HEAVY METALS IN THE CHRISTCHURCH RESIDENTIAL RED ZONE AND IMPLICATIONS FOR COMMUNITY GARDENS

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of

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By

MATTHEW KIM

University of Canterbury

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In loving memory of my Father:

Michael Kim (김신)

8.2.1972 - 19.10.2019

“Spread love everywhere you go. Let no one ever come to you without leaving happier.”

- Mother Teresa -

Abstract

Following the 2010-11 Christchurch earthquakes, a total of 8060 residential buildings in the greater Christchurch area were demolished and removed. After removal, most of this land was levelled and planted with grass as the land was uninhabitable and deemed unsuitable for rebuilding on. This area of unoccupied land is known as the Christchurch Residential Red Zone (RZ) and covers an area of 630-hectares. The establishment of community gardens has been proposed for this area. Community gardens are becoming increasingly important as urban centres expand. They provide healthy produce while also benefiting the socio economic wellbeing of individuals who are disconnected from where and how their food is produced. However, as urban soils are a natural sink for anthropogenically released heavy metal (HM) contaminants, there is an increased risk of HM exposure through working in and eating produce grown in this area. Exposure to high concentrations of HMs has an adverse effect on human health. Therefore, it is essential to gain an understanding of the HM contaminants in the RZ to avoid potential human health risks. In-situ XRF screening of surface soils in the RZ was used to measure 313 soil samples from the RZ. Elevated levels of soil Pb and Zn concentrations were observed. Some 20% of RZ soil samples had Pb concentrations exceeding the New Zealand soil Pb guideline of 210 mg/kg, with one site containing a Pb concentration of 3289 mg/kg. Zn concentrations exceeded the New Zealand soil Zn guideline of 400 mg/kg in 5% of samples, with a maximum Zn concentration of 1894 mg/kg. Samples taken in areas of bare soil with visible debris and rubble had significantly higher concentrations than areas without. The mean Zn concentrations in these areas were 217.88 mg/kg compared to 113.42 mg/kg in areas without, while the mean Pb concentrations in these areas were 226.88 mg/kg compared to 75.44 mg/kg in areas without. Soil HM concentrations should be a key factor in deciding on the future land use of RZ land. The likelihood of human exposure to these HMs in soils would be reduced if these RZ areas were redeveloped into nature reserves or native forests, rather than community gardens where produce is grown and bare soil is exposed.

Too Many DP.

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1. Introduction

Heavy metals (HMs) are elements with atomic weights between 63.5–200.6 g/mol and densities greater than 5 g/cm3 (Srivastava & Majumder, 2008). HMs are present at low concentrations in soils, plants, and animals (including humans), where they are tolerated (Robinson et al., 2009). Exposure to high concentrations of HMs has an adverse effect on human health (Robinson et al., 2009). Even essential nutrients such as copper (Cu) and zinc (Zn) can become environmental contaminants when present in high concentrations. Common HM contaminants are lead (Pb), cadmium (Cd), Zn, mercury (Hg), Cu, metalloid arsenic (As), and nickel (Ni) (Srivastava & Majumder, 2008). HMs are persistent in the environment. Therefore, they can accumulate to toxic levels (Robinson et al., 2009; Sharma et al. 2007). The total concentration of HMs in soils is a function of the natural background concentration and anthropogenic contributions (Guagliardi et al., 2012, as cited in Ashrafzadeh et al., 2018).

Humans are exposed to HMs in contaminated soils through the consumption of food grown on contaminated soils, dermal contact, ingestion, and inhalation of dust and vapours (Nathanail & Earl, 2001). Organ failure, cancer, and death can result from the accumulation of these HMs in the human body (Martin & Griswold, 2009). Pb in soils is of particular concern to developing children as they are more sensitive to Pb exposure than adults. Historical use of Pb in leaded petrol, paint, piping, and roofing has elevated Pb concentrations in urban soils (Carr et al., 2008) and other HMs such as As, Cu and Zn have increased due to mining, transportation, agriculture, and industrial production (Robinson et al., 2009).

The Christchurch City district, which covers an area of 1539 km2, is the largest South Island population centre and New Zealand's third-largest city, with ~370,000 inhabitants according to the 2018 census (Statistics New Zealand, n.d.). After the 2010 and 2011 Christchurch earthquakes, hundreds of hectares of land in Christchurch's eastern suburbs were deemed unsuitable for rebuilding. As a result, roughly 8000 buildings were demolished (Brand & Nicholson, 2016). After removal, most of this land was levelled and planted with grass. However, indigenous vegetation and exotic trees over 4 meters tall were retained for ecological reasons (Brown et al., 2012). This area of unoccupied land is known as the Christchurch Residential Red Zone (RZ).

Different land uses for this area have been proposed by different community organisations in Christchurch. Community gardens are one of the many land uses that have been proposed. Community gardens provide healthy produce while also improving the ecological, cultural, social, and educational aspects of the community (Cheng et al., 2015). But, because urban soils are a natural sink for contaminants, there is a elevated risk of human exposure to HMs through working in contaminated soils and eating produce grown there.

Given that the RZ consists mainly of suburbs built before the 1960s, such as Avonside, Wainoni, Bexley, New Brighton, and Brooklands, it is hypothesized that RZ soils will contain high concentrations of HMs. A single study conducted in the flatland Ōtākaro Avon River Corridor area of the Christchurch Residential RZ by Gilmour (2013), found that Pb was the only element exceeding the residential land use guideline among As, Cd, Cu, and Pb. Similarly, Ashrafzadeh et al. (2018) found that the mean Pb concentration in Christchurch garden soils in neighbourhoods developed before the 1950s exceeded the guideline values (282 mg/kg).

Soils contaminated with HMs can be remediated through a variety of methods. Types of remediation include dig and dump, covering with topsoil, covering with impermeable surfaces, in situ stabilization, or changing land use (e.g. playing fields or native forest instead of community gardens). Some remediation has already occurred in the RZ. Topsoil from Lincoln has been spread over soils in the RZ to reduce exposure to the underlying soil which may be contaminated with HMs.

To avoid potential environmental consequences and human health risks, the concentration of HMs in RZ soils must be quantified before the establishment of community gardens.

1.1 Research aims and objectives

The objectives of this research were to conduct in-situ XRF screening of RZ soils to gain a quantitative understanding of HM concentrations and determine the nature of HM distribution in Christchurch residential RZ soils. Exposure to high concentrations of HMs has an adverse effect on human health. Therefore, it is essential to gain an understanding of the HM contaminants in the RZ to avoid potential environmental consequences and human health risks and to gain a better understanding of the suitability and implications of different types of proposed land uses, specifically community gardens. While many studies have been conducted regarding the common HM contaminants in soils, the health effects of HMs, and the pathways of exposure (Assi et al., 2016; Laidlaw et al., 2017; Kandic et al., 2019), none have specifically focused on what key HM contaminants are present in RZ soils, the concentration of these HM contaminants, and the nature of HM spatial distribution. This research will complement the regeneration work that is currently underway in the RZ by providing data and recommendations for land use that minimizes human exposure to HMs. Furthermore, the results from this research project will contribute to the development of risk management strategies and potentially lead the way for future research projects in the RZ.

The aim of this study is to:

1. Identify the key contaminants in RZ soils that pose a threat to humans and ecosystems by using in-situ screening analysis.
2. Determine the nature of the spatial distribution of HMs in RZ soils.
3. Determine the implications of community gardens.
4. Compare and contrast remediation methods or management strategies that can minimize and mitigate the exposure to these HM contaminants.

2. Literature Review

2.1 Sources of lead and zinc in soils

The total concentration of HMs in the soil is determined by the background concentration as well as anthropogenic contributions, which include the use of soil conditioners such as compost, fertilizers, and manures, paints, vehicle emissions, agrichemicals (herbicides, insecticides, and fungicides), heating, and local industries (Ashrafzadeh et al., 2018). Elevated HM concentrations have been found in urban soils around the world (Ashrafzadeh et al., 2018).

Soils are the largest sink for environmental Pb, absorbing 60-70% of annual worldwide atmospheric Pb emissions (Rooney, 2002). Batteries (Assi et al., 2016), Pb-based paints, solders from food packaging, plumbing, and leaded gasoline were historically the primary sources of Pb exposure globally (Mason et al., 2014). Soils in urban and suburban areas are more likely to have contaminated soils than compared to rural soils as they are more influenced by anthropogenic activities (Ashrafzadeh et al., 2018).

Pb contamination of soil is an issue of environmental justice since it disproportionately affects urban, poor, and minority populations (Clark et al., 2006). A study by Clark et al. (2006) found that 30% of soil mass and 32% of soil Pb was represented by soils with size fractions between 0.5 and 0.25mm. Clark et al. (2006) also found that soils <0.044mm represented 5% of soil mass but contained a disproportionate amount of soil Pb (10%). Because leaded gasoline combustion produces fine particulate matter (PM), the Pb observed in these size fractions is most likely from this source (Clark et al., 2006). Fine particles, notably PM less than 100 µm, are often considered to be wind-transferable. Because wind can transfer these particles into neighbouring gardens, they pose the greatest risk of inhalation or ingestion (Clark et al., 2006).

Soil Pb concentrations were found to be greater in older buildings and neighbourhoods (Tong, 1998). Pb contamination of surface soils has an impact on human and environmental health, and food quality (Rooney, 2002). The concentration of Pb contaminants in soils is influenced by a number of different variables. Distance from the nearest arterial road, building age, and the use of Pb-based paints were the main variables that explained 75% of Pb variability in garden soils (Kandic et al., 2019). Pb concentrations in backyard garden soils were found to have a significant correlation to the distance from arterial roads (Kandic et al., 2019). Kandic et al. (2019), discovered that Pb concentrations in backyard garden soils were found to decrease with increased distance to the nearest arterial road. Zn

Pb concentrations in backyard garden soils are influenced by building characteristics such as age and construction materials. Jordan and Hogan (1975) and Kandic et al. (2019) discovered that the concentration of soil Pb increases with the age of the building. Buildings over 35 years old had much higher backyard soil Pb concentrations than newer dwellings (Kandic et al., 2019). Kandic et al. (2019) showed that the distance from arterial roads shows a larger link with backyard garden soil Pb concentrations than building age. In backyard garden soils, the median Pb concentration increased from 960 mg/kg in buildings 20-100 years old to 1040 mg/kg in buildings over 100 years old (Kandic et al., 2019). As the majority of the buildings in the RZ were constructed between 1940-1970, HM soil contamination is more likely as HMs accumulate over time.

Kandic et al. (2019) also found that wooden buildings had higher Pb concentrations in garden soils than brick and concrete ones, while Jordan and Hogan (1975) discovered a significant correlation between high Pb concentrations in soils and painted wooden buildings. Pb levels were found to be significantly lower in locations where buildings were made of asbestos, brick, concrete, or coloured concrete (Jordan & Hogan, 1975).

Vehicle emissions were formerly a major source of Pb exposure, but with the development of Pb-free fuels, this is no longer an issue (Shukla et al., 2018). Following the ban on leaded gasoline, the US concentrated on paints, with Pb-based paint in old buildings now being the primary source of Pb poisoning in children (CDC, 2005).

Industrial activities such as steel processing, waste combustion, mining, and heating are thought to be the leading sources of anthropogenically produced Zn (Garba & Abubakar, 2018). The corrosion of galvanized metals, tire wear, engine oil, brake dust and automotive grease also contribute to soil Zn concentrations (Garba & Abubakar, 2018).

2.2 Human exposure

It is necessary to understand the concentration of Pb in urban soils to minimize human exposure to Pb in soil and to produce and implement remediation strategies (Clark et al., 2006). Exposure pathways include the inhalation of dust, ingestion of soil, physical contact, or eating unpeeled or unwashed vegetables (Ashrafzadeh et al., 2018; Ministry of Health, 2018). Pb is most commonly absorbed through the respiratory and gastrointestinal systems (Shukla et al., 2018). Pb poisoning is a public health concern, especially in developing countries (Assi et al., 2016). Children are the most vulnerable population, particularly in urban and suburban areas, as they are more susceptible to the adverse effects of Pb and more vulnerable to inadvertent ingestion of soils than adults (Ashrafzadeh et al., 2018; Day, 1977). Children are often encouraged to participate in community gardening, even though they are the most vulnerable to contaminants (Cheng et al., 2015). In cities with Pb-contaminated soils, childhood Pb poisoning is a major environmental health concern (Ashrafzadeh et al., 2018). Efforts to reduce Pb exposure would benefit community gardeners.

2.3 Health effects of lead exposure

There is no safe level for Pb exposure (Shukla et al., 2018). Low levels of Pb exposure can have a negative impact on people's health (Shukla et al., 2018). The health effects of Pb have been the subject of several detailed reviews in recent years (Laidlaw et al., 2017). Because Pb has no biological function in the body, it has serious health consequences when it enters the body (Assi et al., 2016). Immunological deficiencies, anaemia, decreased brain function, hearing loss, and changes in behaviour that can lead to delinquency are some of the side effects that can be experienced (Assi et al., 2016; Carroll & McDonald, 2018). Excessive exposure to Pb can also harm the reproductive systems in both men and women (Shukla et al., 2018). These effects include reduced sperm motility and activity in men, and pre-eclampsia, pregnancy-induced hypertension, premature membrane rupture, infertility, and premature delivery for women (Shukla et al., 2018). The most dangerous neurological impact of Pb poisoning is lead encephalopathy, which is a reaction to high levels of Pb that can lead to death (Mason et al., 2014).

The amount of Pb absorbed through the intestine is estimated to be between 10-15% of what is ingested, however, if there is a deficit of iron (Fe), calcium (Ca), or Zn, this amount increases (Shukla et al., 2018). And 30-40% of Pb that is inhaled is absorbed in the blood (Shukla et al., 2018). Once the Pb is absorbed through the gastrointestinal tract or respiratory system, it is stored in soft tissues as well as the skeleton (Shukla et al., 2018). Therefore, if there is evidence of Pb or other HM contamination in soils, vigilance should be exercised in gardening practices and the types of produce to be cultivated on such soil.

2.4 Lead contamination in Christchurch

Pb concentrations in Christchurch soils have been elevated due to the anthropogenic use of Pb in roofing materials, leaded gasoline, domestic heating, insecticides, Pb-based paints, and plumbing (Jordan & Hogan, 1975). The weathering of paint and atmospheric deposition are the two principal sources of Pb in Christchurch soils (Day, 1977). Day (1977) discovered that the combustion of leaded gasoline was responsible for 99% of all atmospheric/airborne Pb in Christchurch. New Zealand began phasing out leaded gasoline in 1986, and it was ultimately banned in 1996 (Wilson & Horrocks, 2008).

Pb-based paint, which was widely used until 1965 was outlawed in New Zealand in 1979, however, it can still be found in some older buildings (Hill Laboratories, 2018; Level, 2021). Buildings constructed before the 1980s are likely to have been painted with Pb-based paints (Ministry of Health, 2021). Flakes of old paint can enter soils as a result of natural weathering or during the demolition or renovation of buildings (Jordan & Hogan, 1975). Pb plumbing can also be found in buildings built before 1940 (Level, 2021; Mason et al., 2014).

Several studies in Christchurch and around the world have indicated that Pb concentrations in urban soils are significantly above natural background concentrations, and are substantially greater in older neighbourhoods than in newly built areas (Ashrafzadeh et al., 2018; Cheng et al. 2015; Davies et al. 1987). Ashrafzadeh et al. (2018) found Pb concentrations in urban Christchurch soils that were 4000% greater than the urban background soil Pb concentration (level 1) of 23.3-57.3 mg/kg from Tonkin and Taylor (2007), and more than 1200% greater than the New Zealand Soil Contaminant Standards for Health for Inorganic Substances of 210 mg/kg. Most urban Pb soil samples exhibited concentrations greater than the Canterbury background soil concentrations (Ashrafzadeh et al., 2018).

In another study, Day (1977) found that Pb levels dropped towards the outskirts of Christchurch and increased in high-traffic regions. Background concentrations decreased from 3000 mg/kg in the city centre, to 1800 mg/kg, 6km away from the centre, and 500 mg/kg at the edge of the urban area at 9km (Day, 1977).

2.5 Community gardens

As urban centres expand, urban agriculture is becoming increasingly important. Urban agriculture has the potential to benefit communities, the local economy, and the wellbeing of those who are disconnected from where and how their food is produced. The quality of food grown in urban gardens is influenced by soil, water, and air quality. A community garden is a parcel of land that is collaboratively gardened by a group of individuals who live in an urban area (Al-Delaimy & Webb, 2017). Community gardens are commonly built on vacant properties with historically elevated levels of HM contamination, such as former parking lots and areas where old buildings have been demolished (Al-Delaimy & Webb, 2017). Community gardens on previously abandoned lands can provide a variety of benefits, including inexpensive and nutritious food, decreased airborne dust, and carbon sequestration (Cheng et al., 2015). Urban agriculture not only provides nutritious food, but also promotes urban environmental sustainability, social equality and justice, and educational benefits (Cheng et al., 2015). According to Alaimo et al. (2008), community gardeners consume more fresh fruits and vegetables than non-gardeners, and a diet rich in these products can lower the risk of stroke, diabetes, heart disease, obesity, and some forms of cancer.

However, urban agriculture and gardening increase the risk of exposure through ingestion and inhalation of HM contaminants in soils (Cheng et al., 2015; Hunter et al., 2019; Kandic et al., 2019). Several studies have found that urban garden soils can contain high concentrations of HMs (Cheng et al., 2016; Clark et al., 2006). A study by Litt et al. (2002) in Boston, USA, found Pb levels of 12,875 mg/kg in yard soils. Similarly, urban garden soils in New York City, USA, also revealed extremely high soil Pb values of up to 8,912 mg/kg (Cheng et al., 2016).

High concentrations of Pb and other HMs may be present in RZ soils. This can result in produce from urban community gardens not meeting food safety standards which can put community members at risk. Therefore, it is crucial to monitor the contaminant levels in the soil and produce to make sure that they are at safe levels (Al-Delaimy & Webb, 2017). The types of produce grown in the community gardens and gardening practices implemented can also influence the exposure to HMs. Sangster et al. (2012) discover that vegetables grown in community gardens contaminated with Pb, in Omaha, Nebraska (USA), had elevated Pb concentrations. Pb concentrations in leafy greens, eggplant, and tomatoes grown in soils containing more than 100 mg/kg of Pb, exceeded the US Food and Drug Administration's (FDA) Pb standard of 0.5 mg/kg (Sangster et al., 2012). However, onions, and tomatoes grown in soils containing less than 100 mg/kg of Pb did not exceed the FDA Pb standards (Sangster et al., 2012). Similarly, Luo et al. (2012) found that the concentrations of Pb in the edible parts of vegetables in most samples exceeded the maximum threshold approved for consumption in China. Root vegetables and green leafy vegetables are thought to be more prone to absorbing and storing contaminates from contaminated soil (Al-Delaimy & Webb, 2017). Sangster et al. (2012) mentioned that the high Pb levels observed in the leafy greens may be explained, at least in part, by the lack of washing before testing, as soil particles remaining on the greens could be a source of Pb.

Although evidence suggests that produce grown in urban soils may be contaminated with HMs, limited research has been done to try to correlate community garden produce or working in such gardens with individual levels of exposure (Al-Delaimy & Webb, 2017). Similarly, limited research has been done to measure the levels and effects of HM exposure from various edible plants in urban community gardens (Al-Delaimy & Webb, 2017).

2.6 Research gap

Previously, urban agricultural research has concentrated on three key issues: 1) soil contamination in urban agricultural locations, 2) contamination absorption and presence in and on produce, and 3) gardeners' safety concerns about contaminants (Moller, 2016). However, no study to date has comprehensively examined the key HM contaminants in RZ soils, the concentration of these contaminants, and how these HM contaminants in RZ soils are spatially distributed. Little is known about the current levels of HM contaminants present throughout the RZ soils. Throughout the literature, there is consistent evidence that older neighbourhoods have significantly higher Pb concentrations than newly built areas. However, limited research on HM concentrations in RZ soils has been undertaken. With only one study by Gilmour (2013) being publicly available. Gilmour (2013) found soil Pb concentrations above the Soil Contaminant Standard guideline in the Ōtākaro Avon River Corridor area of the Residential RZ. Pb concentrations in RZ soils ranged from 39-260 mg/kg and had a mean of 123 mg/kg (Gilmour, 2013). However, this study only had a small sample size (n=16) which increases the likelihood of a Type II error and decreases the statistical power of the study (does not represent the true concentration of Pb in RZ soils) (Button et al., 2013). Additionally, several studies have used a Field-portable X-ray fluorescence (XRF) spectrometer to test soil for contamination (Clark et al., 2006), but none of these studies has specifically focused on the distribution of HM contaminants in the RZ.

Because high concentrations of HMs are harmful to human health, it's crucial to learn about the HM contaminants in the RZ, their concentrations, and distribution to avoid negative environmental consequences and human health risks, as well as to better understand the suitability and implications of community gardens. Given the changed nature of the land in the RZ, it is hypothesised that RZ soils will contain elevated concentrations of HMs such as Pb, and Zn, as concentrations of these HMs in Christchurch soils have been elevated due to anthropogenic activities. This study will provide information on the spatial distribution and concentration of contaminants in the RZ, as well as suggestions for land use, which will supplement existing regeneration efforts in the RZ. In addition, the findings of this study will aid in the development of risk management strategies and may pave the way for future research initiatives in the RZ.

3. Methodology

The primary goal of this chapter is to provide an in-depth description of the methods utilized in the field as well as the subsequent analysis of the collected data. This chapter will also outline the rationale for choosing these methods and why the methods suit the objective. The methods outlined in this chapter have allowed for multiple in-situ measurements of HMs in RZ soils to be taken and proved to be the most effective in gaining a better understanding of multiple areas in the RZ. This section begins with information on the research area, as well as photos taken during fieldwork and the main pieces of equipment used. Following the introduction of the research area, the rationale, field methods and analysis used will be given.

3.1 Study area

The Christchurch Residential RZ itself stretches from the city to the sea and has an area of 630-hectares (6.3 km^2) (Scott & Carville, 2016). The Christchurch Residential RZ was formed as a result of the 2010/11 Christchurch earthquakes and includes parts of the Port Hills, Kaiapoi, Brooklands, as well as the flatland area of the RZ located in the Ōtākaro Avon River Corridor (Scott & Carville, 2016). Figure 3.1 shows the extent of the Christchurch Residential RZ and Figure 3.2 shows the Ōtākaro Avon River Corridor area of the Christchurch Residential RZ. The fieldwork occurred across 8 sites in the Christchurch Residential RZ. The sites had a combined total area of approximately 11.01-hectares (0.1101 km^2) (Figure 3.3).

Following the 2010-11 Christchurch earthquakes, the government offered to purchase insured RZ properties in August 2011, and by December 2015, 5,442 property owners in the RZ had accepted the offer (Regenerate Christchurch, 2019). To date, a total of 8060 residential buildings in the Christchurch area have been 'red zoned' by the Crown (Brand & Nicholson, 2016; LINZ, 2021). This meant that the land was uninhabitable and could not be built on (Davis, 2018; Nielsen, 2016; Vallance & Tait, 2013).

The residential buildings in the RZ were demolished and grass was planted. Indigenous vegetation and exotic trees over 4 meters tall were retained for aesthetic and ecological reasons (Brown et al., 2012). Figure 3.4 illustrates the landscape and vegetation that exists in the Ōtākaro Avon River Corridor RZ area. On behalf of the Crown, Land Information New Zealand (LINZ) took over responsibility for these areas in 2015 and the Waimakariri RZ land was transferred to the Waimakariri District Council and Te Kōhaka o Tūhaitara Trust in 2018, while ownership of the remaining property is gradually transferring to the Christchurch City Council (CCC) (LINZ, 2021). The CCC owns the Port Hills RZ and manages the flatland areas in the Ōtākaro Avon River Corridor and the Port Hills RZ (LINZ, 2021).

As residential buildings in the RZ were cleared away and replaced with open parkland, remaining communities were faced with a loss of community connections and infrastructure, depopulation, and uncertainty about the future of this area (Regenerate Christchurch, 2019). Native habitats, trails and walks, recreation facilities, agriculture, and communal spaces such as community gardens are among the future plans for this area, which may increase human exposure to HMs as soils in the RZ may be contaminated with HMs and other toxic agents. Ashrafzadeh et al. (2018) reported Pb levels in residential Christchurch soils that were in excess of the residential land use guideline values (210 mg/kg).

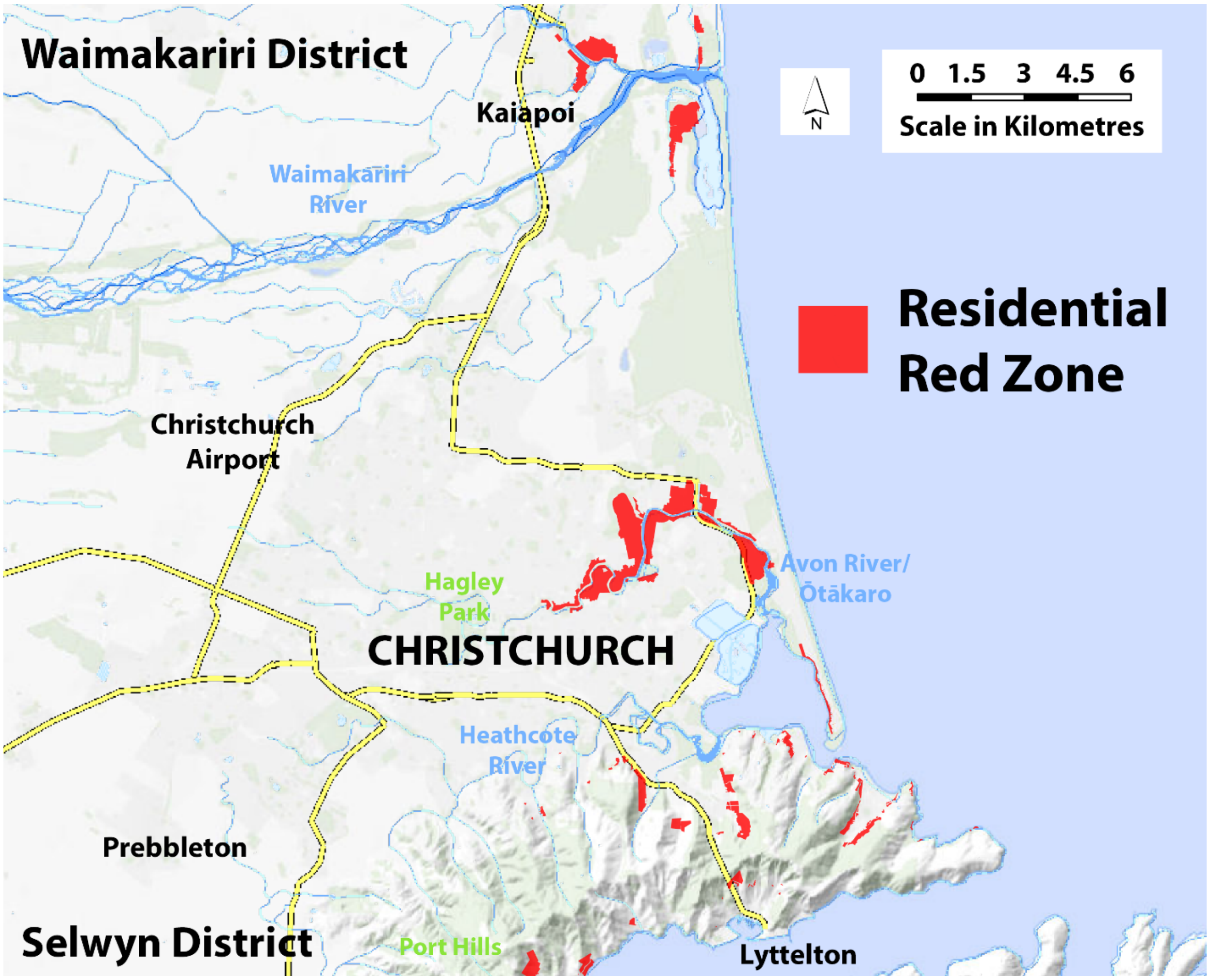


Figure 3.1. Map of the Residential Red Zone and the greater Christchurch area (New Zealand Government, 2020). CC BY-SA 4.0.

