Phytotoxicology Soil Investigation: School Yards and Beaches Port Colborne (April 2000)

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Phytotoxicology Soil Investigation:

Results of Soil Sampling in School Yards and Beaches in the Port Colborne Area, April 2000

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I. INTRODUCTION

Results of the Ontario Ministry of the Environment (MOE) Phytotoxicology studies conducted in the Port Colborne area in 1998 and 1999 confirmed that soil to a depth of at least 15 cm over a wide area is contaminated with nickel, and to a lesser extent with copper and cobalt[1]. The zone of contamination lies mainly to the northeast of the former INCO refinery, which is understood to be the source of the metals. Soil nickel background concentrations (43 µg/g) are exceeded beyond 19 km northeast of INCO and extend over an area greater than 316 km^2. Soil nickel concentrations exceed the MOE effects-based soil remediation criterion (200 µg/g) up to 9 km northeast of the refinery over a 29 km^2 area. The areas of elevated copper and cobalt in soil are much smaller and the concentrations are significantly lower than the extent of nickel contamination. A thorough description of the soil heavy metal contamination in the Port Colborne area is available in the 1999 MOE report[1].

Even though a joint MOE/Regional Niagara Public Health Department report[4] concluded that the soil heavy metal contamination did not pose a risk to human health, the community still expressed concerns about the levels of metals in the soil at school playgrounds. In addition, similar concerns were expressed regarding the contamination status of the public beaches in the area. In response to these concerns the City of Port Colborne requested the MOE sample playground soil at all of the city’s schools, commercial day cares, and public beaches. This work was conducted in the spring of 2000 by scientists of the MOE Ecological Standards and Toxicology Section (formerly the Phytotoxicology section). This report summarizes the results of that investigation.

II. METHODS

A list of 19 schools and commercial day cares in Port Colborne was obtained from the city’s municipal office. Because several of the day cares shared school facilities, separate soil sampling was not required at all day cares. One day care (Helen Kinear Children Center) used only the indoor part of the church property, and so this center was not included in this study. A total of 13 school and or day care properties and 3 beach sites were sampled (Table 1). The beaches sampled included Nickel Beach, Lorraine Beach, and Lakeshore Rd. Beach.

The sampling was completed on April 5 and 6, 2000 by MOE Phytotoxicology scientists William McIlveen and Marian Chiu. At each property, the investigators identified themselves to the school principals or another person in charge of the facility and explained what was to be sampled. School officials had been previously contacted by the MOE Niagara District office, so the Phytotoxicology investigators were expected, and no difficulties were encountered obtaining access to all proposed sample areas.

At each location the layout of the property was assessed and decisions were made with regards to the most appropriate sampling strategy. For most properties, samples were collected from at least two distinct sites, whereas larger school yards had up to five separate sample locations. All sampling at each site was completed in duplicate. Each replicate sample consisted of a minimum of 15 soil cores collected using standard Phytotoxicology soil sampling procedures[2]. Some of the sports fields were quite large and considerably more than 15 cores were collected. For example, the approach to sampling a soccer filed is normally to walk from one goal line to the opposite goal line down the center of the field collecting soil cores all along the way, so that the sample represents the entire length of the field. In addition, the area around the goals and the center of the field is where the turf is most worn and bare soil most often occurs, and so potential exposure to contaminated soil would be greatest. All soil samples were 0 to 5 cm in depth. This is a standard surface soil collection depth, and it represents the layer of soil that the children are potentially exposed to.

Soil samples were processed at the MOE Ecological Standards and Toxicology Section processing laboratory using standard MOE protocols (air-dried, homogenized, ground and sieved to 355 micron size fraction, and stored in glass jars)[2]. Samples were then forwarded to the MOE Laboratory Services Branch for analysis of trace metals on a dry weight basis by inductively-coupled plasma-atomic emission spectrometry (ICP-AES) for total aluminum, barium, beryllium, calcium, cadmium, cobalt, copper, chromium, iron, magnesium, Manganese, molybdenum, nickel, lead, strontium, vanadium, and zinc.

Concern about Arsenic in Soil

The soil samples from the Port Colborne schools were not sampled for arsenic. This is because arsenic has not been identified as a contaminant of concern in recent sampling conducted by the MOE across the Port Colborne area. All of the soil samples collected by the MOE for the 1999 Port Colborne report[1] were analyzed for arsenic. None of these samples had arsenic concentrations that exceeded the normal background range for arsenic in Ontario soil (17 µg/g). Arsenic has been detected at elevated concentrations at a few residential and at least one agricultural property immediately adjacent to the INCO refinery. However the source of that arsenic contamination is unknown at this time.

All of the MOE 1999 soil arsenic data, and arsenic data obtained from soil samples collected by INCO's consultant Jacques Whitford, were compared to soil nickel concentrations at the same sample sites using linear regression analysis. This statistical test assesses the degree of interdependence between the two soil contaminants. The result showed conclusively that soil arsenic levels are highly positively correlated with soil nickel levels ($r^2 = 0.84$, 92 degrees of freedom, $p<0.001$). In other words, soil arsenic levels increased as soil nickel levels increased. The soil arsenic level in Port Colborne can be predicted to a high degree of accuracy using the following regression formula:

µg/g arsenic in soil = (0.00521 X **µg/g nickel** in soil) + 5.218879

This is very compelling evidence suggesting that arsenic was released with nickel and other metals into the air from the INCO refinery. However, even though arsenic was emitted from the refinery and was deposited on the soil in the Port Colborne area, arsenic never accumulated in soil to the degree that nickel, copper, and cobalt accumulated. Whereas it is common to find substantially elevated soil nickel concentrations almost anywhere in Port Colborne, it is extremely rare to find even marginally elevated soil arsenic levels. Furthermore, the few soil samples found to have elevated arsenic levels have all come from samples collected immediately adjacent to INCO, and the source of that arsenic contamination is unknown, although it is suspected to be buried industrial waste.

