Soil Sampling Project

BC Ministry of Environment and Climate Change Strategy

October, 2016; reissued January, 2019; reissued February, 2020

BRITISH COLUMBIA

Executive Summary

Biosolids are wastewater treatment residuals which have been treated and stabilized. In British Columbia, biosolids are beneficially used as a soil amendment in agriculture and other applications, including landscaping and site reclamation. The land application of biosolids and compost is regulated by the Organic Matter Recycling Regulation (OMRR). The goal of the OMRR is to protect human health and the environment. The regulation facilitates the beneficial use of select organic materials that have value as soil amendments, e.g., biosolids or compost, by stipulating requirements for land application.

Due to public concerns over the land application of biosolids, in June 2015 the Province announced that a technical working group, comprised of scientists and academics, would conduct a scientific review of biosolids. The scientific review included two parts:

1. preparation of a literature review on the risks associated with the land application of biosolids, and compost derived from biosolids, with relevance to the Nicola Valley, and
2. development of a sampling plan for
    a. soils from the interior of the Province; and
    b. biosolids from BC wastewater treatment plants (WWTPs).

The literature review was published in June 2016. The results and analysis of the soil sampling project were originally published in October 2016. This report is re-issued herein to:

- correct errata in the October 2016 publication including addition of phthalate data;
- update the OMRR standards, amended July 27, 2018;
- update the benchmark data from Canadian Council of Ministers of the Environment (CCME);
- update the benchmark data from BC Contaminated Sites Regulation (CSR) as amended June 14, 2018; and,
- update terminology used in the October 2016 publication to be consistent with industry standards.

The publication of a second report within the scientific review will provide the results and analysis of the biosolids sampling from two WWTPs and is anticipated in early 2019.

The purpose of the soils sampling project was to sample soil at sites that received applications of biosolids and/or compost derived from biosolids in order to assess possible impacts from the applications. Three sites within BC, with both control and treated plots, were selected and are referred to as Site A, Site B, and Site C.

In addition to assessing metal levels, sampling was conducted for a range of other compounds in order to address questions that have arisen from consultation with First Nations and stakeholders, including:

- contaminants of emerging concern (CECs), referred to as "emerging contaminants of concern" (ESOCs) in the October 2016 publication; and
- persistent organic pollutants (POPs), referred to as "legacy organics" in the October 2016 publication.

CECs and POPs are not mutually exclusive. For example, some CECs, such as polybrominated diphenyl ethers in fire retardants, are also identified as POPs. The OMRR does not regulate concentrations of CECs or POPs.

The soil sampling results from this project indicated:

- The metals which are not currently regulated under OMRR were either not detected or were below the CCME and the CSR standards.
- The concentrations of OMRR-regulated metals in the soils, including copper, were below the OMRR standards.
- Copper was above the CCME standard on the treated plots on Site A, which may in part be attributed to historical use of pesticides on Site A. (Site A is an orchard which received regular applications of fertilizers. Older orchards generally have elevated levels of metals due to past pesticide use. Historical pesticides contained arsenic, lead, zinc and/or copper.)
- Copper on Site A was statistically significantly different between the control plots and the treated plots. The application of soil amendments, such as biosolids or fertilizers, is likely the cause of the increased copper concentrations on the treated plots on Site A.
- Most of the POPs and CECs were not detected. All detection limits were less than the CCME and the CSR standards, with one exception (control plot #1, on Site A, 3-chlorophenol).
- The few POPs and CECs that were detected were present in low concentrations and were below the CSR and the CCME standards.
- Soil that received biosolids applications had higher total organic carbon, total organic nitrogen, and available phosphate. These results indicate that biosolids have value as a soil amendment, consistent with the findings from the literature.

The results of this soil sampling project indicate that the plots with historic land application of biosolids has complied with the OMRR soil standards at all sites sampled. In addition, the comparison of CECs and POPs against the CSR benchmarks indicated that the samples did not exceed the limits for contaminated soils, as defined within the CSR.

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1. Introduction

Biosolids are wastewater treatment plant residuals which have been treated. Biosolids, and compost derived from biosolids, are beneficially used as soil amendments in agriculture and other applications, including landscaping and site reclamation. The results of several ecological studies completed in the BC interior found an increased plant biomass in soil plots that received biosolids (Newman et al., 2014; Wallace et al., 2009; Wallace et al., 2016). Elevated levels of these parameters in soil typically result in improved plant response and increased yields.

As biosolids are derived from wastewater treatment plants (WWTPs), metals[1] may be present along with other anthropogenic compounds including:

- contaminants of emerging concern (CECs)[2] ; and
- persistent organic pollutants (POPs)[3].

CECs include of a variety of compounds, such as endocrine disrupting compounds, which may be present in WWTPs due to the use of pharmaceuticals, personal care products and fire retardants. Generally, CECs have been difficult to quantify because they are present in small concentrations and suitable test methods have not been developed for many. Concerns are emerging regarding the impact of these compounds in small concentrations in the environment.

POPs are carbon-based compounds that:

- persist in the environment;
- bioaccumulate (i.e., they are found at higher concentrations at higher levels in the food chain); and,
- may be harmful to humans and/or wildlife.

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[1] In the previous October 2016 publication of this report, the term “trace elements” was used to describe some compounds. To be consistent with the chemical terminology in the second report in this series and to simplify text, the term “metals” is used throughout this publication to include metals, and trace elements.

[2] In the previous October 2016 publication of this report, the term “emerging contaminants of concern (ESOCS)” was used to describe the variety of human-sourced compounds that are present in very small amounts in the environment. The term "contaminants of emerging concern” is more commonly used to describe these compounds and is used in the guidance documents for the Contaminated Sites Regulation. To be consistent with the terminology in the second report in this series, the term “contaminants of emerging concern” (CECs), is used throughout this publication.

[3] In the previous October 2016 publication of this report, the term “legacy organics” was used to describe carbon-based compounds that persist in the environment. The term "persistent organic pollutants” is more commonly used to describe these compounds. To be consistent with the international terminology and the second report in this series, the term “persistent organic pollutants” (POPs) is used throughout this publication.

POPs studied in this report include: polycyclic aromatic hydrocarbons (PAHs); polychlorinated biphenyls (PCBs); phthalates; polychlorinated dibenzo-p-dioxins (PCDDs); and polychlorinated dibenzofurans (PCDFs).

CECs and POPs are not mutually exclusive. Examples of compounds that are characterized as CECs and POPs are included in Figure 1, which shows that some CECs, such as polybrominated diphenyl ethers in fire retardants, are also identified as POPs.

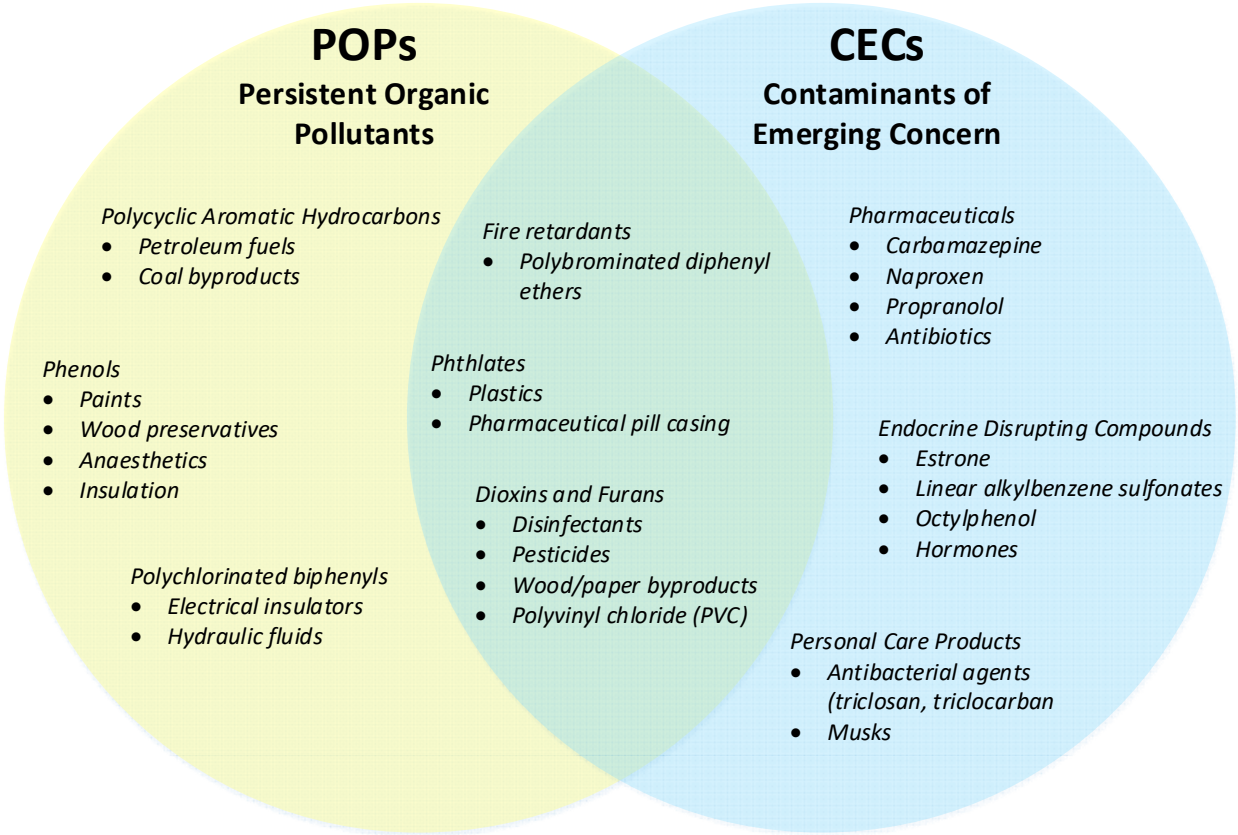

Figure 1. Examples of POPs and CECs

POPs and CECs are discussed in more detail in Appendix 1.

1.1. Biosolids Management in BC

There are approximately 38,000 dry tonnes of biosolids produced per year in BC, which are beneficially used or disposed of by a variety of means (Sylvis, 2016), as illustrated in Figure 2.

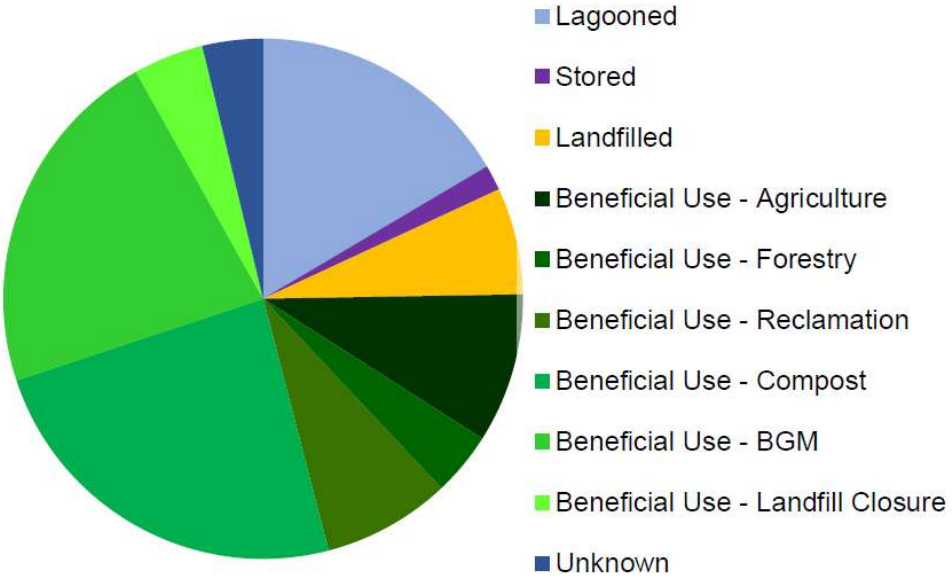

Figure 2. Biosolids Management Methods in BC

The lagooned portion shown in Figure 2 refers to sludge that is stored/treated in lagoons and has not yet been treated to produce biosolids. Lagooned sludge is likely to be processed into biosolids and land applied. Approximately 72% of biosolids and biosolids-derived products (e.g., compost) in BC are currently land applied as a soil amendment for beneficial use for the following purposes:

- agriculture;
- forestry and silviculture;
- mine or gravel pit reclamation;
- composting (mostly agricultural land application);
- landscaping; and
- landfill closure.

Land application results in numerous benefits including:

- recycling of organic matter and nutrients;
- diverting organic material away from landfill disposal, resulting in a subsequent reduction in greenhouse gas emissions;
- providing users with a suitable soil amendment product;
- providing users with an alternative to chemical fertilizers and manure; and
- providing municipalities with an effective method to manage biosolids.

The land application of biosolids and compost is regulated by the Organic Matter Recycling Regulation (OMRR). The goal of the OMRR is to protect human health and the environment. The regulation facilitates the beneficial use of select organic materials that have value as soil amendments by stipulating requirements for land application of these materials, including but not limited to:

- maximum limits of pathogens in biosolids and compost prior to land application;
- maximum allowable concentrations of metals in biosolids and compost prior to land application;
- maximum concentrations of metals in receiving soils prior to land application;
- establishment of maximum concentrations for metals in amended soils;
- oversight by qualified professionals;
- setbacks from water resources; and,
- grazing and harvest periods.

1.2. Project Objectives

Public concern regarding the land application of biosolids and compost has been increasing in BC and other jurisdictions (Canadian Municipal Water Consortium, 2015) in part due to perceived risks to human health and the environment. In response to concerns in the interior of BC, specifically in the Nicola Valley, the Ministry of Environment and Climate Change Strategy (ENV) initiated a scientific review of biosolids land applications in 2015. A Technical Working Group (TWG) was formed in 2015 to undertake the scientific review which included two parts:

1. preparation of a literature review on the risks associated with the land application of biosolids, and compost derived from biosolids, with relevance to the Nicola Valley, and
2. development of a sampling plan for
    a. soils from the interior of the Province; and
    b. biosolids from BC WWTPs.

The review of scientific and academic literature was conducted by Land Resource Consulting Services (LRCS, 2016). The TWG contribution included oversight of the scientific literature review and development of the two sampling plans to measure levels of potential contaminants in soils to which biosolids and/or compost have been applied. The TWG sampling plans were reviewed by members of an independent science panel comprised of biosolids subject matter experts. The panel was established in 2016 to provide science-based guidance to inform Provincial policy on biosolids management. This report describes the results of the first plan, the soil sampling project. The second plan, the biosolids sampling project, will be published separately.

In April 2016, the Province announced that it would conduct a review of the Organic Matter Recycling Regulation (OMRR), which regulates biosolids production, storage and use throughout the Province. Aspects of the OMRR review related to the land application of biosolids will be informed by the scientific review. At the time of publication of this report the OMRR review is in progress.

The objectives of this soil sampling project are:

1) to determine whether levels of select compounds in soils that received applications of biosolids and/or compost derived from biosolids exceed soil quality standards in the OMRR or the Contaminated Sites Regulation (CSR); and,
2) to obtain soil nutrient and organic matter data as an indication of the agronomic benefits associated with biosolids application.

A comparison of the BC regulatory standards in the CSR and the OMRR with other jurisdictions is included in Appendix 2.

1.3. Project Scope

This project was limited to the sampling of select compounds and soil parameters, including those identified by the TWG sampling plan, at three sites located in BC. These three sites include: Site A located within the Okanagan Region, Site B located within the Cariboo Region, and Site C located within the Thompson-Nicola Region. Further description and details of these sites is presented in Section 2.2. The assessment of agronomic benefits is limited to soil data for a sub-set of selected parameters and does not include any yield or plant health data. The agronomic assessment is intended only to provide an indicator of benefits.

Metal concentrations were analyzed in soil at sites in the interior of the province that received applications of biosolids and/or compost derived from biosolids. In the October 2016 publication, concentrations of metals were compared to the CSR (ENV, 2016a) and OMRR (ENV, 2016b) standards as they existed in 2016. This updated report compares the measured concentrations against the most recent OMRR standards (OMRR, 2018b).

POPs and CECs are not specifically regulated under the OMRR; however, to address questions that have arisen from consultation with First Nations and stakeholders, sampling was conducted for a range of CECs and POPs including:

- polycyclic aromatic hydrocarbons;
- phthalates;
- phenols;
- polychlorinated biphenyls; and
- polychlorinated dioxins and furans.

The metal, CEC, and POP results were also compared with the most conservative standard identified in the most recent CSR standards (CSR, 2018a) and Canadian Council of Ministers of the Environment (CCME) standards (CCME, 2010). The standards selected for each sample site are discussed in more detail in Section 1.5. This was completed to gauge the environmental relevance of any detected substance, and to provide context where standards for the OMRR do not exist.

An assessment of many of the CECs and POPs is outside the scope of this study due to a lack of developed standards for these substances, and a lack of accredited labs for performing the related analyses. The knowledge pertaining to these compounds is evolving and several related risk assessments and literature reviews are underway or have been recently completed including the recent work of the Canadian Water Network (McCarthy et al., 2015) and the ENV biosolids literature review (LRCS, 2016)). A more extensive discussion of CECs in included in Appendix 1.

1.4. Limitations of the Interpretation of Results

The interpretation of results from this project should be restricted to the uses which are stated in the project objectives and scope in Sections 1.2 and 1.3.

The number of sites and samples was limited. Ideally at least 10 to 30 samples are needed for a rigorous study to provide a strong foundation for the statistical analysis and subsequent conclusions. The project included a limited number of samples and therefore the resulting statistical analysis should be interpreted as being limited in scope as well.