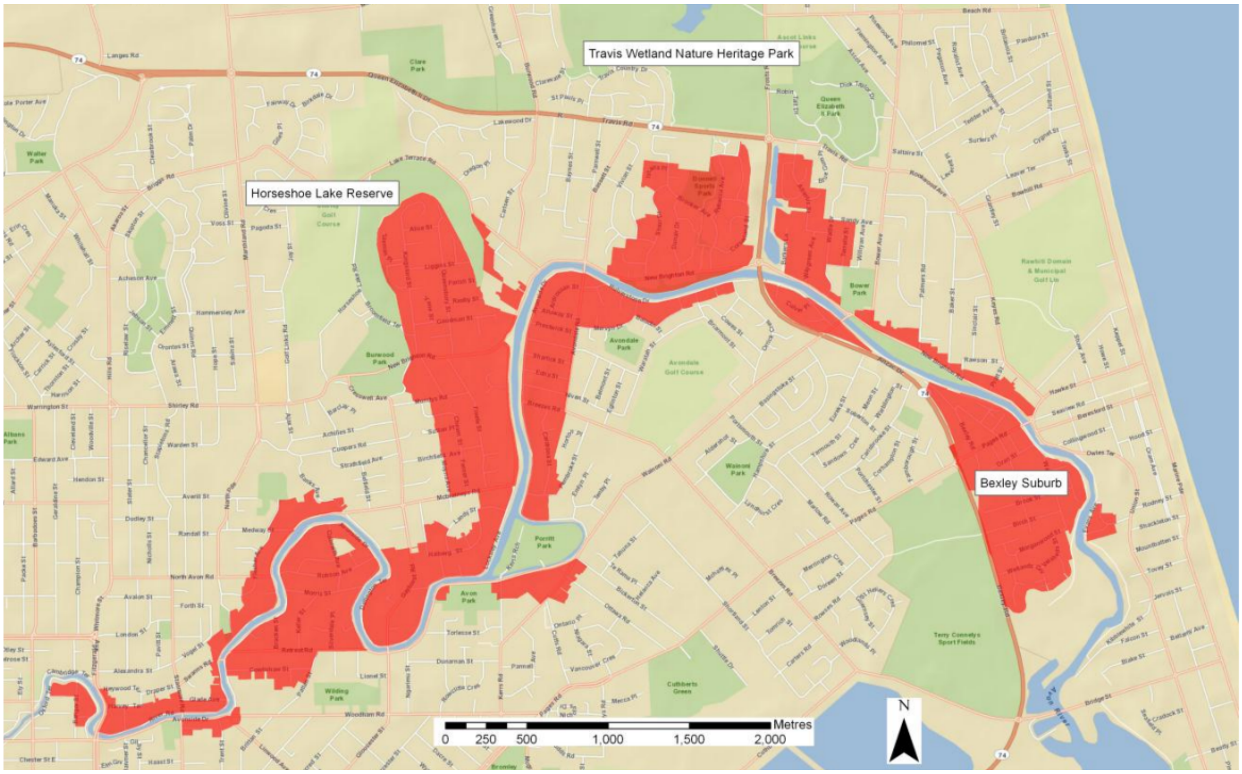


Figure 3.2. Map of the Ōtākaro Avon River Corridor area of the Christchurch Residential Red Zone (shown in red). (Gilmour, 2013).

Figure 3.3. Map of the Ōtākaro Avon River Corridor red zone area which shows the locations of study sites 1-8. *Note.* The red dots represent the sample locations and the red lines represent the perimeter of the sample sites. Made using ArcMap 10.8.1 and Paint 3D on a base map of NZ 10m Satellite Imagery (2018-2019).

Figure 3.4. Photograph of two red zoned sites that have been planted with grass. (Top) off River Road, Richmond, and (Bottom) off Breezes Road, Avondale.

3.11 Soils

The majority of the Canterbury Plains is made up of free-draining gravelly materials, whereas less permeable silty sands and clays are more predominant closer to the shore (Begg et al., 2015). Most of the soil parent materials come from basement rocks in the Canterbury foothills and

Southern Alps (Begg et al., 2015). Since its establishment in the 1850s, the soils and geomorphology of Christchurch's urban area have been significantly affected through drainage, the moving of waterways, the infilling of hollows, and urban land development (Christchurch City Council, 2003). Water tables at or near the ground surface, combined with lower permeability within the fine-textured deposits, result in imperfectly drained soils over most of the Christchurch lowland urban area (Begg et al., 2015; Christchurch City Council, 2003). Ōtākaro Avon River Corridor land is mostly composed of poorly consolidated silts, which are especially prone to the effects of earthquakes (Regenerate Christchurch, 2019). Figure 3.5 shows the soil drainage characteristics at the study site.

Study sites 5 and 8 have imperfectly drained soils (Kaiapoi_16a.1 and Kaiapoi_17a.1) and sites 1-4 and 6-7 have well-drained soils (Waimakariri_3b.1 and Waimakariri_4b.1) a description of these soils can be found in Appendix E. Generally, both of these soil types are well-drained with very low vulnerability to waterlogging in non-irrigated conditions and have high soil water holding capacity.

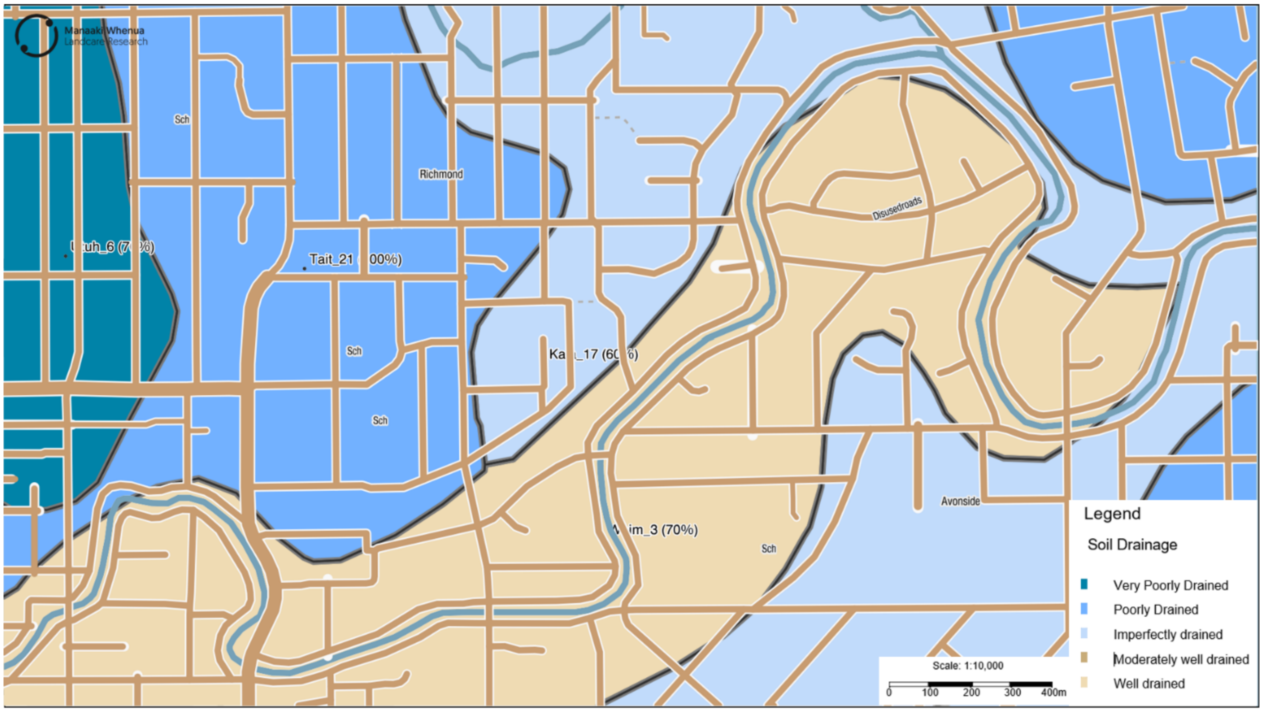


Figure 3.5. Map of the different soil drainage types in the Ōtākaro Avon River Corridor (Landcare Research NZ Limited, 2021). CC BY-SA 3.0.

3.2 Field Portable X-ray Fluorescence Spectrometry

Typically, HM concentrations in soils are determined using atomic absorption spectroscopy (AAS), inductively coupled plasma mass spectrometry (ICP–MS), or inductively coupled plasma optical emission spectrometry (ICP-OES), all of which require lengthy and costly digestions (Blaylock et al., 1997; Clevenger et al., 1991). The turnaround times associated with these methods are generally insufficient to ensure the optimal utilization of data (Kalnicky & Singhvi, 2001). This limits the number of samples that can be processed, making large-scale, in-situ research challenging (Clark et al., 2006). The use of Field portable X-ray fluorescence (FP-XRF) technology has become a well-established analytical method for in-situ screening over the past 30 years (Kalnicky & Singhvi, 2001; Shackley, 2018).

FP-XRF Spectrometers are an effective tool for rapidly determining the total elemental composition of surface layers of in-situ soils (detectable elements typically range from sodium

(11) to uranium (92) in most instruments), which can be used to conduct contaminated site investigations and guide site remediation (Olympus, 2021; Rumsby, 2013, 2015). It is extremely cost-effective and quickly identifies areas of interest that require further extensive sampling and research (Clark et al., 2006). However, as FP-XRF is susceptible to a variety of sampling and analytical errors, it is only used as a screening or semi-quantitative assessment tool (Rumsby, 2013, 2015). The primary causes of error impacting this technique's accuracy are sampling errors caused by variations in sample moisture content and variability in the elemental distribution in the soil (Rumsby, 2013, 2015).

Although FP-XRF is less accurate and has a larger measurement bias than AAS, ICP-MS, and ICP-OES, increasing sample density with in-situ measurements can help to effectively identify the level of contamination, with the added benefit of lowering the probability of incorrectly identifying a site due to poor site characterization (Rumsby, 2015). Even with precise data points, a small sample size makes it difficult to obtain an assessment that accurately characterizes and locates site contamination (Crumbling, 2001). Small sample sizes can also produce erroneous project decisions and misleading conclusions (Crumbling, 2001). When many samples are evaluated, a far more accurate image of the site emerges, even if the analytical method is less accurate (Crumbling, 2001). FP-XRF is a better method for soil screening. Figure 3.6 illustrates that many lower quality data points taken using the FP-XRF can offer a more precise characterization of contamination than a small number of more accurate laboratory analyses (Crumbling, 2001; Rumsby, 2015).

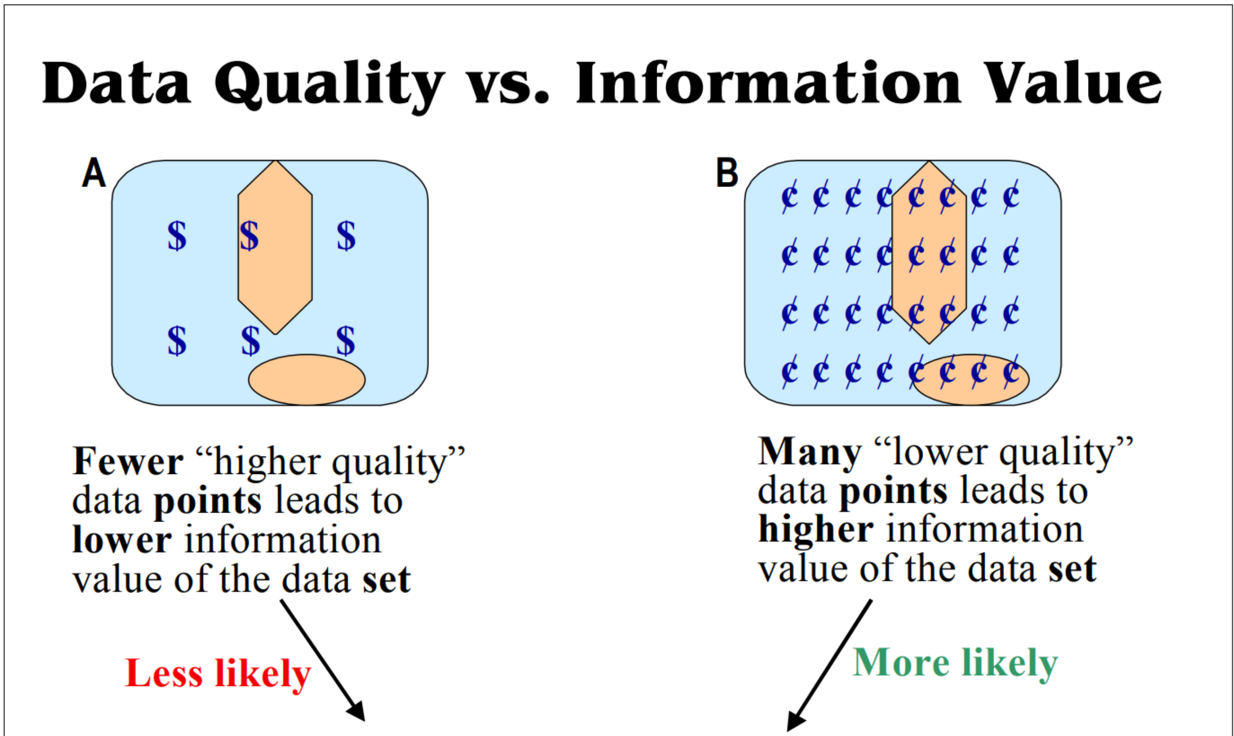


Figure 3.6. Two different sampling and analysis scenarios for a site. *Note.* The orange shapes depict hot spot locations (areas where contamination levels are much greater than in the surrounding area) (Crumbling, 2001).

3.3 Sampling

The optimal strategy for any research study is to investigate the whole population. However, this is not always possible due to practicality. Sampling is the process of selecting a subset of individuals from the total population that aims to represent and estimate the properties and/or parameters of the larger population (Acharya et al., 2013; Pennock et al., 2008). Taking a representative sample of the population can reduce the expenses, time taken, and labour required to conduct the study (Acharya et al., 2013). Sampling is a necessary part of any field research programme in soil science due to the impracticability of measuring the whole population (Pennock et al., 2008).

Designing a sampling strategy involves determining the most efficient strategy for selecting the samples that will be used to estimate the properties of the population (Pennock et al., 2008). Many extensive guides exist for various sampling designs and the statistical procedures that are suitable for each design. This section will detail in situ and discrete sampling as well as targeted and systematic sampling and the concerns that should be taken into account when selecting a sampling design.

When analyzing soil samples with an FP-XRF, there are two sample preparation methods to consider: in-situ and discrete sampling (Kalnicky & Singhvi, 2001). Discrete samples are a small mass of soil (usually 100-200g) collected from a single spot within a study area, and in-situ sampling is a sampling approach that allows measurements to be taken at the original site without the need to remove physical samples. The number of analyses required, the site/contaminant history, allocated time, and the intended sampling design are all factors that influence which method is used (Kalnicky & Singhvi, 2001). For the in-situ analysis of contaminated soils, an FP-XRF can be placed directly on the soil surface to measure HM contamination. When using an FP-XRF, in-situ analysis offers more flexibility by enabling the rapid collection of data for multiple sample points, eliminating physical sampling and the chain of custody concerns, and providing real-time data that can be used to make quick field decisions (Kalnicky & Singhvi, 2001).

Significantly more preparation time is required for discrete sampling as this requires samples to be taken to a lab to be analyzed. Discrete sampling does not provide a complete understanding of the contamination; however, in-situ sampling using a FP-XRF allows one to identify small levels of contamination to build an accurate map of the contamination (Bosco, 2013). This limits the number of samples that can be taken in the given timeframe. The benefits of the discrete sampling method include increased analytical accuracy and precision when compared to in-situ samples (Kalnicky & Singhvi, 2001).

Targeted sampling is often used when the properties of a specific area are being investigated. However, it can only be used if there is a strong understanding of the site's history and the location of site activities (Rumsby, 2015). The number of samples taken depends in part on the number of target areas that have been selected for sampling. The number of samples taken at each target location and the number of different sites will be determined by the use of potentially contaminating activities on the site, the contamination mechanism, and the aim of the study (Rumsby, 2015). If the target area is large or anticipated to be extremely diverse, additional measurements will be required (Rumsby, 2015).

Systematic sampling is appropriate for level and near-level landscapes and allows for quantitative conclusions to be made about the area of interest (Pennock et al., 2008). For many field studies, the most common sampling designs consist of systematic sampling using transects or grids (Pennock et al., 2008). It is advised that more than 20 samples are taken for sites between 400 m^2 and 2000 m^2 when the site history indicates that HM concentrations are expected to be relatively uniform (Rumsby, 2015). More than 20 samples may be required for sites that are larger than 2000 m^2 and/or sites with complex histories, where spatially diverse contamination is more likely (Rumsby, 2015). Although statisticians frequently criticize systematic sampling designs, they are popular in the field of earth sciences because of their ease of use and efficiency in collecting data (Pennock et al., 2008). The transects starting point and/or orientation should ideally be chosen at random (Pennock et al., 2008). The most important point to remember when using systematic sampling with constant spacing is that the objects to be sampled should not be organized in an orderly fashion that aligns with the transect spacing (Pennock et al., 2008). Figure 3.7 shows the layout of a transect sampling campaign.

Although In-situ XRF analysis requires minimal sample preparation, it is only a screening level technique (Rumsby, 2013, 2015). Screening can be used to provide preliminary identification of HM contaminants, identify hot spot locations within a site, provide the spatial extent and spatial variability of HM contaminants, and assist with remediation (Rumsby, 2015).

Figure 3.7. Layout of a transect sampling campaign. *Note.* The red dots represent the transect sample locations and the red line represents the ideal path to take when transect sampling. Adapted from a base map of NZ 10m Satellite Imagery (2018-2019) and Paint 3D.

3.4 Methods

This section describes the methods used to collect data from the field to achieve the project's objectives. This study's research approach utilizes unique environmental science methods to determine the threat to humans and ecosystems, mitigation strategies, and spatial distribution of HMs in RZ soils. Section 3.41 will describe the equipment used for sampling. Section 3.42 describes the calibration process and requirements. Section 3.43 details the methods used for in situ soil sampling in the RZ. This includes the use of FP-XRF technology to analyze a large number of samples in a short period. And section 3.44 details the methods used for the statistical analysis of data gathered using the FP-XRF.

3.41 Equipment

An M series Vanta XRF handheld analyzer (Figure 3.8), was used to test for HM contaminant concentrations in the soils around the Christchurch Residential RZ. The M series Vanta XRF analyzer is a handheld energy-dispersive XRF spectrometer. The Vanta XRF analyzer delivers rapid and accurate chemical analysis for environmental testing and element identification and analysis (Olympus, 2021). The XRFs ultra-rugged waterproof/dustproof construction allows for a wide range of analytical testing in harsh environments (Olympus, 2021). A description of the Vanta XRF analyzer components can be found in Appendix x.

Figure 3.8. M series Vanta XRF analyzer that was used for in-situ field testing of soils in the RZ.

3.42 Calibration

For the quantitative use of XRF methods for environmental applications, the XRF analyzer must be calibrated using standards with known compositions (Kalnicky & Singhvi, 2001). Analysis of certified reference material (CRM) should provide findings that are within 20% of the certified values to ensure that the FP-XRF calibration is acceptable (Kalnicky & Singhvi, 2001; Rumsby, 2015). Only then can this data be used for quantitative environmental applications. While this criterion is less strict than that used in traditional laboratory XRF analysis, it is a suitable option for most FP-XRF environmental applications (Kalnicky & Singhvi, 2001). Each time the XRF analyzer is turned on, an energy calibration check should be performed (Rumsby, 2013).

Calibration was undertaken by analyzing standard reference material (SRM) from NIST. This was done using the Vanta workstation (Figure 3.9), the M series Vanta XRF analyzer and the CRM (NIST 2710a). The results from the analysis of the NIST 2710a Montana I Soil SRM were compared to the certified data. As seen in Appendix F, the values for Pb and Zn were well within the 20% limit at 1.83% and -1.99%, respectively.

Figure 3.9. Photograph of the Vanta workstation that was used for calibration (XRF analyzer is connected underneath).

3.43 Field sampling

A combination of both systematic and targeted sampling was used in this study to gain a better understanding of hot spots and background concentrations. Targeted sampling was undertaken in areas where elevated contaminant concentrations were likely to occur, such as along fence lines, under trees, near roads and footpaths, and in bare patches of soil and rubble. And systematic sampling using transects was taken across the whole study site in roughly equal increments of 5m to get a good understanding of HM distribution in the sites. The transects starting point and orientation were chosen at random, mostly out of convenience. The locations of the study sites were chosen randomly. These locations were convenient to sample as they had easy access and open ground. Figure 3.10 demonstrates how the sample locations of targeted samples were chosen. Measurements were mostly taken in areas of rubble, exposed soil, near rows of trees, and on the border of the property, rather than in the middle of the property where it is less likely to find high concentrations of HMs. Figure 3.11 shows an area of interest for targeted sampling.

Figure 3.10. Aerial map of a Red Zone property in Avondale that shows the areas of interest when conducting targeted sampling. *Note.* The red highlighting represents the areas of high priority when measuring HM concentrations in RZ soils. The highest concentration of HMs is expected to occur in the areas highlighted in red. Adapted from a base image from Google Earth Pro using Paint 3D.

Figure 3.11. Photograph of an area of interest for targeted sampling in the RZ off Harvey Terrace, Richmond. *Note.* This area is an example of an area that can be targeted for sampling as it has a higher likelihood of having elevated soil HM concentrations (bare patch of soil that is next to vegetation and has visible brick fragments).

XRF spectrometry is a common analytical technique that is used for in situ screening with faster turnaround times than conventional methods of soil analysis (Kalnicky & Singhvi, 2001). However, as the FP-XRF is not capable of measuring the concentration of every HM (Rumsby, 2015), Pb concentrations will be used as a proxy to identify areas of soil contamination as it is often correlated with other contaminants such as Hg (Ashrafzadeh et al., 2018), that cannot be measured (at biologically relevant concentrations) using FP-XRF. Screening level analysis is useful for identifying potential hot spots in a given site and for determining the extent of contamination (Rumsby, 2013, 2015).

Soil HM concentration measurements were taken using the M series Vanta XRF handheld analyzer at eight sites in the RZ. Initially, it was planned to collect soil HM concentration measurements from multiple suburbs including Brooklands, Bromley and New Brighton, however, it was decided to focus on the flatland areas in the Ōtākaro Avon River Corridor due to time constraints and unsatisfactory weather conditions. A total of 313 samples were taken using the FP-XRF spectrophotometer over three different sampling campaigns in the RZ. The first of the three sampling campaigns was conducted on the 24th of June, 2021. On this day a total of 117 samples were taken from sites 1, 2 and 3. Subsequent campaigns occurred on the 5th and 8th of July, 2021 where another 105 (sites 4-5) and 91 (sites 6-8) samples were taken, respectively. Each sample took roughly 5 minutes to take and a total of 24 hours were spent out in the field collecting these samples. Figure 3.12 shows the XRF handheld analyzer in action. Originally a separate handheld GPS unit was used to log the location of each measurement, however, this data was scrapped as the M series Vanta XRF handheld analyzer had a built-in GPS that logged each sample point automatically. The steps of the sampling technique and the initial pre-checks before undertaking XRF investigations are listed below.

Steps to sampling:

1. Switch the XRF handheld analyzer on and allow sufficient time to warm up.
2. Conduct an energy calibration check (usually done in the lab before getting to the field site).
3. Select a suitable XRF programme (Geochem (2) 50 kV three-beam).
4. Select analysis times (10 seconds).
5. Locate an area to sample that is not inundated with water or has lots of vegetation cover.
6. Clear away any grass or large rocks that might damage the lens on the XRF analyzer.
7. Level the surface area and pack down the soil
8. Place a clear plastic Ziplock bag over the soil that is going to be sampled.
9. Point the XRF analyzer toward the ground.
10. Hold the XRF analyzer and keep the nose of the probe flush with the ground.
11. Press the trigger on the XRF analyzer to fire the beams.
12. Wait for the beams to finish (2x 10-second beams).
13. Record the sample number and other relevant information.
14. Remove any dirt or organic matter from the measurement window after use (Make sure that the window is not ripped or punctured).

15. Move on to the next sample. Repeat steps 5-14.

Figure 3.12. Photograph of the XRF handheld analyzer in action, at site 1 (Oxford Terrace, Christchurch Central City).

3.44 Quality assurance

During collection, there was a risk of sampling error and cross contamination between samples due to the large number of samples taken. To limit the risk of sampling errors, various quality control measures were undertaken. The FP-XRF was cleaned after taking samples from each site by brushing and wiping away any remaining traces of soil, and the clear plastic Ziplock bag was also replaced after each site to limit the transfer of soils between different sites.

3.45 Statistical treatment and analysis

Field data collected using the XRF analyzer was extracted and put into an Excel spreadsheet. Repeated data was excluded from the data set for statistical analysis. The data set was then split into two groups; targeted and transect samples (Appendix 1). Only Pb and Zn samples were statistically analyzed as other HM concentrations had large gaps in data due to the limits of detection (LOD) of the XRF analyzer. LOD is the smallest concentration of an element that can be identified with accuracy (Rumsby, 2015).

Basic statistical calculations such as the geometric mean and STDEV-range were calculated and then the data was log-transformed for statistical analyses. The R-values were calculated for each element and its correlation to Pb was calculated. Statistical analyses were conducted using the statistical software IBM SPSS Statistics 27. The significance of differences between the targeted and transect soil Pb concentrations, targeted and transect soil Zn concentrations, targeted soil Pb and Zn concentrations, and transect soil Pb and Zn concentrations was tested by one-way analysis of variance (ANOVA) followed by a Post-Hoc test (Tukey's Honest Significant Difference test), at the 95% confidence level ($p < 0.05$). Pearson correlation coefficient was used to determine the correlations between concentrations of targeted and transect Pb and Zn samples.

An ANOVA is a type of omnibus test statistic that examines the means of multiple samples to see if one group's mean is statistically different from the others. The null hypothesis for the test is that the two means are equal. As a result, a statistically significant result shows that the two means are not equal. While ANOVA can aid in analysing the differences in means between two independent variables, it cannot tell you which statistical groups were different. If the ANOVA test produces a significant F-statistic, a Post-Hoc analysis such as Tukey's Honest Significant Difference (Tukey's HSD) test is needed to determine which groups have different means. The Tukey's HSD test gives a p-value, which is used to determine whether or not the relationship between variables is significant.