Even though arsenic has been clearly shown not to be a widespread soil contaminant in Port Colborne, and it is the opinion of the MOE that arsenic is very unlikely to be present in elevated levels in soil from Port Colborne schools, there still remains considerable concern in the community about this contaminant. Therefore, the MOE has retrieved the April 2000 soil samples from archival storage and will re-submit them for arsenic analyses. Analyses for non-emergency samples takes several months, and so the release of this report is not further delayed, the arsenic results will be released later as an addendum.

III. RESULTS

The complete analytical results for each school property and beach site are summarized separately in Appendix 2. Nickel was the only contaminant that exceeded MOE effects-based guidelines at some schools and beaches. Copper and cobalt, the other two contaminants known to be present at elevated levels in the Port Colborne area, were higher than background at some schools and beaches but did not exceed effects-based guidelines. All of the other 14 elements were at or below their respective background levels. Table 2 is a summary of the range of nickel, copper, and cobalt concentrations encountered at the schools and beaches. Significant results and characteristics of the individual schools are discussed separately.

The soil data from the schools and beaches are compared to the MOE *Guideline for Use at Contaminated Sites in Ontario*[3]. This document describes two MOE soil guidelines: 1) Table F, and 2) Table A. Table F is background-based. It reflects the maximum concentration that is expected in Ontario soil that has not been influenced by a source of pollution. Table A is effects-based. Effects-based concentrations are set to protect against the potential for adverse effects to human health, ecological health, and the natural environment, whichever is the most sensitive. By protecting the most sensitive parameter the rest of the environment is protected by default. The MOE *Guideline* is explained in more detail in Appendix 1. The rationale for the nickel, copper, and cobalt Table A guidelines is ecological, not human health, because the natural environment is more sensitive than human health to potential injury from these chemicals. Specifically, the Table A guidelines for these three contaminants are set to protect vegetation, mostly sensitive agricultural crops. For example, concentrations of nickel, copper, and cobalt in soil above the MOE Table A guidelines *may cause* sensitive crops (typically cereal grains) to grow more slowly, have lower yields, or develop characteristic discolouration associated with metal toxicity.

St. Therese Catholic School (Appendix 2A)

Based on the 1998/1999 MOE studies St. Therese Catholic School is in the zone of highest soil metal contamination. The yard was quite large, therefore separate samples were obtained from the two soccer fields, the open field to the northwest, the open field to the east of the school building, and from the fenced playground. Soil was reported to have been recently added to the area of the soccer fields, but this was difficult to differentiate from the areas where soil had not been replaced.

The soil metal concentrations were quite consistent across all four sports fields, with soil nickel levels ranging from 1,045 µg/g to 1,450 µg/g. In contrast, the soil within the fenced play area had a much lower Ni level (270 µg/g). All five sample sites exceeded the nickel effects-based MOE Table A guideline of 200 µg/g. Copper and cobalt concentrations exceeded the background-based Table F guideline at four of the five sample sites, but did not exceed Table A criteria. All other chemicals were within normal background ranges at all sample sites.

St. John Bosco Catholic School (Appendix 2B)

Three sites were sampled at St. John Bosco Catholic School. The school had been rebuilt on a previous school site, and surface soil disturbance had occurred during construction of the present buildings. The area on the north side of the school was believed to be original soil, while soil in the fenced play area had been scraped away from the old school site. The baseball fields to the south still had visible sod rolls, suggesting recent landscaping or site disturbance. Nickel was the only chemical present in soil above natural background levels. The Table A effects-based guideline was not exceeded. The maximum soil nickel level was 105 µg/g, which occurred at the north lawn area and in sand from the fenced enclosure.

St. Patrick Catholic School (Appendix 2C)

Soil samples were obtained from the football field located to the south of the school and from inside the perimeter fence of the playground area. Nickel was the only chemical present in soil above natural background levels, although the Table A effects-based guideline was not exceeded. The maximum soil nickel level was 80 µg/g, which occurred on the football field.

Lakeshore Catholic High School (Appendix 2D)

Samples of soil were obtained from the football and soccer fields just north of the school. The latter may not be part of the school property.

Soil nickel levels exceeded the Table F guideline from the football field and exceeded the Table A guideline from the soccer field. The maximum soil nickel level was 320 µg/g. All other chemicals were within natural background levels at both sample sites.

C.M. Thompson Public School (Appendix 2E)

The school yard of C. M. Thompson Public School contained a baseball diamond and a soccer field. Both of these were sampled. The northeast corner of the school yard had some playground equipment adjacent to an area that had obviously been recently disturbed for a new garden planting. Because of the fresh disturbance, no samples were collected there. All chemicals except nickel were within their normal background concentrations at both sports fields. Although nickel levels exceeded the Table F soil background guideline at both sports fields, the Table A effects-based guideline was not exceeded. The maximum soil nickel level was 72 µg/g, which occurred around the baseball diamond.

Dewitt-Carter Public School (Appendix 2F)

Dewitt-Carter Public School is shared with three day care facilities including a general daycare, PACT, and Tiny Tots. It is a relatively old school and the yard had no obvious evidence of any recent disturbance. Sand was collected from the sand boxes and soil was collected from around the baseball diamond. All chemicals except nickel were within their normal background concentrations at both sample sites. The soil nickel levels from around the baseball diamond exceeded the Table A effects-based guideline (maximum 590 µg/g).

Humberstone Public School (Appendix 2G)

Humberstone Public School is a relatively new school located immediately west of some of the highest soil nickel concentrations detected in the Port Colborne area. Because of its large size, the yard was divided into four areas for sampling, including the three soccer fields and an area around the playground equipment in the western part of the yard. Soil cobalt concentrations exceeded the MOE background-based Table F guideline at three of the four sample sites and the copper Table F criterion was exceeded at all four sites. The soil nickel levels exceeded the Table A effects-based guideline at all four sample sites, ranging from 720 µg/g in soil from the north soccer field to a maximum of 1,050 µg/g from the central soccer field. All other chemicals were within their normal background concentrations at all four sample sites.