No evaluation of risk is intended. Rather, the results provide an indication about concentrations of various compounds in biosolids-amended soils in comparison with untreated soils as a snapshot in time for specific sites.

The results cannot be extrapolated to other sites and/or situations. It should be noted that some compounds and soil parameters can originate from different sources and pathways other than biosolids application, including from cattle grazing, fertilizer applications or natural sources such as rain or forest fires.

The results cannot be interpolated on these specific sites to conclusively identify the actual sources of the compounds. Based on the knowledge of typical historical activities, the possible sources are discussed in this report. The results cannot be interpolated to quantify the concentrations of metals, CECs or POPs that were not specifically tested for. The results contained in this report are not reflective of a rigorous scientific experiment, which would have required detailing of the many factors that influence sampling plots (e.g., fertilizer application, crop management, atmospheric conditions) and required providing more Control settings. This level of rigour was not possible in this soil sampling project because in some cases the biosolids applications occurred more than ten years ago. Moreover, the sampling was restricted by several other factors including a lack of true replicates on each site and a lack of historical native soil data for organics at the sites.

1.5. Regulatory Standards

The OMRR standards draw from a variety of regulatory requirements including the CSR, and the CCME which are designed to protect human health and the environment. The OMRR sets standards for maximum allowable levels of compounds in soils that have received biosolids application. The OMRR should be consulted for a complete description of all requirements.

The units used to measure compounds include:

- Micrograms per gram (µg/g) which is equivalent to "parts per million" (ppm). For example, 1 µg/g (ppm) is like one drop of ink in a 50 L barrel of water.
- Milligrams per kilogram (mg/kg) which is equivalent to µg/g or ppm. The concentration mg/kg is a common unit for reporting and can be seen throughout the laboratory's raw analytical reports. In this report, µg/g is used.
- Picograms per gram (pg/g) which is equivalent to "parts per trillion" (ppt). A picogram is smaller than a microgram (1 pg = 10^{-6} µg). The concentration pg/g is used to describe very low concentrations of substances. For example, 1 pg/g is like one drop of ink in 20 Olympic-sized swimming pools.

1.5.1. Metal Standards for Soil

In the previous, October 2016 edition of this report, references were made to Schedules 9 and 10 of the OMRR for metals concentrations in soils. Schedules 9 and 10 were repealed in 2016 and replaced with Schedule 10.1. Schedule 10.1 is taken from the numerical standards for soils in the CSR.

Metal standards for soil in the former Schedule 10 were developed using the scientifically rigorous and transparent toxicological protocols developed by the Contaminated Soil Science Task (CSST) Group in 1996 (BC Environment, 1996). These protocols included exposure pathway modeling, and, where data existed, the use of evidence from clinical studies to assess exposure risk. These soil standards varied depending on land use (agricultural, urban park, residential, commercial or industrial), and site-specific factors, as both of these influence exposure pathways, risk and availability of metals. Where CSST protocols were not developed, the OMRR adopted generic soil standards in the former Schedule 9 that were developed by the CCME, using the "No Net Degradation" method, (CCME, 2005). These soil standards were developed to be protective of human health and the environment and varied based on land use.

To harmonize with the changes made to the CSR in 2016, the OMRR was amended with the addition of Schedule 10.1 which contains standards for eleven metals. The CSR and Schedule 10.1 standards are based on land use (e.g., agricultural, urban park, residential, commercial, industrial) and site-specific factors. The site-specific standards for protection of groundwater, are often dependent on the pH of the soil. Site-specific factors for each site, as summarized in Section 1.5.3, were used to determine the appropriate standard for each site.

For metals which are not regulated under the OMRR, standards from the CSR and CCME were instead used for each site. The most conservative of the CSR and CCME standard was used as a benchmark for the site results.

1.5.2. Persistent Organic Pollutants and Contaminants of Emerging Concern

There are no standards for POPs or CECs in the OMRR. For this report, site-specific standards from the CSR and CCME were determined. When both the CSR and the CCME standards were available, the most conservative of the two standards was used for comparison with the site results. The CSR standards were developed from the rigorous CSST science-based protocols, and generic soil standards from the CCME to protect human health and the environment.

As a part of the work done by the TWG, specific CECs and POPs were recommended for analysis in this study, as summarized in Table 1. The TWG selected the contaminants based on:

- persistency;
- bioaccumulation; and
- toxicity.

Table 1. POPs and CECs Selected by the Technical Working Group

phenols	chlorinated phenols: • chlorophenol isomers (*ortho*, *meta*, *para*) • dichlorophenols (2,6-; 2,5-; 2,4-; 3,5-; 2,3-; 3,4-) • trichlorophenols (2,4,6-; 2,3,6-; 2,4,5-; 2,3,5-; 2,3,4-; 3,4,5-) • tetrachlorophenols (2,3,5,6-; 2,3,4,5-; 2,3,4,6-)
	nonchlorinated phenols: • 2,4-dimethylphenol • 2,4-dinitrophenol • 2-methyl 4,6-dinitrophenol • nitrophenol (2-; 4-) • phenol • cresol
	pentachlorophenol
polycyclic aromatic hydrocarbons	acenaphthene anthracene benz[a]anthracene benzo[a]pyrene benzo[b]fluoranthene benzo[k]fluoranthene chrysene dibenz[a,h]anthracene fluorene indeno[1,2,3-cd]pyrene naphthalene phenanthrene pyrene
phthalates	dibutyl phthalate di(2-ethylhexyl) phthalate (also known as bis(2-ethylhexyl) phthalate)
polychlorinated biphenyls	
polychlorinated dibenzo-p-dioxins	
polychlorinated dibenzofurans	

1.5.3. Site Specific Standards

Selection of appropriate standards was based on site-specific risk factors. A more complete description of each site is in Section 2.2. The following is a summary of the site-specific factors and pathways, identified for each site, which were used to select the appropriate site-specific standards:

Site A

- soil pH between 6.99 and 7.85;
- intake of contaminated soil;
- toxicity to soil invertebrates and plants; and,
- groundwater flow to surface water used by aquatic life.

Site B

- soil pH between 6.62 and 7.34;
- intake of contaminated soil;
- groundwater used for drinking water;
- toxicity to soil invertebrates and plants;
- groundwater flow to surface water used by aquatic life;
- groundwater used for livestock watering; and,
- groundwater used for irrigation.

Site C

- soil pH between 7.27 and 7.52;
- intake of contaminated soil;
- groundwater used for drinking water;
- toxicity to soil invertebrates and plants;
- groundwater flow to surface water used by aquatic life;
- groundwater used for livestock watering; and,
- groundwater used for irrigation.

These site-specific factors were not necessarily applicable to all application areas within the plots sampled given soil heterogeneity and distance from receptors. However, these factors and pathways were selected to identify the most stringent standards and provide the most conservative comparison.

2. Methodology

2.1. Site Selection

Three sampling sites were selected based on the following criteria:

1) each site had plots which had received at least one biosolids application (treated plots) and plots which had not received biosolids (control plots). The biosolids were derived from different WWTPs of varying capacities and from a variety of locations within BC;
2) the treated plots and control plots within each site were comparable in terms of land use, plant cover, climate, and geographical location; and,

3) two of the sites were located within geographic regions that were of concern to the public and/or First Nations.

2.2. Site Description

The conditions between the three sites vary considerably (e.g., crop management, application rates and climate). A description of each site is provided below.

2.2.1. Site A (Okanagan Region)

Site A is located in the Okanagan, a semi-arid region of BC. This region receives an average of 346 mm of precipitation per year, with a relatively mild climate and an annual average temperature of 9.5°C. The site is at an approximate elevation of 450 m and is located within the Ponderosa Pine biogeoclimatic zone that is dominated by ponderosa pine (where forests are present), and an understory of blue bunch wheat grass, rough fescue, and arrow-leaved balsamroot.

The five control plots and five treated plots on this site contain 'Spartan' apple trees (*Malus x domestica* Borkh.) that were planted in rows in 1994 (at a row spacing of 1.25 m; trees within a row were spaced 3.5 m from one another). The plots had a length 6.25 m and had a width that corresponded to one row of trees. The soil on the site consists of Skaha gravelly sandy loam, comprised of approximately 65% sand, 30% silt, 5% clay, which is an Orthic Brown soil formed on glacio-fluvial deposits (Forge et al., 2002). This coarse-texture soil is typically characterized by low organic matter and relatively low moisture holding capacity and is common to many tree fruit farms and vineyards in South Okanagan (Neilsen et al., 2003).

The treated plot received two surface applications of biosolids in 1994 and 1997 with a uniform application rate of 45 dry tonnes/ha for each application. The biosolids in both applications were produced from thermophilic anaerobic digestion. Nutrient contents of the biosolids can be obtained from Forge et al. (2003).

The trees on this site are regularly chemically fertilized throughout the growing season. Historical orchards are known to have elevated levels of metals due to past pesticide use. The common historical pesticides contained arsenic, lead, zinc and/or copper. Lead arsenate, for example, was in use in the 1970s and was ultimately banned in 1988 in the U.S. (Hood, 2006). Application of fertilizers has been shown to contribute to accumulations of other metals including cadmium, mercury and lead (Brunetto, et al, 2017).

2.2.2. Site B (Cariboo Region)

Site B is located in the Cariboo Region in the southern BC interior. The climate is mild and semi-arid with an annual average precipitation of 400 mm and an annual average temperature of 4.4°C. The site has an approximate elevation of 1,100 meters and is located in Interior Douglas-Fir biogeoclimatic zone of BC.

The four control plots and four treated plots are dominated by Aridic Boroll (Dark Brown Chernozem) soil, which is often characterized by low organic matter and poor moisture retention.

The site has extensive areas for cattle grazing; however, the plots were fenced prior to biosolids application in 2002 to prevent grazing. The grass grown is dominated mostly by needle and thread grass (*Hesperostipa comata Trin. & Rupr.*). The average slope of the plots is equal to or less than 5%. The dimensions of each plot were 50 m by 25 m.

Biosolids were surface-applied on the four treated plots at 20 dry tonnes/ha in the fall 2002, prior to the enactment of the OMRR. It is the Ministry's understanding that at the time of application the equivalent of Class B biosolids was applied.

Possible effects of biosolids application on plant growth at Site B has been studied previously. As summarized in Table 2, comparisons of the canopy cover and aboveground standing crops on treated and control plots indicate a positive plant growth in biosolids amended plots in 2016.

Table 2. Canopy Cover and Aboveground Standing Crop at Site B

Canopy Cover or Aboveground Standing Crop	Treated	Control	Change (%)	Comments
Grasses (%)	78	42	84.7	Canopy cover: primarily from Kentucky bluegrass
Forbs (%)	16	21	-26.4	Canopy cover: primarily from white pussytoes
Litter (%)	89	35	157.9	Canopy cover: plant matter on the ground
Exposed soil (%)	1	6	-82.9	Canopy cover
Grasses (kg/ha)	1260	556	126.5	Aboveground standing crop
Forbs (kg/ha)	274	235	16.5	Aboveground standing crop

The results indicate that biosolids and compost produced from biosolids, have value as a soil amendment, which agrees with the findings reported in the literature (CWN, 2015). In addition, the results suggest that the agronomic benefits associated with biosolids application can persist for long periods of time after application.

2.2.3. Site C (Thompson-Nicola Region)

Site C is located in the Thompson-Nicola Regional District in the southern interior of BC. The climate is mild and dry with an average annual precipitation of approximately 290 mm. The annual mean temperature is approximately 7°C, whereas the daily maximum temperature in July and January is approximately 26°C and -11°C respectively.

The site is located within the Interior Douglas-fir biogeoclimatic zone. This zone is characterized by forests dominated by Douglas-fir trees with a grassy understorey dominated by bluebunch wheatgrass and rough fescues. This site is at an approximate elevation of 500 m.

This site received two surface applications:

1. Class A compost derived from biosolids, in 2014 and 2015, at an approximate rate of 5 to 11 dry tonnes per hectare; and,
2. Class A biosolids in 2015, at an application rate of approximately 15 dry tonnes per hectare.

All applications were done on established forage stands of grasses and legumes (alfalfa). No domestic animals graze at this site.

The two control plots and two treated plots are relatively flat with an average slope of less than 5%. Each plot measured 20 m by 20 m. The site has predominately a surface layer of silt loam (approximately 15 cm thick), overlain by coarse gravel. There are domestic water wells on-site, and the Nicola River is located approximately 100 m from the site.

2.3. Sampling Protocol

As a part of the work done by the TWG, a work plan was developed that included the sampling plan and potential sites for sampling. Due to logistical constraints, two of the sites selected by the TWG were sampled and a third new site was added to the sampling project to broaden the scope. Table 3 provides a summary of the sampling protocols used at the sites.

Table 3. Description of Sites, Plots and Sampling

Number of:	Site A	Site B	Site C
Plots per site	10 plots (5 treated + 5 control)	8 plots (4 treated + 4 control)	4 plots (2 treated + 2 control)
Grab samples per plot	5 (taken approximately 30 cm from the row center)	20 (taken randomly between each plant transect)	40 (taken in a random pattern)
Grab samples in each composite sample	5	5	10
Composite samples per plot	1	4	4
Composite samples per site	10	32	16

Photographs of the sampling activities are shown in Figure 3. At each site:

- The top organic layer of soil was removed prior to taking each grab sample.

- Grab samples were collected at a depth of 0-15 cm using soil core augers, also known as Dutch Augers, as outlined in Section 12.3.4 of "Land Application Guidelines for Organic Matter Recycling" (Sylvis, 2008).
- Composite samples were created by mixing grab samples in stainless steel bowls.
- Separate bowls and augers were used to avoid cross contamination between treated and control plots.
- For the POPs analysis (PAHs, PCBs and phthalates), the samples were delivered to the laboratory in airtight glass jars.

Photo 1. POPs samples in air-tight jars

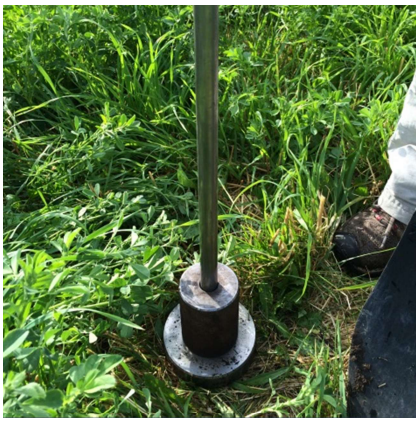

Photo 2. Soil bulk density measurements

Photo 3. Soil sampling with a Dutch Auger

Photo 4. Soil reconnaissance (Site C)

Figure 3. Photographs of Sampling

2.4. Laboratory Analysis

All samples were delivered to ALS laboratory in Burnaby, BC.

2.5. Data Analysis

2.5.1. Statistical Analysis

Statistical analyses were performed on the data collected to assess if differences between plots:

- are the result of random errors; or,
- indicate that the plots are significantly different from each other, due to other factors such as the application of biosolids and/or compost derived from biosolids.

Compounds are not likely to be evenly distributed throughout a soil sample because soil is typically heterogeneous (i.e., differs throughout), unlike media such as water or gas, where the chemical composition is relatively uniform throughout. Therefore, concentrations of compounds in each sample are likely to differ. Furthermore, the average of the results for any given plot is likely to differ between plots either due to other factors (referred to as random errors), such as the differences in past activities among plots.

Based on the statistical analysis, the differences between plots may be statistically insignificant and likely due to random errors, or the differences may be statistically significant, possibly due to the application of biosolids or compost derived from biosolids. As previously discussed, the control plots and treated plots were selected to include as many similar factors as possible. If there is a statistically significant difference between the means, it is likely due to the application of biosolids and/or compost derived from biosolids.

For each site, the mean for each compound analyzed (i.e., analyte) was calculated across the treated plots, and a separate mean was calculated across the control plots. A normality test was performed for all results for each analyte, and individually for control and treated plots to characterize the distribution of the data. An F-test was performed to determine if the variances of the means were equal. Following the F-test, and depending on the distribution of the data sets, the following two tests were then conducted:

1. A Student-t test was performed on all data sets that had normal distribution to determine whether the difference between means was statistically significant at a confidence level of 95%. Depending on the results of the F-test, a t-test for either equal or unequal variances was used.
2. For analytes that did not have a normal distribution, a statistical comparison of non-parametric population distributions for treated and control plots was performed using the Mann-Whitney *U*-test at a $p \leq 0.05$.

It should be noted that a rigorous study would require 10 to 30 samples to provide a strong foundation for the statistical analysis. The project included a limited number of samples and therefore the resulting statistical analysis should be interpreted as being limited in scope.

2.5.1. Relative Percent Difference

The mean of the results was calculated for the control plots and for the treated plots on each site. To compare the means, a relative percent difference (RPD) was calculated as follows:

$$RPD = \frac{(Mean\ of\ Treated - Mean\ of\ Control)}{Average\ of\ (Mean\ of\ the\ Treated\ and\ Mean\ of\ the\ Control)}$$

The RPD provides a way to compare two concentrations while taking into account the size of the concentrations.

2.5.2. Calculation of Toxic Equivalency for Dioxins and Furans

For dioxins and furans, the Toxic Equivalency (TEQ) was calculated. TEQs are used to report the toxicity-weighted masses of mixtures of dioxins. Within the TEQ method, each dioxin is assigned a Toxic Equivalency Factor (TEF) which denotes a given dioxin compound's toxicity relative to that of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), the most toxic dioxin-like chemical known. There are several different TEF standards set by different agencies. The TEFs used in this project were 2005 World Health Organization (WHO) International Programme on Chemical Safety, 2,3,7,8-TCDD Toxicity Equivalency Factors (WHO, 2006) as referenced in the CSR.