Despite the fact that the test is robust when dealing with non-normally distributed data, the ANOVA test is based on the assumption that each sampled population's observations are normally distributed.

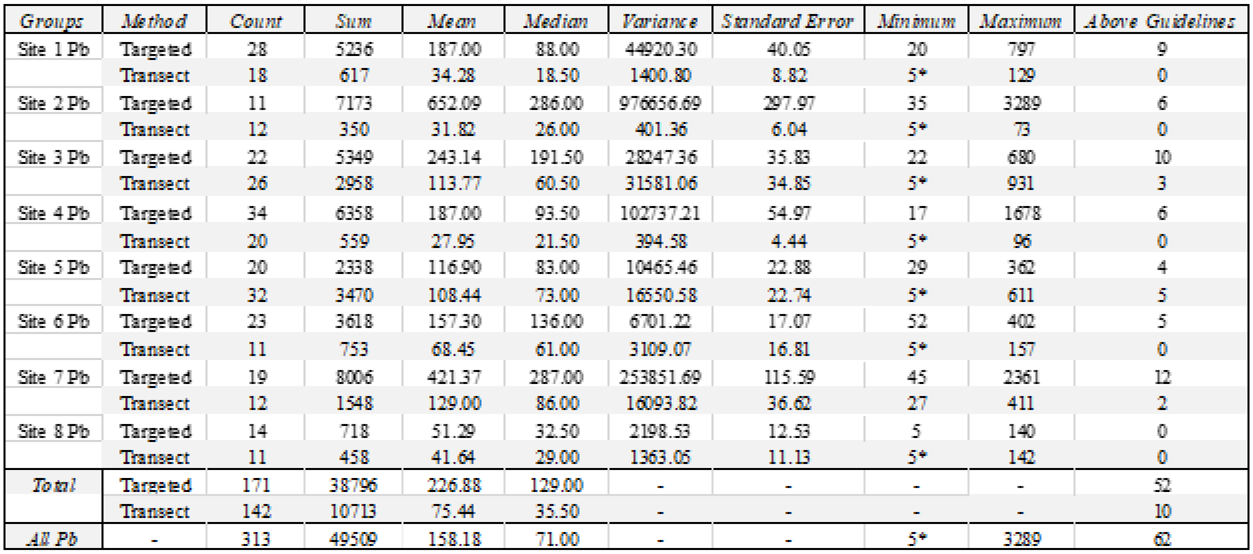
4. Results

4.1. Soil lead and zinc summary statistics

The summary statistics for soil Pb and Zn concentrations in the Christchurch Residential RZ are presented in Tables 4.1 and 4.2. Of the 313 samples collected from the field, 55% (171) were targeted samples and 45% (142) were transect samples.

The Pb samples in the RZ had a mean of 158.18 mg/kg. However, soil Pb concentrations were significantly higher in targeted samples (mean=226.88 mg/kg) than in transect samples (mean=75.44 mg/kg) (Table 4.1). The mean targeted Pb sample value greatly exceeded the upper background values of soils in Canterbury, as well as the New Zealand soil Pb guideline of 210 mg/kg, while the mean transect Pb sample value also exceeded the background values of soils in Canterbury, but was well below the New Zealand soil Pb guideline value. Of the 171 targeted Pb soil samples, 52 samples (~30%) exceeded the New Zealand soil Pb guideline of 210 mg/kg. While, in the transect Pb soil samples, only 10 (~6%) out of the 142 samples were above guideline values. All sites except site 8 had at least one sample that exceeded the guideline values for soil Pb. One site contained a Pb concentration of 3289 mg/kg, compared to its respective upper background concentration of 57.3 mg/kg.

Table 4.1. Summary statistics of targeted and transect soil lead samples from the Ōtākaro Avon River Corridor area in the Christchurch Residential Red Zone.



Groups	*Method*	*Count*	*Sum*	*Mean*	*Median*	*Variance*	*Standard Error*	*Minimum*	*Maximum*	*Above Guidelines*
Site 1 Pb	Targeted	28	5236	187.00	88.00	44920.30	40.05	20	797	9
	Transect	18	617	34.28	18.50	1400.80	8.82	5*	129	0
Site 2 Pb	Targeted	11	7173	652.09	286.00	976656.69	297.97	35	3289	6
	Transect	12	350	31.82	26.00	401.36	6.04	5*	73	0
Site 3 Pb	Targeted	22	5349	243.14	191.50	28247.36	35.83	22	680	10
	Transect	26	2958	113.77	60.50	31581.06	34.85	5*	931	3
Site 4 Pb	Targeted	34	6358	187.00	93.50	102737.21	54.97	17	1678	6
	Transect	20	559	27.95	21.50	394.58	4.44	5*	96	0
Site 5 Pb	Targeted	20	2338	116.90	83.00	10465.46	22.88	29	362	4
	Transect	32	3470	108.44	73.00	16650.58	22.74	5*	611	5
Site 6 Pb	Targeted	23	3618	157.30	136.00	6701.22	17.07	52	402	5
	Transect	11	753	68.45	61.00	3109.07	16.81	5*	157	0
Site 7 Pb	Targeted	19	8006	421.37	287.00	253851.69	115.59	45	2361	12
	Transect	12	1548	129.00	86.00	16093.82	36.62	27	411	2
Site 8 Pb	Targeted	14	718	51.29	32.50	2198.53	12.53	5	140	0
	Transect	11	458	41.64	29.00	1363.05	11.13	5*	142	0
Total	Targeted	171	38796	226.88	129.00	-	-	-	-	52
	Transect	142	10713	75.44	35.50	-	-	-	-	10
All Pb	-	313	49509	158.18	71.00	-	-	5*	3289	62

Note. * = <LOD.

The Zn samples in the RZ had a mean of 170.07 mg/kg. However, soil Zn concentrations were significantly higher in targeted samples (mean=217.88 mg/kg) than in transect samples (mean=113.42 mg/kg) (Table 4.2). The mean targeted Zn sample value greatly exceeded the urban background soil Zn concentration in Canterbury (level 1) of 55.5-91.7 mg/kg from Tonkin and Taylor (2007). However, it was still well below the New Zealand soil Zn guideline of 400 mg/kg. Similarly, the mean transect Zn sample value slightly exceeded the background values of soils in Canterbury, but not the New Zealand soil Zn guideline value. Of the 171 targeted Zn soil samples, 14 samples (~8%) exceeded the New Zealand soil Zn guideline of 400 mg/kg. While, in the transect Zn soil samples, only 3 (~2%) of the 142 samples were above guideline values. All sites had at least one sample that exceeded the guideline values for soil Zn. One site contained a Zn concentration of 1894 mg/kg, compared to its respective upper background concentration of 91.7 mg/kg.

Table 4.2. Summary statistics of targeted and transect soil zinc samples from the Ōtākaro Avon River Corridor area in the Christchurch Residential Red Zone.

Groups	*Method*	*Count*	*Sum*	*Mean*	*Median*	*Variance*	*Standard Error*	*Minimum*	*Maximum*	*Above Guidelines*
Site 1 Zn	Targeted	28	6356	227.00	174	53763.63	43.82	47	974	3
	Transect	18	1475	81.94	68.50	1194.76	8.15	49	170	0
Site 2 Zn	Targeted	11	2850	259.09	236	20713.29	43.39	55	482	3
	Transect	12	1177	98.08	100.00	699.17	7.63	48	136	0
Site 3 Zn	Targeted	22	4915	223.41	191	10346.25	21.69	67	421	1
	Transect	26	4271	164.27	113.00	17161.32	25.69	80	690	1
Site 4 Zn	Targeted	34	7285	214.26	135	97526.93	53.56	54	1894	2
	Transect	20	1349	67.45	59.50	720.58	6.00	40	150	0
Site 5 Zn	Targeted	20	3225	161.25	138.5	10220.93	22.61	51	489	1
	Transect	32	4482	140.06	115.50	8654.19	16.45	46	411	2
Site 6 Zn	Targeted	23	5383	234.04	174	75754.50	57.39	90	1464	1
	Transect	11	831	75.55	75.00	1078.07	9.90	42	143	0
Site 7 Zn	Targeted	19	4169	219.42	170	11670.48	24.78	75	419	1
	Transect	12	1438	119.83	103.50	4666.52	19.72	48	286	0
Site 8 Zn	Targeted	14	2943	210.21	119.5	42002.95	54.77	70	795	2
	Transect	11	1082	98.36	72.00	6090.85	23.53	43	320	0
Total	Targeted	171	37126	217.11	165.00	-	-	-	-	14
	Transect	142	16105	113.42	87.50	-	-	-	-	3
All Zn	-	313	53231	170.07	117.00	-	-	40	1894	17

4.2. Significance between targeted and transect samples for soil lead and zinc

Figure 4.1a shows the difference between the average concentration of targeted and transect soil Pb samples in the RZ. Sites 5 and 8 showed no significant difference between targeted and transect samples, while sites 1 and 7 showed high significance between targeted and transect samples, and sites 2, 3, 4, and 6 showed very high significance between targeted and transect samples. The table of significance can be found in Appendix H.

Figure 4.1b shows the difference between the average concentration of targeted and transect soil Zn samples in the RZ. Site 5 was the only site that showed no significant difference between targeted and transect samples. Sites 3 and 8 showed significant differences, sites 1 and 7 showed highly significant differences and sites 2, 4, and 6 showed very highly significant differences between targeted and transect samples. The table of significance can be found in Appendix X.

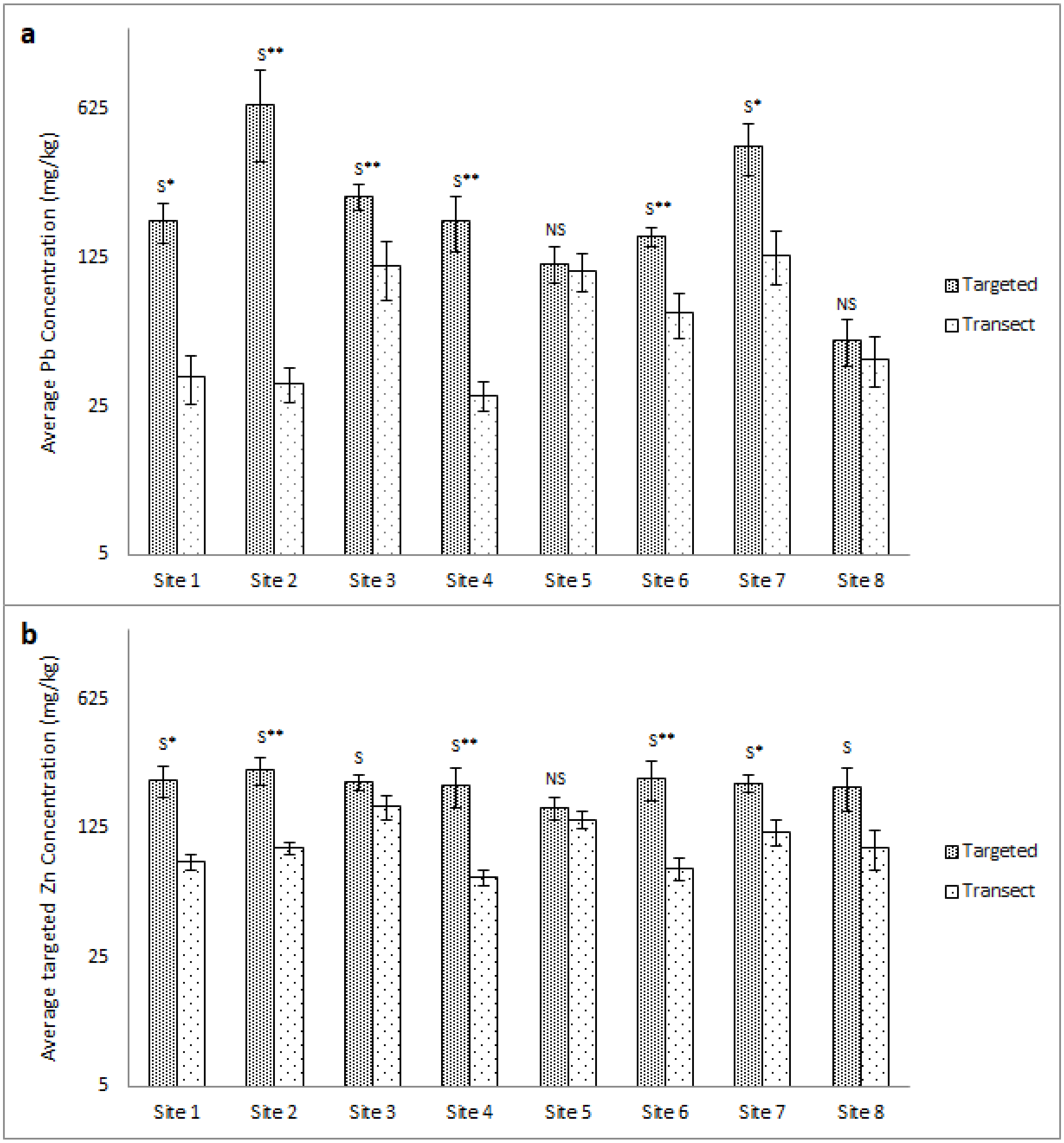


Figure 4.1. Geometric means and standard deviation ranges of targeted and transect lead (a) and zinc (b) samples. *Note.* P-values are given as follows; $p < 0.05$ NS (Not Significant), $0.05 < p < 0.01$ S (Significant), $0.01 < p < 0.001$ S* (Highly Significant), $p < 0.001$ S** (Very Highly Significant).

4.3. Targeted soil lead and zinc samples

Figure 4.2a shows that the average concentration of targeted soil Pb samples from site 1-7 in the RZ, was higher than the upper background soil Pb concentration of 57.3 mg/kg. Site 8 was the only site that did not exceed the upper background concentration. Three of the sites (sites 2, 3, and 7) exceeded the New Zealand soil Pb guideline value (210 mg/kg). Site 8 had significantly lower soil Pb concentration values compared to sites 1, 2, 3, 4, 6, and 7.

Figure 4.2b shows that the average concentration of all targeted soil Zn samples in the RZ was higher than the upper background soil Zn concentration of 91.7 mg/kg, while no sites exceeded the New Zealand soil Zn guideline value (400 mg/kg). No significant difference was found between Zn samples at the different site locations.

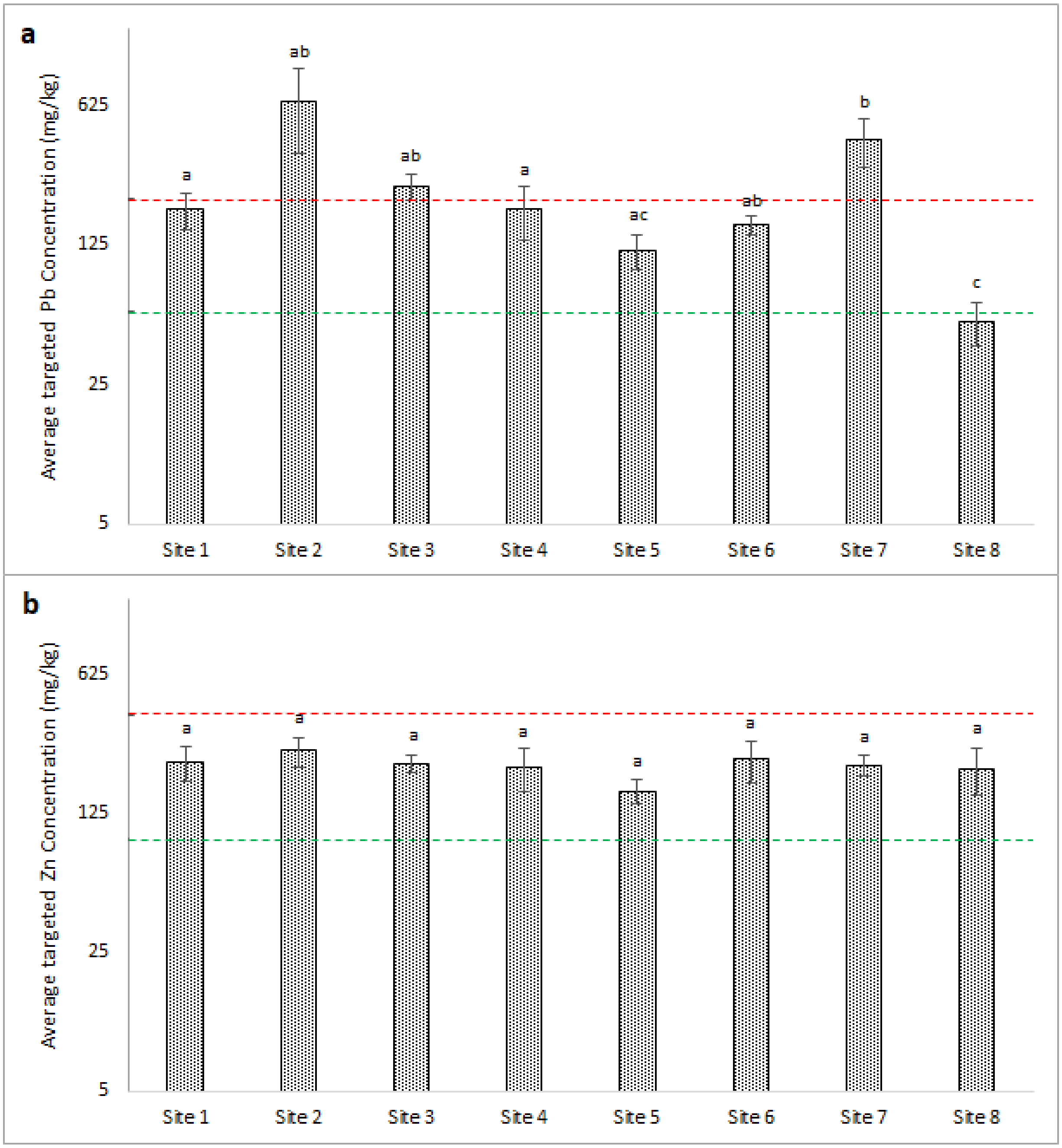


Figure 4.2. Geometric means and standard deviation ranges of targeted lead (a) and zinc (b) samples. *Note.* The red dashed horizontal lines reflect the New Zealand contaminant standards for Pb (210 mg/kg) and Zn (400 mg/kg), while the green dashed horizontal line reflects the upper background soil Pb (57.3 mg/kg) and Zn (91.7 mg/kg) concentrations in Canterbury (Tonkin and Taylor, 2007). The bars labelled with the same letter are not significantly different ($P > 0.05$,

Tukey's Test). Site 1 (n=28), site 2 (n=11), site 3 (n=22), site 4 (n=34), site 5 (n=20), site 6 (n=23), site 7 (n=19), and site 8 (n=14).

4.4. Transect soil lead and zinc samples

Figure 4.3a shows that the average concentration of transect soil Pb samples at sites 3, 5, 6, and 7 was higher than the upper background soil Pb concentration of 57.3 mg/kg. No sites exceeded the New Zealand soil Pb guideline value (210 mg/kg). The average soil Pb concentration at sites 1, 2, 4, 6, and 8 was not significantly different from each other, and the average soil Pb concentration at sites 3, 5, and 7 was also not significantly different from each other.

Figure 4.3b shows that the average concentration of transect soil Zn samples at sites 2, 3, 5, 7, and 8 was higher than the upper background soil Zn concentration of 91.7 mg/kg. No sites exceeded the New Zealand soil Zn guideline value (400 mg/kg). The average soil Zn concentration at sites 2, 7, and 8 was not significantly different from all other sites. The average soil Zn concentration at sites 4 and 6 was significantly different from sites 1, 3 and 5. The average soil Zn concentration at sites 1 and 3 was also significantly different from each other.

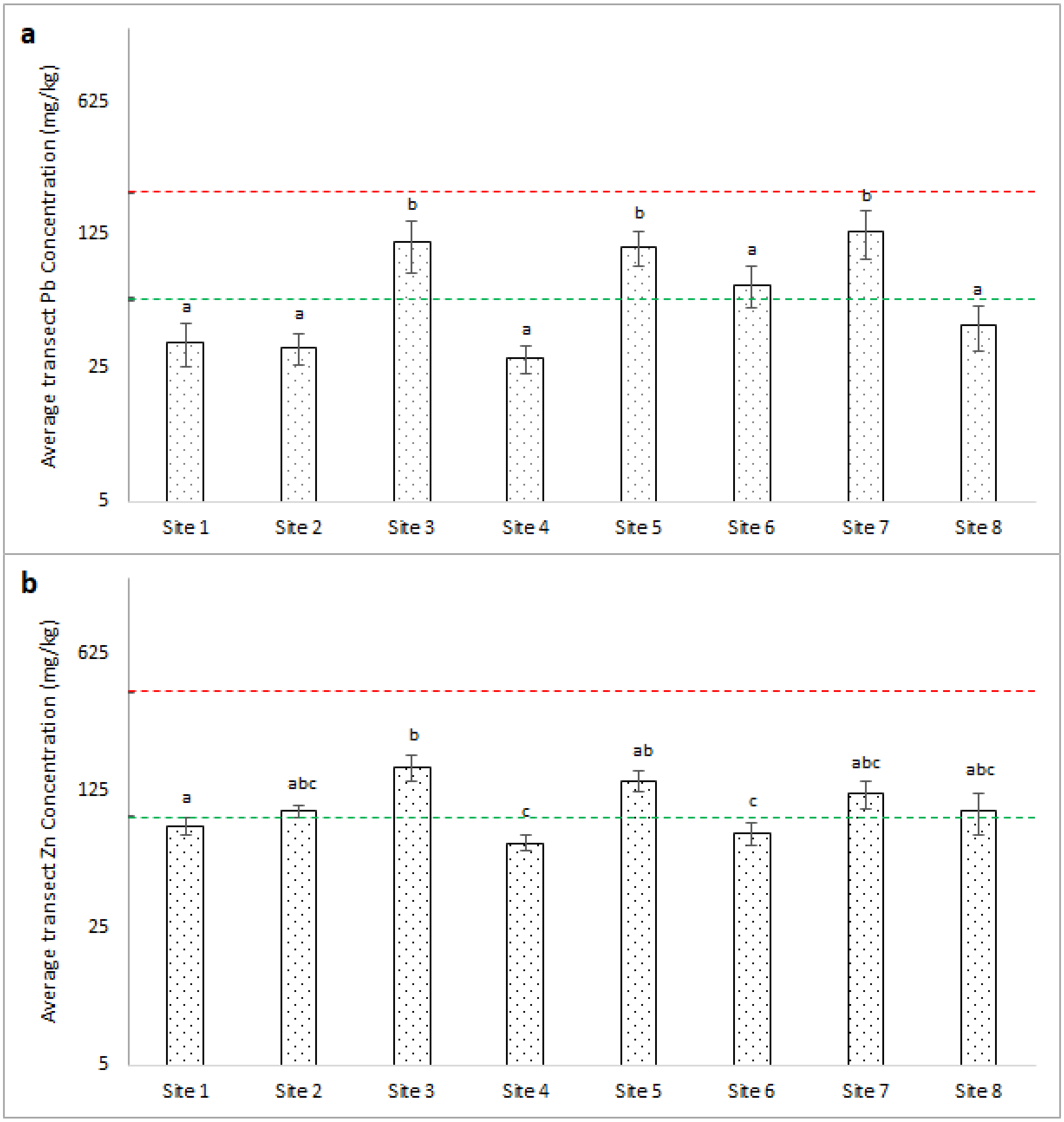


Figure 4.3. Geometric means and standard deviation ranges of transect lead (a) and zinc (b) samples. Note. The red dashed horizontal lines reflect the New Zealand contaminant standards for Pb (210 mg/kg) and Zn (400 mg/kg), while the green dashed horizontal line reflects the upper background soil Pb (57.3 mg/kg) and Zn (91.7 mg/kg) concentrations in Canterbury (Tonkin and Taylor, 2007). The bars labelled with the same letter are not significantly different ($P > 0.05$,

Tukey's Test). Site 1 (n=18), site 2 (n=12), site 3 (n=26), site 4 (n=20), site 5 (n=32), site 6 (n=11), site 7 (n=12), and site 8 (n=11).

4.5. Correlation between soil lead and zinc samples

Figure 4.4 shows the correlation between targeted Pb and Zn samples. The coefficient of determination (R^2) value of 0.5877 (58.77%) represents a significant positive relationship between targeted Zn and Pb concentrations for RZ soils. This shows that 58.77% of the variation in targeted soil Zn concentrations can be explained by variations in targeted soil Pb concentrations in the RZ.

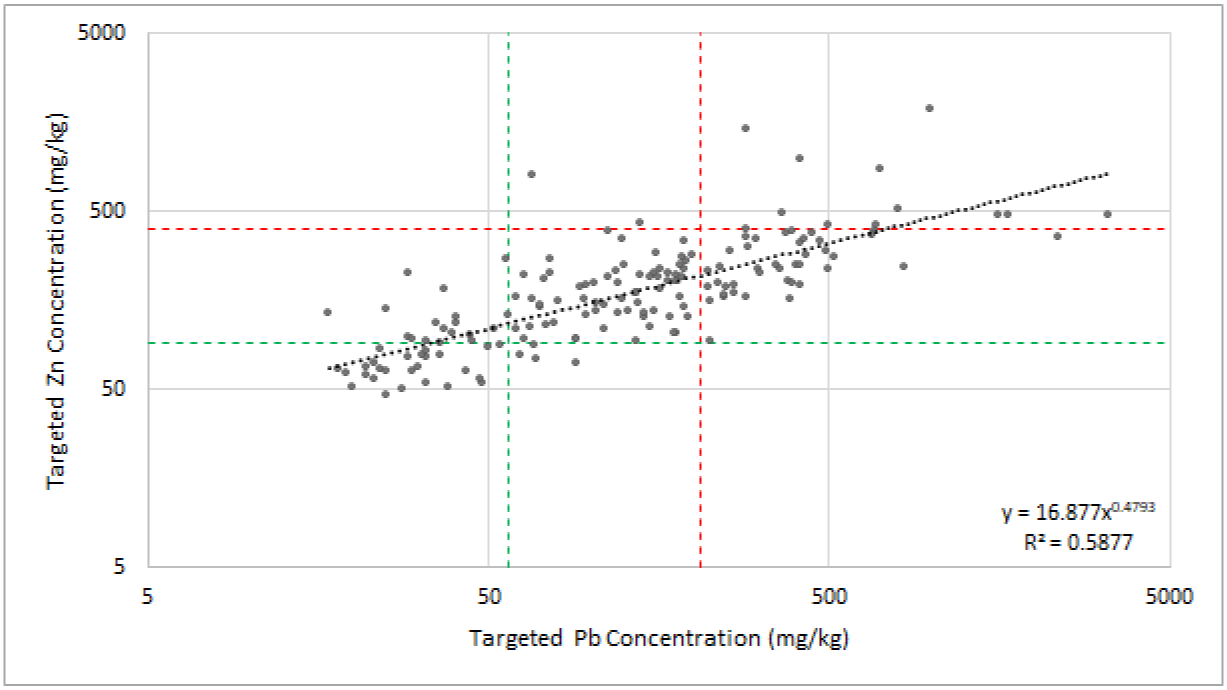


Figure 4.4. Correlation between targeted lead and zinc samples. *Note.* The red dashed vertical line reflects the New Zealand contaminant standards for Pb (210 mg/kg), while the green dashed vertical line reflects the background soil Pb concentration in Canterbury (57.3 mg/kg) (Tonkin and Taylor, 2007). The red dashed horizontal line reflects the New Zealand contaminant standards for Zn (400 mg/kg), while the green dashed horizontal line reflects the background soil Zn concentration in Canterbury (91.7 mg/kg) (Tonkin and Taylor, 2007).