Oakwood Public School and Day Care (Appendix 2H)

Oakwood Public School includes a day care center, although the children in the day care do not normally go outdoors. An outdoor area may be developed in the future, therefore, samples were collected in the vicinity of the proposed play area. In addition, samples were obtained from the soccer field and from around the playground equipment. Nickel exceeded the MOE Table F guideline at all three sample areas, ranging from 61 µg/g around the playground equipment to 195 µg/g in the soccer field. All other chemicals were within their respective background levels at all sites.

Steele Street Public School (Appendix 2I)

Steele Street Public School was built in 1915, with more recent additions and modifications. Soil samples were collected from the baseball field and from around the swings. Soil from the baseball field had 215 µg/g nickel, which exceeded the Table A guideline, while soil near the playground equipment had 89 µg/g nickel, which is about twice the Table F background guideline but below the effects-based criterion. All other chemicals were within their normal background concentrations at both sample sites.

Port Colborne High School (Appendix 2J)

Port Colborne High School contains three day care facilities, including PACT, Little Darling Infant, and the Toddler Care Center. Samples of sand were obtained from within the enclosure of the Toddler Care Center play area, and soil was collected on the football field inside the sports track.

The maximum soil nickel level was 59 µg/g, which exceeded the Table F background-based guideline. All other chemicals were within their normal background concentrations at both sample sites.

Ecole St. Joseph (Appendix 2K)

Ecole St. Joseph is located adjacent to the zone of highest soil contamination. The play areas appeared to have been undisturbed for many years. Two areas were sampled; the first from the area between the baseball diamond and soccer field, and the second was a composite sample of soil from the area around the sand pits and bare soil under the swing sets. Nickel levels exceeded the Table F guideline at both sample sites. The maximum soil nickel concentration was 160 µg/g, obtained from the area between the two sports fields. All other chemicals were within their normal background concentrations at both sample sites. Considering it's location in the community relative to known soil contamination, the soil nickel level at Ecole St. Joseph is quite low.

McKay Public School (Appendix 2L)

McKay Public School includes the First Friends Daycare facility. Samples of soil were collected from the soccer field and the baseball diamond to the south of the school, and from inside the fenced play area on the north side of the school. The soil nickel levels exceeded the Table F guideline at all sample areas. The maximum soil nickel concentration was 155 µg/g. All other chemicals were within their normal background concentrations at all sample sites.

Port Colborne Regional Daycare (Appendix 2M)

A composite soil sample was collected from the two fenced lawn areas. In addition, sand was obtained from the area of the playground equipment. All chemicals were within their normal background concentrations at both sample sites.

Beaches (Appendix 2N)

Three beaches were sampled. The largest and likely the one most used was Nickel Beach, located at the south end of Lake Road. A composite sample was collected by walking along the beach above the normal wave line. The beach at the end of Lorraine Road (Lorraine Beach) consisted of sand and gravelly patches over limestone bedrock. A composite sample was obtained from the sandy portion of the beach. The Lakeshore Rd beach was larger than normal because the lake levels were low. A composite beach sand sample from Lakeshore Rd Beach was obtained from beside a grove of trees near the Surfside Marina on Lakeshore Road. Because the sand on a beach tends to move quite readily under wind and wave action, samples were taken where the beach was considered to be most stable. This included sites adjacent to trees or other established vegetation and above the obvious normal wave line.

The nickel concentration of the sand exceeded the Table A guideline (maximum 240 µg/g) at Nickel Beach. Although no other chemical at Nickel Beach exceeded normal background levels, the copper, cobalt, zinc, and strontium levels were all noticeably higher than the other two beaches. Both the vanadium and iron levels were marginally higher that the Table F background guidelines at Lakeshore Rd Beach. All the chemicals were within normal background levels in sand from Lorraine Beach.

Concentrations of some chemicals, particularly calcium, while within the normal range, were quite different between beaches, indicating that the sand deposits were likely not all derived from the same parent materials. Beach sand is very mobile and can be transported a considerable distance inshore as a result of wind and wave action, and can travel many kilometers along a lakeshore in near-shore water currents.

IV. DISCUSSION AND CONCLUSIONS

The metal concentrations found in the soils at the schools in Port Colborne are comparable to soil metal concentrations previously documented in the surrounding community (MOE, 1999[1]). The schools closest to and downwind (northeasterly direction) of the INCO refinery tend to have higher soil nickel, copper and cobalt concentrations than schools further away from the refinery. Nickel was the only metal to exceed the MOE Table A Guideline, this occurred at some samples at six of the twelve school yards.

In 1997 the MOE and the Regional Niagara Public Health Department jointly issued a report[4] evaluating the health risk associated with elevated levels of nickel, copper, and cobalt in soil in Port Colborne. The report, which included both a human health risk (exposure) assessment and an evaluation of epidemiology data, concluded that there are no adverse health effects anticipated from exposure to these metals in soil in Port Colborne. In addition, the evaluation of population public health data did not indicate any adverse health effects which may have resulted from environmental exposure.

The 1997 health risk assessment used a multimedia exposure model (i.e., it looked at all exposure pathways - air, drinking water, soil, store bought and vegetable garden produce) which evaluated a continuous lifetime exposure of 70 years to the three metals. The maximum soil nickel concentration used in the exposure assessment was 9,750 µg/g. By comparison, the maximum soil nickel concentration found in the school yards in Port Colborne was 1,450 µg/g. At the schools the potential for direct exposure is reduced because the soil is mostly covered in turf grass, which reduces the potential for the resuspension of metals in respirable dust. In addition, children playing in the school yard will receive only a very small portion of the continuous lifetime exposure assumed in the 1997 health risk assessment. For these reasons no adverse health effects are anticipated for children playing in the Port Colborne school yards.

