased in strength and number with depth indicating the presence of less disturbed soil. In Falconbridge, correlations of the naturally occurring elements remained moderate but relatively constant with depth. These correlations, along with the high element concentrations and large number of Table A and F exceedences, indicated that the soil at depth was still relatively disturbed in Falconbridge. Based on this evidence, urban soil sampling in Falconbridge did not fully delineate the vertical extent of elevated concentrations related to smelter emissions.

Figures 7.5.5 and 7.5.6 show the distribution of aluminum and vanadium concentrations at surface in all communities. Unlike other elements, the range of concentrations, mean and median for

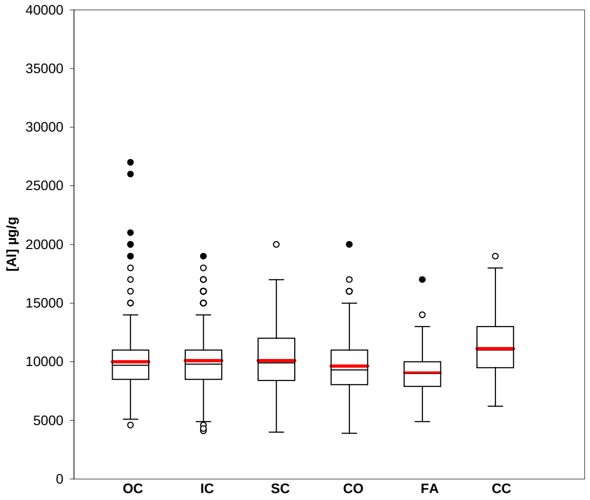


Figure 7.5.5: Aluminum, 0 to 5 cm, in Urban Soil, by Communities

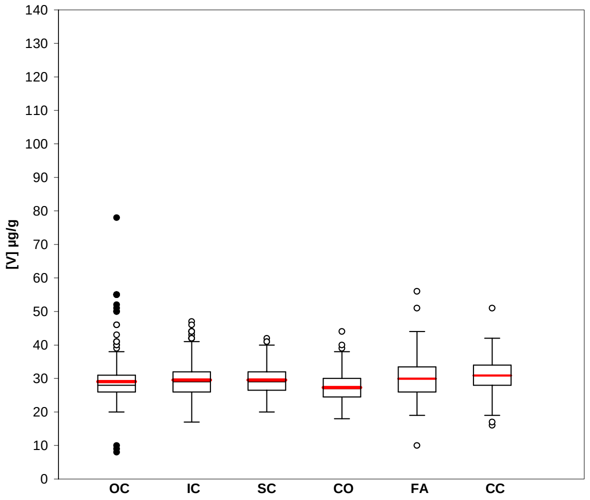


Figure 7.5.6: Vanadium, 0 to 5 cm, in Urban Soil, by Communities

aluminum and vanadium tended to be similar between community groupings. These concentration distributions further indicate that these elements do not appear to be associated with smelter emissions and are likely indicators of the natural chemistry of the soil in the City of Greater Sudbury. Refer to Section 10.3.5 for a complete set of box and whisker graphs comparing element concentrations between community groupings in urban soil.

Sand and Gravel

Generally, the concentrations of metals and arsenic in play and beach sand were quite low. Nickel and copper were the only elements that showed a consistent pattern of elevation in the sand sample type. Both nickel and copper were above Table F in many sand samples, however, only nickel concentrations exceeded Table A and in only a small number of samples. Nickel and copper concentrations in all sand samples were below 1000 µg/g. Arsenic was the only other element in the sand samples that exceeded Table A. Only one play sand sample in Falconbridge exceeded Table A, although three other play sand samples in Falconbridge had elevated arsenic concentrations. Arsenic concentrations in all of these play sand samples were below the adjacent soil concentrations.