Figure 4.5 shows the correlation between targeted Pb and Zn samples. The coefficient of determination (R^2) value of 0.562 (56.2%) represents a significant positive relationship between transect Zn and Pb concentrations for RZ soils. This shows that 56.2% of the variation in transect soil Zn concentrations can be explained by variations in transect soil Pb concentrations in the RZ.

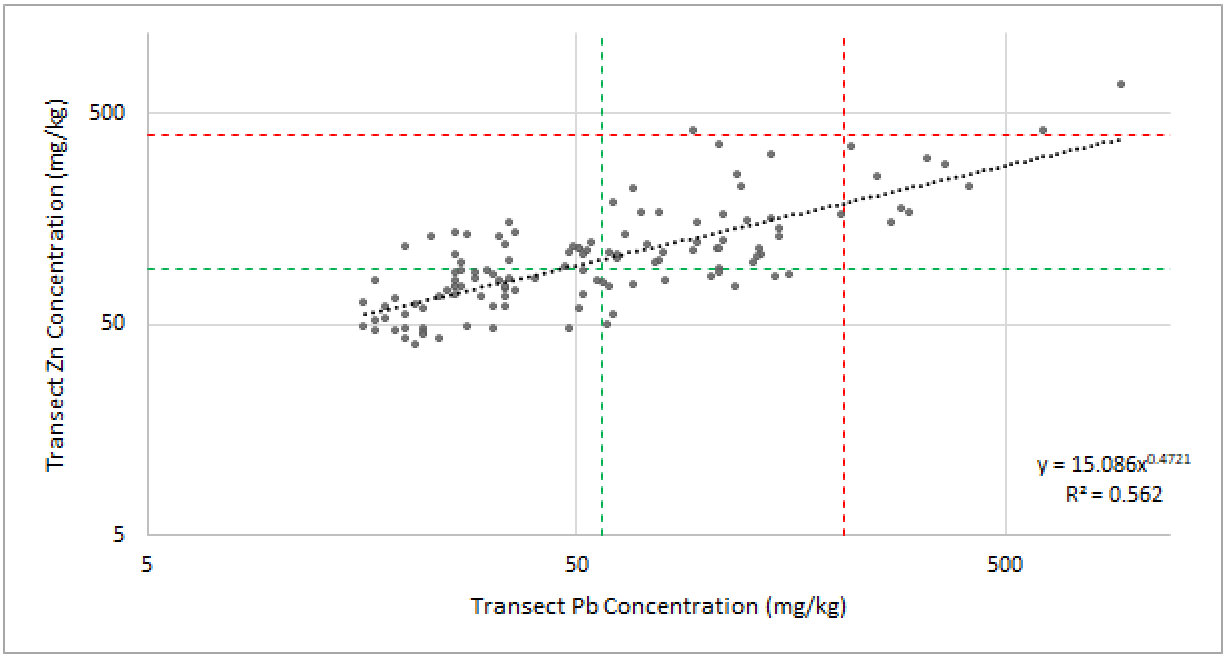


Figure 4.5. Correlation between transect lead and zinc samples. *Note.* The red dashed vertical line reflects the New Zealand contaminant standards for Pb (210 mg/kg), while the green dashed vertical line reflects the upper background soil Pb concentration in Canterbury (57.3 mg/kg) (Tonkin and Taylor, 2007). The red dashed horizontal line reflects the New Zealand contaminant standards for Zn (400 mg/kg), while the green dashed horizontal line reflects the upper background soil Zn concentration in Canterbury (91.7 mg/kg) (Tonkin and Taylor, 2007).

5. Discussion

This section reviews and discusses the observable trends, unexpected results, and implications of the results while comparing the results from this study to the results of other researchers, as well as giving a potential explanation for these results. Section 5.2 outlines the methods of exposure reduction. This section ends with the research limitations and future research suggestions.

5.1 Trends and unexpected results

HMs such as Pb and Zn were expected to be found in high concentrations in RZ soils, and the concentrations of these HMs were expected to be much higher in targeted samples than in transect samples.

The soil Pb and Zn samples taken in the RZ had a mean of 158.18 mg/kg and 170.07 mg/kg respectively (Table 4.1 & 4.2). These elevated levels of soil Pb and Zn concentrations were consistent with the concentrations observed by Ashrafzadeh et al. (2018) in Christchurch soils (Pb=137 mg/kg, Zn=189 mg/kg), only showing a difference of -15.46% for Pb and 10.02% for Zn. The average concentration of soil Pb in the RZ is also similar to those found in Baltimore, Boston, Chicago, Naples, Palermo, and Rome (Ajmone-Marsan & Biasioli, 2010).

The results are also consistent with what was hypothesized. They show that the average soil Pb and Zn concentrations in the RZ had significantly higher concentrations than the background soil concentrations in Canterbury, and that soil samples taken from the RZ (once urban/suburban land) generally had significantly higher Pb and Zn concentrations than rural Pb and Zn soil concentrations as reported by Ashrafzadeh et al. (2018). This suggests that HM concentrations in urban soils have been elevated from previous land uses and anthropogenic activities such as industrial discharges, vehicle emissions, and the demolition of buildings.

The maximum concentrations of Pb and Zn at all sites were significantly higher than their respective background concentrations (Table 4.1 & 4.2). The highest soil Pb concentration observed (3289 mg/kg) was >57 times greater than the Pb soil background concentration in Canterbury, and >15.5 times greater than the national soil Pb standard (210 mg/kg). While the highest soil Zn concentration observed (1894 mg/kg) was >20.5 times greater than the Zn soil background concentration in Canterbury, and >4.5 times greater than the national Zn standard (400 mg/kg). These elevated concentrations of soil Pb greatly exceeded the maximum findings of Seeley and Smy (2021) in community garden soils in Christchurch (462 mg/kg) by >711% and exceeded the maximum findings of Ashrafzadeh et al. (2018) (2615 mg/kg) by >125%. However, they were similar to the maximum soil Pb values in Jakobstad, Finland of 3439 mg/kg (Ajmone-Marsan & Biasioli, 2010). The elevated concentrations of Pb found in this study may be due to the widespread historical use of Pb-based paint in Christchurch.

The maximum levels of soil Zn concentrations found in this study also greatly exceeded the findings of Ashrafzadeh et al. (2018) (799 mg/kg) by >237% and exceeded the maximum findings of Seeley and Smy (2021) (946 mg/kg) by > 200%. However, they were similar to the maximum soil Zn values in Tallin (1560 mg/kg), Wroclaw (1640 mg/kg), Osnabrück (1660 mg/kg), Richmond upon Thames (1810 mg/kg), and Avilés (1959 mg/kg), (Ajmone-Marsan & Biasioli, 2010). This may be due to the widespread use of galvanised steel in building materials and vehicle components.

Some ~30% of targeted Pb samples and ~6% of transect samples were above the national soil Pb guideline values, while ~8% of targeted Zn samples and ~2% of transect samples were above national soil Zn guideline values. These results suggest that targeted sampling is more likely to find higher Pb and Zn concentrations in soils than transect sampling. This also indicates that areas of bare soil with visible debris and rubble are more likely to have elevated Pb and Zn soil concentrations (are hotspots for HMs).

The differences between targeted and transect samples were much lower in Zn samples than Pb samples (Figure 4.1). This shows that some very high levels of soil Pb contamination were found in this study. This may also indicate point source contamination which can lead to areas of increased Pb concentrations and may explain the increased range of Pb concentrations that was observed in this study.

Site 8 had significantly lower soil Pb concentration values compared to all other sites (Figures 4.2 & 4.3). Site 8 had an unusually low mean soil Pb concentration of 51.29 mg/kg in targeted samples (Table 4.1) and did not exceed the upper background concentration of 57.3 mg/kg for urban Canterbury soils, the reason as to why was not quantified. The variations in concentration between the sites could be related to seasonal fluctuations, sample collection, as well as historical land use and traffic density (Garba & Abubakar, 2018). However, it is possible that this site was remediated with topsoil which would explain the low soil Pb concentrations observed at this site.

The correlation between Pb and Zn soil concentrations across both targeted and transect samples at all sites showed that Pb was significantly positively correlated to Zn concentrations (Figures 4.4 & 4.5). This may be associated with vehicle emissions and wear from tires which can contain both these HMs (Garba & Abubakar, 2018), or more broadly indicate the impact of anthropogenic activities on soil contamination. Gulan et al. (2017) found a significant positive correlation (0.838) between Zn and Pb for urban soils in Priština, Kosovo. And in another separate study, Lu et al. (2003) also found a significant positive correlation (0.814) between Zn and Pb for urban soils in Nanjing, China. The lack of a normal distribution and high SD values are frequently used as indicators of anthropogenic activity. This strong correlation between Pb and Zn in RZ soils suggests that these HMs may have come from similar anthropogenic sources such as industrial discharges, vehicle emissions, and building materials, rather than from original parent materials (Gulan et al., 2017).

5.2 Implications

There are multiple implications that can be considered from the findings of this research. The positive relationship between soil Pb and Zn, may allow Zn, which is often measured in soil nutrient analyses (Mitchell et al., 2014), to act as an indicator for anthropogenically elevated concentrations of Pb and other HMs in RZ soils. Community gardeners may use this information to help guide efforts to minimise exposure to Pb and other HM contaminants in RZ soils (Mitchell et al., 2014). This research also provides new insight into the relationship between targeted and transect Pb and Zn soil contaminations in the RZ as no other studies in Christchurch, New Zealand have conducted research with targeted and transect FP-XRF sampling. This information can allow for targeted remediation in the RZ, which may be a more economically viable option for remediation as less work is necessary if specific areas of bare soil and visible rubble are targeted. Community members may use this information to help minimise their exposure to HM contaminants in RZ soils by avoiding contact with these hotspot areas.

A large percentage of urban/suburban soils from the Christchurch Residential RZ, like those from other cities, had Pb and Zn concentrations that exceeded national standards. This will have pronounced implications for the future land use of this area. Whilst the concept of community gardens in the RZ has good intentions for the socioeconomic well being of community members, if remediation measures are not taken the possible implications of HM exposure on human health pose a great threat to vulnerable populations, especially children. Using this RZ land for other uses such as nature reserves and native forests may limit human exposure to HM contaminants that are present in RZ soils.

5.21 Exposure reduction

Community members may be directly exposed to soil Pb and Zn while gardening and indirectly exposed through airborne particles and consuming produce that has been contaminated with HMs. Direct and indirect exposure to soil Pb and Zn can be reduced through various methods. These can be split into protective measures (exposure prevention) and remediation methods. Protective measures to reduce community exposure to HMs in community garden soils include using raised garden beds, the addition of clean topsoil and compost, untreated timber for garden beds and fencing, minimising soil resuspension by reducing disturbance of dry soil, changing land use (e.g. playing fields or native forest instead of community gardens), limiting interaction with soil through appropriate hygiene and food preparation, crop selection, keeping the pH of the soil near neutral, regular soil testing and monitoring, and by maintaining beds and adding clean compost regularly (Mitchell, et al., 2014). While remediation methods include the excavation and dumping of contaminated soils, covering with uncontaminated topsoil, covering with impermeable surfaces, covering with other ground barriers such as grass, in situ stabilization, as well as the use of chelating agents or biosolids to remove or sequester Pb (Clark et al., 2008).

Soil treatments, such as grass seed or sod, may not last if people do not maintain their lawns (Ashrafzadeh et al., 2018).

While this study did not evaluate HM accumulation in food crops from RZ soils, it is likely that such crops may contain HM concentrations exceeding food safety standards, that may be caused by the uptake from plants, or from soil particles that are attached to the plant. HM accumulation, absorption, and distribution patterns differed significantly amongst vegetable crops grown on HM contaminated soils, and so did the HM concentrations in various plant parts (Singh et al., 2012). Singh et al. (2012) also found that HMs generally accumulated most in the edible parts of root and leafy green vegetables. Tree-borne fruits accumulated the least amount of HMs, while leafy green vegetables accumulated the most HMs (Singh et al., 2012). Ashrafzadeh et al. (2018) described that tree-borne fruits, as well as fruits and vegetables that are peeled or enclosed within a capsule or pod, are less likely to have significant amounts of attached soil than low-growing leafy vegetables and unpeeled root vegetables. Selecting crops that are unlikely to have significant concentrations of HMs in soils can minimize human exposure to HMs in soils.

Ground cover and barriers were used in the soil intervention programme provided by Dixon et al. (2006), and soil Pb concentrations were reduced by 1815 mg/kg. Another study by Aschengrau et al. (1994) found that soil Pb was reduced by 2060 mg/kg and the blood Pb levels (BLLs) in children decreased when the top 6 inches of soil were removed. These studies show that in-situ remediation can significantly and quickly reduce Pb exposure. However, Dixon et al. (2006) reported a cost range of \$1095–\$5643 USD (~\$1500-\$8000 NZD) for soil intervention, with an average cost of \$2798 USD (~\$4000 NZD) for each yard (the average yard was 360 m^2). Large-scale ground cover and barriers which are needed for the RZ are impractical due to this cost aspect. The cost to remediate the 8 sites through soil intervention works out to be \$855,721 USD (~\$1,220,000 NZD), and \$48,965,000 USD (~\$69,840,000 NZD) for the whole RZ area (6.3 km^2).

Raised garden beds can be a cheap and effective method of exposure reduction that allows gardeners to continue growing produce on contaminated lands, while also introducing community education and awareness, which can have a significant influence on exposure reduction (Clark et al., 2008). Mitchell et al. (2014) found that concentrations of Pb, Zn, and Ba were lower in samples taken from garden beds rather than non-bed samples. However, as raised garden beds only cover/contain a small percentage of contaminated soil, using them as a remediation or soil intervention programme does not address the principal routes of Pb exposure (e.g., ingestion of soil) (Clark et al., 2008). Therefore, raised garden beds should be considered as an exposure reduction approach rather than a remediation method (Clark et al., 2008).

Strong seasonal winds and low precipitation are frequent in Christchurch, which encourage the development of airborne soil particles (Ashrafzadeh et al, 2018). Furthermore, following the 2010/2011 Christchurch earthquakes, there was a lot of demolition and rebuilding in the Christchurch area, which may have led to more dust formation in some areas (Ashrafzadeh et al, 2018). Clark et al. (2008) reported that Pb is redistributed in gardens by soil particles transported by wind. Therefore, it is crucial to keep maintaining raised garden beds by adding clean compost or mulch regularly, as airborne soil particles from outside the beds can pollute garden beds over time. Clark et al. (2008) recommended that the top 3–5 cm of soil be removed and replaced with compost or new topsoil once a year to maintain low Pb concentrations. These are economically viable and practical strategies that nonprofits and community organisations can implement for exposure reduction (Clark et al., 2008).

Rahman et al. (2004) reported that raised garden beds made from CCA treated timber diffused Cu, Cr, and As into adjacent garden soils. Therefore the use of untreated timber for raised beds, fencing, and posts in proximity to gardens is crucial in minimizing further sources of contamination and exposure.

The approaches mentioned in this section should be promoted among urban gardeners. Furthermore, widespread adoption of healthy gardening practices, such as keeping soil pH near neutral and washing and peeling produce, is a critical strategy for reducing human exposures to soil contaminants, especially if resources for a thorough site evaluation are insufficient (Mitchell, et al., 2014).

5.3 Limitations

Although using the FP-XRF for screening has many benefits, it also has many limitations. Apart from Pb and Zn, this study was unable to find consistent values of other HMs such as Hg, Cd, and As in RZ soils due to the LOD of the FP-XRF which are listed in Appendix G.

Seeley and Smy (2021) compared soil HM contaminant results from data collected through FP-XRF sampling and ICP-MS analysis to find similarities between the observed results. They found that both Pb and Zn concentrations in soils were underestimated by the FP-XRF when compared to results from ICP-MS analysis as water molecules increased the bulk of the soil without adding to the HM concentration. The concentrations obtained by in-situ XRF analysis were on average 25–50% lower than those obtained by ICP-MS (Seeley & Smy, 2021). This shows that FP-XRF can produce incorrect readings of HM contaminants in soils, which can impact the decision quality of the data.

Research also found that screening analytical methods such as FP-XRF had greater LOD (Crumbling, 2001; Kalnicky & Singhvi, 2001; Rumsby, 2015), were more biased, less precise, and more sensitive to interferences than compared to definitive methods such as ICP-MS (Crumbling, 2001). This makes it more difficult to get an accurate picture of HM distribution in the RZ, especially for Hg, and Cd, which have extremely low background concentrations of 0.04-0.08 mg/kg and 0.073-0.14 mg/kg respectively (Tonkin and Taylor, 2007).

Determining the sources of HM contaminants in RZ soils was also made more difficult due to the fact that the FP-XRF could not detect organic contaminants, such as organochlorine pesticides and polycyclic aromatic hydrocarbons (PAHs) which can be indicators of HM contaminants (Rumsby, 2015).

5.4 Future research

Concentrations of HMs in the Christchurch Residential RZ soils are not well understood and require further investigations to understand the nature of HMs in the RZ and how they are distributed. Future research that aims to expand on the findings of this study should include gathering more data from different sites in the Christchurch Residential RZ rather than just the flatland Ōtākaro Avon River Corridor area of the RZ. This will allow for a better representation of the distribution and concentrations of HMs in RZ soils. Although FP-XRF is only used as a method of screening analysis, it can still provide evidence of hotspot locations. However, future research should combine the use of FP-XRF screening with ICP-MS analysis as this will allow for more accurate and reliable soil contaminant results.

As this study was unable to address the reason as to why site 8 had significantly lower concentrations of soil Pb than the other seven sites, future work at this site is needed to determine the reason for this. This can include digging down beneath the surface of the top soil for evidence of contaminated soils which will prove that this site was previously remediated.

Finally, future research could also examine the HM concentrations in fruits and vegetables grown in urban/suburban gardens in Christchurch, to quantify the levels of exposure for community gardeners and to aid in future crop selection.

6. Conclusion

In-situ XRF screening of RZ soils was conducted to gain a better understanding of the types of HMs in RZ soils, the concentrations of HMs, and the nature of HM distribution in Christchurch residential RZ soils. This study found elevated concentrations of Pb and Zn in the flatland Ōtākaro Avon River Corridor area of the Christchurch Residential RZ that exceed the urban background concentrations in Canterbury soils, suggesting that HM concentrations in these soils have been elevated from previous land uses and anthropogenic activities such as industrial discharges, vehicle emissions, and the demolition of buildings. These elevated levels of soil Pb and Zn concentrations were consistent with the finding of other researchers. Importantly, targeted samples had a significantly higher mean concentration than non-targeted transect samples. This suggests that areas of bare soil with visible debris and rubble such as brick fragments can indicate the presence of contaminated soils, which may be useful for targeted remediation or in helping community members minimize their exposure to HM contaminants in RZ soils. Exposure to high concentrations of these HMs has an adverse effect on human health. This is why soil HM concentrations should be a key factor in deciding on the future land use of RZ land. The likelihood of human exposure to these HMs in soils would be reduced if these RZ areas were redeveloped into nature reserves or native forests, rather than community gardens where produce is grown and bare soil is exposed. This research can be used to complement the regeneration work that is currently underway in the RZ. Furthermore, the results from this research could contribute to the development of new risk management strategies and potentially lead the way for future research projects in the RZ.

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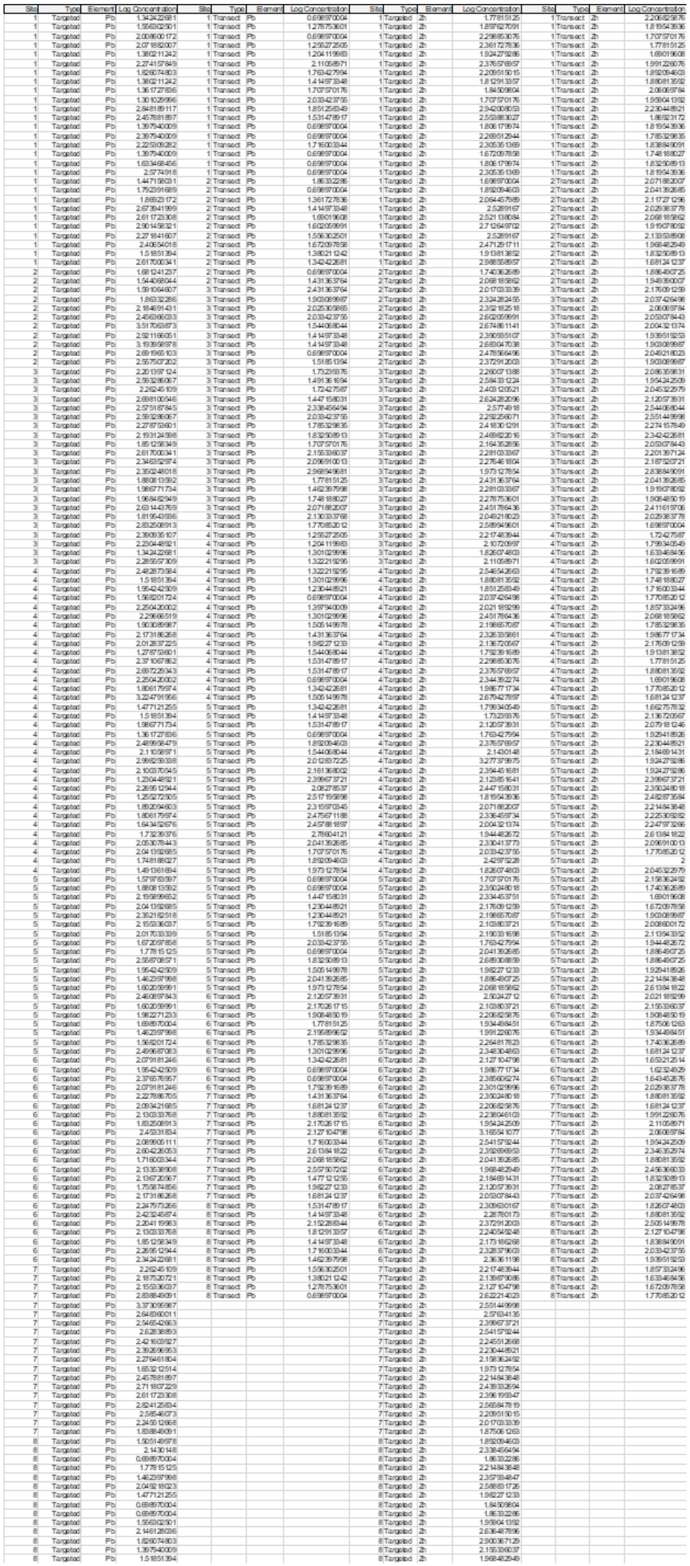
Appendix A: Data from FP-XRF