Only one beach (Nickel Beach) had soil nickel levels that marginally exceeded the MOE Table A guideline (maximum concentration 240 µg/g). This was an unexpected finding, as sand usually has very low levels of base metals. It is the fine clay and silt particles and organic matter in soil that captures and holds deposited contaminants. Beach sand is usually devoid of this material, and so contaminants that fall onto a beach tend not to be retained. The fact that beach sand is chemically and physically quite inert, and the sand is moved around by wind, waves, and onshore currents, explains why the MOE has not found significant contamination in beaches in communities where substantial soil contamination has occurred. The sand samples collected from Nickel Beach were obtained from the edge of the beach close to where vegetation had rooted. It is possible that the sample contained some organic matter from the nearby vegetation, and it was the contaminated organic matter that contributed to the marginally elevated nickel levels in the sand at Nickel Beach. Regardless of the origin of the contamination, the nickel concentrations at Nickel Beach do not pose a human health risk. In fact, since the rationale for the Table A guideline is the protection of sensitive agricultural crops, and none of these are obviously present on the beach, it is arguable if there is even the potential for an adverse ecological effect as a result of the marginally elevated nickel concentrations in the sand at Nickel Beach.

V. REFERENCES CITED

1. **Kuja, A**. 1999. *Phytotoxicology Soil Investigation: INCO - Port Colborne (1998)* Report No. SDB-031-3511-1999, Standards Development Branch, Ontario Ministry of the Environment, Toronto.

2. **McIlveen, W.D.**, and **D.L. McLaughlin**. 1993. *Field investigation manual Part 1: General methodology*. Report No. HCB-014-3511-93, Hazardous Contaminants Branch, Ontario Ministry of the Environment, Toronto.

3. **Ontario Ministry of the Environment and Energy.** 1997. *Guideline for Use at Contaminated Sites in Ontario*. Report No. PIBS 3161 E01.

4. **Leece B. and S. Rifat 1997.** *Technical Report: Assessment of Potential Health Risks of Reported Soil Levels of Nickel, Copper and Cobalt in Port Colborne and Vicinity. May 1997.* Standards Development Branch, Ontario Ministry of the Environment and the Health Services Department, Region of Niagara. MOE Report No. SDB-EA054.94-3540-1997.

Table 1. List of school properties and beaches sampled in Port Colborne, April 5 and 6, 2000.

Site*	Name	Address	Sponsor/Type
1	St. Therese Catholic School	530 Killaly St. East	Niagara District Catholic School Board
2	St. John Bosco Catholic School	755 Fielden Ave.	Niagara District Catholic School Board
3	St. Patrick Catholic School	266 Rosemount Ave.	Niagara District Catholic School Board
4	Lakeshore Catholic High School	150 Janet St	Niagara District Catholic School Board
5	C.M. Thompson Public School	122 Hampton Ave	District School Board of Niagara
6	Dewitt Carter Public School	435 Fares Street	District School Board of Niagara
7	Humberstone Public School	806 Killaly St. East	District School Board of Niagara
8	Oakwood Public School and Day Care	255 Omer Ave	District School Board of Niagara
9	Steele Street Public School	214 Steele Street	District School Board of Niagara
10	Port Colborne High School	211 Elgin Street	District School Board of Niagara
11	McKay Public School	320 Fielden Ave	District School Board of Niagara
12	Ecole St. Joseph	210 Elizabeth Street	French School Board
13	Port Colborne Regional Daycare	487 Northland Ave	Day Care

Beaches included Lakeshore Rd. Beach, Nickel Beach, and Lorraine Beach.
* See Figure 1, page 10.

Table 2. Summary of concentration ranges (µg/g) of nickel, copper, and cobalt at school yards and beaches in the Port Colborne area, April, 2000.

Site*	Name	Number of Sample Sites	Nickel	Copper	Cobalt
1	St. Therese Catholic School	5	***270 - 1450***	57 - ***185***	12 - ***38***
2	St. John Bosco Catholic School	3	17 - ***105***	12 - 29	7 - 10
3	St. Patrick Catholic School	2	14 - **80**	26 - 31	5 - 10
4	Lakeshore Catholic High School	2	***140 - 320***	25 - 43	8 - 13
5	C.M. Thompson Public School	2	43 - ***72***	22 - 28	7 - 8
6	Dewitt-Carter Public School	2	22 - ***590***	3 - 69	2 - 17
7	Humberstone Public School	4	***755 - 1050***	***103 - 105***	***22 - 29***
8	Oakwood Public School & Day Care	2	***61 - 195***	18 - 35	7 - 10
9	Steele Street Public School	2	***89 - 215***	23 - 44	7 - 8
10	Port Colborne High School	2	3 - ***59***	4 - 21	2 - 7
11	McKay Public School	3	***98 - 155***	24 - 25	7 - 8
12	Ecole St. Joseph	2	***96 - 160***	16 - 38	4 - 12
13	Port Colborne Regional Daycare	2	4 - 22	5 - 9	2 - 3
Lorraine Beach			16	1	4
Lakeshore Rd Beach			3	1	5
Nickel Beach			***240***	9	15
MOE Table A Effects-based Soil Guideline**			200	300	50
MOE Table F Background-based Soil Guideline**			43	85	21

Data in bold italic exceed Table F guidelines, shaded data exceed Table A guidelines.
*School locations illustrated in Figure 1, page 10.
** MOE Guideline for Use at Contaminated Sites in Ontario, see Appendix 1.