Generally, the concentrations of metals and arsenic in the gravel sample type (fine particles only) were quite low. Only nickel and copper exceeded Table A for the gravel sample type. The concentrations of metals and arsenic in the playground gravel samples were essentially the same as the park, school and daycare 0 - 5 cm soil samples. Park, school and daycare 0 - 5 cm soil samples were higher than the playground gravel samples at high concentrations only because there were no gravel playgrounds in either Copper Cliff or Falconbridge where the highest soil levels were found. The metals and arsenic concentrations of the ballfield crushed stone samples were in between the play sand and playground gravel concentrations.

Overall, for play sand, beach sand, playground gravel and ballfield crushed stone the highest concentrations of nickel and copper were found in Copper Cliff, Coniston, Falconbridge and the Sudbury Core with the next highest concentrations in the Inner Sudbury Communities. The Outer Sudbury Communities had the lowest concentrations. The range of metals and arsenic concentrations in the sand and gravel samples was considerably less than that observed in urban soil. This is likely the result of sand and gravel being imported for landscaping purposes. Exposure to aerial deposition of metals and arsenic, therefore, was over a shorter period of time compared to adjacent soil.

Undisturbed Natural Soil

Undisturbed natural soil samples were collected from seven sampling locations in the Inner Sudbury Communities and the Sudbury Core. Surface soil concentrations of nickel, copper, cobalt, arsenic, lead, cadmium, selenium, iron and zinc were higher in the undisturbed natural soil than in urban soil collected from adjacent sampling locations. These elements, with the exception of zinc, were also higher in the undisturbed natural soil compared to urban soil collected throughout both the Inner Sudbury Communities and the Sudbury Core. At depth, concentrations of these elements in undisturbed natural soil were generally similar to or lower than concentrations in adjacent urban soil or in urban soil collected throughout the Inner Sudbury Communities and the Sudbury Core. The pH in undisturbed natural soil was lower than the pH in adjacent sand and urban soil samples.

In the undisturbed natural soil samples, nickel, copper, cobalt and arsenic concentrations exceeded Table A at surface and / or 5 - 10 cm. No Table A exceedences for any element were noted at 10 - 20 cm. No other elements exceeded Table A at any depth while nine elements exceeded Table F. Nickel, copper, cobalt, arsenic, lead, selenium, cadmium and iron showed a strong visual trend of decreasing concentration with depth consistent with aerial deposition. Unlike in the urban soil samples, trends of maximum concentrations occurring at either 5 - 10 cm or 10 - 20 cm were not generally observed for the undisturbed natural soil. This may be the result of minimal disturbances occurring at the undisturbed natural soil sample locations resulting in metals and arsenic accumulation at surface or due to the small sample size. Average aluminum, and to a lesser extent chromium and vanadium concentrations, showed a trend of increasing concentration with depth consistent with less disturbed soil at depth. Average zinc concentrations showed no observable change with depth.

Produce

The preliminary sampling of commercial and residential produce done in 2001 shows a pattern of elevated concentrations of nickel, copper, cobalt, arsenic, lead, cadmium and selenium in produce in the City of Greater Sudbury. The concentrations in produce increased with increasing concentrations of these elements in the surrounding garden soil. In the commercial market garden produce, the concentrations of these elements were relatively low, but were still higher than the market garden controls. Concentrations of these elements were higher in approximately 25% of the residential garden produce samples compared to the commercial market garden produce samples.

Leafy vegetables had higher concentrations of all elements compared to root and fruit vegetables mainly due to the inadequate removal of all soil from these vegetables during normal household washing practices. This is not an issue for the commercial market gardens sampled in this study as the concentrations of nickel, copper, cobalt, arsenic, lead, cadmium and selenium in soil were low and therefore the impact would be expected to be much less.

Generally, metals and arsenic concentrations in the commercial and wild blueberries were relatively low. However, concentrations of nickel in the commercial berry farm produce and concentrations of nickel and copper in the wild blueberry samples were elevated above the control samples.