The laboratory analysis measured multiple dioxin and furan congeners. Congeners are chemical substances related to each other by origin, structure or function. Many of the compounds were not detectable at the reported detection limit. To produce a conservative TEQ for each site, the TEQ calculation was done by setting all undetected congeners to the detection limit. The TEFs were then multiplied by the measured concentration or the detection limit for the undetected congeners. The upper bound TEQ, which provided the most conservative estimate, was used for comparisons. A t-test was performed on the mean TEQ values for treated and control plots.

2.5.3. Calculation of Total Polychlorinated Biphenyls

Total PCBs in soil was calculated by taking the sum of the concentrations of PCB Aroclors. Aroclor was the trade name of the commercial PCB mixture manufactured by the Monsanto Chemical Company and produced in the US from approximately 1930 to 1979. There are many types of Aroclors and each has a distinguishing suffix number that indicates the degree of chlorination. The first two digits usually refer to the number of carbon atoms in the phenyl rings. The second two numbers indicate the percentage of chlorine by mass in the mixture. For example, Aroclor 1254 means that the mixture contains approximately 54% chlorine by weight. An exception is Aroclor 1016 which also has 12 carbon atoms but has 42% chlorine by mass.

In this project, the following PCB Aroclors were included in the calculation: 1016, 1221, 1232, 1242, 1248, 1254, 1260, 1262, and 1268. If the Aroclor was not detected in the sample, then the detection limit was used for estimating the total PCBs in soil. This approach is conservative and over-estimates the concentration of the PCBs in soil. The data in this report is consistently dealt with using this conservative approach.

3. Results and Discussion

The analytical results are presented in the tables and figures in the following sections. The results are compared to available standards for benchmarking. The standards that were identified for each site were:

- based on the site-specific factors;
- from the most recent OMRR standards (OMRR, 2018b); and,
- the most conservative of the CSR (CSR, 2018a) and the CCME (CCME, 2010).

In the tables:

- "NS" indicates that no standard was identified.
- "-" indicates that no sample was taken.
- "<" indicates the result was below the detection limit.

The individual results for each plot are shown on the graphs. All data points are shown on the graphs; however, on some graphs, the vertical y-axis does not include the numerical value of the respective standard as some of the standards were very large relative to the results. For the metals, PAHs, and phenols, the graphing of the results is spread over several separate figures due to the large number of analytes.

Any result which was less than detection is shown in the tables and on the graphs as the detection limit. This provides the most conservative scenario.

3.1. Agronomic Parameters

Soil properties are presented in Table 4. There are no standards for these parameters in the OMRR, CSR or CCME.

Table 4. Soil Properties on Each Plot

Analyte	Site	Control Plots - Plot Number					Treated Plots - Plot Number				
		#1	#2	#3	#4	#5	#1	#2	#3	#4	#5
pH (1:2 soil:water) (pH units)	A	7.84	7.61	7.70	7.85	7.67	7.60	7.29	7.11	7.17	6.99
	B	7.22	7.34	7.22	7.26	-	6.93	6.83	6.71	6.62	-
	C	7.27	7.28	-	-	-	7.49	7.52	-	-	-
Cation Exchange Capacity (meq/100g)	A	9.83	10.3	9.44	7.16	9.65	12.4	12.0	10.9	13.4	11.9
	B	20.525	19.025	20.075	19.675	-	20.625	19.975	19.825	19.875	-
	C	-	-	-	-	-	-	-	-	-	-
Total Nitrogen By LECO (µg/g)	A	0.099	0.102	0.105	0.097	0.100	0.155	0.180	0.172	0.179	0.145
	B	0.183	0.15825	0.181	0.16575	-	0.199	0.18425	0.18825	0.18975	-
	C	0.3325	0.34875	-	-	-	0.4025	0.41375	-	-	-
Total Kjeldahl Nitrogen (µg/g)	A	0.116	0.115	0.115	0.099	0.113	0.159	0.182	0.169	0.179	0.153
	B	0.1815	0.15975	0.179	0.16925	-	0.19575	0.1855	0.18475	0.1945	-
	C	0.31	0.3175	-	-	-	0.3725	0.3975	-	-	-
Total Organic Nitrogen (µg/g)	A	0.116	0.115	0.115	0.099	0.113	0.159	0.182	0.169	0.179	0.152
	B	0.1815	0.1595	0.17875	0.16925	-	0.19575	0.18525	0.18425	0.19375	-
	C	0.30875	0.318	-	-	-	0.3745	0.39775	-	-	-

Notes:
"-" indicates that no sample was taken

The pH is a measure of the acidity of the soil and can affect how easily metals may be carried in the groundwater. Soil pH is an important site-specific factor and is used to identify the appropriate standard for each site. Not all areas within a given plot would necessarily have the same pH; however, the average pH for each site was used to identify the site-specific standards.

Cation-exchange capacity is a measure of the ability of soil particles to retain cations (positively-charged ions and is expressed as milli-equivalents/100 g of soil (meq/100g). The cation exchange capacity can be an indicator of the capacity of a soil to retain nutrients and/or pollutants.

3.2.Nutrients and Organic Carbon

The concentrations of nutrients, micro-nutrients, and total organic carbon are presented in Table 5.

Table 5. Plant Available Nutrients in Soils on Each Plot

Analyte	Site	Control Plots - Plot Number					Treated Plots - Plot Number				
		#1	#2	#3	#4	#5	#1	#2	#3	#4	#5
Total Organic Carbon (%)	A	1.11	1.14	1.22	1.1	1.12	1.78	1.98	1.95	1.94	1.56
	B	1.965	1.6525	1.9025	1.785	-	2.1625	2.0275	1.9825	2.115	-
	C	3.925	4.42	-	-	-	4.9175	5.1275	-	-	-
Available Ammonium-N (µg/g)	A	1.2	1.5	1.4	1.3	1.4	1.4	1.6	1.5	1.8	1.7
	B	3.275	5.7	4.925	2.625	-	3.65	3.95	3.325	3.975	-
	C	3.3	2.575	-	-	-	3.3	4.4	-	-	-
Available Nitrate-N (µg/g)	A	1.3	1.7	1.1	<1	2.3	1.4	5.9	6.1	8.1	8.8
	B	5.1	4.75	4.125	4.55	-	5.2	2.825	2.25	1.675	-
	C	-	-	-	-	-	-	-	-	-	-
Available Phosphate-P (µg/g)	A	10.7	12.2	20.3	10.0	9.5	125	151	153	194	165
	B	4.925	3.85	2.8	3.85	-	25.4	24.95	21.725	36.5	-
	C	-	-	-	-	-	-	-	-	-	-
Calcium (µg/g)	A	1550	1400	1340	1250	1440	1820	1560	1450	1800	1580
	B	1747.5	1542.5	1695	1637.5	-	1820	1695	1512.5	1445	1820
	C	-	-	-	-	-	-	-	-	-	-
Copper (µg/g)	A	1.59	1.59	1.36	1.23	1.31	21.1	26.7	21.1	36.1	20.5
	B	1.23	1.3125	1.4075	1.3275	-	3.295	3.705	3.2675	3.7475	-
	C	-	-	-	-	-	-	-	-	-	-
Iron (µg/g)	A	14.5	19.0	20.1	12.3	17.8	52.3	74.2	65.4	78.2	74.2
	B	25.775	20.075	28.9	36.1	-	38.375	45.85	50.675	66.8	-
	C	-	-	-	-	-	-	-	-	-	-
Magnesium (µg/g)	A	250	219	205	193	227	273	241	207	262	220
	B	595.75	636	615.25	643.75	-	536.5	580.5	558.75	553	-
	C	-	-	-	-	-	-	-	-	-	-
Manganese (µg/g)	A	3.73	5.16	5.18	5.08	4.90	2.15	2.85	2.79	3.07	3.47
	B	7.645	6.27	5.96	5.5425	-	7.33	8.5175	9.2025	9.4325	-
	C	-	-	-	-	-	-	-	-	-	-
Potassium (µg/g)	A	101	129	192	119	110	113	172	271	198	220
	B	345.25	324	329.25	336.25	-	363.75	333.75	326.5	363.25	-
	C	-	-	-	-	-	-	-	-	-	-
Sodium (µg/g)	A	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
	B	<50	<50	<50	57	-	<50	<50	<50	<50	-
	C	-	-	-	-	-	-	-	-	-	-
Zinc (µg/g)	A	12.4	14.2	15.3	11.4	15.7	15.9	22.0	22.4	29.0	18.5
	B	1.4625	0.9625	1.615	1.9575	-	2.85	2.995	2.8575	3.9525	-
	C	-	-	-	-	-	-	-	-	-	-

Notes:
"<" indicates the result was below the detection limit
"-" indicates that no sample was taken

Higher nutrient and organic carbon levels are typically associated with improved yields and plant response. Organic carbon, a strong indicator of organic matter, can improve the physical and chemical characteristics of soil and enhance moisture retention and microbial activity, and thus result in many physical and chemical benefits in soil. No graphs are provided for the nutrients and soil parameters because there are no standards associated with these specific test results.

3.2.1. Site A

It is important to note, that since alfalfa fixes atmospheric nitrogen, the differences between control and treated plots on Site A for nitrogen could be due, in part, to differences in rates of nitrogen fixation. Also, the hold time for analysis of plant available nitrate-N was exceeded for samples from Site A. The results are provided as a general indicator of possible trends only.

3.2.2. Site B

The hold time for analysis of plant available nitrate-N was exceeded for samples from Site B. The results are provided as a general indicator of possible trends only.

3.2.3. Site C

The recommended sample analysis hold time for pH at Site C was exceeded. The results are provided as a general indicator of possible trends only.

3.3. Metals

The results for the metals analysis are provided in Table 6.

Table 6. Metals in Soils on Each Plot

Analyte (µg/g)	Site	Control Plots - Plot Number					Treated Plots - Plot Number					Standards	
		#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	CSR or CCME	OMRR
Aluminum	A	9200	9870	8700	7430	7390	8990	7860	8780	8670	11200	40000	NS
	B	13075	13775	13725	13600	-	13175	13100	12775	13125	-	40000	NS
	C	17025	16275	-	-	-	16650	16775	-	-	-	40000	NS
Antimony	A	0.15	0.18	0.15	0.13	0.12	0.28	0.25	0.28	0.31	0.41	20	NS
	B	0.615	0.7225	0.69	0.6075	-	0.58	0.6425	0.5875	0.5725	-	20	NS
	C	0.17	0.1825	-	-	-	0.2125	0.195	-	-	-	20	NS
Arsenic	A	3.07	3.10	2.55	2.47	2.32	2.79	2.83	2.85	2.77	3.90	10	10
	B	5.0825	5.8925	5.9075	4.94	-	4.83	5.185	4.9525	4.6175	-	10	10
	C	2.2925	1.96	-	-	-	2.0925	2.0925	-	-	-	10	10
Barium	A	92.2	86.3	81.2	68.9	72.0	94.4	84.5	87.6	102	123	700	NS
	B	199.25	195.25	200.25	210	-	196.75	192	179	180.25	-	350	NS
	C	109	112.75	-	-	-	125.25	119.75	-	-	-	350	NS
Beryllium	A	0.28	0.31	0.30	0.25	0.26	0.27	0.25	0.27	0.26	0.37	4	NS
	B	0.355	0.38	0.3775	0.3525	-	0.3325	0.33	0.3275	0.3525	-	4	NS
	C	0.39	0.375	-	-	-	0.395	0.4	-	-	-	30	NS

Analyte (µg/g)	Site	Control Plots - Plot Number					Treated Plots - Plot Number					Standards	
		#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	CSR or CCME	OMRR
Boron	A	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	8500	NS
	B	<5	<5	5.025	<5	-	<5	<5	<5	<5	-	8500	NS
	C	<5	<5	-	-	-	<5.1	<5	-	-	-	8500	NS
Cadmium	A	0.187	0.218	0.192	0.182	0.182	0.311	0.338	0.328	0.401	0.441	1	1
	B	0.53325	0.548	0.54875	0.509	-	0.55875	0.605	0.52025	0.4175	-	1	1
	C	0.14225	0.136	-	-	-	0.169	0.16775	-	-	-	1	1
Calcium	A	3800	4190	3870	3200	3490	4360	4130	3690	4390	5340	NS	NS
	B	5602.5	5435	5682.5	5460	5472.5	5027.5	4910	4655	-	-	NS	NS
	C	7557.5	7415	-	-	-	8002.5	7822.5	-	-	-	NS	NS
Chromium	A	15.3	16.0	14.5	12.6	12.1	16.7	15.6	16.3	16.1	23.1	64	100
	B	30.625	33.1	33.425	31	-	29.875	29.775	28.575	29.65	-	64	100
	C	32.2	32.325	-	-	-	32.75	32.25	-	-	-	64	100
Cobalt	A	5.28	5.59	4.82	4.28	4.35	5.06	4.39	4.74	4.70	6.34	25	25
	B	13.725	15.175	14.7	13.3	-	13.275	13.7	12.775	13.175	-	25	25
	C	9.975	9.7075	-	-	-	10.2775	10.6175	-	-	-	25	25
Copper	A	16.7	17.9	14.8	13.5	13.7	75.0	75.3	64.8	91.7	83.3	63	150
	B	32.2	36.3	35.775	30.425	35.625	41.425	37.8	35.7	-	-	63	150
	C	21.775	20.775	-	-	-	26.2	26.05	-	-	-	63	150
Iron	A	16800	17700	15000	13700	13200	17000	14700	14900	15200	20100	35000	NS
	B	26300	29075	27875	26000	26225	27225	25825	26250	-	-	35000	NS
	C	25700	24575	-	-	-	24875	25300	-	-	-	35000	NS
Lead	A	7.48	9.12	8.57	7.90	7.48	14.4	17.3	14.4	16.0	24.6	70	120
	B	5.525	6.2	6.0775	5.705	-	5.8075	6.215	5.83	5.56	-	70	120
	C	3.8275	3.905	-	-	-	4.505	4.3725	-	-	-	70	120
Magnesium	A	3790	3830	3310	3180	2990	3600	3040	3080	3220	4140	NS	NS
	B	6017.5	6802.5	6282.5	5792.5	5757.5	6032.5	5455	6000	-	-	NS	NS
	C	5885	5755	-	-	-	5760	5897.5	-	-	-	NS	NS
Manganese	A	352	396	342	320	303	335	325	322	335	434	2000	NS
	B	636.75	649.25	644.25	615.75	634.5	663.5	595.75	602.25	-	-	2000	NS
	C	561.25	571.25	-	-	-	638.75	648.75	-	-	-	2000	NS
Mercury	A	0.0691	0.463	0.0286	0.0236	0.0372	0.939	0.686	0.359	0.546	0.413	6.6	10
	B	0.0195	0.021375	0.01975	0.0203	-	0.0364	0.0658	0.0288	0.040675	-	6.6	10
	C	0.01865	0.0199	-	-	-	0.028	0.043675	-	-	-	6.6	10
Molybdenum	A	0.51	0.70	0.63	0.48	0.65	1.00	1.11	1.01	1.17	1.33	5	80
	B	1.84	2.0775	2.115	1.74	-	1.855	2.0475	2.075	1.8	-	3	3
	C	0.5725	0.58	-	-	-	0.7625	0.72	-	-	-	3	3
Nickel	A	9.34	10.7	9.67	8.22	8.24	9.74	8.87	9.82	9.74	13.8	45	70
	B	37.675	42.75	40.1	35.85	-	36	37.875	35.375	37.125	-	45	70
	C	21.5	22.15	-	-	-	23.25	22.7	-	-	-	45	70
Phosphorus	A	537	628	537	493	474	978	1030	981	1270	1340	NS	NS
	B	838	840.75	846.5	840.75	-	933.5	998.75	923.75	947	-	NS	NS
	C	511.75	504.25	-	-	-	516.5	555.5	-	-	-	NS	NS
Potassium	A	1780	1960	1830	1480	1500	1510	1500	1870	1540	2360	NS	NS
	B	2522.5	2717.5	2692.5	2495	2447.5	2420	2287.5	2255	-	-	NS	NS
	C	1322.5	1335	-	-	-	1167.5	1175	-	-	-	NS	NS
Selenium	A	<0.2	<0.2	<0.2	<0.2	<0.2	0.37	0.32	0.27	0.38	0.40	1	1
	B	0.575	0.6925	0.6625	0.4225	-	0.545	0.6575	0.5925	0.4475	-	1	1
	C	<0.2	<0.2	-	-	-	<0.2	<0.2	-	-	-	1	1

Analyte (µg/g)	Site	Control Plots - Plot Number					Treated Plots - Plot Number					Standards	
		#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	CSR or CCME	OMRR
Silver	A	0.132	0.097	0.105	0.083	0.071	1.57	1.57	1.17	1.94	1.66	20	NS
	B	0.10375	0.141	0.13125	0.13925	-	0.21125	0.313	0.2475	0.27425	-	20	NS
	C	<0.05	<0.05	-	-	-	<0.052	<0.0635	-	-	-	20	NS
Sodium	A	140	155	150	129	125	140	125	152	140	205	NS	NS
	B	428.5	456.75	482.25	423	407.5	352.25	391.75	340.75	-	-	NS	NS
	C	431.5	398.75	-	-	-	424.75	442	-	-	-	NS	NS
Strontium	A	35.5	35.3	34.1	29.5	31.9	40.4	37.2	35.9	42.1	51.8	NS	NS
	B	52.45	55.275	57.1	51.65	-	51.275	50.2	49.725	46.325	-	NS	NS
	C	62.25	61.2	-	-	-	66	62.925	-	-	-	NS	NS
Sulfur	A	110	170	130	130	140	210	250	180	260	200	500	NS
	B	352.5	427.5	395	330	-	312.5	347.5	392.5	367.5	-	500	NS
	C	355	295	-	-	-	400	392.5	-	-	-	500	NS
Sulfur -Total	A	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	NS	NS
	B	650	625	600	<500	-	550	675	600	550	-	NS	NS
	C	<700	<575	-	-	-	<650	<650	-	-	-	NS	NS
Tin	A	0.30	0.34	0.33	0.27	0.27	2.97	3.08	2.39	3.63	3.34	5	NS
	B	0.3325	0.36	0.3825	0.3575	-	0.53	0.635	0.585	0.5675	-	5	NS
	C	0.4425	1.3775	-	-	-	0.645	0.6925	-	-	-	5	NS
Titanium	A	570	560	537	453	364	423	346	435	372	549	NS	NS
	B	965	1031	1045	982	-	978.5	904.75	929.5	897.25	-	NS	NS
	C	1205	1157.5	-	-	-	1173.5	1152.5	-	-	-	NS	NS
Vanadium	A	39.2	39.8	32.6	30.3	27.8	36.4	31.2	30.5	30.4	40.3	130	NS
	B	52.975	58.725	58.425	53.575	-	52.6	51.425	51.525	50.6	-	100	NS
	C	76.075	70.525	-	-	-	73.55	71.7	-	-	-	100	NS
Zinc	A	84.1	97.4	85.4	80.7	81.5	116	118	119	139	143	150	150
	B	98.625	102.85	102.5	99.5	100.375	108.25	99.225	94.35	-	-	150	150
	C	62.8	68.525	-	-	-	75.275	72.75	-	-	-	150	150

Notes:
"NS" indicates that no standard was identified
"<" indicates the result was below the detection limit
"-" indicates that no sample was taken

The standards from the CSR and the CCME were identified for each site and the lowest of the two standards is shown in the figures that follow. Because the OMRR soil standards are based on the CSR standards, wherever a metals standard from OMRR exists, the CSR standard is the same. There are no standards in OMRR for the following metals:

Aluminum	Antimony	Barium
Beryllium	Boron	Iron
Manganese	Silver	Sulfur
Tin	Vanadium	

For mercury, the CSR standard is expressed as inorganic mercury; however, the analytical results are for total mercury. This provides a more conservative comparison.