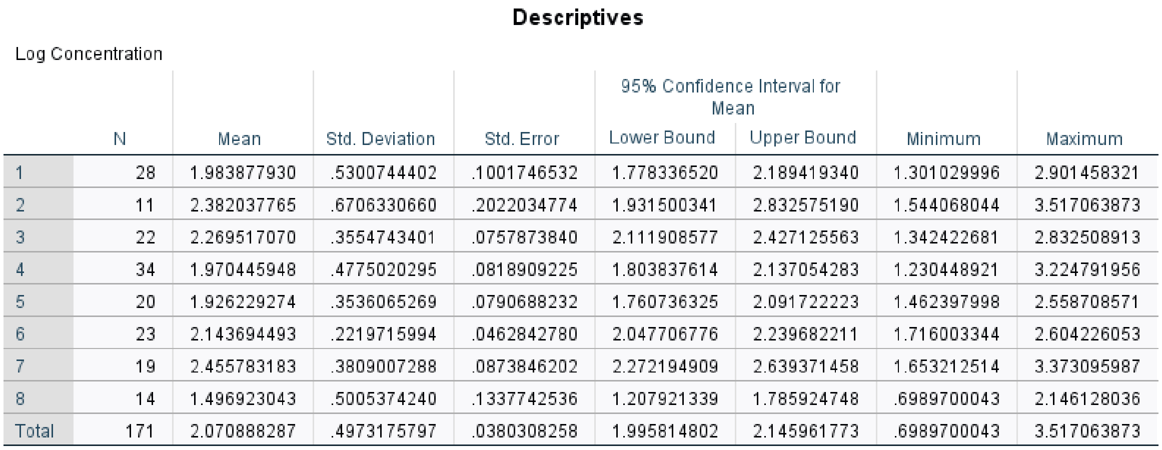
Site	Sample Type	Date	Time	Notes	Latitude	Longitude	Pb	Zn	Al	Si	K	Ca	Fe	Rb	Sr	Y	Zr	Nb	Ba
1	Targeted	24/06/2021	10:47:22	test 001	43.5237	172.64742	22	60	400	3911	5266	5877	11141	69	162	12	129	7	387
1	Targeted	24/06/2021	10:48:37	test 001	43.5237	172.64747	36	79	2668	5733	3730	5430	9694	56	147	9	114	5	360
1	Targeted	24/06/2021	10:50:41	test 00	43.5238	172.64762	102	199	2584	4102	5023	6446	12322	60	172	12	136	7	442
1	Targeted	24/06/2021	10:52:51	test 00	43.5238	172.64723	118	230	2378	3831	5365	4606	12996	56	186	14	131	9	434
1	Targeted	24/06/2021	10:58:20	test 002	43.5237	172.64714	24	84	400	3611	5198	3702	12651	74	162	11	119	8	359
1	Targeted	24/06/2021	11:00:23	test 003	43.5236	172.64734	188	238	3608	4828	4339	6985	11575	38	177	9	128	8	313
1	Targeted	24/06/2021	11:01:51	test 004	43.5236	172.64739	67	162	2471	5535	5753	6415	14023	69	194	19	145	7	393
1	Targeted	24/06/2021	11:03:26	test 005	43.5236	172.64748	24	65	2931	3985	4636	7263	11985	69	162	17	133	8	345
1	Targeted	24/06/2021	11:05:19	test 006	43.5236	172.64775	23	70	400	3987	5112	3439	12935	78	189	15	163	9	332
1	Targeted	24/06/2021	11:06:38	test 007	43.5236	172.64776	20	51	2742	3566	6060	4552	12292	66	143	12	110	5	375
1	Targeted	24/06/2021	11:08:30	test 008	43.5236	172.64814	705	875	3320	3866	5560	5802	15769	60	240	12	136	11	481
1	Targeted	24/06/2021	11:10:38	test 009	43.5236	172.64815	287	358	400	4264	5870	4711	13975	57	177	17	113	8	442
1	Targeted	24/06/2021	11:12:34	test 010	43.5236	172.64811	25	64	2563	3067	3474	3360	9843	56	138	10	102	6	306
1	Targeted	24/06/2021	11:14:43	test 011	43.5237	172.64824	250	186	400	4425	6261	4843	16817	69	195	11	123	9	425
1	Targeted	24/06/2021	11:17:33	test 012	43.5236	172.64827	168	202	400	4062	5656	5812	13853	55	206	17	168	7	423
1	Targeted	24/06/2021	11:20:36	test 013	43.5235	172.64831	25	47	400	3559	6150	4140	12899	64	159	11	124	6	389
1	Targeted	24/06/2021	11:22:14	test 014	43.5235	172.64829	43	64	2005	3122	5864	3998	14628	76	168	7	130	12	320
1	Targeted	24/06/2021	11:23:52	test 015	43.5234	172.64849	378	202	2402	3616	5760	5649	12728	55	182	11	105	8	378
1	Targeted	24/06/2021	11:26:30	test 016	43.5235	172.64852	28	50	2065	3243	6361	4329	13266	72	161	14	127	6	400
1	Targeted	24/06/2021	11:27:43	test 017	43.5235	172.64853	62	78	2025	3684	6437	4605	13438	76	157	11	129	5	374
1	Targeted	24/06/2021	11:29:39	test 018	43.5237	172.64873	74	116	2456	4925	6361	4812	14596	75	178	17	147	7	391
1	Targeted	24/06/2021	11:30:47	test 019	43.5237	172.6487	472	338	3066	3908	6556	5451	17124	72	199	16	134	8	457
1	Targeted	24/06/2021	11:32:26	test 020	43.5237	172.64868	409	332	400	4101	5824	5569	15737	61	231	13	104	7	371
1	Targeted	24/06/2021	11:37:11	test 022	43.5237	172.64842	797	516	400	3256	5148	9621	15382	56	239	10	111	10	478
1	Targeted	24/06/2021	11:38:52	test 023	43.5237	172.64847	187	338	2365	4596	5333	10152	12866	57	178	13	99	7	321
1	Targeted	24/06/2021	11:41:02	test 024	43.5238	172.64862	255	296	2636	4221	5385	8607	12621	51	175	11	117	7	357
1	Targeted	24/06/2021	11:42:35	test 025	43.5241	172.6484	33	82	2991	3928	6771	4225	14068	74	179	15	137	6	369
1	Targeted	24/06/2021	11:43:51	test 026	43.5241	172.64856	414	974	3132	4185	6536	5376	17942	81	219	13	120	11	424
2	Targeted	24/06/2021	13:36:49	test 045	43.5255	172.65253	48	55	2856	3702	6349	3813	13248	69	162	15	151	6	410
2	Targeted	24/06/2021	13:38:22	test 046	43.5258	172.65258	35	117	1820	4200	7164	4126	12813	74	162	11	166	8	396
2	Targeted	24/06/2021	13:39:54	test 047	43.5257	172.65218	39	104	400	3297	5300	3570	10330	65	159	9	159	5	385
2	Targeted	24/06/2021	13:41:59	test 048	43.5257	172.65163	73	211	2328	3465	5577	4285	11430	67	149	13	133	6	383
2	Targeted	24/06/2021	13:44:06	test 049	43.5257	172.65126	153	225	400	3148	6179	4711	12242	59	166	11	125	9	386
2	Targeted	24/06/2021	13:46:58	test 050	43.525	172.65177	286	400	400	3775	5633	6331	14383	52	202	9	128	11	417
2	Targeted	24/06/2021	13:48:59	test 051	43.525	172.65215	3289	473	2701	3670	6450	5153	14999	68	179	5	134	8	479
2	Targeted	24/06/2021	13:50:37	test 052	43.525	172.65223	834	246	400	3918	6153	5142	13553	56	152	14	128	7	343
2	Targeted	24/06/2021	13:51:58	test 053	43.5249	172.65232	1563	482	2722	3988	6635	4909	15180	83	204	18	156	9	712
2	Targeted	24/06/2021	13:53:32	test 054	43.5251	172.65241	492	301	2957	3720	6572	5725	20544	63	347	12	141	11	419
2	Targeted	24/06/2021	13:55:30	test 055	43.5252	172.65257	361	236	2751	4980	8179	5575	17119	81	198	15	160	9	467
3	Targeted	24/06/2021	14:41:17	test 068	43.5244	172.65899	159	182	400	3491	6671	5012	12796	71	189	11	146	7	458
3	Targeted	24/06/2021	14:43:04	test 069	43.5246	172.65891	392	384	400	4510	6837	6677	13592	63	195	12	112	7	424
3	Targeted	24/06/2021	14:44:22	test 070	43.5246	172.65915	183	253	2425	4520	7046	4758	14424	66	193	12	123	7	364
3	Targeted	24/06/2021	14:45:40	test 071	43.5247	172.65926	499	421	2641	3973	7300	5607	16440	76	216	10	157	11	472
3	Targeted	24/06/2021	14:46:57	test 072	43.5247	172.65919	376	378	1922	5250	7637	6088	16160	79	207	15	159	5	383
3	Targeted	24/06/2021	14:49:22	test 073	43.5248	172.6593	392	196	2831	5179	7668	5055	17029	84	193	12	139	10	428
3	Targeted	24/06/2021	14:51:14	test 074	43.5248	172.65957	190	262	400	5056	7450	5031	15721	77	216	13	149	8	476
3	Targeted	24/06/2021	14:52:33	test 075	43.5247	172.65974	156	295	400	3957	6455	4957	12923	66	189	13	127	6	343
3	Targeted	24/06/2021	14:54:08	test 076	43.5247	172.6598	71	146	400	5056	6825	4540	11242	59	286	9	104	4	541
3	Targeted	24/06/2021	14:55:41	test 077	43.5244	172.65977	414	191	2944	5458	7658	5021	13861	70	233	13	112	9	508
3	Targeted	24/06/2021	14:57:03	test 078	43.5245	172.65995	222	189	400	4123	6917	4758	13761	66	215	13	125	6	472
3	Targeted	24/06/2021	14:58:51	test 079	43.5244	172.66011	224	94	400	5177	7106	4011	12366	75	197	11	128	7	487
3	Targeted	24/06/2021	15:01:52	test 080	43.5247	172.66021	76	270	400	4915	7794	4740	13121	70	190	13	118	6	413
3	Targeted	24/06/2021	15:03:45	test 081	43.5248	172.65997	97	191	2454	4453	6594	6635	12559	61	211	10	133	5	328
3	Targeted	24/06/2021	15:05:41	test 082	43.5249	172.65978	93	190	2223	4612	7176	4374	13562	79	201	10	168	5	465
3	Targeted	24/06/2021	15:07:22	test 083	43.525	172.65929	428	283	2494	3842	7129	5691	13716	69	205	16	146	6	455
3	Targeted	24/06/2021	15:09:29	test 084	43.5249	172.65899	66	112	400	3614	6313	4620	12135	63	180	9	153	8	398
3	Targeted	24/06/2021	15:11:25	test 085	43.5249	172.65877	680	389	4704	14385	8884	5462	16258	83	234	5	151	6	573
3	Targeted	24/06/2021	15:14:52	test 086	43.5245	172.65844	246	165					12666	64	221	11	131	7	521
3	Targeted	24/06/2021	15:15:30	test 087	43.5245	172.65842	170	128	400	5841	8430	6257	14883	72	186	13	151	5	426
3	Targeted	24/06/2021	15:17:33	test 088	43.5247	172.65816	22	67	2145	4493	7090	3627	12206	60	187	10	159	6	399
3	Targeted	24/06/2021	15:19:33	test 089	43.5249	172.65778	193	129	400	4292	5552	5191	13380	66	191	10	108	7	368
4	Targeted	5/07/2021	11:51:18	test 116	43.5185	172.66274	304	352	2760	4749	6348	7194	15272	67	184	14	124	6	423
4	Targeted	5/07/2021	11:53:22	test 117	43.5187	172.66266	33	76	400	4985	7275	4289	13108	74	195	10	116	7	428
4	Targeted	5/07/2021	11:55:19	test 118	43.5186	172.66265	90	71	400	4391	5835	5357	12300	64	172	9	130	5	418
4	Targeted	5/07/2021	11:56:37	test 119	43.5188	172.66285	37	109	2461	4715	5907	5206	10746	49	166	10	106	4	306
4	Targeted	5/07/2021	11:58:01	test 120	43.5188	172.66305	178	105	2484	4578	6266	4306	12954	76	207	14	124	7	389
4	Targeted	5/07/2021	11:59:44	test 121	43.5189	172.66335	198	283	400	4295	6587	5160	14008	82	214	9	122	8	479
4	Targeted	5/07/2021	12:01:04	test 122	43.5189	172.66332	80	158	400	4514	6572	5624	12876	71	192	12	120	5	363
4	Targeted	5/07/2021	12:02:14	test 123	43.5187	172.66344	149	212	400	6434	8161	7411	16354	92	242	16	158	6	450
4	Targeted	5/07/2021	12:03:08	test 124	43.5187	172.66349	103	137	1933	4506	7112	5135	13281	70	202	13	130	5	440
4	Targeted	5/07/2021	12:04:25	test 125	43.5186	172.66372	19	62	2024	4869	7068	4217	12775	64	191	10	132	7	406
4	Targeted	5/07/2021	12:05:32	test 126	43.5186	172.66376	235	199	400	6047	7424	4755	14800	80	222	17	149	8	800
4	Targeted	5/07/2021	12:07:30	test 127	43.5188	172.66379	498	238	4330	14416	6848	4892	12730	67	192	13	128	6	531
4	Targeted	5/07/2021	12:08:28	test 128	43.5187	172.6637	178	221	400	5309	6623	5462	11908	64	188	7	119	5	318
4	Targeted	5/07/2021	12:10:24	test 129	43.5189	172.66402	64	97	3059	6243	7491	4342	12484	78	246	10	109	6	511
4	Targeted	5/07/2021	12:11:45	test 130	43.519	172.66392	1678	478	2089	3947	6509	4913	12601	79	205	5	145	8	653
4	Targeted	5/07/2021	12:12:56	test 131	43.519	172.66389	30	63	2370	4383	6787	3732	13346	77	200	11	156	5	422
4	Targeted	5/07/2021	12:14:27	test 132	43.5191	172.6638	33	54	2493	4564	6974	4284	13862	65	242	16	151	5	464
4	Targeted	5/07/2021	12:15:43	test 133	43.5192	172.66361	97	132	3213	6039	7224	4796	13564	79	208	10	147	5	456
4	Targeted	5/07/2021	12:17:25	test 134	43.5193	172.66309	23	58	1913	4415	6669	4258	12670	74	183	14	145	5	391
4	Targeted	5/07/2021	12:20:29	test 136	43.5193	172.66264	309	238	1933	6094	6632	4564	14394	71	224	17	127	9	480
4	Targeted	5/07/2021	12:23:40	test 137	43.5198	172.66195	129	139	2690	4932	6649	5360	12685	64	192	12	144	7	340
4	Targeted	5/07/2021	12:25:08	test 138	43.5198	172.66179	996	1894	3377	3744	5632	12560	15739	63	217	5	124	7	324
4	Targeted	5/07/2021	12:28:17	test 139	43.5195	172.66195	126	248	400	3528	5499	5842	12492	60	190	8	110	4	344
4	Targeted	5/07/2021	12:31:35	test 140	43.5194	172.66203	17	133	400	3502	4091	8155	9106	44	161	7	87	5	283
4	Targeted	5/07/2021	12:33:12	test 141	43.5195	172.66206	186	280	400	4507	5650	10510	12228	65	216	10	131	4	376
4	Targeted	5/07/2021	12:35:07	test 142	43.5192	172.66218	18	66	3066	5888	7968	4260	15309	95	212	14	157	7	425
4	Targeted	5/07/2021	12:37:16	test 143	43.5189	172.66234	78	118	2409	3713	6516	5932	12620	76	205	15	109	6	389
4	Targeted	5/07/2021	12:39:02	test 144	43.5188	172.66209	64	217	400	5953	7242	4890	12488	70	205	10	100	6	397
4	Targeted	5/07/2021	12:42:55	test 145	43.5191	172.66263	44	101	3045	4962	6514	5490	12197	62	217	10	129	6	373
4	Targeted	5/07/2021	12:46:23	test 146	43.5184	172.66316	54	88	400	4294	6583	4600	12598	62	190	13	134	6	374
4	Targeted	5/07/2021	12:48:41	test 147	43.5179	172.66325	113	214	400	6074	7991	20338	17083	68	248	11	118	5	198
4	Targeted	5/07/2021	12:50:20	test 148	43.5179	172.6637	110	108	2033	4832	6267	5828	10785	55	157	6	95	7	339
4	Targeted	5/07/2021	12:51:42	test 149	43.5182	172.66386	56	269	6441	14632	7138	4654	13402	73	185	13	139	7	426
4	Targeted	5/07/2021	12:54:05	test 150	43.5185	172.66389	31	67	5099	8839	6901	4518	12365	63	183	14	131	5	422
5	Targeted	5/07/2021	13:40:53	test 171	43.5135	172.66469	38	51	400	3964	7043	4426	13415	70	171	15	126	8	424
5	Targeted	5/07/2021	13:44:08	test 172	43.5139	172.66529	76	224	2729	4785	4616	8377	10035	37	146	7	54	5	152
5	Targeted	5/07/2021	13:46:34	test 173	43.5142	172.66491	157	216	2151	2984	5449	5368	12822	63	160	10	108	5	323
5	Targeted	5/07/2021	13:47:42	test 174	43.514	172.66467	110	150	3240	4096	6650	5166	13774	73	197	14	128	5	462
5	Targeted	5/07/2021	13:48:48	test 175	43.5141	172.66449	225	158	2768	3850	6249	4138	14328	70	178	16	131	8	415
5	Targeted	5/07/2021	13:49:39	test 176	43.5141	172.66455	143	127	400	4294	6076	4649	14505	66	176	9	125	8	427
5	Targeted	5/07/2021	13:51:02	test 177	43.5141	172.66459	104	155	2049	3628	6802	4504	12676	75	186	10	120	7	419
5	Targeted	5/07/2021	13:52:21	test 178	43.5144	172.66431	47	58	2710	4406	6266	4668	11854	66	184	12	124	8	370
5	Targeted	5/07/2021	13:53:44	test 179	43.5145	172.66421	60	110	2280	3312	4943	5808	10381	54	148	11	86	5	280
5	Targeted	5/07/2021	13:55:00	test 180	43.5146	172.66419	362	489	2127	3679	5439	5887	16472	62	176	16	136	5	571
5	Targeted	5/07/2021	13:56:17	test 181	43.5146	172.66424	90	96	400	3871	6768	5329	14479	73	193	14	133	5	420
5	Targeted	5/07/2021	13:57:45	test 182	43.5148	172.66435	29	77	2629	4660	5907	4231	12828	62	225	11	126	10	460
5	Targeted	5/07/2021	13:58:45	test 183	43.5148	172.66446	40	117	2687	3714	5679	4923	11860	61	188	9	76	7	402
5	Targeted	5/07/2021	14:00:09	test 184	43.5148	172.66465	289	318	1782	3597	5453	16420	12302	62	208	11	107	6	473
5	Targeted	5/07/2021	14:01:18	test 185	43.5149	172.66486	40	127	400	4074	6996	4249	14359	77	227	13	145	7	453
5	Targeted	5/07/2021	14:02:27	test 186	43.5148	172.66514	96	161	2493	4782	7345	9354	16165	87	250	13	138	8	369
5	Targeted	5/07/2021	14:03:47	test 187	43.5149	172.66521	50	86	400	4717	6083	4504	14783	68	213	13	123	5	409
5	Targeted	5/07/2021	14:05:21	test 188	43.5149	172.66565	29	98	400	3926	5620	4504	11375	65	186	8	133	6	461
5	Targeted	5/07/2021	14:06:20	test 189	43.5149	172.66563	37	184	2094	3738	5166	11024	11155	64	199	8	104	5	261
5	Targeted	5/07/2021	14:08:30	test 190	43.5144	172.66468	316	223	400	4193	6043	5047	12887	73	180	11	103	7	428
6	Targeted	8/07/2021	11:33:35	test 223	43.5211	172.66582	120	134	1883	2945	4550	5191	10343	61	165	8	108	6	443
6	Targeted	8/07/2021	11:35:04	test 224	43.5211	172.66578	90	97	2164	3639	5938	4357	13505	73	172	12	110	5	371
6	Targeted	8/07/2021	11:36:38	test 225	43.5212	172.66583	238	243	2347	3767	5879	4992	13188	54	161	12	121	5	367
6	Targeted	8/07/2021	11:37:45	test 226	43.5214	172.66583	120	200	2199	2936	5494	4782	12613	51	144	13	115	7	353
6	Targeted	8/07/2021	11:39:10	test 227	43.5214	172.66584	169	224	2120	3065	6092	4429	12613	63	157	8	115	7	396
6	Targeted	8/07/2021	11:40:26	test 228	43.5216	172.66564	124	161	2087	3654	6166	4862	13555	66	187	9	143	4	408
6	Targeted	8/07/2021	11:41:31	test 229	43.5216	172.6656	135	173	2543	4084	5560	4827	10768	57	213	14	115	7	484
6	Targeted	8/07/2021	11:43:27	test 230	43.5216	172.66561	68	90	1840	3116	4914	13286	10041	47	245	10	82	7	452
6	Targeted	8/07/2021	11:45:10	test 231	43.5215	172.66554	284	1464	400	2961	5116	4335	10902	56	149	11	97	5	400
6	Targeted	8/07/2021	11:46:19	test 232	43.5216	172.66549	123	348	3344	3282	4815	4845	11048	56	154	8	97	4	296
6	Targeted	8/07/2021	11:48:17	test 233	43.5215	172.66544	402	247	3734	2967	5668	5997	11948	63	176	12	116	5	413
6	Targeted	8/07/2021	11:49:54	test 234	43.5216	172.66534	52	110	2070	3119	5146	7471	11236	48	161	9	98	5	348
6	Targeted	8/07/2021	11:50:52	test 235	43.5216	172.6653	136	93	400	3080	5411	5726	11697	55	142	9	98	6	278
6	Targeted	8/07/2021	11:51:54	test 236	43.5216	172.66528	137	153	1866	3487	6472	5708	13893	69	198	12	128	8	433
6	Targeted	8/07/2021	11:53:22	test 237	43.5216	172.66525	57	132	400	3451	5773	4888	11921	59	143	17	114	5	311
6	Targeted	8/07/2021	11:55:59	test 238	43.5216	172.66512	149	113	400	3235	5981	5413	14277	62	168	12	116	10	348
6	Targeted	8/07/2021	11:57:36	test 239	43.5215	172.66513	177	204	400	3614	5188	5186	12080	55	125	10	98	6	356
6	Targeted	8/07/2021	11:59:22	test 240	43.5214	172.66514	265	194	2219	2791	5205	4629	16347	52	166	15	122	5	357
6	Targeted	8/07/2021	12:01:09	test 241	43.5212	172.66518	160	236	2364	3505	6458	4956	19062	75	166	13	120	9	401
6	Targeted	8/07/2021	12:02:12	test 242	43.5212	172.66527	135	174	2309	3838	5995	4390	13790	61	145	9	113	8	343
6	Targeted	8/07/2021	12:03:28	test 243	43.5211	172.66513	71	149	2328	4353	5171	3757	13041	56	135	11	123	6	330
6	Targeted	8/07/2021	12:05:43	test 244	43.521	172.66542	186	213	400	2783	4431	4648	11571	38	131	15	80	5	310
6	Targeted	8/07/2021	12:07:03	test 245	43.521	172.66554	220	231	1969	2929	5165	6133	19072	56	201	13	103	9	337
7	Targeted	8/07/2021	12:43:36	test 257	43.5173	172.66541	183	165	2515	4052	6470	5663	12408	69	170	15	130	5	363
7	Targeted	8/07/2021	12:44:56	test 258	43.5174	172.66544	154	138	3221	3621	6234	4407	13349	67	158	10	137	5	384
7	Targeted	8/07/2021	12:46:35	test 259	43.5174	172.66553	143	134	2259	3664	6962	5116	13748	81	182	10	157	7	407
7	Targeted	8/07/2021	12:48:28	test 260	43.5176	172.66551	690	419	3097	4492	5985	8983	14545	64	220	11	139	6	448
7	Targeted	8/07/2021	12:50:23	test 261	43.5176	172.66546	2361	356	2038	3486	5436	7215	12953	58	208	5	107	11	385
7	Targeted	8/07/2021	12:51:31	test 262	43.5176	172.66542	445	377	2854	4941	5919	6986	14119	68	202	5	124	8	350
7	Targeted	8/07/2021	12:52:26	test 263	43.5176	172.66537	352	251	400	4271	5769	6743	11733	55	169	8	102	4	410
7	Targeted	8/07/2021	12:53:41	test 264	43.5176	172.6654	425	348	400	4264	5555	7581	13815	57	208	12	141	7	380
7	Targeted	8/07/2021	12:55:15	test 265	43.5177	172.66529	264	176	2869	4366	6213	5190	12948	64	169	12	139	9	369
7	Targeted	8/07/2021	12:56:07	test 266	43.5176	172.66528	247	170	2308	4469	6390	5045	12639	65	185	10	158	4	416
7	Targeted	8/07/2021	12:57:47	test 267	43.5178	172.6652	189	144	400	3421	6005	5962	13867	57	173	12	143	5	375
7	Targeted	8/07/2021	12:59:05	test 268	43.5179	172.66546	45	94	2722	3808	5477	7463	8160	59	160	6	124	4	366
7	Targeted	8/07/2021	13:00:19	test 269	43.5179	172.66562	287	164	400	4041	6716	5492	14265	67	175	8	115	6	390
7	Targeted	8/07/2021	13:03:05	test 270	43.518	172.66552	515	275	2599	4056	6730	5171	14324	79	175	16	130	7	393
7	Targeted	8/07/2021	13:05:43	test 271	43.5181	172.66532	409	249	400	3348	5247	7942	13543	58	180	16	106	5	325
7	Targeted	8/07/2021	13:08:12	test 272	43.5181	172.66532	667	368	400	3476	5738	7687	11644	55	166	10	100	5	454
7	Targeted	8/07/2021	13:10:30	test 273	43.5181	172.66529	385	162	2649	4779	7361	5580	14106	78	204	12	130	7	469
7	Targeted	8/07/2021	13:11:29	test 274	43.518	172.66517	176	104	2602	2965	6118	6227	12203	65	164	11	140	7	413
7	Targeted	8/07/2021	13:14:50	test 275	43.5178	172.66501	69	75	2228	3966	6963	3989	13570	72	178	12	130	7	399
8	Targeted	8/07/2021	14:07:21	test 288	43.5172	172.67648	32	78	400	5700	7641	4433	14237	83	204	13	188	7	469
8	Targeted	8/07/2021	14:08:44	test 289	43.5172	172.67649	139	218	2675	3880	4681	8328	10013	48	192	7	94	6	331
8	Targeted	8/07/2021	14:09:48	test 290	43.5172	172.67646	5	73	400	5792	6626	4226	11157	65	219	14	120	7	432
8	Targeted	8/07/2021	14:10:59	test 291	43.5173	172.6766	60	164	1918	3717	5842	11421	11334	62	197	13	132	5	334
8	Targeted	8/07/2021	14:11:54	test 292	43.5172	172.67655	29	228	400	5507	6554	11069	8570	58	234	9	146	6	417
8	Targeted	8/07/2021	14:13:54	test 293	43.5173	172.67666	112	388	400	3908	5389	5625	11850	54	174	10	133	7	350
8	Targeted	8/07/2021	14:15:02	test 294	43.5175	172.67655	30	96	400	4241	6973	4520	15560	75	187	14	147	5	395
8	Targeted	8/07/2021	14:15:57	test 295	43.5174	172.67655	5	70	2305	3700	5942	4043	13460	68	170	11	130	8	364
8	Targeted	8/07/2021	14:17:09	test 296	43.5175	172.67635	5	73	400	4270	6774	4345	11336	70	210	12	133	7	424
8	Targeted	8/07/2021	14:18:28	test 297	43.5175	172.67615	36	91	2354	3827	6651	4985	15718	84	188	16	160	5	387
8	Targeted	8/07/2021	14:20:18	test 298	43.5174	172.67622	140	433	2683	5208	7187	4804	16212	87	197	14	169	7	390
8	Targeted	8/07/2021	14:23:06	test 299	43.5176	172.67663	67	795	3639	7227	4435	6530	12627	43	160	12	83	4	286
8	Targeted	8/07/2021	14:24:06	test 300	43.5176	172.6767	25	143	5795	12817	4778	6272	9660	54	141	8	93	5	295
8	Targeted	8/07/2021	14:25:53	test 301	43.5175	172.67683	33	93	2495	4822	5084	6258	10592	63	144	13	117	6	281