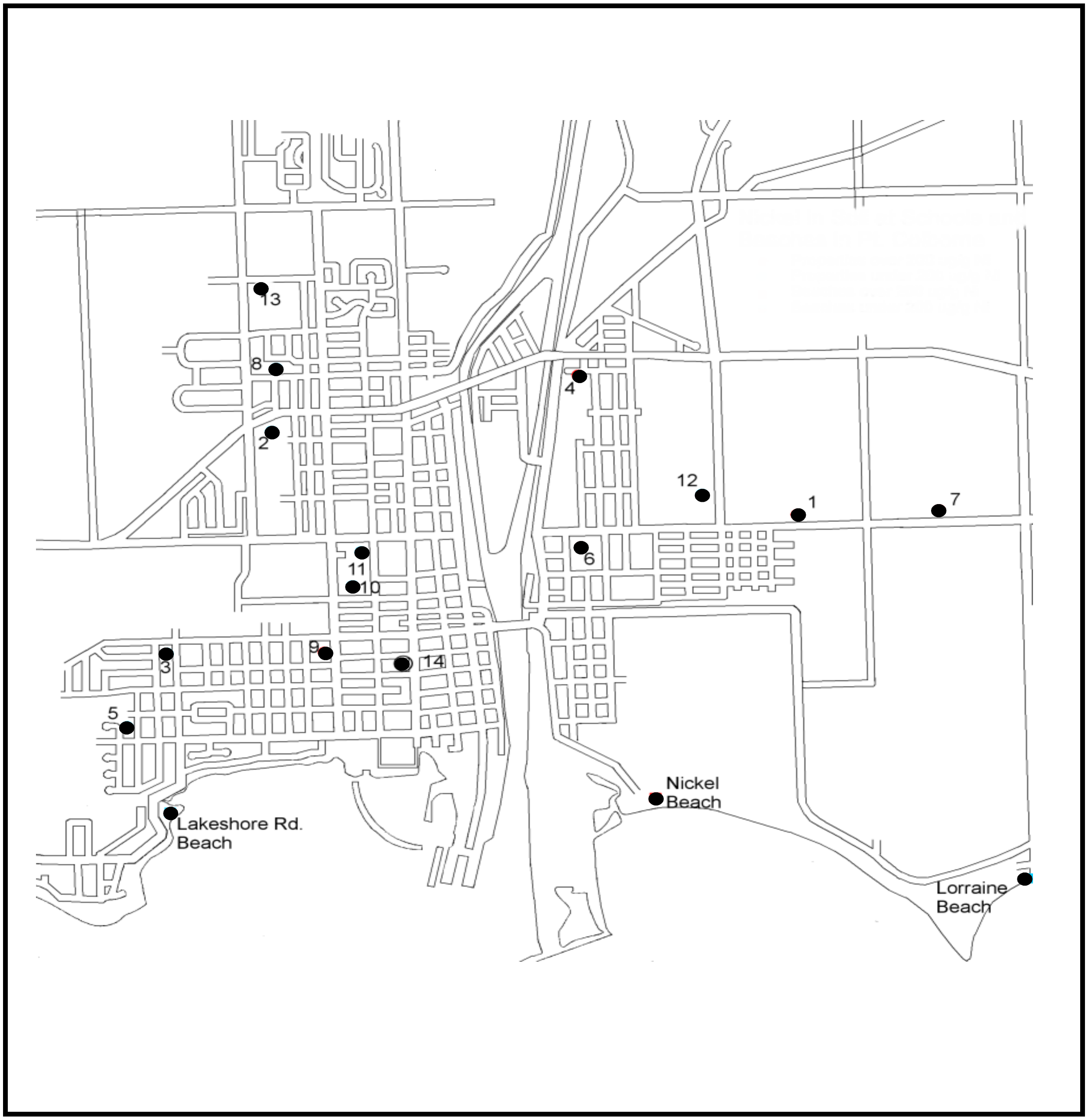

Figure 1. Location of schools and beaches in Port Colborne sampled April 2000. Numbers refer to schools identified in Table 1.

Appendix 1A
Derivation and Significance of the MOE Soil Remediation Criteria (Clean-up Guidelines)

The MOE Soil Remediation Criteria have been developed to provide guidance in cleaning up contaminated soil. They are not action levels, in that an exceedence of one or more of the criteria does not automatically mean that a clean-up must be conducted. A site clean-up may be conducted when a contaminated property is sold and/or the land use is changed. For example, the owner of an industrial property who plans to sell his/her land to a developer who intends to build residential homes can use the Remediation Criteria to clean up the soil to meet the residential land use criteria. This will allow the site to be reused for residential land-use without concern for adverse effects.

When contamination is found at a site where a change in land-use is not planned, the criteria may be used to assist in making decisions about adverse effects and the need for remediation. This is different from the previously described situation where a decision to change the land-use has already been made and the level of remediation required to rule out the potential for adverse effects is established by the new land use. Decisions on the need to undertake remedial action when the criteria are exceeded, and where the land use is not changing, require consideration of factors such as:

< the demonstrated presence or likelihood of an adverse effect (on and off property);

< an understanding of the type of protection provided by the criteria gained through knowledge of the exposure pathways and receptors which were considered in the development of the criteria, and through understanding how that combination of pathways and receptors relate to those which could be found at the site;

< 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;

< an understanding of the environmental characteristics of the contaminants and of the site conditions that could influence the migration of the contaminants and how this effects their exposure and response characteristics.

In each case, the decision to undertake or not undertake site remediation should entail all of these factors plus any additional factors specific to the site in question. When the decision is made that remedial action is needed, the criteria can be used as clean-up targets. If these criteria are unacceptable to the proponent undertaking the remediation, they have an option to develop local back-ground-based criteria or conduct a site specific risk assessment.

The Soil Remediation Criteria are effects-based concentrations set to protect against the potential for adverse effects to human health, ecological health, and the natural environment, whichever is the most sensitive. By protecting the most sensitive parameter the rest of the environment is protected by default. There are different Soil Remediation Criteria for soil texture, soil depth, and ground water use. The criteria have also been established so that there will not be a potential for adverse effects through contaminant transfer from soil to indoor air, from ground water or surface water through release of volatile gases, from leaching of contaminants in soil to ground water, or from ground water discharge to surface water. However, use of these criteria may not ensure that corrosive, explosive, or unstable soil conditions will be eliminated.

The Soil Remediation Criteria were developed from published U.S. EPA and Ontario environmental data bases. Currently there are criteria for about 25 inorganic elements and about 90 organic compounds. Criteria were developed only if there were sufficient, defendable, effects-based data on the potential to cause an adverse effect. All of the criteria address human health and aquatic toxicity, but terrestrial ecological toxicity information was not available for all elements or compounds. 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 on the Remediation Criteria please refer to the Guideline for Use at Contaminated Sites in Ontario. Revised December 1996, Ontario Ministry of Environment and Energy, PIBs 3161E01, ISBN 0-7778-5905-X.1.

Appendix 1B
Derivation and Significance of the MOEE "Ontario Typical Range" Soil Guidelines.