The OMRR, CSR and CCME do not have a standard for total sulphur. The total sulphur lab test provides the concentration of a combination of organic (slow release) and inorganic sulphur.

The CSR standard does not apply to the sodium results, because the laboratory method used for this study (strong acid digestion) was not the same as the prescribed method for CSR comparisons (saturated paste).

Except for copper on treated plots in Site A, all individual results were below the CCME standards. The Site A results are discussed in more detail in Section 3.2.1.

For most metals, the differences between the treated and control plots were not statistically significant. For metals with a normal distribution, the difference between the means was not statistically significant at a $p \leq 0.05$. For metals that did not have a normal distribution, the Mann-Whitney *U* test was performed to determine statistical significance. The statistically significant differences are identified in Table 7 and discussed within each site in the following sections.

Table 7. Metals: Comparison Between Treated and Control Plots

	Relative Percent Difference Between Treated and Control Plots			Significant Difference (|RPD|>50%): Mean of Treated Plot > Control Plot		
Analyte	**A**	**B**	**C**	**A**	**B**	**C**
Aluminum	7%	-4%	0%			
Antimony	71%	-10%	14%	√		
Arsenic	11%	-11%	-2%			
Barium	20%	-7%	10%			
Beryllium	1%	-9%	4%			
Boron	0%	0%	1%			
Cadmium	62%	-2%	19%	√		
Calcium	17%	-13%	6%			
Chromium	22%	-8%	1%			
Cobalt	4%	-7%	6%			
Copper	134%	12%	20%	√		
Iron	7%	-2%	0%			
Lead	73%	0%	14%	√		
Magnesium	0%	-5%	0%			
Manganese	2%	-2%	13%			
Mercury	130%	72%	60%	√	√	√
Molybdenum	62%	0%	25%	√		
Nickel	12%	-7%	5%			
Phosphorus	71%	12%	5%	√		
Potassium	3%	-10%	-13%			
Selenium	54%	-5%	0%	√		
Silver	177%	68%	14%	√	√	
Sodium	9%	-19%	4%			
Strontium	22%	-9%	4%			
Sulfur	47%	-6%	20%			
Sulfur -Total	0%	0%	2%			

	Relative Percent Difference Between Treated and Control Plots			Significant Difference (|RPD|>50%): Mean of Treated Plot > Control Plot		
Analyte	**A**	**B**	**C**	**A**	**B**	**C**
Tin	164%	47%	-31%	√		
Titanium	-16%	-8%	-2%			
Vanadium	-1%	-8%	-1%			
Zinc	39%	0%	12%			

The graphs that follow are spread over five separate figures due to the large number of metals and the range in values of the standards. The results are graphed in Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8. In some graphs, the y-axis does not include the standard, which allowed for all data points to be seen more clearly.