Site	Sample Type	Date	Time	Notes	Latitude	Longitude	Pb	Zn	Al	Si	K	Ca	Fe	Rb	Sr	Y	Zr	Nb	Ba
1	Transect	24/06/2021	13:04:49	test 027	-43.5238	172.64704	5	161	2350	2996	3320	6244	4802	42	104	6	77	5	251
1	Transect	24/06/2021	13:06:07	test 028	-43.5238	172.6471	19	66	400	2925	5968	4028	12454	64	143	11	122	8	327
1	Transect	24/06/2021	13:07:08	test 029	-43.5238	172.64719	5	51	400	3491	6498	4178	12721	68	142	10	109	5	313
1	Transect	24/06/2021	13:08:12	test 030	-43.5238	172.64728	18	60	2563	2897	5674	4235	12710	60	145	8	105	6	247
1	Transect	24/06/2021	13:09:22	test 031	-43.5238	172.64735	16	49	2311	3005	5320	4236	10221	50	122	8	91	5	228
1	Transect	24/06/2021	13:10:20	test 032	-43.5239	172.64741	129	98	2175	3330	5372	4318	12287	58	148	14	116	4	314
1	Transect	24/06/2021	13:11:31	test 033	-43.5239	172.64749	58	78	1976	3271	6253	4416	13343	66	158	13	120	7	343
1	Transect	24/06/2021	13:12:34	test 034	-43.5238	172.64767	26	76	1847	3093	5793	4135	11490	60	150	12	107	5	283
1	Transect	24/06/2021	13:13:46	test 035	-43.5239	172.64783	51	115	3285	3284	6224	4742	12353	65	130	7	104	8	325
1	Transect	24/06/2021	13:14:54	test 036	-43.5239	172.6479	108	91	2814	3277	6579	4381	11313	53	135	11	106	6	302
1	Transect	24/06/2021	13:16:10	test 037	-43.5239	172.64802	71	170	2856	3167	5650	4324	11706	52	156	11	120	5	333
1	Transect	24/06/2021	13:17:10	test 038	-43.5239	172.64809	34	74	2561	3274	5707	4238	10938	58	137	14	91	4	342
1	Transect	24/06/2021	13:18:14	test 039	-43.5239	172.6482	5	66	2151	3390	5823	4168	11426	60	153	10	109	7	260
1	Transect	24/06/2021	13:19:27	test 040	-43.5239	172.64831	5	61	1963	3447	5742	4502	12107	61	128	10	98	7	259
1	Transect	24/06/2021	13:21:20	test 041	-43.5239	172.64851	52	69	2810	3390	5511	4289	10000	50	116	12	86	5	244
1	Transect	24/06/2021	13:22:19	test 042	-43.5239	172.64861	5	56	2118	3436	5830	3890	11341	55	121	11	92	6	300
1	Transect	24/06/2021	13:23:52	test 043	-43.5239	172.64871	5	68	2611	4503	6424	4109	13790	81	159	17	121	6	315
1	Transect	24/06/2021	13:25:14	test 044	-43.5239	172.64883	5	66	2907	4428	7345	5108	11172	60	152	10	93	5	353
2	Transect	24/06/2021	13:57:30	test 056	-43.5253	172.65257	73	118	2216	4058	6306	4375	10875	57	140	9	106	5	321
2	Transect	24/06/2021	13:58:46	test 057	-43.5253	172.65245	5	110	400	3388	4744	4320	6565	35	104	9	81	4	268
2	Transect	24/06/2021	14:00:41	test 058	-43.5253	172.65232	23	131	1594	3918	5093	4425	8389	35	92	5	67	5	167
2	Transect	24/06/2021	14:02:02	test 059	-43.5253	172.65218	26	107	2871	3920	4852	4533	6385	35	95	11	79	5	231
2	Transect	24/06/2021	14:03:14	test 060	-43.5253	172.65205	49	117	2775	4269	6232	4861	12101	67	152	13	138	7	388
2	Transect	24/06/2021	14:04:39	test 061	-43.5253	172.65195	40	83	400	3713	5612	4401	9312	42	114	8	90	5	263
2	Transect	24/06/2021	14:05:30	test 062	-43.5253	172.6518	36	136	400	4677	5177	5280	10589	57	160	9	109	6	367
2	Transect	24/06/2021	14:08:55	test 063	-43.5253	172.65172	47	93	3057	3371	5891	4147	10398	52	138	8	124	5	290
2	Transect	24/06/2021	14:09:59	test 064	-43.5254	172.65171	24	68	1926	3481	5878	3881	9836	51	129	8	105	6	259
2	Transect	24/06/2021	14:11:05	test 065	-43.5254	172.65155	22	48	400	4053	6003	3503	10393	62	158	9	143	6	303
2	Transect	24/06/2021	14:12:26	test 066	-43.5253	172.65146	5	77	3254	3549	5777	4042	10173	71	163	9	144	6	432
2	Transect	24/06/2021	14:13:29	test 067	-43.5254	172.65135	27	89	400	3712	5838	4200	11318	65	158	5	138	5	389
3	Transect	24/06/2021	15:21:06	test 090	-43.5249	172.65766	270	150	2387	4424	6916	6752	13756	73	207	15	127	9	444
3	Transect	24/06/2021	15:23:10	test 091	-43.5246	172.65732	80	109	3364	4277	5563	4827	13217	59	149	12	110	7	256
3	Transect	24/06/2021	15:24:37	test 092	-43.5246	172.65744	106	115	2827	5610	7842	5181	11553	64	136	11	115	7	399
3	Transect	24/06/2021	15:26:06	test 093	-43.5246	172.65751	108	113	400	4752	7851	4725	15118	86	176	14	153	10	474
3	Transect	24/06/2021	15:27:13	test 094	-43.5246	172.65769	35	101	2383	4002	6239	4930	11958	72	172	11	149	8	293
3	Transect	24/06/2021	15:28:39	test 095	-43.5246	172.65784	26	87	400	3578	6501	3969	12068	66	153	12	142	6	351
3	Transect	24/06/2021	15:30:32	test 096	-43.5246	172.65797	26	80	400	3892	5155	5360	9698	58	123	8	129	5	380
3	Transect	24/06/2021	15:31:52	test 097	-43.5246	172.65811	5	112	400	4495	6530	5266	11845	68	146	14	129	7	393
3	Transect	24/06/2021	15:33:26	test 098	-43.5247	172.65837	33	80	2401	3788	6455	3982	9958	61	142	10	143	5	367
3	Transect	24/06/2021	15:35:26	test 099	-43.5246	172.65844	54	122	2385	4350	6724	4648	10669	56	134	10	118	5	307
3	Transect	24/06/2021	15:36:49	test 100	-43.5246	172.65863	31	90	2045	4269	5988	5091	8968	67	140	8	117	7	385
3	Transect	24/06/2021	15:38:03	test 101	-43.5246	172.65878	53	111	400	4095	6761	4456	11915	67	150	10	130	5	344
3	Transect	24/06/2021	15:39:32	test 102	-43.5246	172.65893	28	132	400	4070	6133	5277	8657	55	121	9	94	6	346
3	Transect	24/06/2021	15:40:53	test 103	-43.5247	172.65905	218	350	2301	4497	6669	5399	13453	57	172	14	129	4	352
3	Transect	24/06/2021	15:48:04	test 104	-43.5247	172.65915	108	356	400	4438	6217	5785	11292	53	127	8	96	5	209
3	Transect	24/06/2021	15:49:24	test 105	-43.5247	172.65929	61	188	1908	3843	4957	5494	10207	53	128	11	107	4	291
3	Transect	24/06/2021	15:51:19	test 106	-43.5246	172.65939	68	220	2896	4570	5880	6677	9639	76	144	5	134	7	339
3	Transect	24/06/2021	15:52:58	test 107	-43.5246	172.65939	51	113	2840	3991	5558	4325	10668	69	164	8	106	7	375
3	Transect	24/06/2021	15:54:26	test 108	-43.5246	172.65953	143	159	2049	3837	6219	4605	11189	53	158	12	124	6	378
3	Transect	24/06/2021	15:55:38	test 109	-43.5246	172.65965	125	154	400	4730	7410	5552	13951	63	186	11	127	6	346
3	Transect	24/06/2021	15:58:00	test 110	-43.5246	172.65972	931	690	2765	5594	8303	7495	17932	84	217	11	151	15	390
3	Transect	24/06/2021	15:59:08	test 111	-43.5246	172.65982	60	110	400	3350	6878	4359	12774	74	168	8	157	9	411
3	Transect	24/06/2021	16:00:13	test 112	-43.5246	172.65996	29	83	2130	4151	6837	3560	13581	84	156	15	160	11	427
3	Transect	24/06/2021	16:01:31	test 113	-43.5247	172.66005	56	81	400	3899	6215	4717	12358	82	149	5	134	10	380
3	Transect	24/06/2021	16:02:53	test 114	-43.5247	172.66018	118	258	400	5163	7722	4528	15927	79	193	19	118	5	388
3	Transect	24/06/2021	16:03:51	test 115	-43.5247	172.66021	135	107	1975	3698	6161	5025	12541	60	173	9	107	6	392
4	Transect	5/07/2021	12:57:48	test 151	-43.5194	172.66339	59	50	4604	10686	7556	4494	14495	83	178	15	146	6	398
4	Transect	5/07/2021	12:58:52	test 152	-43.5194	172.66336	18	53	2308	4981	6038	5052	10410	62	179	8	81	8	395
4	Transect	5/07/2021	13:00:34	test 153	-43.5194	172.6633	16	63	2388	6299	5527	5394	9117	53	153	5	62	6	326
4	Transect	5/07/2021	13:01:29	test 154	-43.5193	172.66327	20	43	2526	4955	6308	5001	11363	61	173	11	98	6	387
4	Transect	5/07/2021	13:02:29	test 155	-43.5192	172.66324	21	40	6952	11931	6217	5043	11148	67	167	12	87	6	393
4	Transect	5/07/2021	13:03:32	test 156	-43.5192	172.66316	21	62	3894	6194	4585	5783	8250	59	159	5	76	5	375
4	Transect	5/07/2021	13:04:28	test 157	-43.519	172.66315	20	56	2298	3951	5147	5832	10214	60	166	7	73	4	368
4	Transect	5/07/2021	13:05:22	test 158	-43.519	172.66316	17	52	2235	4041	5627	4377	10661	65	184	12	83	4	368
4	Transect	5/07/2021	13:06:13	test 159	-43.519	172.66311	5	59	1875	3389	4894	4831	10273	56	160	6	82	6	316
4	Transect	5/07/2021	13:07:21	test 160	-43.5189	172.66302	25	72	4164	6594	6330	4729	12095	64	173	9	89	7	341
4	Transect	5/07/2021	13:08:17	test 161	-43.5189	172.66294	20	117	3066	4042	5648	5984	12042	60	201	13	108	5	412
4	Transect	5/07/2021	13:09:13	test 162	-43.5189	172.66281	32	61	3050	6573	6577	4857	13461	63	181	7	92	4	402
4	Transect	5/07/2021	13:10:13	test 163	-43.5188	172.66275	27	97	3155	5713	5523	4118	12521	55	183	12	108	6	368
4	Transect	5/07/2021	13:11:17	test 164	-43.5187	172.66269	96	150	2005	4379	5499	5649	10427	53	157	8	86	5	336
4	Transect	5/07/2021	13:12:23	test 165	-43.5187	172.6626	35	82	4234	6982	4991	3989	9775	49	142	6	80	5	257
4	Transect	5/07/2021	13:13:56	test 166	-43.5186	172.6625	34	60	5075	7832	4936	4076	10042	46	117	9	80	4	191
4	Transect	5/07/2021	13:15:00	test 167	-43.5186	172.66243	34	76	3696	5287	6599	4759	10794	50	138	8	87	5	244
4	Transect	5/07/2021	13:16:46	test 168	-43.5185	172.66236	5	49	400	3354	4933	4380	8079	44	94	5	60	4	179
4	Transect	5/07/2021	13:17:48	test 169	-43.5185	172.66232	22	59	1921	3361	4941	3920	11177	60	142	8	92	6	287
4	Transect	5/07/2021	13:19:03	test 170	-43.5185	172.66227	32	48	2340	3663	6235	5160	12266	66	162	11	117	6	344
5	Transect	5/07/2021	14:10:38	test 191	-43.5136	172.66471	22	46	400	4195	5692	4199	12095	67	209	12	85	6	403
5	Transect	5/07/2021	14:11:48	test 192	-43.5137	172.6649	26	137	2681	3088	6147	4160	12801	69	190	13	135	7	403
5	Transect	5/07/2021	14:12:56	test 193	-43.5136	172.66509	34	120	3829	2975	6078	4819	13835	75	173	16	133	8	407
5	Transect	5/07/2021	14:14:22	test 194	-43.5134	172.66496	5	85	400	4306	6642	3776	12924	76	166	14	169	5	382
5	Transect	5/07/2021	14:15:42	test 195	-43.5134	172.66473	78	170	400	4517	5579	9704	12872	60	188	12	98	6	281
5	Transect	5/07/2021	14:16:42	test 196	-43.5134	172.66463	35	153	2740	3359	4812	7566	10634	59	151	8	85	6	241
5	Transect	5/07/2021	14:18:14	test 197	-43.5137	172.6646	103	84	400	4030	6539	4628	12993	68	166	13	101	6	423
5	Transect	5/07/2021	14:19:03	test 198	-43.5138	172.66455	145	84	400	5358	6467	4334	15308	89	200	11	133	11	365
5	Transect	5/07/2021	14:21:07	test 199	-43.5146	172.66452	251	251	2537	4333	5598	3958	13067	71	189	10	110	7	422
5	Transect	5/07/2021	14:23:26	test 200	-43.5148	172.6644	121	224	400	5931	6751	5711	12190	63	172	5	93	5	403
5	Transect	5/07/2021	14:26:15	test 201	-43.5149	172.66438	329	304	400	3425	5382	5511	12676	66	168	14	108	5	340
5	Transect	5/07/2021	14:27:11	test 202	-43.5149	172.6645	207	164	400	2883	5161	5668	9780	52	140	9	76	5	338
5	Transect	5/07/2021	14:28:01	test 203	-43.5148	172.66456	299	168	1977	2830	5222	4810	9885	51	148	12	78	4	325
5	Transect	5/07/2021	14:29:14	test 204	-43.5147	172.66455	287	177	400	3297	5521	5275	10834	54	164	8	81	5	383
5	Transect	5/07/2021	14:30:23	test 205	-43.5146	172.66454	611	411	2496	4128	5142	7807	11154	49	158	9	68	5	315
5	Transect	5/07/2021	14:31:18	test 206	-43.5145	172.66453	110	125	400	4580	5791	5457	11593	64	190	10	102	5	375
5	Transect	5/07/2021	14:32:19	test 207	-43.5145	172.66459	51	59	3316	4677	6386	5014	11622	58	170	10	98	6	374
5	Transect	5/07/2021	14:33:27	test 208	-43.5144	172.66466	78	100					11352	65	166	9	86	4	360
5	Transect	5/07/2021	14:34:11	test 209	-43.5143	172.66468	94	111	2212	4321	6088	5379	11960	57	166	14	109	5	387
5	Transect	5/07/2021	14:35:06	test 210	-43.5143	172.66467	5	144	400	4100	4735	7079	9906	44	175	10	67	5	301
5	Transect	5/07/2021	14:35:53	test 211	-43.5142	172.66465	5	55	1932	3808	6184	4376	11294	63	170	8	90	4	422
5	Transect	5/07/2021	14:36:50	test 212	-43.5141	172.66469	28	49	2761	3950	5043	5551	10189	59	168	7	75	6	338
5	Transect	5/07/2021	14:37:47	test 213	-43.5141	172.66473	17	47	2511	3907	5534	4663	10073	67	187	8	92	5	416
5	Transect	5/07/2021	14:38:42	test 214	-43.514	172.66476	17	80	400	4265	5578	4756	10906	52	141	8	75	5	148
5	Transect	5/07/2021	14:39:35	test 215	-43.5139	172.66481	62	102	2543	4337	5599	5077	11490	54	136	5	72	6	232
5	Transect	5/07/2021	14:40:32	test 216	-43.5138	172.66477	33	130	2462	3537	4097	6202	9189	52	158	6	67	3	351
5	Transect	5/07/2021	14:41:23	test 217	-43.5138	172.66479	108	88	2524	3990	5520	4826	11370	62	171	13	75	7	316
5	Transect	5/07/2021	14:42:17	test 218	-43.5137	172.66477	5	77	3278	3166	3306	6644	6412	47	142	6	66	5	337
5	Transect	5/07/2021	14:43:33	test 219	-43.5136	172.66482	68	77	2422	5181	6379	6159	12671	62	160	5	109	5	321
5	Transect	5/07/2021	14:44:45	test 220	-43.5135	172.66479	32	85	400	4205	5078	6374	9438	50	140	5	79	4	329
5	Transect	5/07/2021	14:45:45	test 221	-43.5134	172.66481	110	164	400	5527	6570	5667	13945	73	175	12	122	6	329
5	Transect	5/07/2021	14:46:52	test 222	-43.5134	172.66481	94	411	400	2921	4373	5392	7247	34	97	7	65	3	211
6	Transect	8/07/2021	12:09:04	test 246	-43.5215	172.66576	132	105	2379	3201	5350	4417	9292	53	143	6	93	5	355
6	Transect	8/07/2021	12:10:00	test 247	-43.5214	172.66572	148	143	2618	3951	4468	6487	8292	46	142	8	86	3	277
6	Transect	8/07/2021	12:11:06	test 248	-43.5214	172.66568	81	81	2641	2916	8977	3728	438	19	55	6	44	5	190
6	Transect	8/07/2021	12:13:38	test 249	-43.5215	172.66564	60	75	400	3358	5053	4365	10118	63	160	10	99	7	297
6	Transect	8/07/2021	12:14:36	test 250	-43.5215	172.6656	157	86	2017	3075	4162	4180	7355	50	133	8	83	5	327
6	Transect	8/07/2021	12:16:20	test 251	-43.5215	172.66552	61	55	3011	2993	5589	2497	1999	30	75	6	55	5	231
6	Transect	8/07/2021	12:18:00	test 252	-43.5215	172.66542	20	48	2379	2448	1855	2404	1953	14	40	4	28	5	123
6	Transect	8/07/2021	12:19:09	test 253	-43.5215	172.66531	22	45	2427	2552	1366	2661	1589	10	31	5	24	5	144
6	Transect	8/07/2021	12:20:13	test 254	-43.5215	172.66525	5	42	2004	2052	1416	1922	573	5	12	5	7	5	86
6	Transect	8/07/2021	12:21:40	test 255	-43.5215	172.6652	5	44	2359	2870	3104	2289	1528	7	31	5	22	5	84
6	Transect	8/07/2021	12:23:33	test 256	-43.5215	172.66515	62	107	2211	3001	3552	3173	3908	23	58	5	24	5	141
7	Transect	8/07/2021	13:16:26	test 276	-43.5176	172.66477	27	76	400	4282	5821	4841	9550	58	162	11	154	5	380
7	Transect	8/07/2021	13:17:31	test 277	-43.5177	172.66484	48	48	1881	5461	5841	4045	10806	57	145	9	128	5	306
7	Transect	8/07/2021	13:18:33	test 278	-43.5177	172.66485	76	98	2750	3871	6013	4245	10319	54	145	11	130	7	339
7	Transect	8/07/2021	13:19:57	test 279	-43.5177	172.66493	148	129					11949	69	180	10	130	5	387
7	Transect	8/07/2021	13:20:35	test 280	-43.5177	172.66504	134	115	400	4851	6412	4712	13586	79	201	12	167	7	389
7	Transect	8/07/2021	13:21:26	test 281	-43.5176	172.66508	52	90	400	3450	5932	4483	11035	65	155	12	118	6	357
7	Transect	8/07/2021	13:22:38	test 282	-43.5177	172.66512	411	222	2384	4089	5839	5598	11893	74	181	14	124	5	366
7	Transect	8/07/2021	13:23:41	test 283	-43.5177	172.66521	117	76	3101	3591	5310	5851	10863	50	159	12	99	5	383
7	Transect	8/07/2021	13:24:57	test 284	-43.5177	172.66532	361	286	2165	5083	5744	5647	12503	57	166	14	117	5	374
7	Transect	8/07/2021	13:26:01	test 285	-43.5177	172.6654	30	68	2860	7085	5468	3516	10181	50	131	10	121	5	295
7	Transect	8/07/2021	13:27:17	test 286	-43.5177	172.66538	96	121	400	4043	4678	5046	10488	56	149	8	111	5	333
7	Transect	8/07/2021	13:28:23	test 287	-43.5177	172.66549	48	109	2493	4155	7208	3369	645	8	54	5	20	5	147
8	Transect	8/07/2021	14:27:35	test 302	-43.5173	172.67683	34	67	3081	7963	7066	4914	12154	71	184	12	149	5	403
8	Transect	8/07/2021	14:30:30	test 304	-43.5173	172.67669	26	76	2537	3906	5441	5783	11884	54	161	11	109	4	307
8	Transect	8/07/2021	14:31:25	test 305	-43.5174	172.67661	142	320	8145	11866	4443	5445	6681	40	112	5	75	5	320
8	Transect	8/07/2021	14:32:30	test 306	-43.5174	172.67654	65	134	3350	5551	6514	5257	14080	65	200	16	160	12	384
8	Transect	8/07/2021	14:33:24	test 307	-43.5173	172.67646	26	69	4890	8194	5152	5470	11240	58	163	15	127	5	400
8	Transect	8/07/2021	14:34:18	test 308	-43.5174	172.67642	52	108	2471	5916	6379	5584	13153	59	177	15	146	5	359
8	Transect	8/07/2021	14:35:52	test 309	-43.5174	172.67638	29	87	2058	5583	6817	6131	12696	65	176	13	124	6	392
8	Transect	8/07/2021	14:36:44	test 310	-43.5174	172.67633	36	72	2202	5364	6072	4490	12263	58	162	10	115	4	376
8	Transect	8/07/2021	14:37:35	test 311	-43.5174	172.67629	24	43	2725	4125	5551	4247	11887	55	158	10	140	4	437
8	Transect	8/07/2021	14:38:35	test 312	-43.5175	172.67617	19	47	2392	4588	5258	5436	9336	63	137	9	119	6	425
8	Transect	8/07/2021	14:39:23	test 313	-43.5173	172.67622	5	59	3030	6530	6612	6130	13999	71	173	14	125	6	355

Appendix B: Cleaned data for IBM SPSS Statistics Analysis



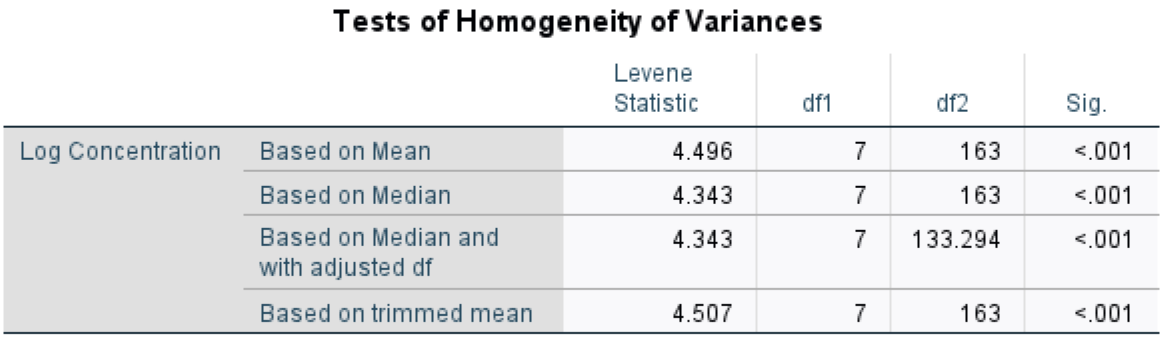
Appendix C: Results From IBM SPSS Statistics Analysis



Descriptives

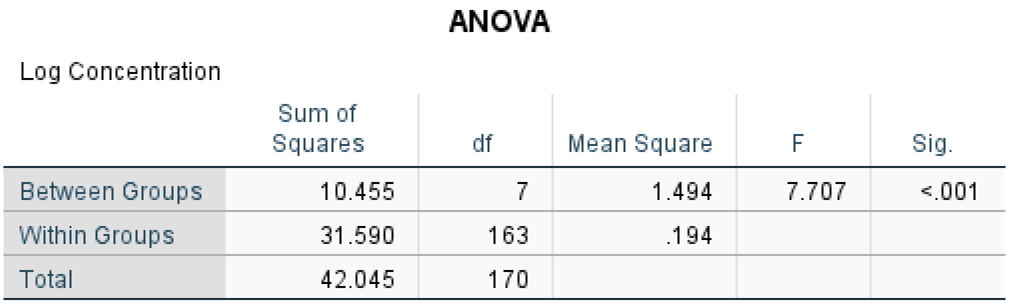
Log Concentration

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	28	1.983877930	.5300744402	.1001746532	1.778336520	2.189419340	1.301029996	2.901458321
2	11	2.382037765	.6706330660	.2022034774	1.931500341	2.832575190	1.544068044	3.517063873
3	22	2.269517070	.3554743401	.0757873840	2.111908577	2.427125563	1.342422681	2.832508913
4	34	1.970445948	.4775020295	.0818909225	1.803837614	2.137054283	1.230448921	3.224791956
5	20	1.926229274	.3536065269	.0790688232	1.760736325	2.091722223	1.462397998	2.558708571
6	23	2.143694493	.2219715994	.0462842780	2.047706776	2.239682211	1.716003344	2.604226053
7	19	2.455783183	.3809007288	.0873846202	2.272194909	2.639371458	1.653212514	3.373095987
8	14	1.496923043	.5005374240	.1337742536	1.207921339	1.785924748	.6989700043	2.146128036
Total	171	2.070888287	.4973175797	.0380308258	1.995814802	2.145961773	.6989700043	3.517063873



Tests of Homogeneity of Variances

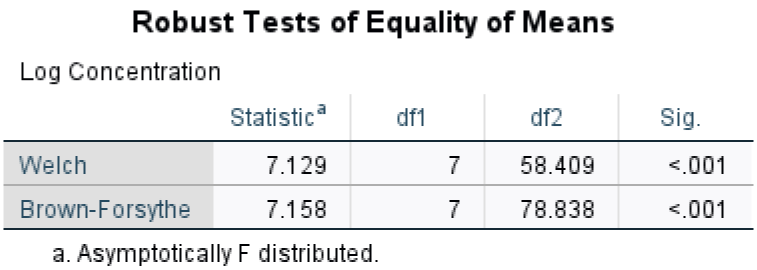
		Levene Statistic	df1	df2	Sig.
Log Concentration	Based on Mean	4.496	7	163	<.001
	Based on Median	4.343	7	163	<.001
	Based on Median and with adjusted df	4.343	7	133.294	<.001
	Based on trimmed mean	4.507	7	163	<.001



ANOVA

Log Concentration

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10.455	7	1.494	7.707	<.001
Within Groups	31.590	163	.194		
Total	42.045	170			

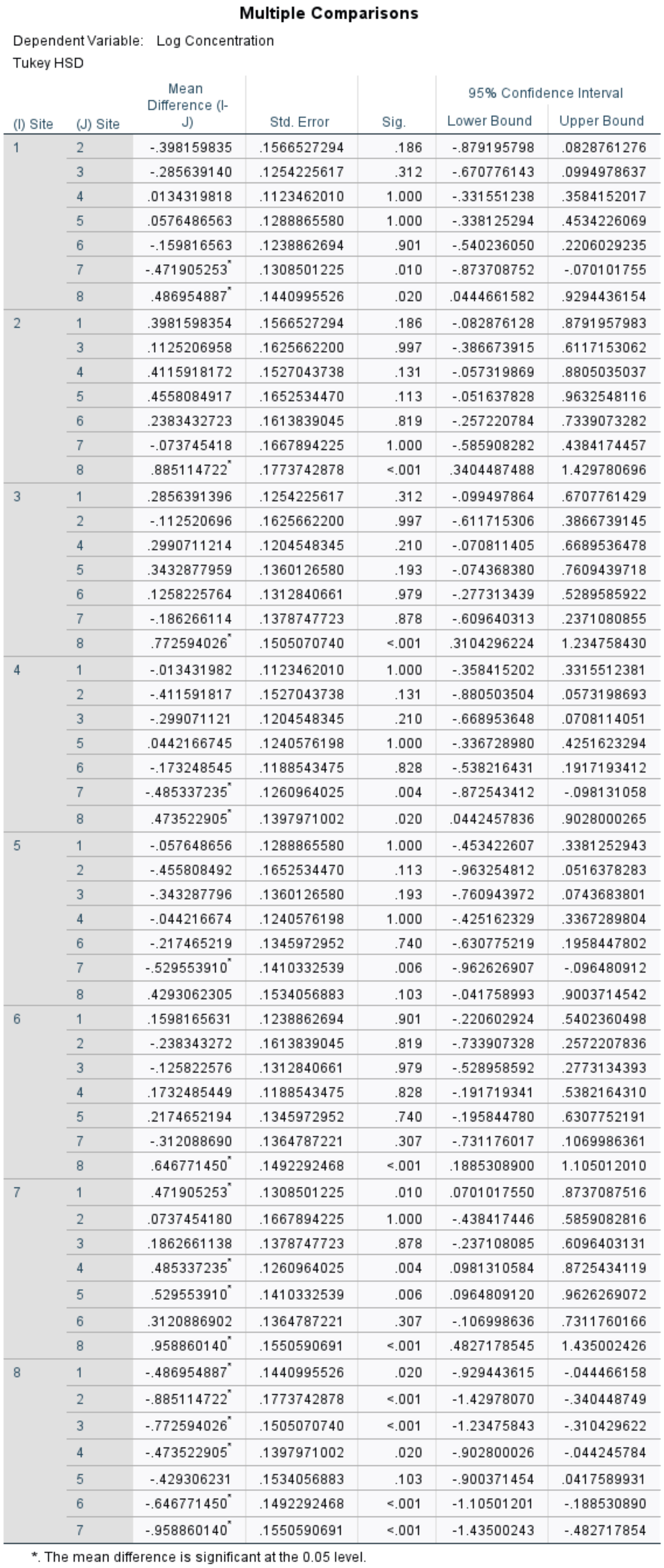


Robust Tests of Equality of Means

Log Concentration

	Statistic[a]	df1	df2	Sig.
Welch	7.129	7	58.409	<.001
Brown-Forsythe	7.158	7	78.838	<.001

a. Asymptotically F distributed.