The MOEE "Ontario Typical Range" (OTR) guidelines are being developed to assist in interpreting analytical data and evaluating source-related impacts on the terrestrial environment. The OTRs are used to determine if the level of a chemical parameter in soil, plants, moss bags, or snow is significantly greater than the normal background range. An exceedence of the OTR_{98} (*the OTR_{98} is the actual guideline numbe*r) may indicate the presence of a potential point source of contamination.

The OTR_{98} represents the expected range of concentrations of chemical parameters in surface soil, plants, moss bags, and snow from areas in Ontario not subjected to the influence of known point sources of pollution. The OTR_{98} represents 97.5 percent of the data in the OTR distribution. This is equivalent to the mean plus two standard deviations, which is similar to the previous MOEE "Upper Limit of Normal" (ULN) guidelines. In other words, 98 out of every 100 background samples should be lower than the OTR_{98}.

The OTR_{98} may vary between land use categories even in the absence of a point source of pollution because of natural variation and the amount and type of human activity, both past and present. Therefore, OTRs are being developed for several land use categories. The three main land use categories are Rural, New Urban, and Old Urban. Urban is defined as an area that has municipal water and sewage services. Old Urban is any area that has been developed as an urban area for more than 40 years. Rural is all other areas. These major land use categories are further broken into three subcategories; Parkland (which includes greenbelts and woodlands), Residential, and Industrial (which includes heavy industry, commercial properties such as malls, and transportation rights-of-way). Rural also includes an Agricultural category.

The OTR guidelines apply only to samples collected using standard MOEE sampling, sample preparation, and analytical protocols. Because the background data were collected in Ontario, the OTRs represent Ontario environmental conditions.

The OTRs are not the only means by which results are interpreted. Data interpretation should involve reviewing results from control samples, examining all the survey data for evidence of a pattern of contamination relative to the suspected source, and where available, comparison with effects-based guidelines. The OTRs are particularly useful where there is uncertainty regarding local background concentrations and/or insufficient samples were collected to determine a contamination gradient. OTRs are also used to determine where in the anticipated range a result falls. This can identify a potential concern even when a result falls within the guideline. For example, if all of the results from a survey are close to the OTR_{98} this could indicate that the local environment has been contaminated above the *anticipated average,* and therefore the pollution source should be more closely monitored.

The OTRs identify a range of chemical parameters resulting from natural variation and normal human activity. ***As a result, it must be stressed that values falling within a specific OTR_{98} should not be considered as acceptable or desirable levels; nor does the OTR_{98} imply toxicity to plants, animals or humans.*** Rather, the OTR_{98} is a level which, if exceeded, prompts further investigation on a case by case basis to determine the significance, if any, of the above normal concentration. Incidental, isolated or spurious exceedences of an OTR_{98} do not necessarily indicate a need for regulatory or abatement activity. However, repeated and/or extensive exceedences of an OTR_{98} that appears to be related to a potential pollution source does indicate the need for a thorough evaluation of the regulatory or abatement program.

The OTR_{98} supersedes the Phytotoxicology ULN guideline. The OTR program is on-going. The number of OTRs will be continuously updated as sampling is completed for the various land use categories and sample types. For more information on these guidelines please refer to *Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags, and Snow. MOEE Report Number HCB-151-3512-93, PIBs Number 2792, ISBN 0-778-1979-1*.

Appendix 2A Concentrations of chemical elements in soil collected from St. Therese Catholic School, Port Colborne, April 6, 2000.

Element	Sample Location					MOE Guideline	
	North Open Field	Central Soccer Field	Around Play Set	East Soccer Field	East Open Field	Table F	Table A
Aluminum	16,000	18,000	13,500	17,000	23,500	(30,000)	NG
Barium	87	120	73	106	145	210	1000
Beryllium	0.6	0.8	0.5	0.8	1.0	1.2	1.2
Cadmium	0.3	0.5	0.3	0.5	0.9	1	12
Calcium	4,650	9,550	6,450	8,500	9,050	(55,000)	NG
Chromium	20	25	17	21	30	71	1000
Cobalt	***30***	***38***	12	***30***	***37***	21	50
Copper	***140***	***150***	57	***130***	***185***	85	300
Iron	18,000	20,000	12,500	13,000	18,000	(35,000)	NG
Lead	45	48	31	37	53	120	200
Magnesium	3,550	4,900	3,400	4,200	5,100	(20,000)	NG
Manganese	430	510	200	205	240	(2,200)	NG
Molybdenum	0.6	0.8	0.5	0.6	0.7	2.5	40
Nickel	**1,350**	**1,250**	**270**	**1,045**	**1,450**	43	200
Strontium	15	28	39	50	65	(64)	NG
Vanadium	35	38	27	30	41	91	250
Zinc	110	115	71	87	120	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.

Appendix 2B — Concentrations of chemical elements in soil collected from St. John Bosco Catholic, Port Colborne, April 6, 2000.

Element	Sample Location			MOE Guideline	
	North Lawn Area	Sand from Fenced Enclosure	Baseball Field	Table F	Table A
Aluminum	17,500	21,000	13,000	(30,000)	NG
Barium	89	110	65	210	1000
Beryllium	0.7	1.0	0.5	1.2	1.2
Cadmium	0.3	0.4	0.3	1	12
Calcium	5,800	9,250	9,650	(55,000)	NG
Chromium	22	26	18	71	1000
Cobalt	8	10	7	21	50
Copper	24	29	12	85	300
Iron	19,000	23,000	16,000	(35,000)	NG
Lead	44	33	19	120	200
Magnesium	3,850	5,200	4,900	(20,000)	NG
Manganese	230	315	410	(2,200)	NG
Molybdenum	0.5	0.5	0.5	2.5	40
Nickel	***105***	***105***	17	43	200
Strontium	41	55	29	(64)	NG
Vanadium	34	42	28	91	250
Zinc	80	93	59	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.

Appendix 2C — Concentrations of chemical elements in soil collected from St. Patrick Catholic School, Port Colborne, April 5, 2000.