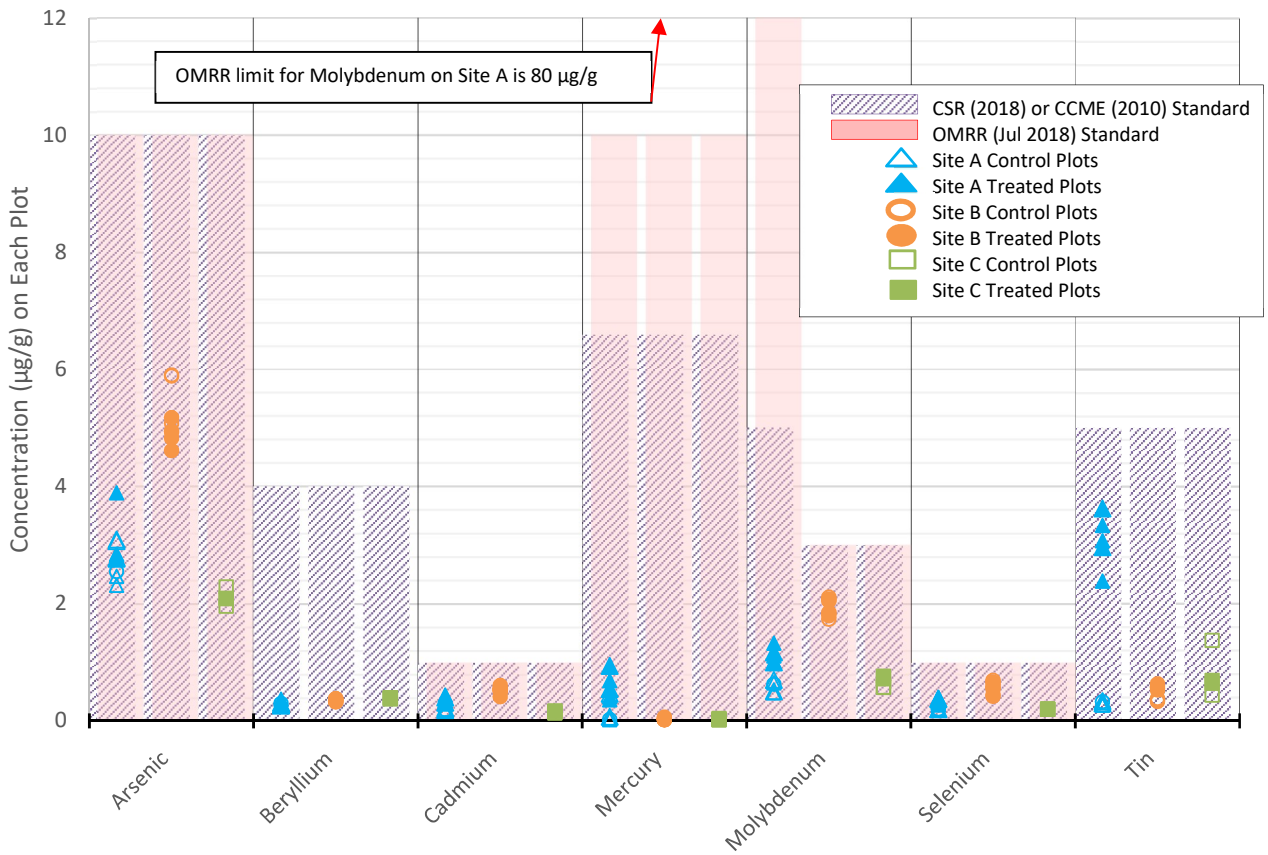

Figure 4. Metals (Graph 1 of 5) in Soils on Each Plot

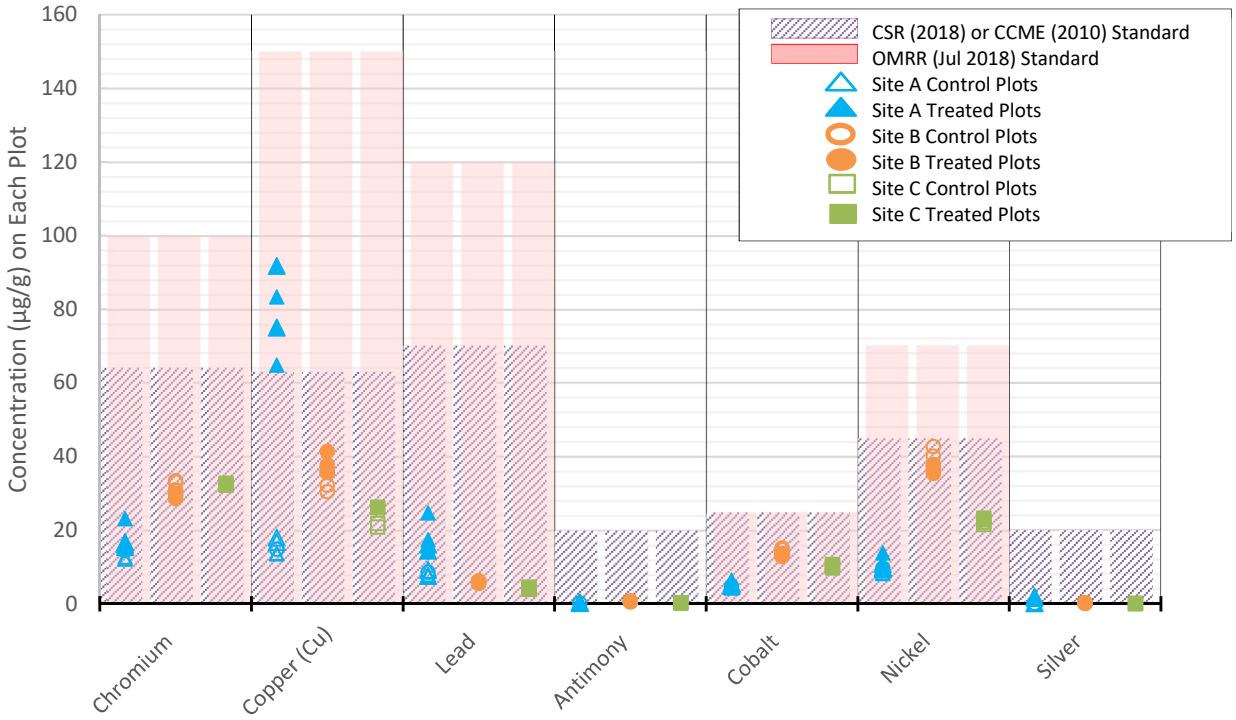

Figure 5. Metals (Graph 2 of 5) in Soils on Each Plot

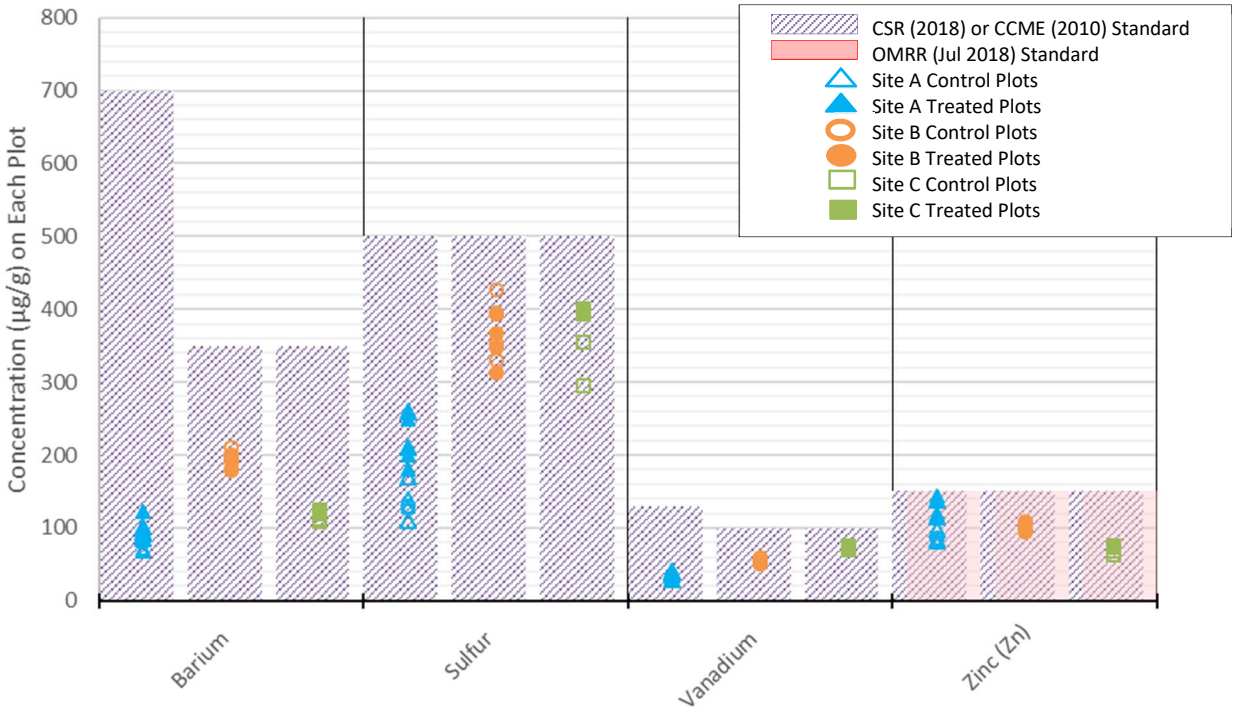

Figure 6. Metals (Graph 3 of 5) in Soils on Each Plot

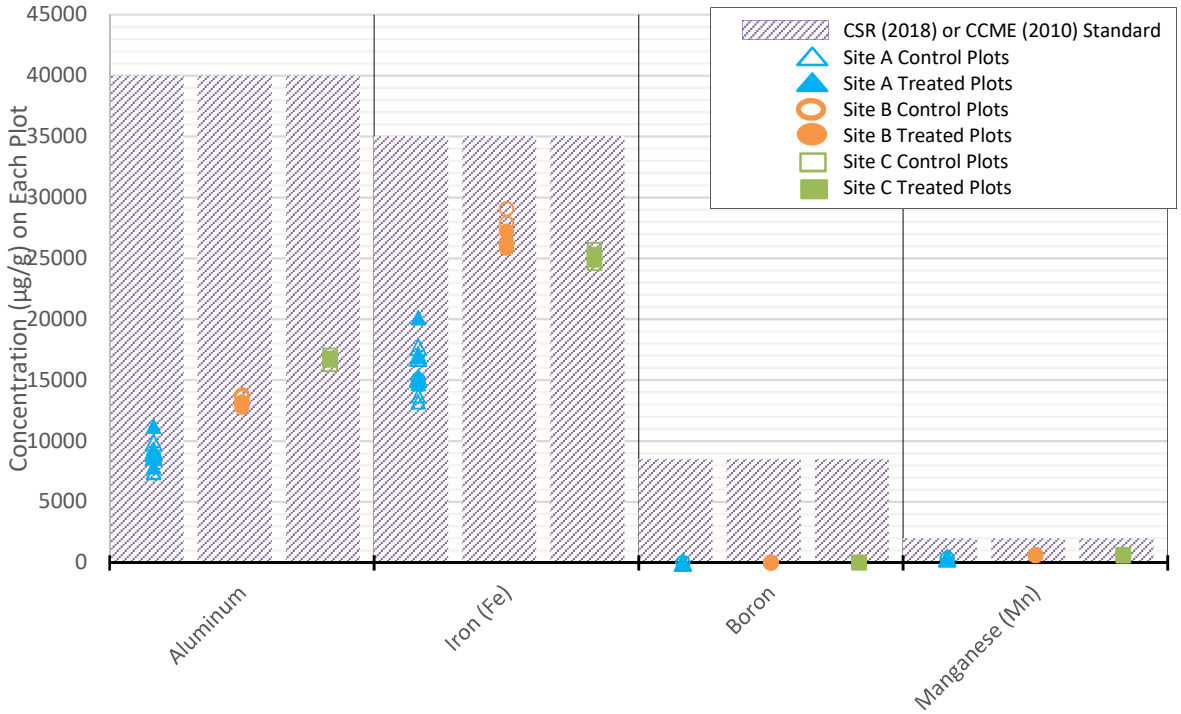

Figure 7. Metals (Graph 4 of 5) in Soils on Each Plot

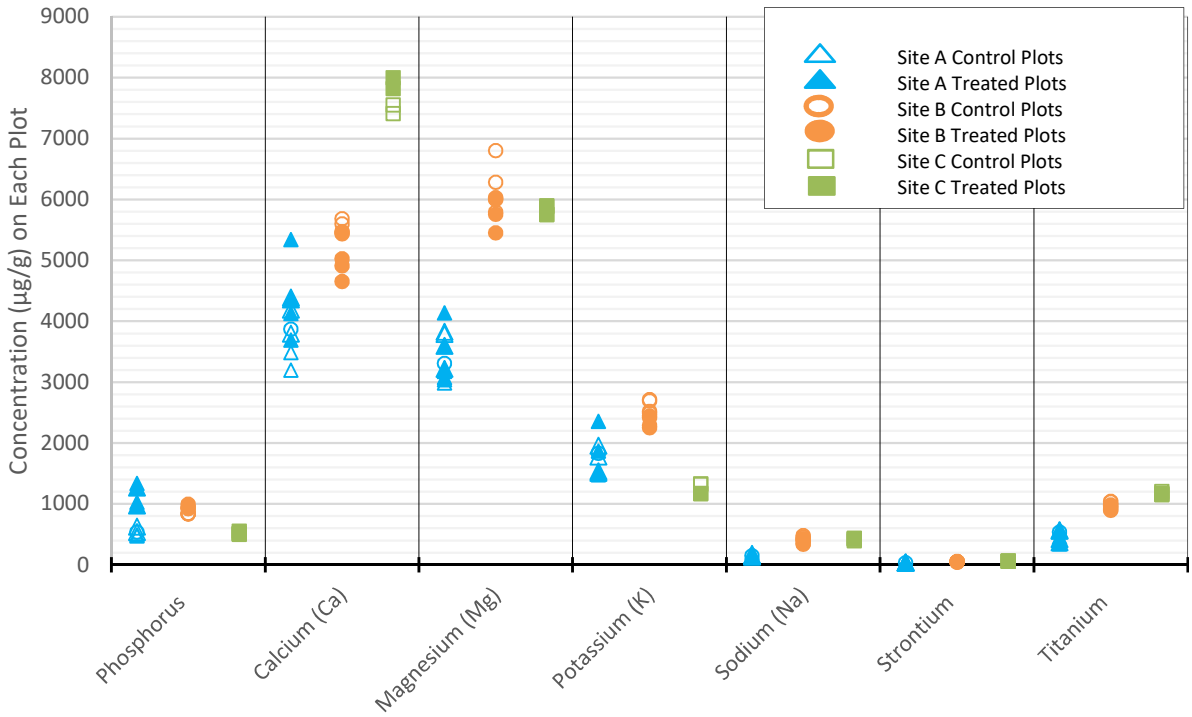

Figure 8. Metals (Graph 5 of 5) in Soils on Each Plot

No standards were available for the metals shown in Figure 8. The data points have been graphed to depict the general distribution of results over treated plots and control plots.

The figures provide context to Table 6. While Table 7 indicated where the differences between results were statistically significant, the figures help illustrate the magnitude of difference between the control plots and treated plots.

The concentration some metals may be due to the historical use of chemicals, i.e., fertilizers and pesticides, in the orchard. Although there is no direct evidence of which pesticides were used at these sites, copper, and other metals such as arsenic, lead and zinc, are known to have been common components in pesticides in orchards in North America.

3.3.1. Site A

As shown in Figure 5, the copper concentrations were below the OMRR standard on all plots; however, the treated plots had concentrations of copper which exceeded the CCME standard. All other metals were below the CSR and the CCME standards.

The means of the treated plots were statistically significantly higher than the control plots for several metals:

Antimony	Cadmium	Phosphorus
Copper	Lead	Mercury
Molybdenum	Phosphorus	Selenium
Silver	Tin	

The higher concentration of some metals on the treated plots may be an indication that the application of soil amendments, such as biosolids and/or fertilizers, have contributed to the higher concentrations.

3.3.2. Site B

At Site B, all measured metals concentrations were below the OMRR and the more stringent of the CSR and the CCME standards.

The majority of metals appeared higher in concentration in the control than in the treated plots, however none of the differences were statistically significant. This is similar to the results for Site A where there were no metal concentrations on the control plots that were statistically significantly greater than the treated plots.

For two metals, the differences between the treated plots and control plots were statistically significant at a $p \leq 0.05$, or based on Mann-Whitney *U* test, depending on the distribution. Two metals, silver and mercury, were higher in concentration in the treated plots than in the control plots. The difference between the treated and controlled plots was statistically significant indicating that the difference was not due to random distribution of the metals. The metal concentration difference between the plots may be due to land application of soil amendments.

With the exception of the two metals, silver and mercury, the remainder of the metals on Site B did not have means that were statistically different between the control and treated plots.

3.3.3. Site C

At Site C, all measured metals concentrations were below the OMRR, the CSR and the CCME standards.

For those metals which appeared higher in concentration in control plots than in treated plots, there was no statistically significant difference. This is similar to the results for both Site A and Site B where there were no metal concentrations on the control plots that were statistically significantly greater than the treated plots.

Mercury was higher in concentration in the treated plots than in the control plots. However, the holding time for mercury exceeded the allowable time for the laboratory method. The results for mercury are inconclusive but are provided here only as an indication relative to the standards.

3.4. Polycyclic Aromatic Hydrocarbons

PAHs can result from natural processes such as forest fires and/or microbial activity and subsequent decomposition of organic material.

For all three sites, the concentrations of individual PAH results, as summarized in Table 8, were below the CSR standards. The results are shown in multiple figures (Figure 9, Figure 10, Figure 11, and Figure 12) with different scales on each of the vertical axes to accommodate the wide range in the standards.

Table 8. Polycyclic Aromatic Hydrocarbons in Soils on Each Plot

Analyte (µg/g)	Site	Control Plots - Plot Number					Treated Plots - Plot Number					Standards	
		#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	CSR or CCME	OMRR
2-Methyl-naphthalene	A	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	60	NS
	B	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	60	NS
	C	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	-	60	NS
Acenaph-thene	A	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	950	NS
	B	<0.005	<0.005	<0.005	<0.005	-	<0.005	<0.005	<0.005	<0.005	-	950	NS
	C	<0.005	<0.005	-	-	-	<0.005	<0.005	-	-	-	950	NS
Acenaph-thylene	A	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	NS	NS
	B	<0.005	<0.005	<0.005	<0.005	-	<0.005	<0.005	<0.005	<0.005	-	NS	NS
	C	<0.005	<0.005	-	-	-	<0.005	<0.005	-	-	-	NS	NS
Anthracene	A	0.004	0.004	0.004	0.004	0.004	0.0049	0.0080	0.004	0.004	0.0047	2.5	NS
	B	0.004	0.004	0.004	0.004	-	0.004	0.004	0.004	0.004	-	2.5	NS
	C	0.004	0.004	-	-	-	0.004	0.004	-	-	-	2.5	NS
Benz(a) anthracene	A	<0.01	<0.01	<0.01	<0.01	<0.01	0.020	0.043	<0.01	<0.019	0.011	0.1	NS
	B	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	0.1	NS
	C	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	-	0.1	NS
Benzo(a) pyrene	A	<0.01	<0.01	<0.01	<0.01	<0.01	0.021	0.036	0.012	0.022	0.011	5	NS
	B	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	5	NS
	C	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	-	5	NS
Benzo(b) fluoranthene	A	<0.01	<0.01	<0.01	<0.01	<0.01	0.038	0.063	0.025	0.047	0.024	0.1	NS
	B	<0.01	<0.01	<0.01	<0.01	-	0.0105	<0.01	<0.01	<0.01	-	0.1	NS
	C	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	-	0.1	NS
Benzo (b+j+k) fluoranthene	A	<0.015	<0.015	<0.015	<0.015	<0.015	0.051	0.086	0.025	0.063	0.024	0.1	NS
	B	<0.015	<0.015	<0.015	<0.015	-	<0.015	<0.015	<0.015	<0.015	-	0.1	NS
	C	<0.015	<0.015	-	-	-	<0.015	<0.015	-	-	-	0.1	NS

Analyte (µg/g)	Site	Control Plots - Plot Number					Treated Plots - Plot Number					Standards	
		#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	CSR or CCME	OMRR
Benzo(g,h,i) perylene	A	<0.01	<0.01	<0.01	<0.01	<0.01	<0.015	0.022	0.011	0.017	<0.01	NS	NS
	B	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	NS	NS
	C	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	-	NS	NS
Benzo(k) fluoranthene	A	<0.01	<0.01	<0.01	<0.01	<0.01	0.013	0.023	0.01	0.016	<0.01	0.1	NS
	B	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	0.1	NS
	C	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	-	0.1	NS
Chrysene	A	<0.01	<0.01	<0.01	<0.01	<0.01	0.024	0.047	<0.02	0.022	<0.015	200	NS
	B	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	200	NS
	C	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	-	200	NS
Dibenz(a,h) anthracene	A	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.0057	<0.005	<0.005	<0.005	0.1	NS
	B	<0.005	<0.005	<0.005	<0.005	-	<0.005	<0.005	<0.005	<0.005	-	0.1	NS
	C	<0.005	<0.005	-	-	-	<0.005	<0.005	-	-	-	0.1	NS
Fluoran-thene	A	<0.01	<0.01	<0.01	<0.01	<0.01	0.037	0.080	0.020	0.033	0.033	50	NS
	B	<0.01	<0.01	<0.01	<0.01	-	0.01025	<0.01	<0.01	<0.01	-	50	NS
	C	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	-	50	NS
Fluorene	A	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	600	NS
	B	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	600	NS
	C	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	-	600	NS
Indeno (1,2,3-c,d) pyrene	A	<0.01	<0.01	<0.01	<0.01	<0.01	0.018	0.026	0.012	0.020	0.011	0.1	NS
	B	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	0.1	NS
	C	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	-	0.1	NS
Naph-thalene	A	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.013	0.013	NS
	B	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	0.013	NS
	C	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	-	0.013	NS
Phenan-threne	A	<0.01	<0.01	<0.01	<0.01	<0.01	0.024	0.027	<0.015	0.018	0.029	0.046	NS
	B	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	0.046	NS
	C	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	-	0.046	NS
Pyrene	A	<0.01	<0.01	<0.01	<0.01	<0.01	0.036	0.070	0.020	0.032	0.032	0.1	NS
	B	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	0.1	NS
	C	<0.01	<0.01	-	-	-	<0.01	<0.01	-	-	-	0.1	NS
IACR (CCME)	A	<0.15	<0.15	<0.15	<0.15	<0.15	0.46	0.82	0.26	0.54	0.27	1	NS
	B	<0.15	<0.15	<0.15	<0.15	-	<0.15	<0.15	<0.15	<0.15	-	1	NS
	C	<0.15	<0.15	-	-	-	<0.15	<0.15	-	-	-	1	NS
B(a)P Total Potency Equivalent	A	<0.020	<0.020	<0.020	<0.020	<0.020	0.033	0.058	<0.020	0.036	<0.020	0.6	NS
	B	<0.020	<0.020	<0.020	<0.020	-	<0.020	<0.020	<0.020	<0.020	-	0.6	NS
	C	<0.020	<0.020	-	-	-	<0.020	<0.020	-	-	-	0.6	NS

Notes:
"NS" indicates that no standard was identified
"<" indicates the result was below the detection limit
"-" indicates that no sample was taken

The Index of Additive Cancer Risk (IACR) is a calculation that was done by the laboratory and used for comparison with the CCME standard. Similarly, the B(a)P Total Potency Equivalent is a summation of select PAHs which was calculated by the laboratory and compared to the CCME standard.