The concentrations of nickel, copper, cobalt, arsenic, lead, cadmium and selenium in residential garden soils in the communities sampled were elevated but in general were lower than the highest concentrations found in the adjacent yards. The highest garden soil concentrations were found in Falconbridge followed by Copper Cliff, Coniston, Gatchell and then Lively. Nickel, copper, cobalt, arsenic, lead and selenium all exceeded Table A in garden soil in at least one community. No Table A exceedances were present in Lively while at minimum nickel and copper exceeded Table A in the rest of the communities. Market garden soils were lower than all of the five community residential garden soils and did not exceed Table A. Only nickel in market garden soil exceeded Table F. Soil at the wild blueberry patches exceeded both Table A and F while soil at the commercial berry farms only exceeded Table F.

8.0 CONCLUSIONS & RECOMMENDATIONS

Based on a review of historical sampling programs in the Sudbury area, the Ministry determined that additional sampling was warranted with regards to residential and publically- accessible urban green spaces within the City of Greater Sudbury. Soil and produce samples were collected by Ministry representatives during the period of July to November 2001 throughout the City of Greater Sudbury.

The scope of the soil study was not to exhaustively characterize the metal and arsenic concentrations at all possible sample locations within each property, rather it was to collect soil data that was representative of each sampled property. The need for further and more intensive sampling will be decided by the consultants and Technical Committee carrying out and overseeing the human health and ecological risk assessments currently underway in the City of Greater Sudbury. Ministry recommendations on potential areas requiring further investigation have been provided in Section 8.2.

8.1 Conclusions

The following conclusions can be drawn in response to the six study objectives listed below.

Objective #1 *To provide a screening level assessment of metal and arsenic concentrations in the upper 20 centimetres of soil within the City of Greater Sudbury;*

- This objective was met as sufficient data in the upper 20 centimetres of soil was collected to provide a screening level assessment of the spatial distribution of metals and arsenic concentrations across the City of Greater Sudbury.

In total, 6,734 soil samples were collected from 770 properties in the City of Greater Sudbury in four land uses (residential, schools, parks and agricultural). Three main types of soil samples were collected (soil, sand and gravel) to a maximum depth of 20 centimetres. Representative soil samples were collected from 24 local communities or geographic groupings within the City of Greater Sudbury.

Objective #2 *To determine if localized areas of higher metals and arsenic concentrations exist in the upper 20 centimetres of soil within the City of Greater Sudbury;*

- This objective was also met as substantial differences were noted in metals and arsenic concentrations between geographic areas, soil sample types and land uses.

Nickel, copper, cobalt, arsenic, lead and selenium soil concentrations exceeded the Ministry Table F background guideline and Table A effects based guidelines within the City of Greater Sudbury. In addition, cadmium, chromium, iron, zinc, antimony, molybdenum, barium and vanadium also exceeded Ministry Table F background criteria within the City of Greater Sudbury.

in all soil sample types , generally metal and arsenic concentrations were highest in Falconbridge, Copper Cliff, slightly lower in Coniston and decreased towards the Outer Sudbury Communities.

Concentrations in urban soil were highest in both Falconbridge and Copper Cliff, however, concentrations of copper, lead, selenium, zinc and barium were higher in Copper Cliff than in Falconbridge while the concentrations of cobalt, arsenic, cadmium, iron and chromium were higher in Falconbridge. Only nickel concentrations generally remained similar between Copper Cliff and Falconbridge. Concentrations of these elements were highest in urban soil compared to the other soil, sand or gravel sample types.

Undisturbed natural soil was only collected in the Inner Sudbury Communities and the Sudbury Core. Concentrations of nickel, copper, cobalt, arsenic, lead, cadmium, selenium, iron and zinc were higher in the undisturbed natural soil than in adjacent urban soil.

The highest residential garden soil concentrations were found in Falconbridge followed by Copper Cliff, Coniston, Gatchell and then Lively. Concentrations of nickel, copper, cobalt, arsenic, lead, cadmium and selenium in residential garden soils were elevated but generally lower than urban soil.