Element	Sample Location		MOE Guideline	
	Football Field	Around Swings	Table F	Table A
Aluminum	16,000	7,450	(30,000)	NG
Barium	74	68	210	1000
Beryllium	1	1	1.2	1.2
Cadmium	1	0	1	12
Calcium	17,500	38,000	(55,000)	NG
Chromium	23	13	71	1000
Cobalt	10	5	21	50
Copper	31	26	85	300
Iron	20,000	12,000	(35,000)	NG
Lead	48	8	120	200
Magnesium	7,950	5,600	(20,000)	NG
Manganese	485	510	(2,200)	NG
Molybdenum	1	1	2.5	40
Nickel	***80***	14	43	200
Strontium	28	***69***	(64)	NG
Vanadium	35	20	91	250
Zinc	100	68	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.

Appendix 2D Concentrations of chemical elements in soil collected from Lakeshore Catholic High School, Port Colborne, April 6, 2000.

Element	Sample Location		MOE Guideline	
	Soccer Field	Football Field	Table F	Table A
Aluminum	16,500	12,000	(30,000)	NG
Barium	105	78	210	1000
Beryllium	0.7	0.5	1.2	1.2
Cadmium	0.4	0.3	1	12
Calcium	11,750	9,600	(55,000)	NG
Chromium	21	16	71	1000
Cobalt	13	8	21	50
Copper	43	25	85	300
Iron	19,500	13,500	(35,000)	NG
Lead	31	30	120	200
Magnesium	5,300	4,450	(20,000)	NG
Manganese	315	240	(2,200)	NG
Molybdenum	0.5	0.5	2.5	40
Nickel	***320***	***140***	43	200
Strontium	31	32	(64)	NG
Vanadium	34	26	91	250
Zinc	92	61	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.

Appendix 2E Concentrations of chemical elements in soil collected from C.M. Thompson Public School, Port Colborne, April 5, 2000.

Element	Sample Location		MOE Guideline	
	Soccer Field	Play Set	Table F	Table A
Aluminum	15,800	18,500	(30,000)	NG
Barium	90	115	210	1000
Beryllium	0.7	0.8	1.2	1.2
Cadmium	0.75	0.7	1	12
Calcium	13,500	11,000	(55,000)	NG
Chromium	29	24	71	1000
Cobalt	7	8	21	50
Copper	22	28	85	300
Iron	16,500	18,500	(35,000)	NG
Lead	31	31	120	200
Magnesium	6,500	6,800	(20,000)	NG
Manganese	275	250	(2,200)	NG
Molybdenum	0.5	0.5	2.5	40
Nickel	***59***	***72***	43	200
Strontium	38	32	(64)	NG
Vanadium	32	37	91	250
Zinc	95	98	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.

Appendix 2F — Concentrations of chemical elements in soil collected from DeWitt-Carter Public School, Port Colborne, April 6, 2000.

Element	Sample Location		MOE Guideline	
	Sand from Sand Boxes	Baseball Field	Table F	Table A
Aluminum	1,950	14,000	(30,000)	NG
Barium	9	91	210	1000
Beryllium	0.5	0.7	1.2	1.2
Cadmium	0.2	0.2	1	12
Calcium	22,000	10,500	(55,000)	NG
Chromium	6	21	71	1000
Cobalt	2	17	21	50
Copper	3	69	85	300
Iron	8,850	19,000	(35,000)	NG
Lead	6	41	120	200
Magnesium	6,000	5,900	(20,000)	NG
Manganese	135	365	(2,200)	NG
Molybdenum	0.5	0.5	2.5	40
Nickel	22	***590***	43	200
Strontium	28	23	(64)	NG
Vanadium	21	32	91	250
Zinc	14	87	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.

Appendix 2G — Concentrations of chemical elements in soil collected from Humberstone Public School, Port Colborne, April 5, 2000.

Element	Sample Location				MOE Guideline	
	Play Set	Central Soccer Field	North Soccer Field	East Soccer Field	Table F	Table A
Aluminum	16,000	17,500	17,000	19,500	(30,000)	NG
Barium	92	115	115	120	210	1000
Beryllium	0.7	0.8	0.8	0.9	1.2	1.2
Cadmium	0.5	0.6	0.5	0.5	1	12
Calcium	12,000	12,450	32,150	7,400	(55,000)	NG
Chromium	22	24	23	26	71	1000
Cobalt	***22***	***29***	21	***22***	21	50
Copper	***106***	***135***	***103***	***105***	85	300
Iron	20,500	20,500	19,000	20,500	(35,000)	NG
Lead	37	44	30	33	120	200
Magnesium	6,800	4,450	4,750	4,750	(20,000)	NG
Manganese	405	390	350	360	(2,200)	NG
Molybdenum	0.8	0.7	0.6	0.5	2.5	40
Nickel	***795***	***1,050***	***720***	***755***	43	200
Strontium	44	26	34	22	(64)	NG
Vanadium	38	37	35	38	91	250
Zinc	102	125	102	110	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.

Appendix 2H Concentrations of chemical elements in soil collected from Oakwood Public School and Day Care, Port Colborne, April 6, 2000.

Element	Sample Location			MOE Guideline	
	Soccer Field	Sand from Play Set	Proposed Play Area	Table F	Table A
Aluminum	18,000	13,150	15,500	(30,000)	NG
Barium	103	79	84	210	1000
Beryllium	0.8	0.6	0.7	1.2	1.2
Cadmium	0.50	0.3	0.3	1	12
Calcium	10,300	12,150	7,500	(55,000)	NG
Chromium	24	18	20	71	1000
Cobalt	10	7	7	21	50
Copper	35	18	21	85	300
Iron	20,000	15,500	17,500	(35,000)	NG
Lead	39	30	33	120	200
Magnesium	5,900	5,850	5,150	(20,000)	NG
Manganese	275	255	355	(2,200)	NG
Molybdenum	0.5	0.6	0.5	2.5	40
Nickel	***195***	***61***	***78***	43	200
Strontium	39	31	30	(64)	NG
Vanadium	37	28	34	91	250
Zinc	100	87	89	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.

Appendix 2I — Concentrations of chemical elements in soil collected from Steele St. Public School, Port Colborne, April 5, 2000.