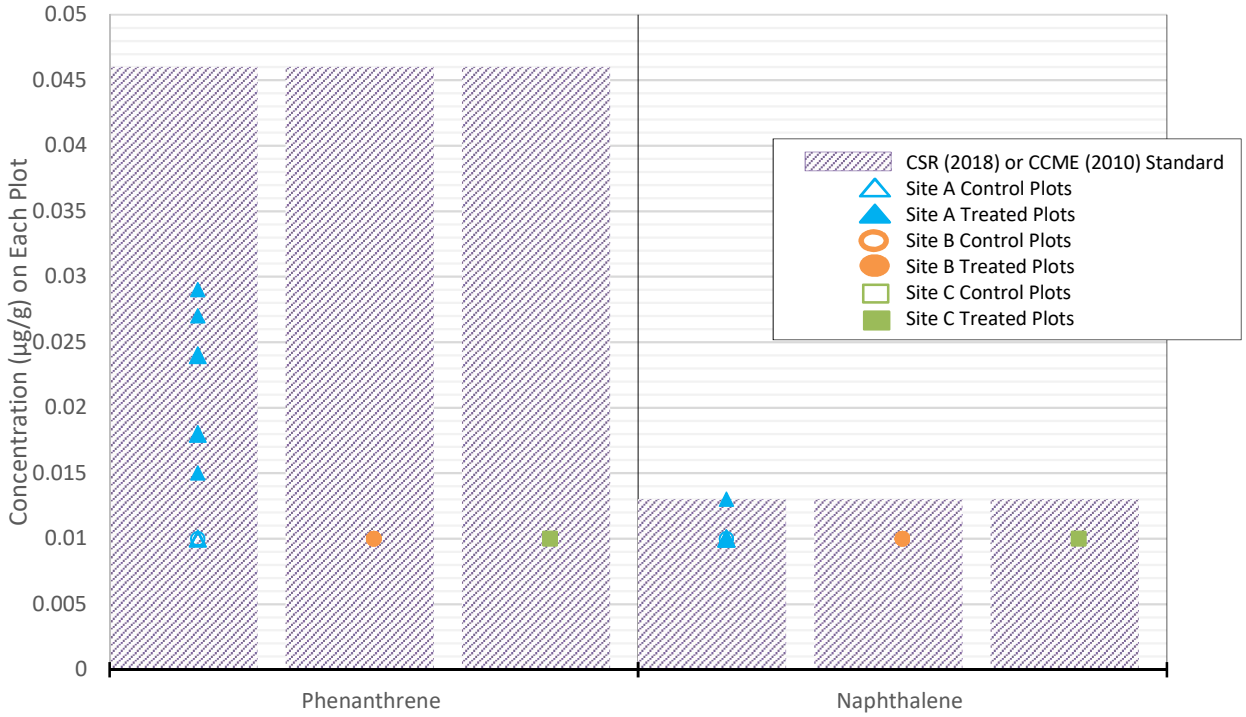

Figure 9. Polycyclic Aromatic Hydrocarbons (Graph 1 of 4) in Soils on Each Plot

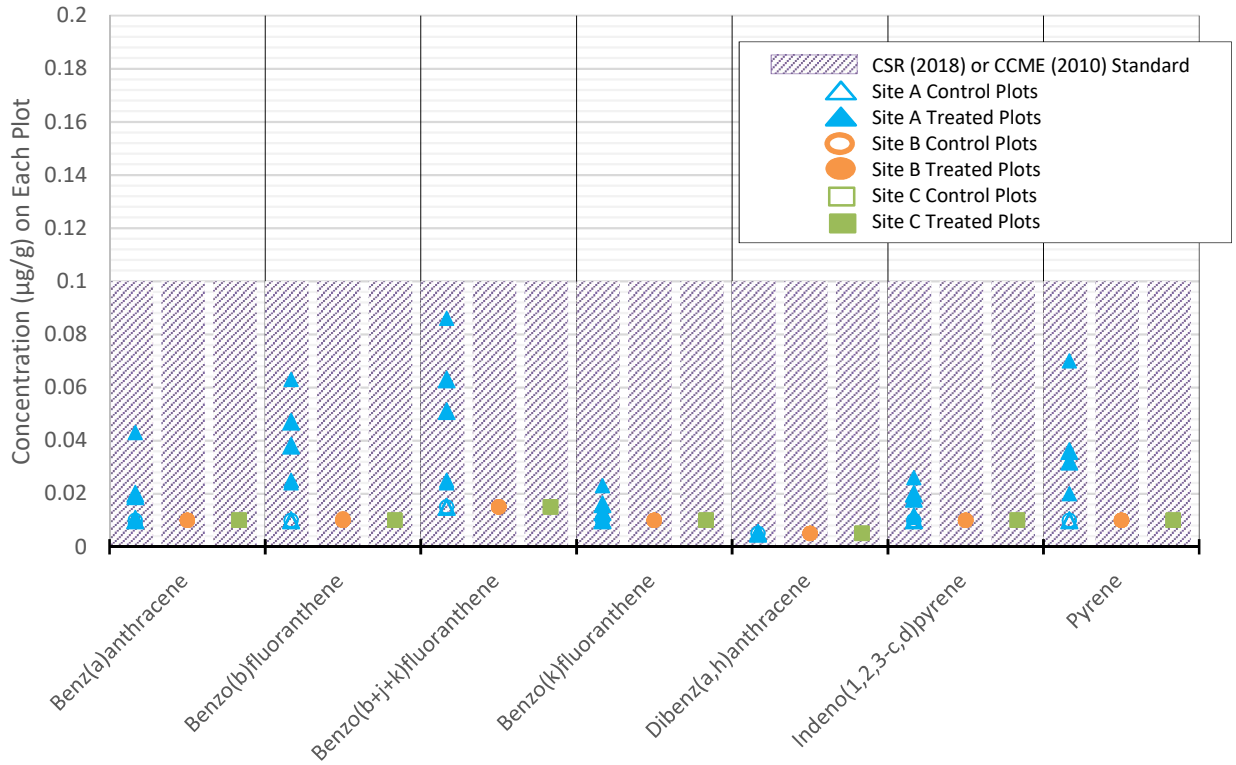

Figure 10. Polycyclic Aromatic Hydrocarbons (Graph 2 of 4) in Soils on Each Plot

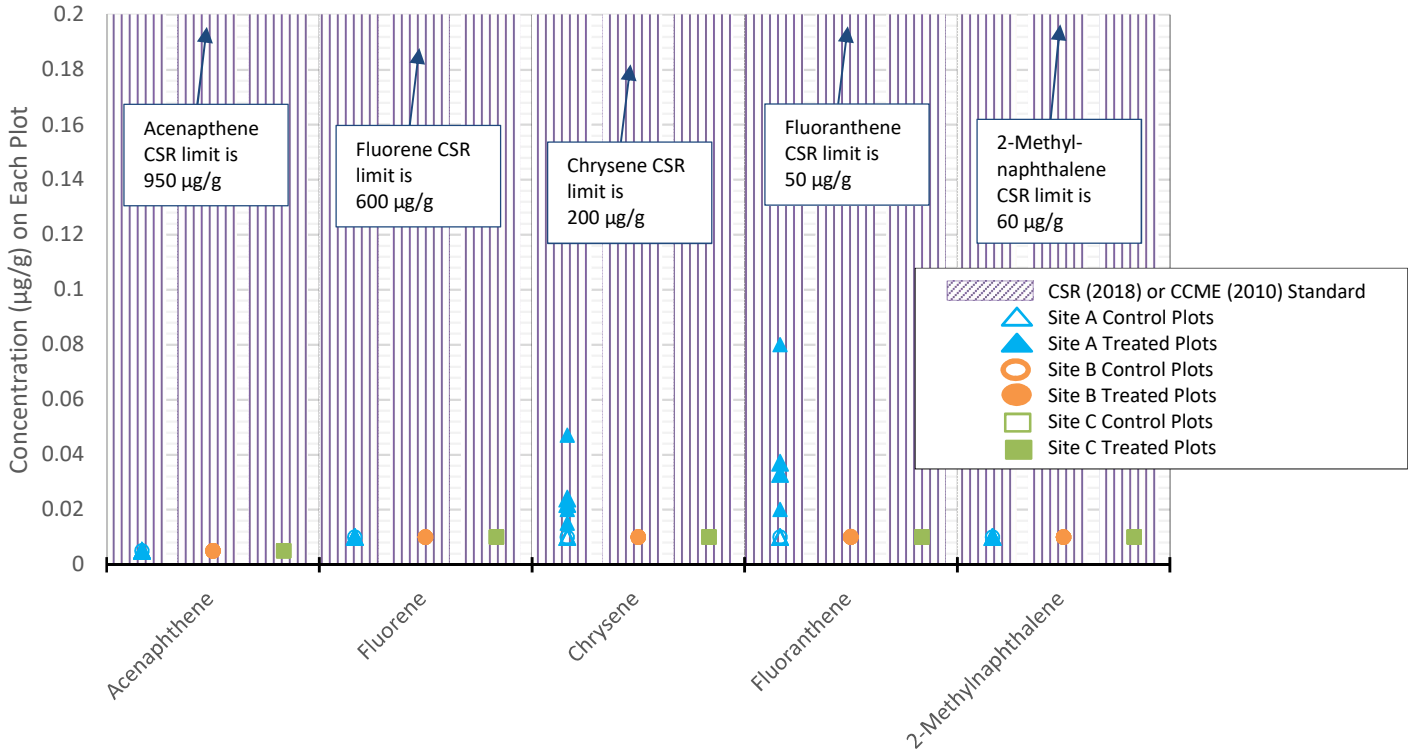

Figure 11. Polycyclic Aromatic Hydrocarbons (Graph 3 of 4) in Soils on Each Plot

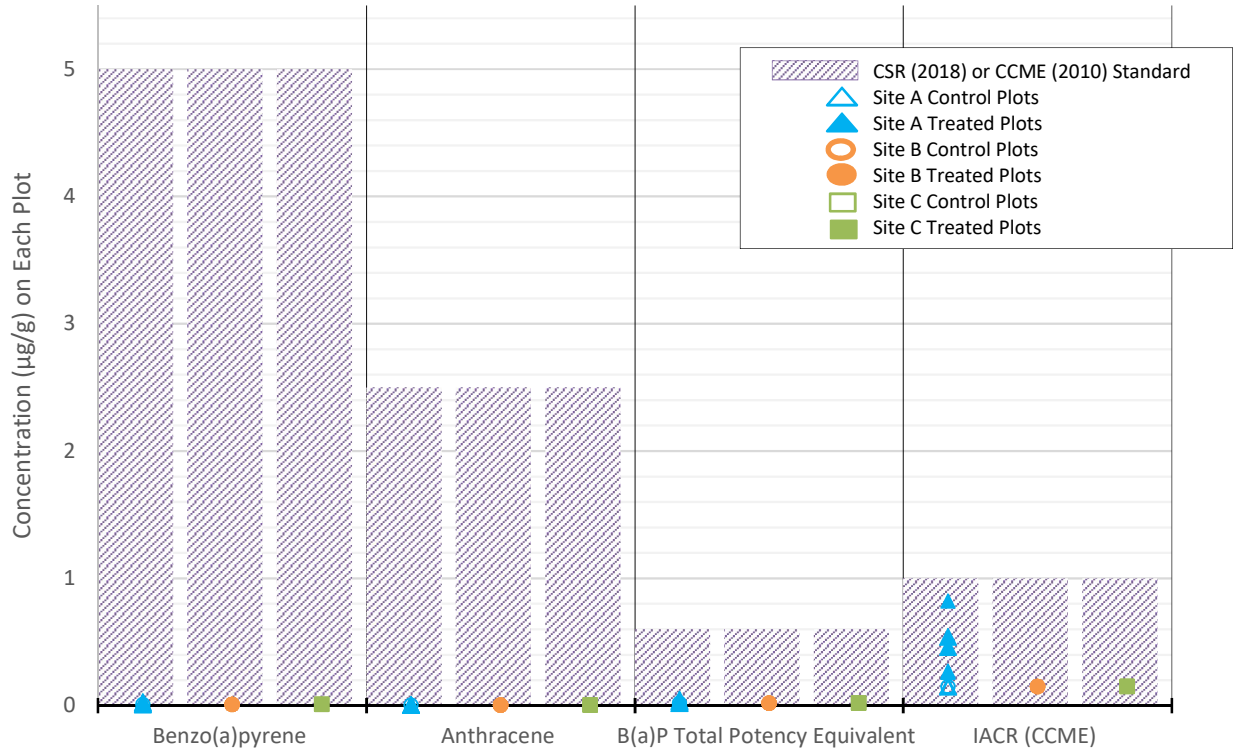

Figure 12. Polycyclic Aromatic Hydrocarbons (Graph 4 of 4) in Soils on Each Plot

3.4.1. Site A

At all control plots within Site A, all PAH results were below the detection limits and the standards.

On the treated plots in Site A, most compounds were detected. The detected PAHs were all below the OMRR, and the CSR and CCME standards. Naphthalene, on treated plot # 5 on Site A, was measured at 0.013 mg/kg which is coincident with the OMRR standard. As a result, Figure 9 shows the naphthalene concentration for the treated plot on Site A at the CSR standard.

In all cases where detection occurred, the means were higher in the treated plots than the control plots. However, the differences were not statistically significant. The slightly higher PAHs on the treated plots may be due to higher microbial activity, or another source of random error.

3.4.2. Site B

On all plots within Site B, all PAH results were below the detection limits, which were below the standards.

3.4.3. Site C

The sample hold time for polycyclic aromatic hydrocarbons at Site C was exceeded. The data is inconclusive and is provided here as an indication only. The results were below the detection limits, which were below the standards.

3.5. Phthalates

The data results and standards for the phthalates analysed in this project are summarized in Table 9. Figure 13 shows the concentrations of four phthalates with corresponding CSR standards for Sites A, B and C. Three phthalates were not detected, and do not have corresponding OMRR, CSR or CCME standards. These three phthalates were not graphed.

Table 9. Phthalates in Soils on Each Plot

Analyte (µg/g)	Site	Control Plots - Plot Number					Treated Plots - Plot Number					Standards	
		#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	CSR or CCME	OMRR
bis(2-Ethylhexyl) Phthalate	A	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	30	NS
	B	0.54575	<0.5	<0.5	<0.5	-	<0.5	<0.5	<0.5	<0.5	-	30	NS
	C	0.10375	0.19675	-	-	-	0.20375	<0.5	-	-	-	30	NS
Butylbenzyl Phthalate	A	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	3000	NS
	B	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	-	3000	NS
	C	<0.05	<0.05	-	-	-	<0.05	<0.05	-	-	-	3000	NS
Diethyl Phthalate	A	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	15000	NS
	B	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	-	15000	NS
	C	<0.05	<0.05	-	-	-	<0.05	<0.05	-	-	-	15000	NS
Diisobutyl Phthalate	A	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NS	NS
	B	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	-	NS	NS
	C	<0.05	<0.05	-	-	-	<0.05	<0.05	-	-	-	NS	NS
Dimethyl Phthalate	A	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NS	NS
	B	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	-	NS	NS
	C	<0.05	<0.05	-	-	-	<0.05	<0.05	-	-	-	NS	NS
Di-n-butyl Phthalate	A	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.096	<0.05	<0.05	30	NS
	B	<0.0625	<0.0625	<0.0625	<0.05	-	<0.05	<0.0625	<0.0875	<0.05	-	30	NS
	C	<0.05	<0.05	-	-	-	<0.05	<0.05	-	-	-	30	NS
Di-n-Octyl Phthalate	A	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NS	NS
	B	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	-	NS	NS
	C	<0.05	<0.05	-	-	-	<0.05	<0.05	-	-	-	NS	NS

Notes:
"NS" indicates that no standard was identified
"<" indicates the result was below the detection limit
"-" indicates that no sample was taken

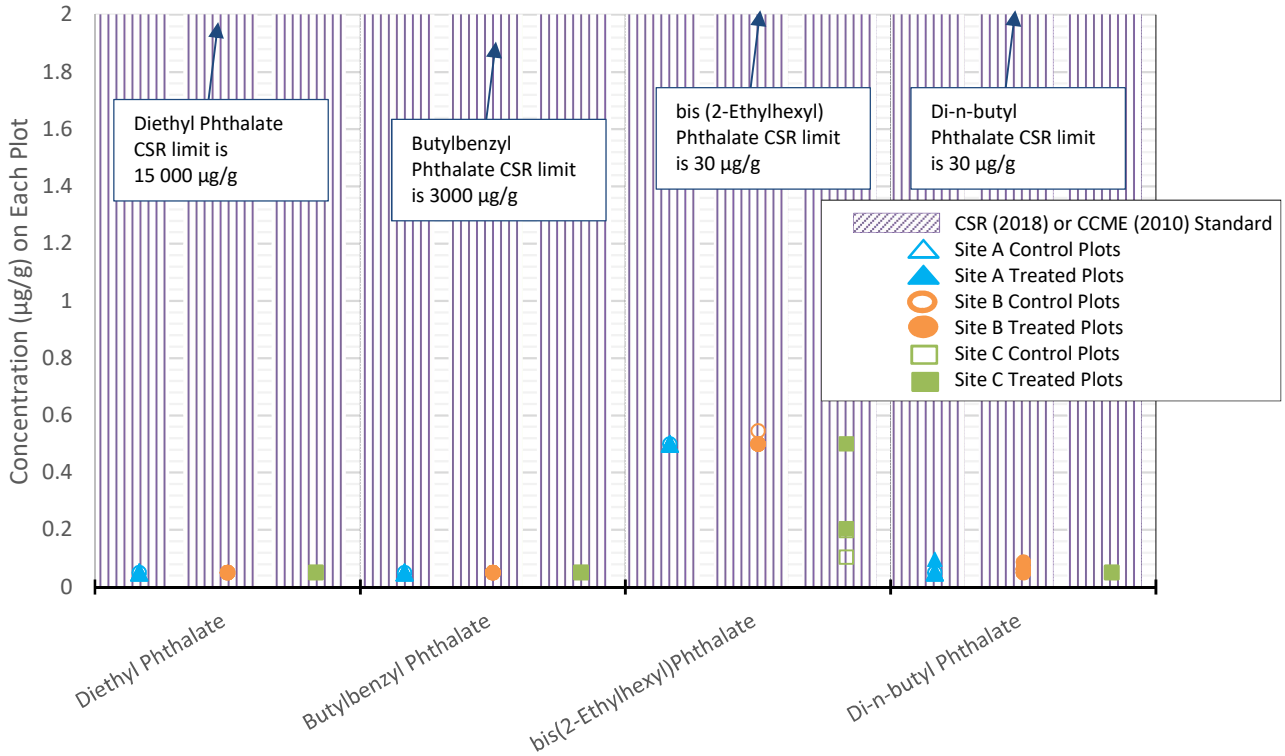

Figure 13. Phthalates in Soils on Each Plot

Two out of seven phthalates were detected, and both were below the corresponding CSR standard. The phthalate species detected were:

1. Bis (2-Ethylhexyl) Phthalate, which is the most common phthalate. It is used as a plasticizer and found in many households and medical equipment. It is also used in the manufacture of PVC pipe, which is commonly used for irrigation piping.
2. Di-n-butyl phthalate, which is a plasticizer and is used in the production of PVC and other common items such as nail polish. Usage has declined since 2006 when it was banned in the U.S. for certain products such as children's toys.

The use of PVC for irrigation piping and other pumping applications in the farm industry is one possible source of these two phthalates.

3.5.1. Site A

With the exception of di-n-butyl phthalate on one of the treated plots, no phthalates were detected on Site A.

3.5.2. Site B

Bis (2-Ethylhexyl) Phthalate was detected on one control plot. It was not detected on the treated plots. The detection limit was raised for di-n-butyl phthalate. The reason for raising the limit may be due to interference in the lab or due to the sample quality.

The detections may be due to random error(s). No other phthalates were detected on Site B.

3.5.3. Site C

Bis(2-Ethyhexyl) Phthalate was detected on both the control plots and one treated plot; however, the recommended sample analysis hold time for phthalates at Site C was exceeded. The data is therefore inconclusive.

3.6. Phenols

The phenols results and corresponding CSR standards are summarized in Table 10 and shown in Figure 14, Figure 15 and Figure 16.

Table 10. Phenols in Soils on Each Plot

Analyte (µg/g)	Site	Control Plots - Plot Number					Treated Plots - Plot Number					Standards	
		#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	CSR or CCME	OMRR
2,3,4,5-Tetrachloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
2,3,4,6-Tetrachloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
2,3,4-Trichloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
2,3,5,6-Tetrachloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
2,3,5-Trichloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
2,3,6-Trichloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
2,3-Dichloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
2,4 & 2,5-Dichloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
2,4,5-Trichloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
2,4,6-Trichloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
2,4-Dimethyl phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	850	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	850	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	850	NS
2,6-Dichloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS

Analyte (µg/g)	Site	Control Plots - Plot Number					Treated Plots - Plot Number					Standards	
		#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	CSR or CCME	OMRR
2-Chloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
3,4-Dichloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.035	<0.0275	<0.0275	<0.023	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
3,5-Dichloro Phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
3-Chloro Phenol	A	<0.06	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
4-Chloro-3-methyl phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	1500	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	1500	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	1500	NS
4-Chloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.05	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.05	NS
m-Cresol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	NS	NS
	B	<0.02025	<0.02	<0.021	<0.02	-	<0.02175	0.0295	0.027	<0.02075	-	NS	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	NS	NS
o-Cresol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	NS	NS
	B	<0.03325	0.0315	0.0385	0.03075	-	0.03825	0.06775	0.05625	0.039	-	NS	NS
	C	<0.02	<0.02	-	-	-	<0.0205	<0.02	-	-	-	NS	NS
p-Cresol	A	<0.02	<0.02	<0.02	<0.02	<0.02	0.047	0.044	0.046	0.054	0.031	NS	NS
	B	<0.02425	<0.02125	0.028	<0.02275	-	<0.029	0.04425	0.035	0.026	-	NS	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	NS	NS
Pentachloro phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.1	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.1	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.1	NS
Phenol	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	3.8	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	3.8	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	3.8	NS

Notes:
"NS" indicates that no standard was identified
"<" indicates the result was below the detection limit
"-" indicates that no sample was taken

All results and detection limits were below the CSR standards. There are no standards within the OMRR for phenols.

The only phenols detected were the cresols (e.g., *o*-cresol, *m*-cresol, and *p*-cresol). Cresol sources are both naturally occurring and anthropogenic. Manufactured cresols are used in a wide variety of applications including pharmaceuticals (beta-blockers) and wood preservative (creosote). Natural sources may include forest fires or decomposition of organic matter. The *m*-cresol, *o*-cresol and *p*-cresol do not have corresponding standards but are graphed in Figure 16 for comparison of the sites and plots.