Commercial agricultural operations were generally located in the Outer Sudbury Communities, and therefore had soil concentrations that were lower than urban and residential garden soil.

The highest sand and gravel concentrations were found in Copper Cliff, Coniston, Falconbridge and the Sudbury Core. Generally, the concentrations of metals and arsenic in sand and gravel were lower than other sample types. Nickel and copper were the only elements that showed a consistent pattern of elevation.

Generally, soil metal and arsenic concentrations in all sample types were highest in residential properties compared to park and school properties.

Objective #3 *To determine if metal and arsenic concentrations change with depth in the upper 20 centimetres of soil, in order to identify if element concentrations are related to aerial deposition from smelter emissions in the City of Greater Sudbury;*

- This objective was met, however, additional sampling is required to delineate the trends. A distinct trend of decreasing concentrations with depth for nickel, copper, cobalt, arsenic, lead, cadmium, selenium, chromium, iron and zinc was observed in the upper 20 centimetres of soil throughout the City of Greater Sudbury. Concentrations of these ten elements appear to be elevated due to aerial deposition from local smelting operations.

Samples from multiple depth intervals were collected from urban soil and undisturbed natural soil within the City of Greater Sudbury. Generally, concentrations of nickel, copper, cobalt, arsenic, lead, cadmium, selenium, chromium, iron and zinc decreased with depth in 50% to 85% of the urban soil sample locations throughout the City of Greater Sudbury. This pattern of decreasing concentrations with depth is consistent with aerial deposition from a continuous long term emission source. The major exception was arsenic in Falconbridge where concentrations in 80% of the sample locations increased with depth. This trend of maximum element concentrations below the surface was present to some extent in all community groupings for most elements. This trend indicates that sampling may not have vertically delineated all element concentrations within the City of Greater Sudbury, especially arsenic concentrations in Falconbridge. The maximum arsenic concentrations in the City of Greater Sudbury were present below the surface in Falconbridge.

In all of the undisturbed natural soil sample locations, concentrations of nickel, copper, cobalt, arsenic, lead, selenium, cadmium and iron decreased with depth, consistent with aerial deposition. The trend of maximum element concentrations below surface was not observed for this sample type.

Objective #4 *To determine the strength of relationships between metal and arsenic concentrations in the upper 20 centimetres of soil within the City of Greater Sudbury in order to identify if element concentrations are related to smelter emissions;*

- This objective was met. Strong, statistically significant correlations were present between nickel, copper, cobalt, arsenic, lead, cadmium, selenium, iron, chromium, zinc and barium in Coniston, Falconbridge and Copper Cliff. The number and strength of these correlations decreased with increased distance from the smelter communities and were strongest at surface. Concentrations of these eleven elements appear to be elevated due to aerial deposition from local smelting operations.

Concentrations and correlations of aluminum and vanadium were generally constant with depth throughout the City of Greater Sudbury. These element concentrations appeared to be indicative of the natural chemistry of the soil in the City of Greater Sudbury. Ontario background concentrations of aluminum and vanadium generally correlate with elements such as nickel, cobalt and copper. Throughout the City of Greater Sudbury, however, nickel and copper concentrations did not correlate with aluminum and vanadium but did correlate with cobalt, arsenic, lead, cadmium, selenium, iron, chromium, zinc and barium. The overall strength and number of these correlations increased with proximity to the smelter operations and were strongest at surface. The number, strength and spatial distribution of these correlations indicate that concentrations of these eleven elements are elevated due to aerial deposition from local smelting operations.

Objective #5 *To identify metal and arsenic concentrations in produce grown within the City of Greater Sudbury, in order to support exposure estimates for the human health risk assessment;*

- This objective was not met although elevated concentrations of nickel, copper, cobalt, arsenic, lead, cadmium and selenium were observed in produce within the City of Greater Sudbury. The concentrations in produce increased with increasing concentrations of these elements in the adjacent soil.

In total, 245 produce samples were collected from 52 residential gardens, commercial market gardens, berry farms or wild blueberry patches. Four types of produce samples were collected: Root Vegetables, Fruit Vegetables, Leafy Vegetables and Berries.