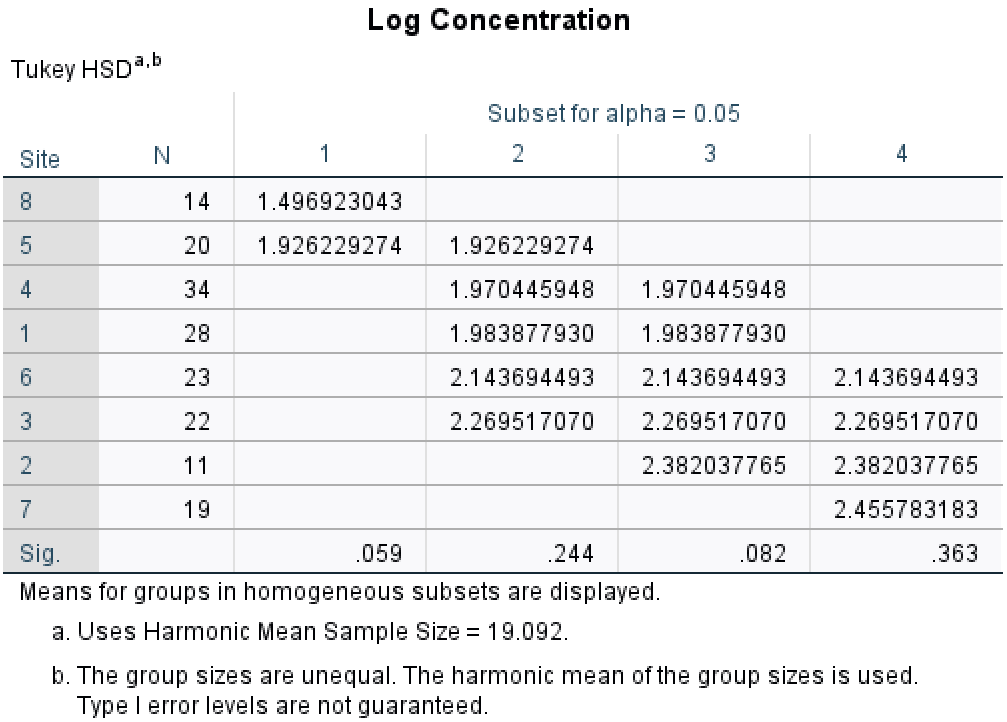
Multiple Comparisons

Dependent Variable: Log Concentration

Tukey HSD

(I) Site	(J) Site	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-.398159835	.1566527294	.186	-.879195798	.0828761276
	3	-.285639140	.1254225617	.312	-.670776143	.0994978637
	4	.0134319818	.1123462010	1.000	-.331551238	.3584152017
	5	.0576486563	.1288865580	1.000	-.338125294	.4534226069
	6	-.159816563	.1238862694	.901	-.540236050	.2206029235
	7	-.471905253*	.1308501225	.010	-.873708752	-.070101755
	8	.486954887*	.1440995526	.020	.0444661582	.9294436154
2	1	.3981598354	.1566527294	.186	-.082876128	.8791957983
	3	.1125206958	.1625662200	.997	-.386673915	.6117153062
	4	.4115918172	.1527043738	.131	-.057319869	.8805035037
	5	.4558084917	.1652534470	.113	-.051637828	.9632548116
	6	.2383432723	.1613839045	.819	-.257220784	.7339073282
	7	-.073745418	.1667894225	1.000	-.585908282	.4384174457
	8	.885114722*	.1773742878	<.001	.3404487488	1.429780696
3	1	.2856391396	.1254225617	.312	-.099497864	.6707761429
	2	-.112520696	.1625662200	.997	-.611715306	.3866739145
	4	.2990711214	.1204548345	.210	-.070811405	.6689536478
	5	.3432877959	.1360126580	.193	-.074368380	.7609439718
	6	.1258225764	.1312840661	.979	-.277313439	.5289585922
	7	-.186266114	.1378747723	.878	-.609640313	.2371080855
	8	.772594026*	.1505070740	<.001	.3104296224	1.234758430
4	1	-.013431982	.1123462010	1.000	-.358415202	.3315512381
	2	-.411591817	.1527043738	.131	-.880503504	.0573198693
	3	-.299071121	.1204548345	.210	-.668953648	.0708114051
	5	.0442166745	.1240576198	1.000	-.336728980	.4251623294
	6	-.173248545	.1188543475	.828	-.538216431	.1917193412
	7	-.485337235*	.1260964025	.004	-.872543412	-.098131058
	8	.473522905*	.1397971002	.020	.0442457836	.9028000265
5	1	-.057648656	.1288865580	1.000	-.453422607	.3381252943
	2	-.455808492	.1652534470	.113	-.963254812	.0516378283
	3	-.343287796	.1360126580	.193	-.760943972	.0743683801
	4	-.044216674	.1240576198	1.000	-.425162329	.3367289804
	6	-.217465219	.1345972952	.740	-.630775219	.1958447802
	7	-.529553910*	.1410332539	.006	-.962626907	-.096480912
	8	.4293062305	.1534056883	.103	-.041758993	.9003714542
6	1	.1598165631	.1238862694	.901	-.220602924	.5402360498
	2	-.238343272	.1613839045	.819	-.733907328	.2572207836
	3	-.125822576	.1312840661	.979	-.528958592	.2773134393
	4	.1732485449	.1188543475	.828	-.191719341	.5382164310
	5	.2174652194	.1345972952	.740	-.195844780	.6307752191
	7	-.312088690	.1364787221	.307	-.731176017	.1069986361
	8	.646771450*	.1492292468	<.001	.1885308900	1.105012010
7	1	.471905253*	.1308501225	.010	.0701017550	.8737087516
	2	.0737454180	.1667894225	1.000	-.438417446	.5859082816
	3	.1862661138	.1378747723	.878	-.237108085	.6096403131
	4	.485337235*	.1260964025	.004	.0981310584	.8725434119
	5	.529553910*	.1410332539	.006	.0964809120	.9626269072
	6	.3120886902	.1364787221	.307	-.106998636	.7311760166
	8	.958860140*	.1550590691	<.001	.4827178545	1.435002426
8	1	-.486954887*	.1440995526	.020	-.929443615	-.044466158
	2	-.885114722*	.1773742878	<.001	-1.42978070	-.340448749
	3	-.772594026*	.1505070740	<.001	-1.23475843	-.310429622
	4	-.473522905*	.1397971002	.020	-.902800026	-.044245784
	5	-.429306231	.1534056883	.103	-.900371454	.0417589931
	6	-.646771450*	.1492292468	<.001	-1.10501201	-.188530890
	7	-.958860140*	.1550590691	<.001	-1.43500243	-.482717854

*. The mean difference is significant at the 0.05 level.



Log Concentration

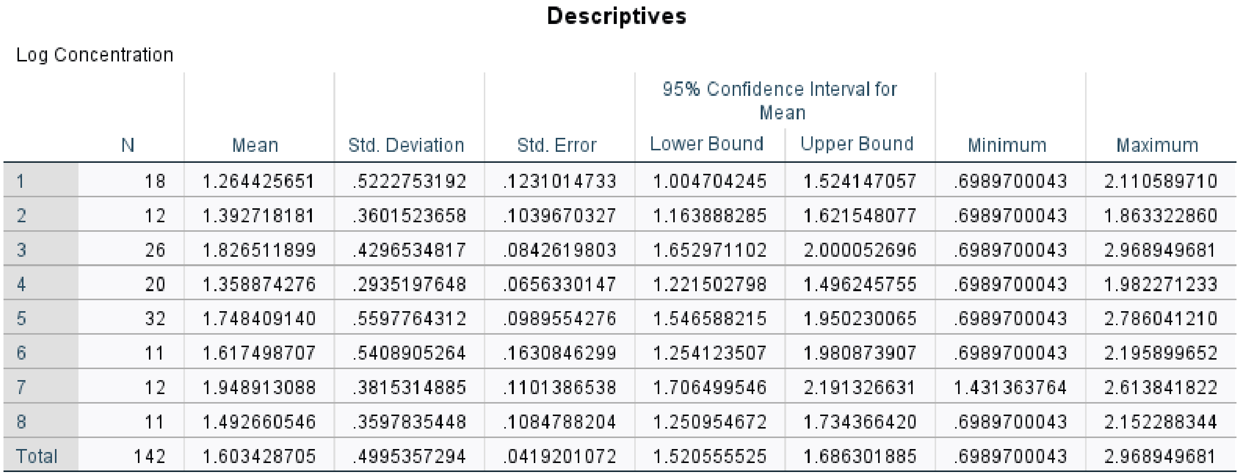
Tukey HSD[a,b]

Site	N	Subset for alpha = 0.05			
		1	2	3	4
8	14	1.496923043			
5	20	1.926229274	1.926229274		
4	34		1.970445948	1.970445948	
1	28		1.983877930	1.983877930	
6	23		2.143694493	2.143694493	2.143694493
3	22		2.269517070	2.269517070	2.269517070
2	11			2.382037765	2.382037765
7	19				2.455783183
Sig.		.059	.244	.082	.363

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 19.092.

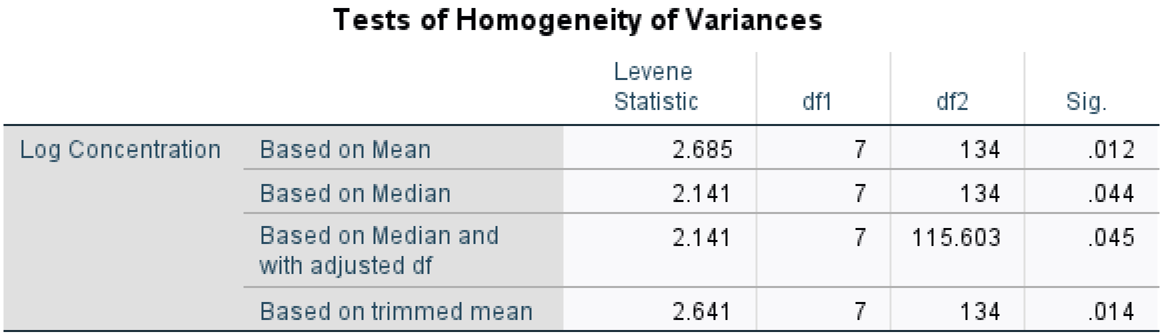
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.



Descriptives

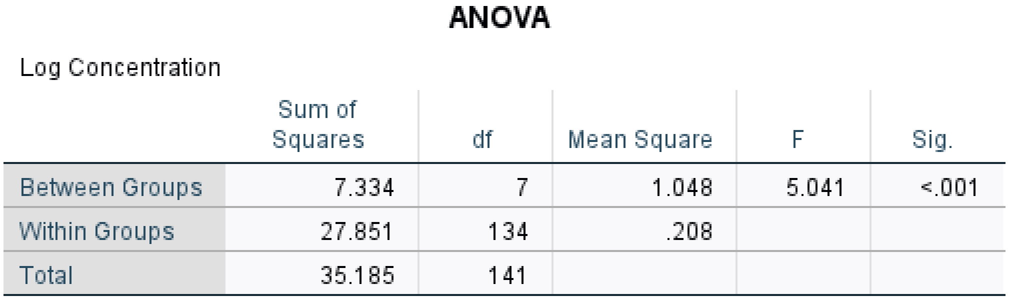
Log Concentration

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	18	1.264425651	.5222753192	.1231014733	1.004704245	1.524147057	.6989700043	2.110589710
2	12	1.392718181	.3601523658	.1039670327	1.163888285	1.621548077	.6989700043	1.863322860
3	26	1.826511899	.4296534817	.0842619803	1.652971102	2.000052696	.6989700043	2.968949681
4	20	1.358874276	.2935197648	.0656330147	1.221502798	1.496245755	.6989700043	1.982271233
5	32	1.748409140	.5597764312	.0989554276	1.546588215	1.950230065	.6989700043	2.786041210
6	11	1.617498707	.5408905264	.1630846299	1.254123507	1.980873907	.6989700043	2.195899652
7	12	1.948913088	.3815314885	.1101386538	1.706499546	2.191326631	1.431363764	2.613841822
8	11	1.492660546	.3597835448	.1084788204	1.250954672	1.734366420	.6989700043	2.152288344
Total	142	1.603428705	.4995357294	.0419201072	1.520555525	1.686301885	.6989700043	2.968949681



Tests of Homogeneity of Variances

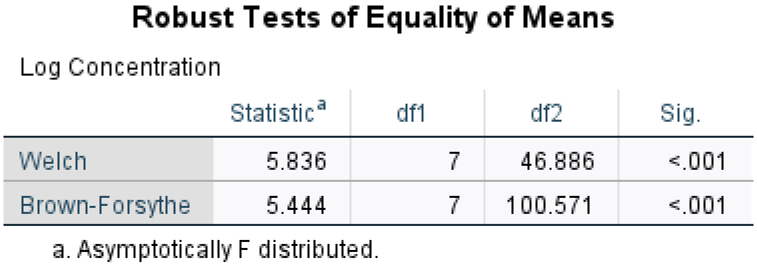
		Levene Statistic	df1	df2	Sig.
Log Concentration	Based on Mean	2.685	7	134	.012
	Based on Median	2.141	7	134	.044
	Based on Median and with adjusted df	2.141	7	115.603	.045
	Based on trimmed mean	2.641	7	134	.014



ANOVA

Log Concentration

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.334	7	1.048	5.041	<.001
Within Groups	27.851	134	.208		
Total	35.185	141			

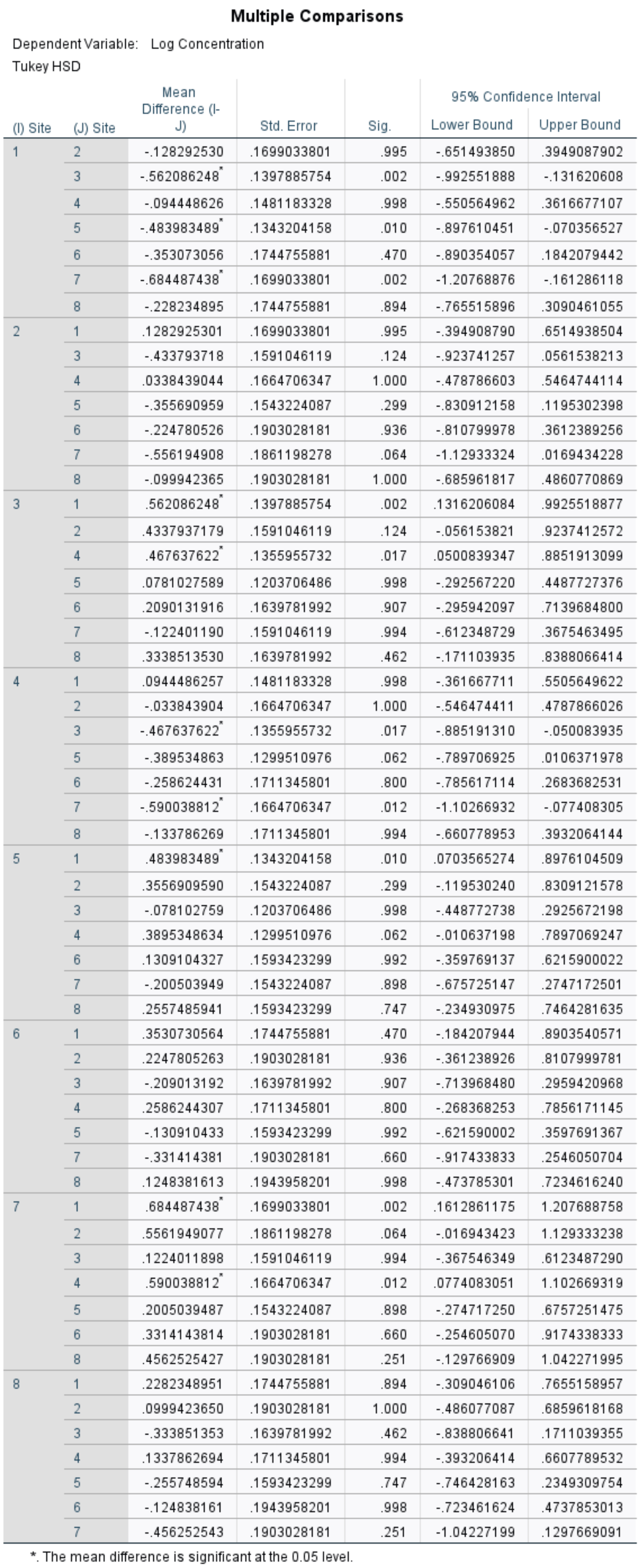


Robust Tests of Equality of Means

Log Concentration

	Statistic[a]	df1	df2	Sig.
Welch	5.836	7	46.886	<.001
Brown-Forsythe	5.444	7	100.571	<.001

a. Asymptotically F distributed.



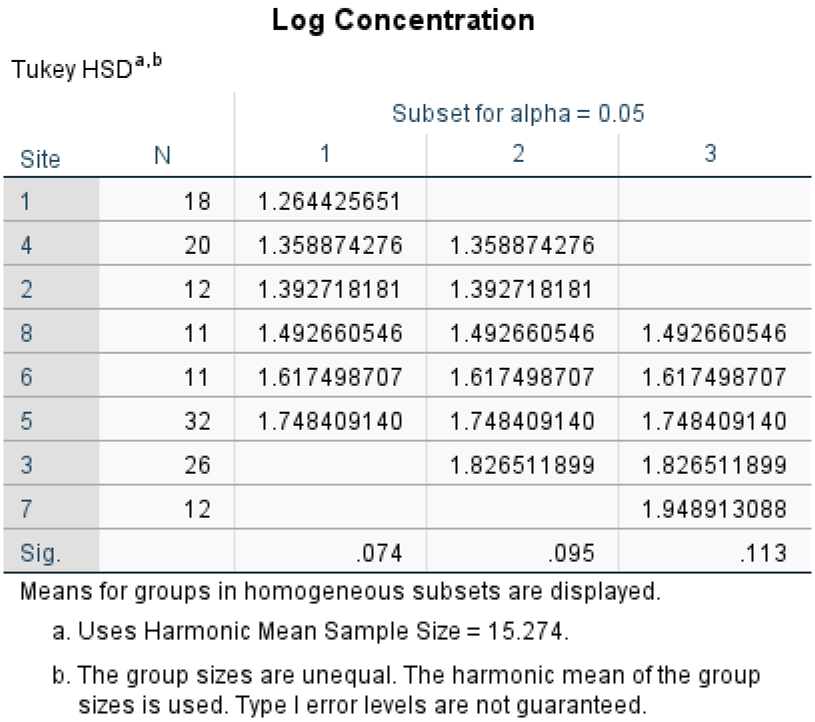
Multiple Comparisons

Dependent Variable: Log Concentration

Tukey HSD

(I) Site	(J) Site	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-.128292530	.1699033801	.995	-.651493850	.3949087902
	3	-.562086248*	.1397885754	.002	-.992551888	-.131620608
	4	-.094448626	.1481183328	.998	-.550564962	.3616677107
	5	-.483983489*	.1343204158	.010	-.897610451	-.070356527
	6	-.353073056	.1744755881	.470	-.890354057	.1842079442
	7	-.684487438*	.1699033801	.002	-1.20768876	-.161286118
	8	-.228234895	.1744755881	.894	-.765515896	.3090461055
2	1	.1282925301	.1699033801	.995	-.394908790	.6514938504
	3	-.433793718	.1591046119	.124	-.923741257	.0561538213
	4	.0338439044	.1664706347	1.000	-.478786603	.5464744114
	5	-.355690959	.1543224087	.299	-.830912158	.1195302398
	6	-.224780526	.1903028181	.936	-.810799978	.3612389256
	7	-.556194908	.1861198278	.064	-1.12933324	.0169434228
	8	-.099942365	.1903028181	1.000	-.685961817	.4860770869
3	1	.562086248*	.1397885754	.002	.1316206084	.9925518877
	2	.4337937179	.1591046119	.124	-.056153821	.9237412572
	4	.467637622*	.1355955732	.017	.0500839347	.8851913099
	5	.0781027589	.1203706486	.998	-.292567220	.4487727376
	6	.2090131916	.1639781992	.907	-.295942097	.7139684800
	7	-.122401190	.1591046119	.994	-.612348729	.3675463495
	8	.3338513530	.1639781992	.462	-.171103935	.8388066414
4	1	.0944486257	.1481183328	.998	-.361667711	.5505649622
	2	-.033843904	.1664706347	1.000	-.546474411	.4787866026
	3	-.467637622*	.1355955732	.017	-.885191310	-.050083935
	5	-.389534863	.1299510976	.062	-.789706925	.0106371978
	6	-.258624431	.1711345801	.800	-.785617114	.2683682531
	7	-.590038812*	.1664706347	.012	-1.10266932	-.077408305
	8	-.133786269	.1711345801	.994	-.660778953	.3932064144
5	1	.483983489*	.1343204158	.010	.0703565274	.8976104509
	2	.3556909590	.1543224087	.299	-.119530240	.8309121578
	3	-.078102759	.1203706486	.998	-.448772738	.2925672198
	4	.3895348634	.1299510976	.062	-.010637198	.7897069247
	6	.1309104327	.1593423299	.992	-.359769137	.6215900022
	7	-.200503949	.1543224087	.898	-.675725147	.2747172501
	8	.2557485941	.1593423299	.747	-.234930975	.7464281635
6	1	.3530730564	.1744755881	.470	-.184207944	.8903540571
	2	.2247805263	.1903028181	.936	-.361238926	.8107999781
	3	-.209013192	.1639781992	.907	-.713968480	.2959420968
	4	.2586244307	.1711345801	.800	-.268368253	.7856171145
	5	-.130910433	.1593423299	.992	-.621590002	.3597691367
	7	-.331414381	.1903028181	.660	-.917433833	.2546050704
	8	.1248381613	.1943958201	.998	-.473785301	.7234616240
7	1	.684487438*	.1699033801	.002	.1612861175	1.207688758
	2	.5561949077	.1861198278	.064	-.016943423	1.129333238
	3	.1224011898	.1591046119	.994	-.367546349	.6123487290
	4	.590038812*	.1664706347	.012	.0774083051	1.102669319
	5	.2005039487	.1543224087	.898	-.274717250	.6757251475
	6	.3314143814	.1903028181	.660	-.254605070	.9174338333
	8	.4562525427	.1903028181	.251	-.129766909	1.042271995
8	1	.2282348951	.1744755881	.894	-.309046106	.7655158957
	2	.0999423650	.1903028181	1.000	-.486077087	.6859618168
	3	-.333851353	.1639781992	.462	-.838806641	.1711039355
	4	.1337862694	.1711345801	.994	-.393206414	.6607789532
	5	-.255748594	.1593423299	.747	-.746428163	.2349309754
	6	-.124838161	.1943958201	.998	-.723461624	.4737853013
	7	-.456252543	.1903028181	.251	-1.04227199	.1297669091

*. The mean difference is significant at the 0.05 level.



Log Concentration

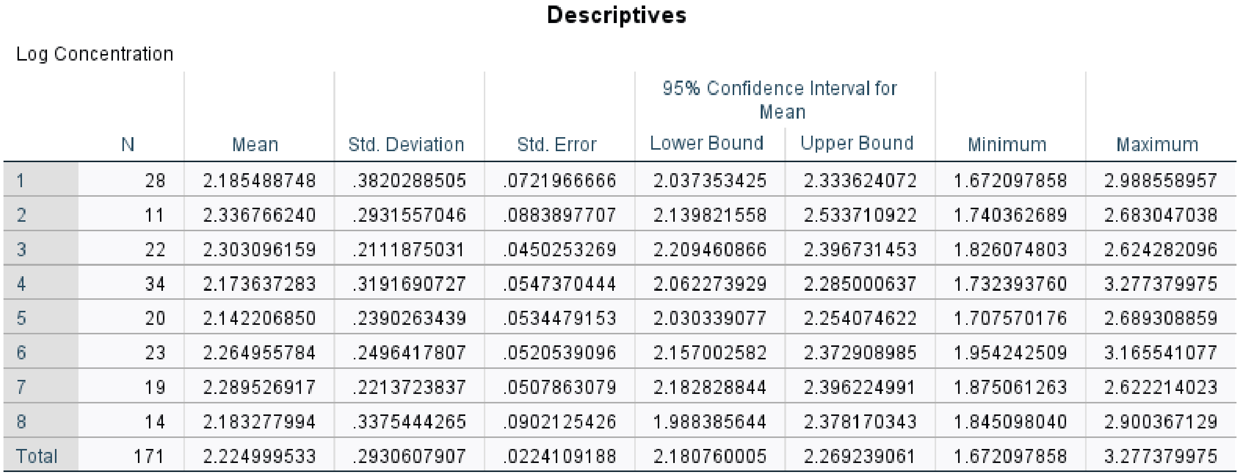
Tukey HSD[a,b]

Site	N	Subset for alpha = 0.05		
		1	2	3
1	18	1.264425651		
4	20	1.358874276	1.358874276	
2	12	1.392718181	1.392718181	
8	11	1.492660546	1.492660546	1.492660546
6	11	1.617498707	1.617498707	1.617498707
5	32	1.748409140	1.748409140	1.748409140
3	26		1.826511899	1.826511899
7	12			1.948913088
Sig.		.074	.095	.113

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 15.274.

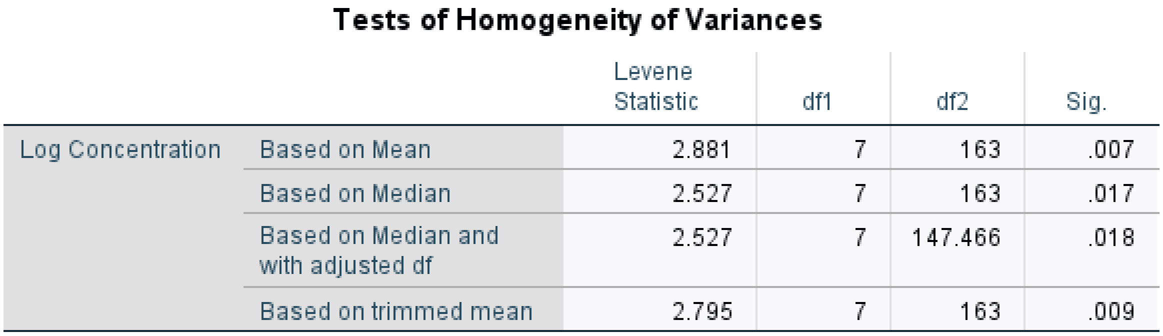
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.