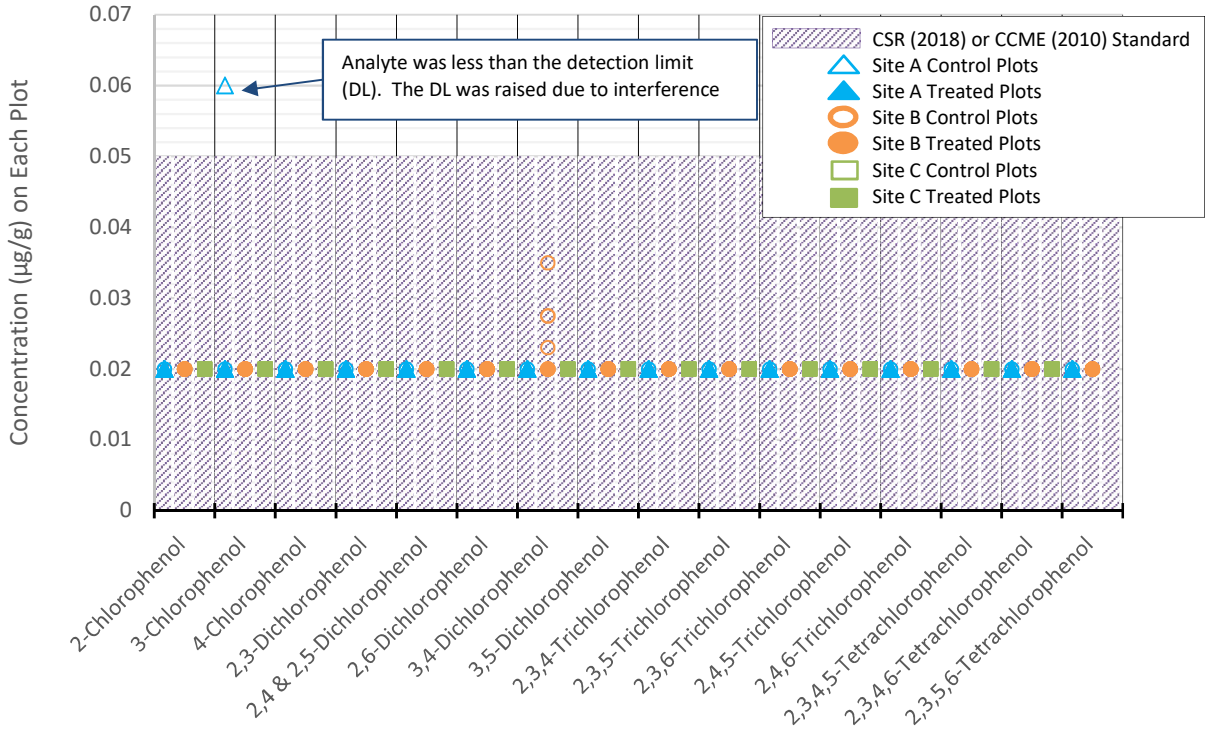

Figure 14. Phenols (Graph 1 of 3) in Soils on Each Plot

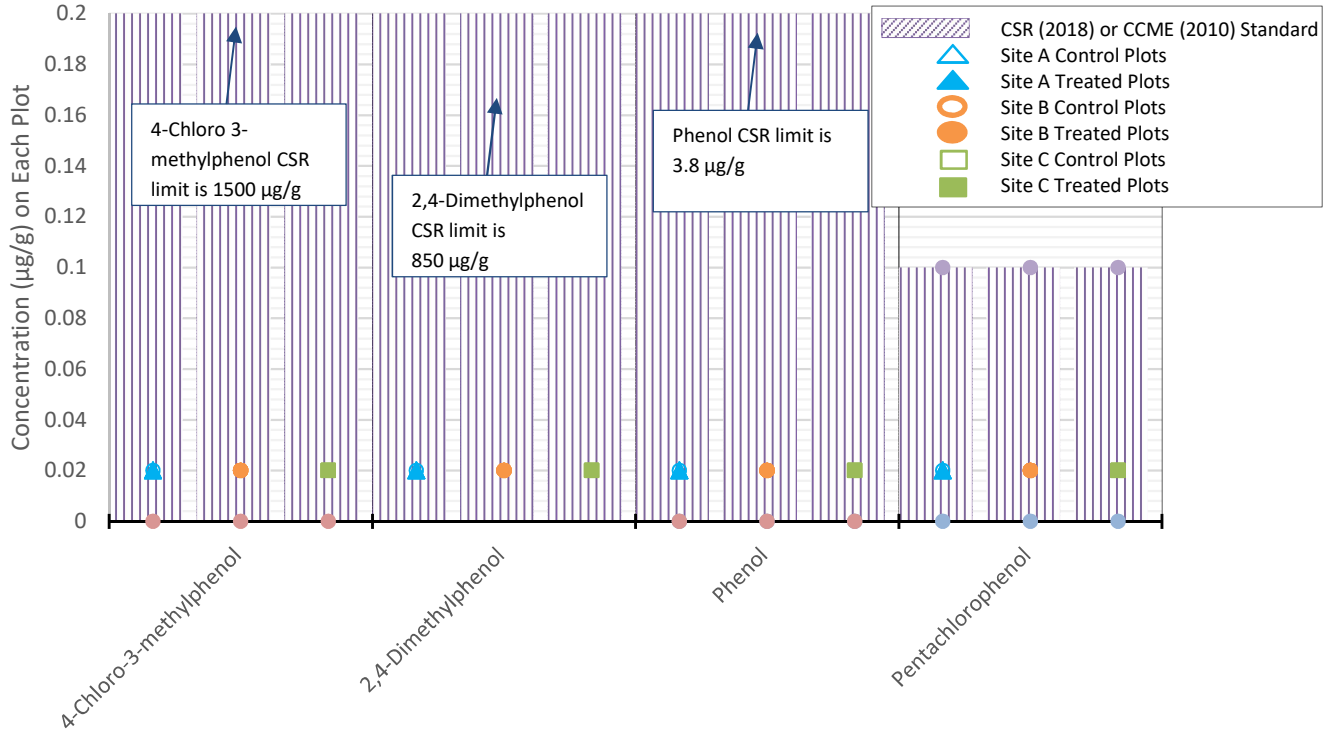

Figure 15. Phenols (Graph 2 of 3) in Soils on Each Plot

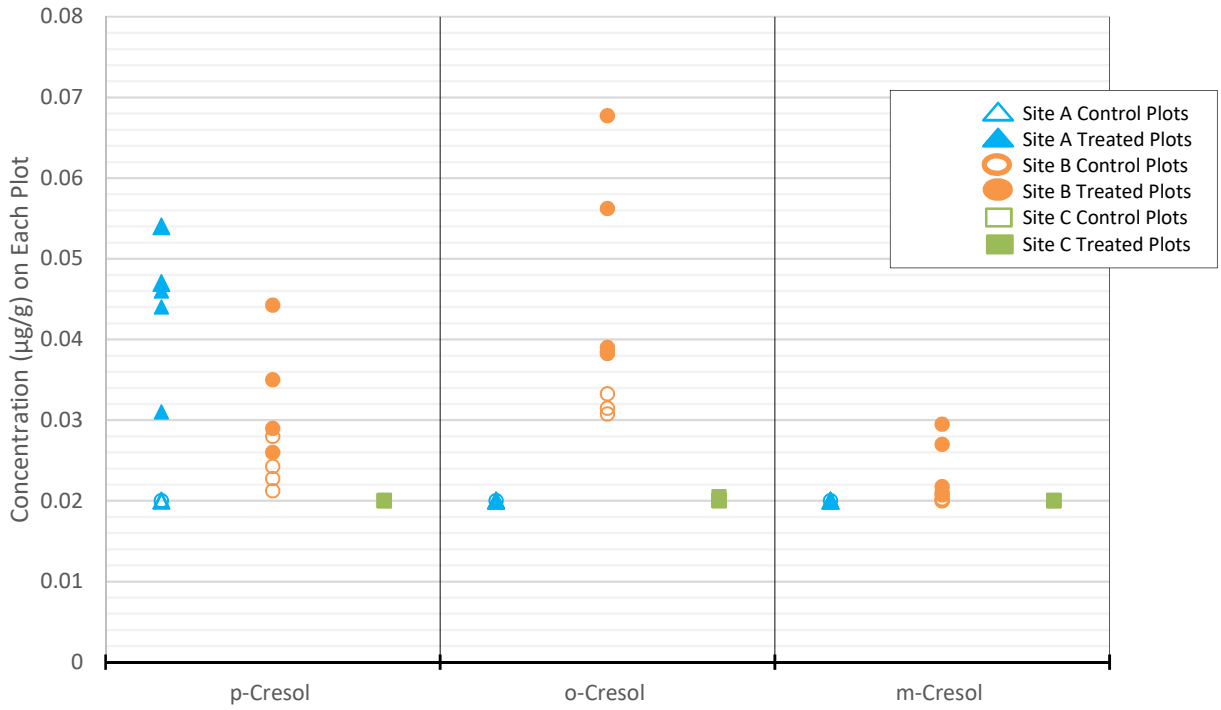

Figure 16. Phenols (Graph 3 of 3) in Soils on Each Plot

3.6.1. Site A

The only phenol detected on Site A was *p*-cresol, on the treated plots. The difference between the control plots and treated plots indicates that the source of the *p*-cresol may be from biosolids or other soil amendments.

3.6.2. Site B

At Site B, the only phenols that were detected were the cresols *o*-cresol, *m*-cresol, and *p*-cresol which were present in both the control and treated plots. The means were statistically higher in treated plots when compared to the control plots. A comparison of means for the other phenols in Table 10 was not feasible since all measurements were below the detection limit in both control and treated plots. The detection limit was the same for all phenols. The source of the cresols may be anthropogenic as indicated by the difference in the plots.

3.6.3. Site C

No phenols were detected on Site C.

3.7. Polychlorinated Biphenyls

The PCBs analyzed as part of this study are among the most common in the environment. The analytical results are summarized in Table 11 and graphed in Figure 17.

Table 11. Polychlorinated Biphenyls in Soils at All Sites

Analyte (µg/g)	Site	Control Plots - Plot Number					Treated Plots - Plot Number					Standards	
		#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	CSR or CCME	OMRR
PCB-1016	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.5	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.5	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.5	NS
PCB-1221	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.5	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.5	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.5	NS
PCB-1232	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.5	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.5	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.5	NS
PCB-1242	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.5	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.5	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.5	NS
PCB-1248	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.5	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.5	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.5	NS
PCB-1254	A	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.5	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.5	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.5	NS
PCB-1260	A	<0.09	<0.09	<0.2	<0.1	<0.1	<0.2	<0.2	<0.3	<0.3	<0.2	0.5	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.5	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.5	NS
PCB-1262	A	<0.09	<0.09	<0.2	<0.1	<0.1	<0.2	<0.2	<0.3	<0.3	<0.2	0.5	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.5	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.5	NS
PCB-1268	A	<0.09	<0.09	<0.2	<0.1	<0.1	<0.2	<0.2	<0.3	<0.3	<0.2	0.5	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	0.5	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	0.5	NS
Total PCBs	A	<0.09	<0.09	<0.2	<0.1	<0.1	<0.2	<0.2	<0.3	<0.3	<0.2	1.5	NS
	B	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02	-	1.5	NS
	C	<0.02	<0.02	-	-	-	<0.02	<0.02	-	-	-	1.5	NS

Notes:
"NS" indicates that no standard was identified
"<" indicates the result was below the detection limit
"-" indicates that no sample was taken

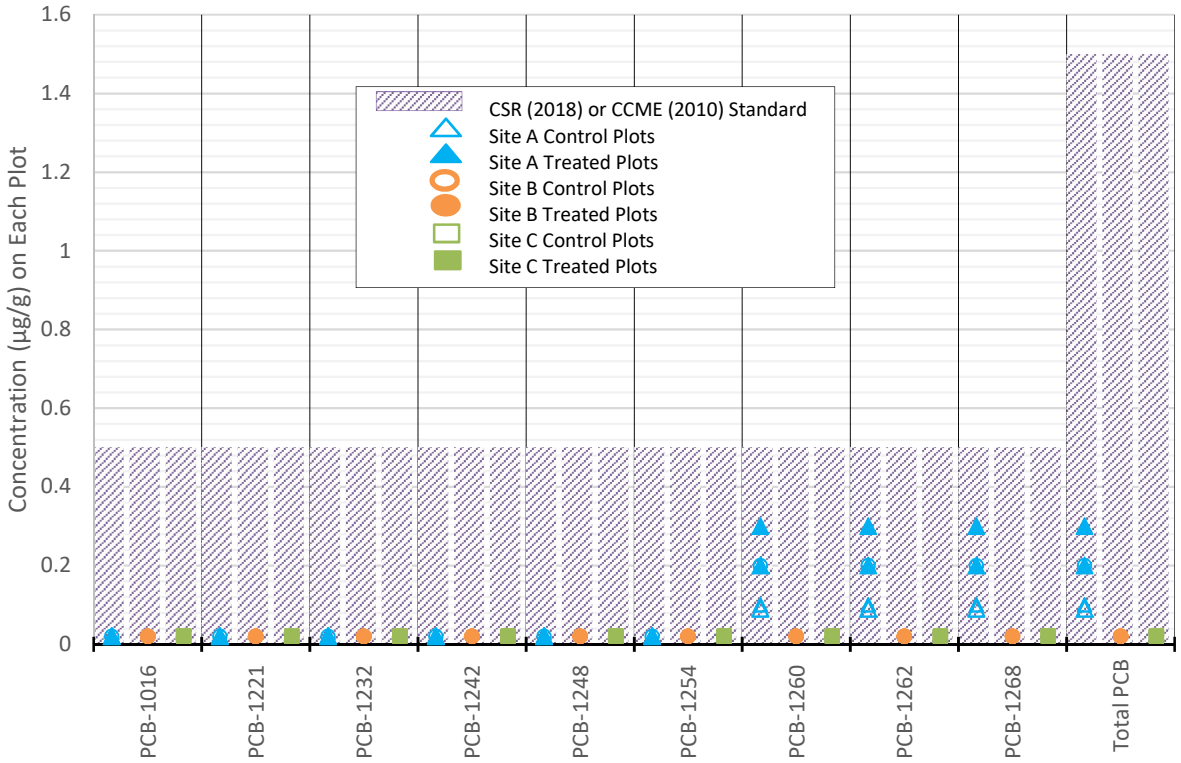

Figure 17. Polychlorinated Biphenyls in Soils on Each Plot

The PCBs were below the detection limit on the treated plots and control plots at all sites. Subsequently the total PCB concentration, which was calculated based on the detection limits, was below the CSR standard. The conservative methodology to calculate the total PCB concentration is discussed in Section 2.5.3.

3.8. Polychlorinated Dioxins and Furans

The results of the analysis of polychlorinated dibenzo-*p*-dioxin (PCDD) and polychlorinated dibenzofuran (PDFF) congeners are summarized in Table 12.

The TEQ is the sum of the product of the 17 congeners of each PCDD or PCDF and their associated TEF. The TEQ denotes a given dioxin compound's toxicity relative to that of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), the most toxic dioxin-like chemical known. The conservative methodology to calculate the TEQ is discussed in Section 2.5.2.

There were no corresponding standards identified for each congener therefore the results have not been individually graphed in this report. A TEQ was calculated for each plot and is graphed in Figure 18 with the corresponding CSR standards. The TEQ for each plot was below the CSR standard.