Concentrations of nickel, copper, cobalt, arsenic, lead, cadmium and selenium were highest in produce from residential gardens. Leafy vegetables in residential gardens had higher concentrations of all elements compared to root and fruit vegetables. Generally, metals and arsenic concentrations in the commercial produce and wild blueberries were relatively low. However, concentrations of nickel in the commercial market garden and berry farm produce and concentrations of nickel and copper in the wild blueberry samples were elevated above the control samples.

This objective was not met due to the deficiencies in the produce sampling program design and laboratory quality control issues.

Objective #6 *To identify additional work that may be appropriate to support the Human Health Risk Assessment (HHRA) and the Environmental Risk Assessment (ERA) based upon this screening level study.*

- This objective has been met. Potential areas requiring further study or investigation are discussed in Section 8.2.

8.2 Data Gaps and Recommendations

As discussed previously, the 2001 sampling program for the City of Greater Sudbury was meant to fill identified knowledge gaps with screening level information only. As a result, intensive characterization of the soil metal and arsenic concentrations was not completed for the study area. Further sampling and / or analysis will be required to support the community based human health and ecological risk assessment currently underway in the City of Greater Sudbury. Ministry recommendations on potential areas requiring further investigation have been provided below.

1. Further soil sampling is required below 20 centimetres to fully delineate the vertical extent of elevated metals and arsenic concentrations within Falconbridge.

2. Bioaccessibility analysis should be completed for metals and arsenic from representative soil samples from different soil types in each community grouping. This analysis should be completed for samples with concentrations at the 10th, 50th and 95th percentile, at all depth intervals.

3. All soil analysis from this study was recorded as total metal concentrations in soil. Prior to analysis, all soil material that passed through the 2 mm sieve was ground to pass through a 355 micron sieve. Soil analysis for human health studies focuses on the fine fraction of the soil material. The fine fraction is defined as all soil material that passes through the 355 micron sieve without grinding. For the purposes of the human health risk assessment, element concentrations in the fine fraction of the soil material should be determined for metals and arsenic on samples with concentrations at the 10th, 50th and 95th percentile in all community groupings.

4. Laboratory soil texture analysis was not completed for any soil samples from this study. Soil texture data was solely based on field observations. Laboratory characterization of soil texture may be useful for bioaccessibility analysis and metals transport modelling during the community based risk assessment and therefore should be completed.

5. TOC, pH and conductivity were only measured for 10% of the soil samples. These parameters, especially pH, should be measured for a large percent of the soil samples to aid in data interpretation. The apparent difference between the pH of undisturbed natural soil and adjacent urban soil should be further investigated.

6. Statistical analysis should be conducted on replicate samples collected from each property within the City of Greater Sudbury to determine within-site and between-site sampling and analytical variability.

7. Soil metal and arsenic concentration profiles varied between elements and geographic locations. Further study to determine accumulation and transport mechanisms responsible for the differences in these profiles is required to properly assess current and potential risk. This study may examine biologically mediated soil mixing, element specific movement (a function of soil pH, redox, moisture content etc) and / or historical changes in smelter process / ore source.

8. A comprehensive garden and commercial produce sampling program should be completed for the purposes of the human health risk assessment. The program should include: multiple sampling events over the year, collection of replicate samples, variation of produce types and varieties (i.e. root, leafy etc.), consistent produce varieties between properties, statistically significant sample size for each community grouping and garden type, proper control sample locations, soil sampling from each produce sampling location (soil analysis should include the same analytical suite as produce samples plus soil type) and analysis of correlations between produce and soil concentrations.

9. Property owners should be informed that better washing of leafy vegetables would be recommended where elevated soil concentrations are found.

10. The results of this study should be compared with previous research (MOE and other) including historical soil and vegetation quality assessments and regional and local soil and geological surveys. This comparison should be completed to fully assess short and long term data trends.

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