Element	Sample Location		MOE Guideline	
	Baseball Field	Around Swings	Table F	Table A
Aluminum	11000	12000	(30,000)	NG
Barium	83	74	210	1000
Beryllium	0.6	0.6	1.2	1.2
Cadmium	0.8	0.7	1	12
Calcium	20000	10000	(55,000)	NG
Chromium	19	18	71	1000
Cobalt	8.4	6.8	21	50
Copper	44	23	85	300
Iron	15500	16000	(35,000)	NG
Lead	46	50	120	200
Magnesium	5000	5200	(20,000)	NG
Manganese	675	310	(2,200)	NG
Molybdenum	0.8	0.5	2.5	40
Nickel	***215***	***89***	43	200
Strontium	44	25	(64)	NG
Vanadium	26	33	91	250
Zinc	120	99	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.

Appendix 2J — Concentrations of chemical elements in soil collected from Port Colborne High School, Port Colborne, April 5, 2000.

Element	Sample Location		MOE Guideline	
	Football Field	Sand from Play Set	Table F	Table A
Aluminum	12,000	1,800	(30,000)	NG
Barium	70	9	210	1000
Beryllium	0.5	0.5	1.2	1.2
Cadmium	0.4	0.2	1	12
Calcium	14,000	23,500	(55,000)	NG
Chromium	17	4	71	1000
Cobalt	7	2	21	50
Copper	21	4	85	300
Iron	16,500	6,200	(35,000)	NG
Lead	22	6	120	200
Magnesium	4,600	5,300	(20,000)	NG
Manganese	475	145	(2,200)	NG
Molybdenum	0.5	0.5	2.5	40
Nickel	***59***	3	43	200
Strontium	30	34	(64)	NG
Vanadium	30	12	91	250
Zinc	62	13	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.

Appendix 2K Concentrations of chemical elements in soil collected from Ecole St. Joseph , Port Colborne, April 6, 2000.

Element	Sample Location		MOE Guideline	
	Around Swings	Baseball Fields	Table F	Table A
Aluminum	3,750	16,500	(30,000)	NG
Barium	23	91	210	1000
Beryllium	0.5	0.8	1.2	1.2
Cadmium	0.2	0.2	1	12
Calcium	30,500	9,850	(55,000)	NG
Chromium	7	22	71	1000
Cobalt	4	12	21	50
Copper	16	38	85	300
Iron	7,600	20,500	(35,000)	NG
Lead	10	27	120	200
Magnesium	7,100	5,150	(20,000)	NG
Manganese	225	330	(2,200)	NG
Molybdenum	0.5	0.5	2.5	40
Nickel	***96***	***160***	43	200
Strontium	43	56	(64)	NG
Vanadium	15	36	91	250
Zinc	28	79	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.

Appendix 2L Concentrations of chemical elements in soil collected from McKay Public School, Port Colborne, April 5, 2000.

Element	Sample Location			MOE Guideline	
	Soccer Field	Baseball Field	Around Play Set	Table F	Table A
Aluminum	14,500	15,000	14,000	(30,000)	NG
Barium	72	68	75	210	1000
Beryllium	0.6	0.6	0.7	1.2	1.2
Cadmium	0.6	0.6	0.8	1	12
Calcium	5,750	7,900	12,500	(55,000)	NG
Chromium	19	18	21	71	1000
Cobalt	8	8	7	21	50
Copper	25	24	25	85	300
Iron	15,000	15,500	16,000	(35,000)	NG
Lead	32	32	39	120	200
Magnesium	3,950	3,200	5,850	(20,000)	NG
Manganese	460	400	425	(2,200)	NG
Molybdenum	0.5	0.5	0.6	2.5	40
Nickel	***155***	***135***	***98***	43	200
Strontium	15	15	27	(64)	NG
Vanadium	31	31	31	91	250
Zinc	80	82	104	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.

Appendix 2M Concentrations of chemical elements in soil collected from Port Colborne Regional Day Care, Port Colborne, April 6, 2000.

Element	Sample Location		MOE Guideline	
	Sand from Gym Set	Lawn	Table F	Table A
Aluminum	2,350	6,350	(30,000)	NG
Barium	16	29	210	1000
Beryllium	0.5	0.5	1.2	1.2
Cadmium	0.2	0.2	1	12
Calcium	27,500	21,500	(55,000)	NG
Chromium	5	10	71	1000
Cobalt	2	3	21	50
Copper	5	9	85	300
Iron	7,050	9,700	(35,000)	NG
Lead	6	14	120	200
Magnesium	5,700	5,800	(20,000)	NG
Manganese	190	260	(2,200)	NG
Molybdenum	0.5	0.5	2.5	40
Nickel	4	22	43	200
Strontium	39	33	(64)	NG
Vanadium	13	19	91	250
Zinc	20	53	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.

Appendix 2N Concentrations of chemical elements in soil collected from three public beaches, Port Colborne, April 5 and 6, 2000.

Element	Sample Location			MOE Guideline	
	Nickel Beach	Lorraine Beach	Lakeshore Beach	Table F	Table A
Aluminum	1,450	1,900	2,650	(30,000)	NG
Barium	7	6	4	210	1000
Beryllium	0.5	0.5	0.5	1.2	1.2
Cadmium	0.2	0.2	0.2	1	12
Calcium	34,000	18,000	7,500	(55,000)	NG
Chromium	3	16	27	71	1000
Cobalt	15	4	5	21	50
Copper	9	1	1	85	300
Iron	6,100	27,500	***52,500***	(35,000)	NG
Lead	8	2	8	120	200
Magnesium	6,600	4,900	2,650	(20,000)	NG
Manganese	155	230	385	(2,200)	NG
Molybdenum	0.5	0.5	0.5	2.5	40
Nickel	***240***	16	3	43	200
Strontium	45	26	13	(64)	NG
Vanadium	6	67	***125***	91	250
Zinc	63	17	19	160	800

All data are µg/g air dry weight, mean of duplicate samples.
Data in bold italic exceed MOE Table F background-based guidelines, shaded data exceed MOE Table A effects-based guidelines (see Appendix 1A).
Table F guidelines in brackets are MOE OTR_{98} (see Appendix 1B).
NG - guideline not available.