Table 12. Polychlorinated Dioxins and Furans in Soils on Each Plot

Analyte (pg/g)	Site	Control Plots - Plot Number					Treated Plots - Plot Number					Standards	
		#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	CSR or CCME	OMRR
1,2,3,4,6,7,8-HpCDD	A	3.96	1.98	3.28	2.75	3.70	27.2	29.7	21.6	31.4	24.3	NS	NS
	B	0.38525	0.34225	0.2935	0.2015	-	8.615	3.8725	1.58875	3.245	-	NS	NS
	C	1.54	1.612	-	-	-	4.2325	3.4775	-	-	-	NS	NS
1,2,3,4,6,7,8-HpCDF	A	1.09	0.372	0.592	0.712	0.694	4.68	5.20	3.89	5.78	4.18	NS	NS
	B	0.05025	0.05095	<0.05025	0.08075	-	1.43175	0.70575	0.27275	0.6165	-	NS	NS
	C	<0.14225	<0.1335	-	-	-	<0.37375	0.33525	-	-	-	NS	NS
1,2,3,4,7,8,9-HpCDF	A	1.1	0.033	0.042	0.043	0.056	0.373	0.421	0.283	0.389	0.250	NS	NS
	B	<0.0205	<0.0145	<0.02425	<0.017	-	<0.06725	<0.06725	<0.0405	<0.0495	-	NS	NS
	C	<0.04375	<0.0185	-	-	-	<0.0585	<0.14425	-	-	-	NS	NS
1,2,3,4,7,8-HxCDD	A	<0.36	<0.037	0.073	<0.053	0.149	0.680	0.750	0.763	1.21	1.02	NS	NS
	B	<0.02025	<0.01875	<0.024	<0.016	-	<0.089	<0.0765	<0.05025	<0.056	-	NS	NS
	C	<0.0595	<0.0375	-	-	-	<0.0855	<0.1475	-	-	-	NS	NS
1,2,3,4,7,8-HxCDF	A	0.36	0.043	0.043	0.035	0.055	0.473	0.428	0.351	0.540	0.368	NS	NS
	B	<0.0115	<0.0115	<0.017	<0.01425	-	<0.07075	<0.045	<0.032	<0.0365	-	NS	NS
	C	<0.03375	<0.018	-	-	-	<0.059	<0.093	-	-	-	NS	NS
1,2,3,6,7,8-HxCDD	A	<0.37	0.100	0.225	0.180	0.180	2.31	2.35	1.81	2.80	2.17	NS	NS
	B	0.0205	0.021	0.02275	0.0155	-	<0.35275	<0.1545	0.08725	<0.131	-	NS	NS
	C	0.09675	0.08625	-	-	-	<0.153	<0.173	-	-	-	NS	NS
1,2,3,6,7,8-HxCDF	A	0.54	0.04	0.032	0.034	0.052	0.320	0.464	0.325	0.559	0.353	NS	NS
	B	<0.01225	<0.01075	<0.01625	<0.0117	-	<0.063	<0.046	<0.02875	<0.0385	-	NS	NS
	C	<0.037	<0.02025	-	-	-	<0.05375	<0.08775	-	-	-	NS	NS
1,2,3,7,8,9-HxCDD	A	<0.38	0.127	0.160	0.150	0.249	1.45	1.32	1.20	2.00	1.49	NS	NS
	B	<0.02375	<0.03075	<0.02875	<0.01975	-	0.162	<0.1115	<0.06475	<0.08275	-	NS	NS
	C	0.1285	0.11725	-	-	-	<0.138	<0.14425	-	-	-	NS	NS
1,2,3,7,8,9-HxCDF	A	0.52	0.057	0.049	0.047	0.076	0.197	0.178	0.190	0.24	0.212	NS	NS
	B	0.03075	0.02775	<0.02525	0.02825	-	<0.0435	<0.061	<0.04725	<0.04875	-	NS	NS
	C	0.048	<0.02425	-	-	-	<0.07325	<0.152	-	-	-	NS	NS
1,2,3,7,8-PeCDD	A	<0.49	<0.043	0.052	<0.036	<0.05	0.583	0.452	0.572	0.768	0.510	NS	NS
	B	<0.01475	<0.01268	<0.022	<0.01363	-	<0.05825	<0.04775	<0.0365	<0.047	-	NS	NS
	C	<0.065	<0.03075	-	-	-	<0.0755	<0.18875	-	-	-	NS	NS
1,2,3,7,8-PeCDF	A	0.33	0.039	0.043	0.033	0.034	0.323	0.385	0.328	0.502	0.359	NS	NS
	B	0.023	0.0190	<0.01785	0.0188	-	<0.0365	<0.035	<0.02975	<0.02975	-	NS	NS
	C	0.05675	<0.02425	-	-	-	<0.08175	<0.1235	-	-	-	NS	NS
2,3,4,6,7,8-HxCDF	A	0.52	0.048	0.050	0.092	0.100	0.500	0.578	0.410	0.698	0.898	NS	NS
	B	<0.01075	<0.011	<0.017	<0.01183	-	<0.06525	<0.05525	<0.03225	<0.04625	-	NS	NS
	C	<0.03425	<0.02125	-	-	-	<0.06225	<0.09175	-	-	-	NS	NS
2,3,4,7,8-PeCDF	A	1.70	0.103	0.133	0.108	0.130	0.831	0.570	0.571	0.848	0.726	NS	NS
	B	<0.01323	<0.0086	<0.01275	<0.01095	-	<0.05925	<0.031	<0.02825	<0.03275	-	NS	NS
	C	<0.03425	<0.02325	-	-	-	<0.09275	<0.10775	-	-	-	NS	NS
2,3,7,8-TCDD	A	<0.3	<0.075	<0.041	<0.044	<0.11	0.136	0.153	0.102	0.264	0.19	NS	NS
	B	<0.02	<0.021	<0.0305	<0.02225	-	<0.0615	<0.0755	<0.07375	<0.06575	-	NS	NS
	C	<0.086	<0.04125	-	-	-	<0.15575	<0.2035	-	-	-	NS	NS

Analyte (pg/g)	Site	Control Plots - Plot Number					Treated Plots - Plot Number					Standards	
		#1	#2	#3	#4	#5	#1	#2	#3	#4	#5	CSR or CCME	OMRR
2,3,7,8-TCDF	A	0.22	0.068	0.070	0.047	0.11	0.822	0.692	0.683	0.554	0.994	NS	NS
	B	0.039	<0.023	<0.03325	0.043	-	<0.08925	<0.07	<0.0855	<0.0635	-	NS	NS
	C	<0.0775	<0.05025	-	-	-	<0.572	<0.15825	-	-	-	NS	NS
OCDD	A	22.0	10.5	18.4	15.4	20.3	165	185	143	184	143	NS	NS
	B	2.425	2.2075	1.909	1.077	-	77.075	36.75	14.515	31.55	-	NS	NS
	C	9.65	10.19	-	-	-	24.25	20.175	-	-	-	NS	NS
OCDF	A	0.86	0.544	0.760	0.896	0.938	7.12	7.75	5.99	9.69	6.43	NS	NS
	B	0.029475	0.02825	0.04475	0.084	-	3.1005	1.31225	0.48	1.137	-	NS	NS
	C	0.137	0.11075	-	-	-	0.6105	0.6195	-	-	-	NS	NS
Toxicity Equivalent (TEQ)	A	1.246	0.201	0.213	0.188	0.313	1.803	1.721	1.577	2.366	1.815	10	NS
	B	0.058	0.055	0.076	0.056	-	0.341	0.245	0.178	0.214	-	10	NS
	C	0.225	0.132	-	-	-	0.410	0.550	-	-	-	10	NS

Notes:
"NS" indicates that no standard was identified
"<" indicates the result was below the detection limit
"-" indicates that no sample was taken

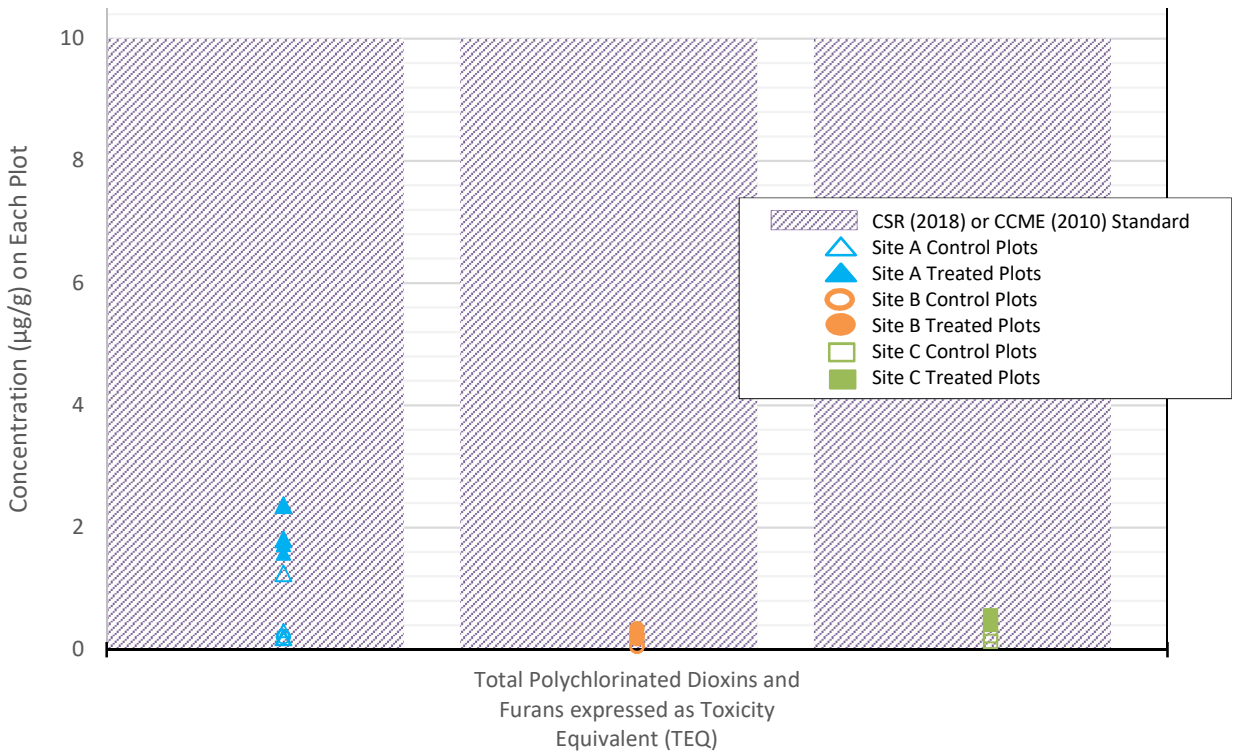

Figure 18. Polychlorinated Dioxins and Polychlorinated Furans in Soils on Each Plot

3.8.1. Site A

The TEQs for all plots within Site A were below the CSR standard. There was no statistically significant difference between the control plots and the treated plots.

3.8.2. Site B

Site B had a TEQ value that was statistically higher at $p \leq 0.05$ for treated plots when compared to control plots. It is important to note that some soils may have higher TEQ levels due to natural causes (e.g., forest fires) or anthropogenic causes not related to biosolids applications; however, it is likely that that the statistically higher result obtained at the treated plots on Site B is due to the application of biosolids.

3.8.3. Site C

Site C had a TEQ value that was statistically higher at $p \leq 0.05$ for treated plots when compared to control plots. It is likely that that the statistically higher result obtained at the treated plots on Site C are due to the application of biosolids.

3.9. Quality Assurance and Quality Control

ENV reviewed the analytical laboratory's quality control (QC) reports associated with the relevant lab work orders.

Sample hold times exceeded the recommended hold times for a number of parameters on each site as listed in Table 13. Exceeding the recommended hold times can impact the reported parameter concentrations. For example, PAHs may degrade over time and be under reported if analyzed after the recommended hold time has lapsed. Lighter weight PAHs, such as acenaphthene and phenanthrene, are more susceptible to degradation than heavier PAHs. The possible impact on sample results should be considered when evaluating the data.

The results for these parameters are provided in previous tables and graphs for the purpose of indicating possible trends but are inconclusive otherwise.

Table 13. Samples Which Exceeded Allowable Hold Times

Parameter	Site(s)	Recommended Hold Time (days)	Actual Hold Time (days)
Moisture Content	C	14	54
pH	C	30	54
Total Nitrogen	C	28	56
Total Carbon	C	28	56
Total Inorganic Carbon	C	28	60
Plant available Nitrate-N	A, B, C	3	75
Mercury	C	28	54
Polycyclic Aromatic Hydrocarbons	C	14	54
Phthalates	C	14	63
Chlorinated Phenols	C	14	55
Phenols	C	14	55

3.9.1. Site A

The QC report for Site A indicated that not all the quality control checks met their internal targets for method blanks for dioxins and furans, and method blanks for bis(2-ethylhexyl) phthalate.

3.9.2. Site B

QC qualifiers and comments for the analysis of samples from Site B were reported for method blanks and duplicate results for individual dioxin and furan parameters. The laboratory noted that "selected low level sample data may be elevated", therefore the reported dioxin and furan results may be viewed as being conservative.

Method blank results were also reported for bis(2-Ethylhexyl) phthalate which may indicate contamination in the field or in the laboratory. The detection limits were increased and results below the detection limit may be viewed as conservative.

3.9.3. Site C

The QC report for the data associated with Site C qualified the results for the dioxin and furan parameters based on method blanks and duplicates.

The QC report qualified some PAH and total Kjeldahl nitrogen results based on the duplicates.

4. Conclusions

The sampling results at all three sampling sites did not indicate there are soil quality concerns with respect to the metals, persistent organic pollutants or nutrients analyzed in this soil sampling project.

The concentrations of all of the detected compounds in this study were below their respective OMRR, CSR and CCME standards with the exception of copper on Site A. As discussed in Section 3.3, all the plots on Site A had copper concentrations less than the OMRR standard of 150 µg/g. However, all five of the treated plots had copper concentrations greater than the CCME standard of 63 µg/g. The elevated concentration of copper may be due in part to the historical use of chemicals i.e., fertilizers and pesticides, in the orchard. Application of soil amendments, such as biosolids and/or fertilizers, may have also contributed to the copper concentrations.

Elevated concentrations of the other metals were calculated to be statistically significant in the means of the treated plots in all three sites. Elevated metals in the treated plots may be an indication that the soil amendments, such as biosolids and/or fertilizers, have contributed to the metal concentrations in the soil. Because the amendments used were different for each of the sites, it is not possible to conclude that biosolids were the source for each occurrence.

In all cases, with one exception, the detection limit of the POPs and CECs were less than the CSR and CCME standards. The exception (3-chlorophenol on control plot #1, on site A,) was not detected; however, the detection limit was raised to 0.06 µg/g due to interferences in the laboratory test. The value of 0.06 µg/g is greater than the CSR limit of 0.05 µg/g as listed in Part 3 of Schedule 3.1 of the CSR. The value of 0.06 µg/g is listed in Table 10 and graphed in Figure 14 in Section 3.6.1.

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Appendix 1 POPs and CECs

Contaminants of emerging concern (CEC) include a wide range of chemicals such as: pharmaceuticals and personal care products (PPCPs); musks (synthetic fragrances); polybrominated diphenyl ethers; and endocrine disrupting compounds. CECs have the following common characteristics (McCarthy et al., 2015):

1) they have been detected in at least one environmental compartment, and they tend to be present in relatively low—even trace—amounts;
2) they are believed to have potential for deleterious impacts on human and/or environmental health, but these risks have not been thoroughly evaluated.

The physical/chemical characteristics of the CECs will determine whether they partition to the effluent (liquid) stream at the wastewater treatment plant (WWTP) or the solids stream. Partitioning refers to the distribution of a substance between two immiscible solvents (i.e., two solvents that are unable to mix). In the case of CECs, these substances may be distributed between the liquid portion of wastewater and the solids found in wastewater. The CECs present in biosolids tend to be hydrophobic compounds that partition to solids. The concern in the context of biosolids land application is that some of these compounds may be persistent, bioaccumulative, and/or toxic, but available evidence of adverse effects in the scientific literature are currently either lacking or not definitive (Clarke and Smith, 2011).

Overall, some studies suggest that the potential for CEC uptake into crops under normal farming conditions is low. For example a field experiment was undertaken to evaluate the uptake of pharmaceuticals, hormones and parabens from soil fertilized with biosolids at a regulated application rate into tomatoes, carrots, potatoes and sweet corn produced under normal farming conditions. Biosolids and crop samples were analyzed for 118 pharmaceuticals and transformation products, 17 hormones/hormone transformation products, and 6 parabens. The results indicated a low risk (Sabourin et al., 2012).

Contaminants of Emerging Concern	**Products**
Pharmaceuticals and personal care products (PPCPs)	used in items such as soaps, lotions, cosmetics, prescription and over-the-counter medicines, and fragrances
Musks	used in personal care products such as soap, shampoo and fragrances
Polybrominated Diphenyl Ether (PBDEs)	Flame retardant commonly added to plastics, textiles, appliances and electrical equipment

POPs include substances whose use has been banned or severely restricted by government agencies. However, they can also include compounds that are still widely produced and/or may be the result of natural processes. For example, PAHs, dioxins and furans are products of incomplete combustion (Harrad and Jones, 1992) and could appear in the environment as a result of forest fires (Fiedler et al., 1990). In addition, phenols and PAHs may also occur in coal tar (cresol and naphthalene). Some organisms synthesize phenolic compounds in response to ecological pressures such as pathogen or insect attack, UV radiation and wounding. Some animals, plants and organisms produce trace amounts of naphthalene or phthalates (Daniel, et al., 1999; Haider and Martin, 1967; Mahmoud et al., 2006; Husein et al., 2014). The following table provides examples of industrial and natural sources of typical POPs.

Persistent Organic Pollutants	**Natural Source**	**Industrial Use or Source**
Phenols	naturally produced by plants, animals and organisms; naturally occurring in coal tar (e.g., cresol)	used in paints, paint remover, rubber, wood preservatives, textiles, perfumes, plastics, anaesthetic, antiseptic, and insulation
Polycyclic Aromatic Hydrocarbons	naturally produced by some plants, animals and organisms	released by petroleum or coal-derived products through combustion processes (vehicle exhaust, airplanes and industrial processes)
Phthalates	naturally produced by some microorganisms such as bacteria, fungi and yeasts and by some plants	plasticizer used in: pharmaceuticals (e.g., pill casings), adhesives, building materials, vinyl flooring, personal care products, medical devices, detergents, packaging, toys, modelling clay, waxes, and food products
Polychlorinated biphenyls	none known	used in electrical insulators, adhesives, lubricants, hydraulic fluids, flame retardants, waterproofing materials, insulating/cooling agents
Polychlorinated dibenzo-p-dioxins, Polychlorinated dibenzofurans	naturally occurring as a result of incomplete combustion (i.e., forest fires)	created when products like herbicides, pesticides, dyes, disinfectants and PVC are manufactured; created in the pulp and paper industry by wood pulp bleaching

Appendix 2 How BC Standards Compare to Other Jurisdictions

With respect to regulated concentrations of metals in soils amended with biosolids, the BC standards in the OMRR and the CSR generally fall in the middle of the respective ranges. In several cases, the BC standards are on the low end of the range (e.g., Cr, Cu and Zn). Two exceptions are lead (Pb) at 500 µg/g and mercury (Hg) at 15 µg/g.

Comparison of the BC OMRR and CSR standards with other jurisdictions for the range in regulated concentrations of selected metals in soils amended with biosolids are summarized below:[4]

Metals (µg/g)	OMRR or CSR standard	Ranges of Metals Standards in USA, EU and 24 European countries
Cadmium (Cd)	2.5 - 25	0.4 — 20
Chromium (Cr)	60	30 — 1450
Copper (Cu)	150	20 — 775
Lead (Pb)	500	40 — 450
Mercury (Hg)	15	0.1 — 9
Nickel (Ni)	150	15 — 230
Zinc (Zn)	450	50 — 1500

[4] Environmental, economic and social impacts of the use of sewage sludge on land Draft Summary Report 1. Assessment of Existing Knowledge, available at: http://ec.europa.eu/environment/archives/waste/sludge/pdf/part_ii_report.pdf