Descriptives

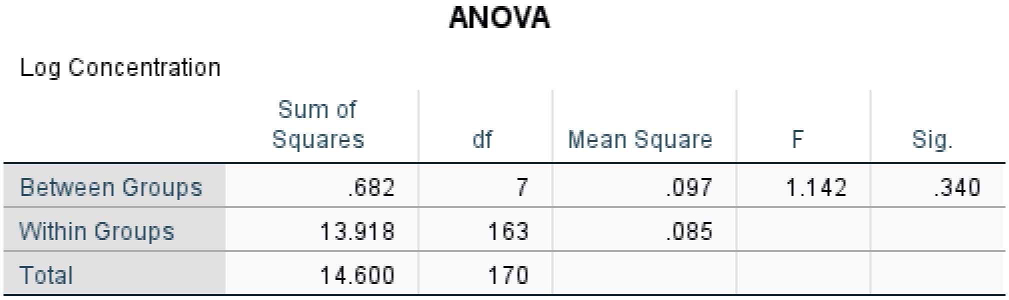
Log Concentration

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	28	2.185488748	.3820288505	.0721966666	2.037353425	2.333624072	1.672097858	2.988558957
2	11	2.336766240	.2931557046	.0883897707	2.139821558	2.533710922	1.740362689	2.683047038
3	22	2.303096159	.2111875031	.0450253269	2.209460866	2.396731453	1.826074803	2.624282096
4	34	2.173637283	.3191690727	.0547370444	2.062273929	2.285000637	1.732393760	3.277379975
5	20	2.142206850	.2390263439	.0534479153	2.030339077	2.254074622	1.707570176	2.689308859
6	23	2.264955784	.2496417807	.0520539096	2.157002582	2.372908985	1.954242509	3.165541077
7	19	2.289526917	.2213723837	.0507863079	2.182828844	2.396224991	1.875061263	2.622214023
8	14	2.183277994	.3375444265	.0902125426	1.988385644	2.378170343	1.845098040	2.900367129
Total	171	2.224999533	.2930607907	.0224109188	2.180760005	2.269239061	1.672097858	3.277379975



Tests of Homogeneity of Variances

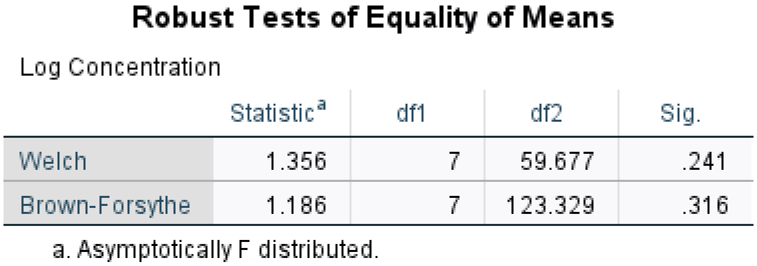
		Levene Statistic	df1	df2	Sig.
Log Concentration	Based on Mean	2.881	7	163	.007
	Based on Median	2.527	7	163	.017
	Based on Median and with adjusted df	2.527	7	147.466	.018
	Based on trimmed mean	2.795	7	163	.009



ANOVA

Log Concentration

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.682	7	.097	1.142	.340
Within Groups	13.918	163	.085		
Total	14.600	170			

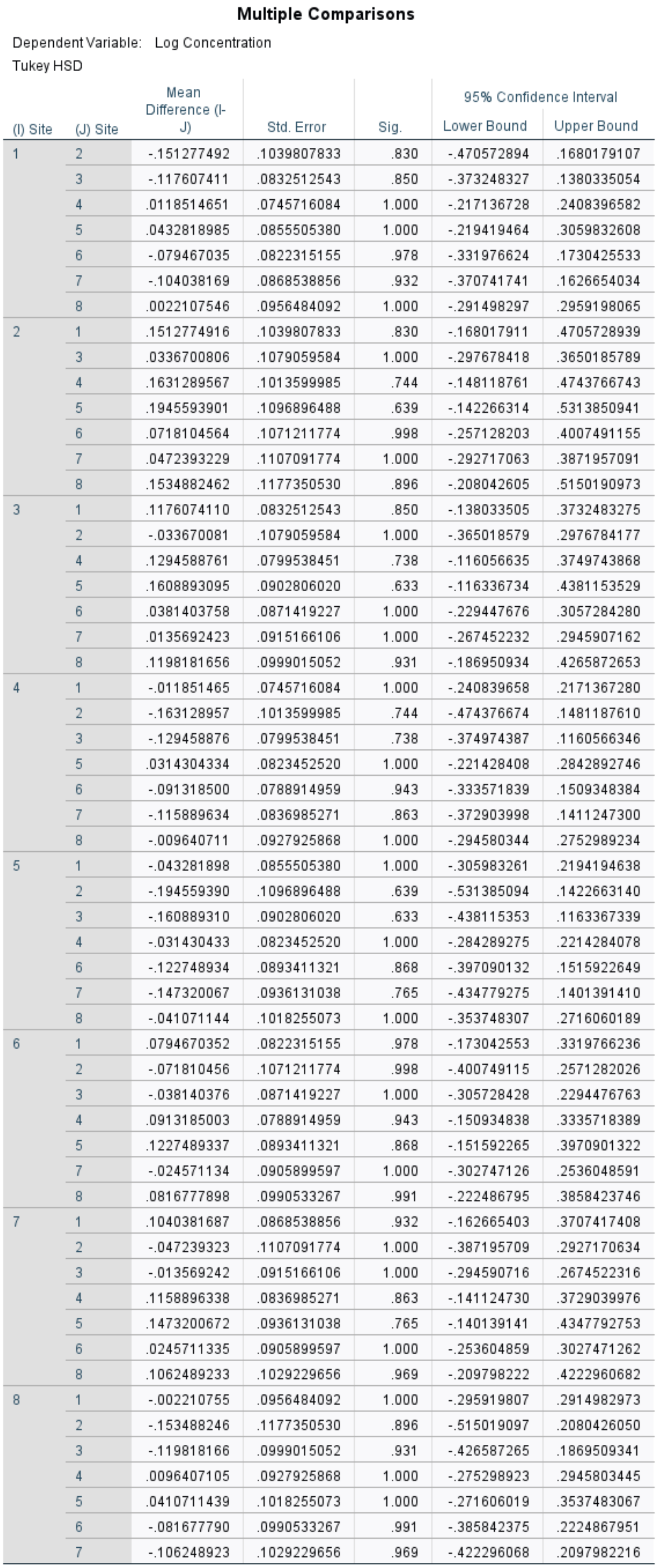


Robust Tests of Equality of Means

Log Concentration

	Statistic[a]	df1	df2	Sig.
Welch	1.356	7	59.677	.241
Brown-Forsythe	1.186	7	123.329	.316

a. Asymptotically F distributed.

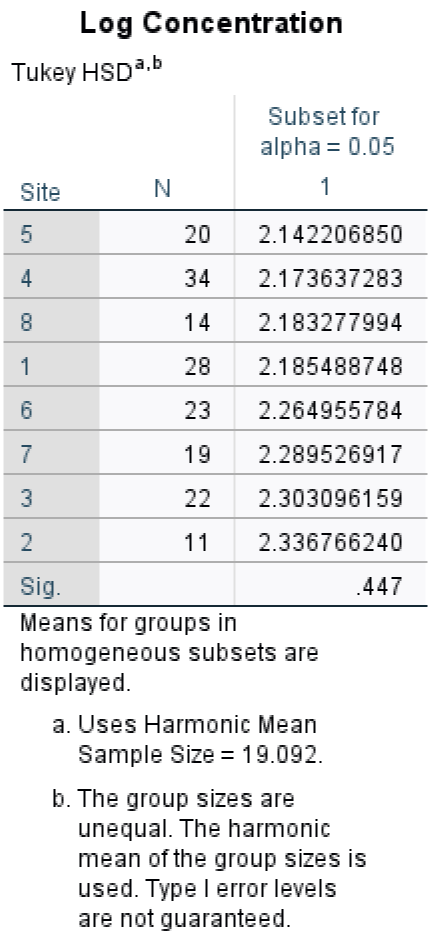


Multiple Comparisons

Dependent Variable: Log Concentration

Tukey HSD

(I) Site	(J) Site	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-.151277492	.1039807833	.830	-.470572894	.1680179107
	3	-.117607411	.0832512543	.850	-.373248327	.1380335054
	4	.0118514651	.0745716084	1.000	-.217136728	.2408396582
	5	.0432818985	.0855505380	1.000	-.219419464	.3059832608
	6	-.079467035	.0822315155	.978	-.331976624	.1730425533
	7	-.104038169	.0868538856	.932	-.370741741	.1626654034
	8	.0022107546	.0956484092	1.000	-.291498297	.2959198065
2	1	.1512774916	.1039807833	.830	-.168017911	.4705728939
	3	.0336700806	.1079059584	1.000	-.297678418	.3650185789
	4	.1631289567	.1013599985	.744	-.148118761	.4743766743
	5	.1945593901	.1096896488	.639	-.142266314	.5313850941
	6	.0718104564	.1071211774	.998	-.257128203	.4007491155
	7	.0472393229	.1107091774	1.000	-.292717063	.3871957091
	8	.1534882462	.1177350530	.896	-.208042605	.5150190973
3	1	.1176074110	.0832512543	.850	-.138033505	.3732483275
	2	-.033670081	.1079059584	1.000	-.365018579	.2976784177
	4	.1294588761	.0799538451	.738	-.116056635	.3749743868
	5	.1608893095	.0902806020	.633	-.116336734	.4381153529
	6	.0381403758	.0871419227	1.000	-.229447676	.3057284280
	7	.0135692423	.0915166106	1.000	-.267452232	.2945907162
	8	.1198181656	.0999015052	.931	-.186950934	.4265872653
4	1	-.011851465	.0745716084	1.000	-.240839658	.2171367280
	2	-.163128957	.1013599985	.744	-.474376674	.1481187610
	3	-.129458876	.0799538451	.738	-.374974387	.1160566346
	5	.0314304334	.0823452520	1.000	-.221428408	.2842892746
	6	-.091318500	.0788914959	.943	-.333571839	.1509348384
	7	-.115889634	.0836985271	.863	-.372903998	.1411247300
	8	-.009640711	.0927925868	1.000	-.294580344	.2752989234
5	1	-.043281898	.0855505380	1.000	-.305983261	.2194194638
	2	-.194559390	.1096896488	.639	-.531385094	.1422663140
	3	-.160889310	.0902806020	.633	-.438115353	.1163367339
	4	-.031430433	.0823452520	1.000	-.284289275	.2214284078
	6	-.122748934	.0893411321	.868	-.397090132	.1515922649
	7	-.147320067	.0936131038	.765	-.434779275	.1401391410
	8	-.041071144	.1018255073	1.000	-.353748307	.2716060189
6	1	.0794670352	.0822315155	.978	-.173042553	.3319766236
	2	-.071810456	.1071211774	.998	-.400749115	.2571282026
	3	-.038140376	.0871419227	1.000	-.305728428	.2294476763
	4	.0913185003	.0788914959	.943	-.150934838	.3335718389
	5	.1227489337	.0893411321	.868	-.151592265	.3970901322
	7	-.024571134	.0905899597	1.000	-.302747126	.2536048591
	8	.0816777898	.0990533267	.991	-.222486795	.3858423746
7	1	.1040381687	.0868538856	.932	-.162665403	.3707417408
	2	-.047239323	.1107091774	1.000	-.387195709	.2927170634
	3	-.013569242	.0915166106	1.000	-.294590716	.2674522316
	4	.1158896338	.0836985271	.863	-.141124730	.3729039976
	5	.1473200672	.0936131038	.765	-.140139141	.4347792753
	6	.0245711335	.0905899597	1.000	-.253604859	.3027471262
	8	.1062489233	.1029229656	.969	-.209798222	.4222960682
8	1	-.002210755	.0956484092	1.000	-.295919807	.2914982973
	2	-.153488246	.1177350530	.896	-.515019097	.2080426050
	3	-.119818166	.0999015052	.931	-.426587265	.1869509341
	4	.0096407105	.0927925868	1.000	-.275298923	.2945803445
	5	.0410711439	.1018255073	1.000	-.271606019	.3537483067
	6	-.081677790	.0990533267	.991	-.385842375	.2224867951
	7	-.106248923	.1029229656	.969	-.422296068	.2097982216



Log Concentration

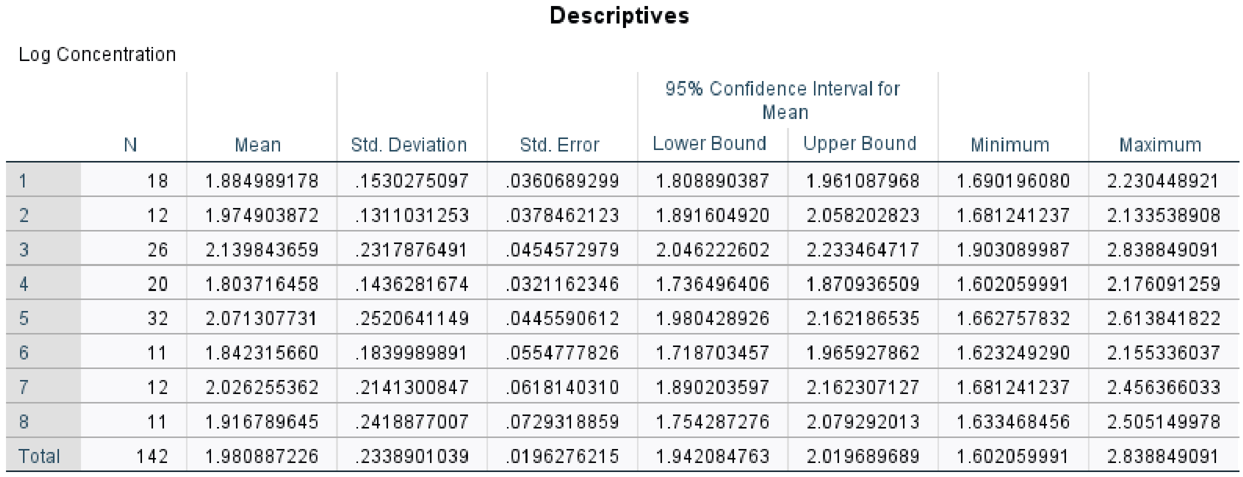
Tukey HSD[a,b]

Site	N	Subset for alpha = 0.05 1
5	20	2.142206850
4	34	2.173637283
8	14	2.183277994
1	28	2.185488748
6	23	2.264955784
7	19	2.289526917
3	22	2.303096159
2	11	2.336766240
Sig.		.447

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 19.092.

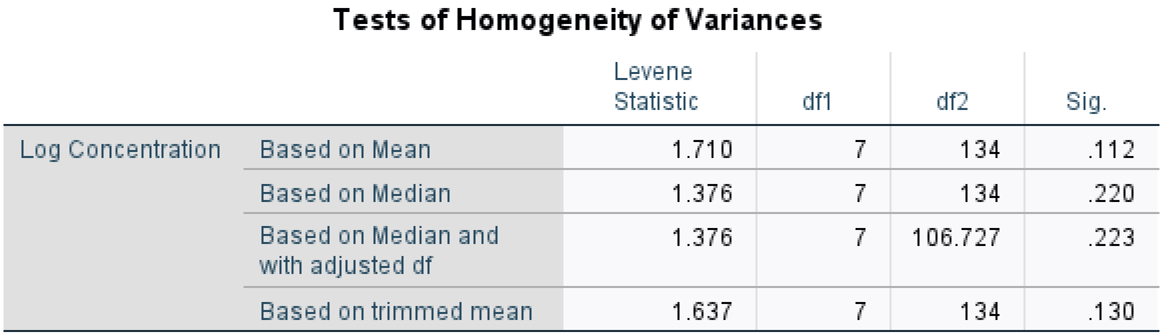
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.



Descriptives

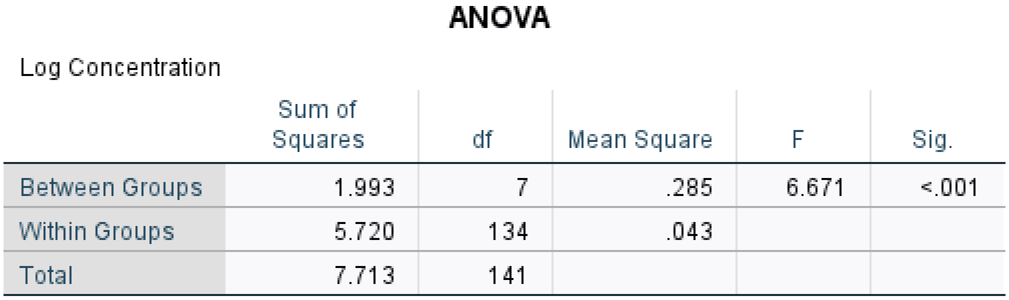
Log Concentration

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	18	1.884989178	.1530275097	.0360689299	1.808890387	1.961087968	1.690196080	2.230448921
2	12	1.974903872	.1311031253	.0378462123	1.891604920	2.058202823	1.681241237	2.133538908
3	26	2.139843659	.2317876491	.0454572979	2.046222602	2.233464717	1.903089987	2.838849091
4	20	1.803716458	.1436281674	.0321162346	1.736496406	1.870936509	1.602059991	2.176091259
5	32	2.071307731	.2520641149	.0445590612	1.980428926	2.162186535	1.662757832	2.613841822
6	11	1.842315660	.1839989891	.0554777826	1.718703457	1.965927862	1.623249290	2.155336037
7	12	2.026255362	.2141300847	.0618140310	1.890203597	2.162307127	1.681241237	2.456366033
8	11	1.916789645	.2418877007	.0729318859	1.754287276	2.079292013	1.633468456	2.505149978
Total	142	1.980887226	.2338901039	.0196276215	1.942084763	2.019689689	1.602059991	2.838849091



Tests of Homogeneity of Variances

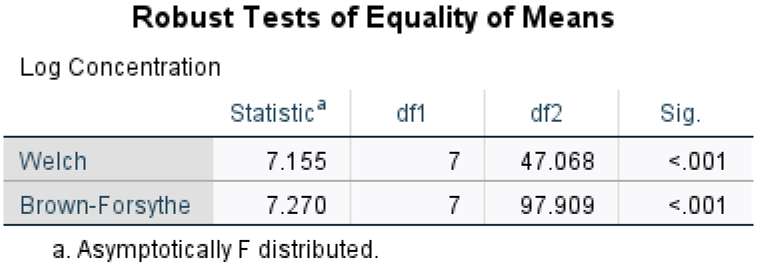
		Levene Statistic	df1	df2	Sig.
Log Concentration	Based on Mean	1.710	7	134	.112
	Based on Median	1.376	7	134	.220
	Based on Median and with adjusted df	1.376	7	106.727	.223
	Based on trimmed mean	1.637	7	134	.130



ANOVA

Log Concentration

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.993	7	.285	6.671	<.001
Within Groups	5.720	134	.043		
Total	7.713	141			

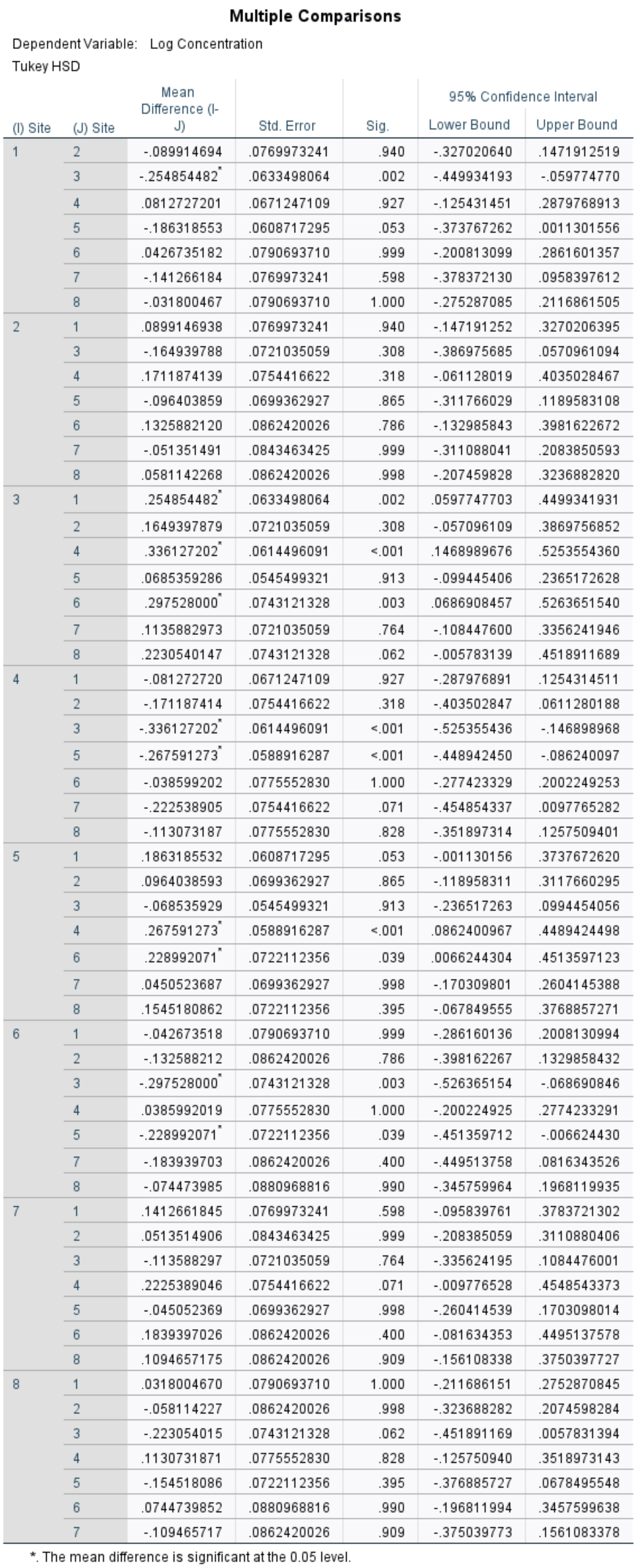


Robust Tests of Equality of Means

Log Concentration

	Statistic[a]	df1	df2	Sig.
Welch	7.155	7	47.068	<.001
Brown-Forsythe	7.270	7	97.909	<.001

a. Asymptotically F distributed.



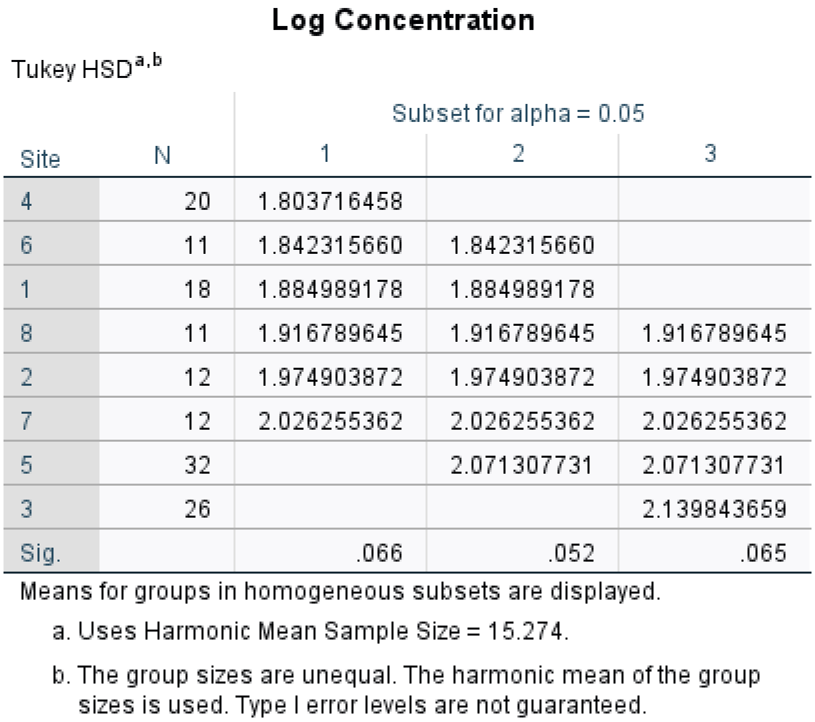
Multiple Comparisons

Dependent Variable: Log Concentration

Tukey HSD

(I) Site	(J) Site	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-.089914694	.0769973241	.940	-.327020640	.1471912519
	3	-.254854482*	.0633498064	.002	-.449934193	-.059774770
	4	.0812727201	.0671247109	.927	-.125431451	.2879768913
	5	-.186318553	.0608717295	.053	-.373767262	.0011301556
	6	.0426735182	.0790693710	.999	-.200813099	.2861601357
	7	-.141266184	.0769973241	.598	-.378372130	.0958397612
	8	-.031800467	.0790693710	1.000	-.275287085	.2116861505
2	1	.0899146938	.0769973241	.940	-.147191252	.3270206395
	3	-.164939788	.0721035059	.308	-.386975685	.0570961094
	4	.1711874139	.0754416622	.318	-.061128019	.4035028467
	5	-.096403859	.0699362927	.865	-.311766029	.1189583108
	6	.1325882120	.0862420026	.786	-.132985843	.3981622672
	7	-.051351491	.0843463425	.999	-.311088041	.2083850593
	8	.0581142268	.0862420026	.998	-.207459828	.3236882820
3	1	.254854482*	.0633498064	.002	.0597747703	.4499341931
	2	.1649397879	.0721035059	.308	-.057096109	.3869756852
	4	.336127202*	.0614496091	<.001	.1468989676	.5253554360
	5	.0685359286	.0545499321	.913	-.099445406	.2365172628
	6	.297528000*	.0743121328	.003	.0686908457	.5263651540
	7	.1135882973	.0721035059	.764	-.108447600	.3356241946
	8	.2230540147	.0743121328	.062	-.005783139	.4518911689
4	1	-.081272720	.0671247109	.927	-.287976891	.1254314511
	2	-.171187414	.0754416622	.318	-.403502847	.0611280188
	3	-.336127202*	.0614496091	<.001	-.525355436	-.146898968
	5	-.267591273*	.0588916287	<.001	-.448942450	-.086240097
	6	-.038599202	.0775552830	1.000	-.277423329	.2002249253
	7	-.222538905	.0754416622	.071	-.454854337	.0097765282
	8	-.113073187	.0775552830	.828	-.351897314	.1257509401
5	1	.1863185532	.0608717295	.053	-.001130156	.3737672620
	2	.0964038593	.0699362927	.865	-.118958311	.3117660295
	3	-.068535929	.0545499321	.913	-.236517263	.0994454056
	4	.267591273*	.0588916287	<.001	.0862400967	.4489424498
	6	.228992071*	.0722112356	.039	.0066244304	.4513597123
	7	.0450523687	.0699362927	.998	-.170309801	.2604145388
	8	.1545180862	.0722112356	.395	-.067849555	.3768857271
6	1	-.042673518	.0790693710	.999	-.286160136	.2008130994
	2	-.132588212	.0862420026	.786	-.398162267	.1329858432
	3	-.297528000*	.0743121328	.003	-.526365154	-.068690846
	4	.0385992019	.0775552830	1.000	-.200224925	.2774233291
	5	-.228992071*	.0722112356	.039	-.451359712	-.006624430
	7	-.183939703	.0862420026	.400	-.449513758	.0816343526
	8	-.074473985	.0880968816	.990	-.345759964	.1968119935
7	1	.1412661845	.0769973241	.598	-.095839761	.3783721302
	2	.0513514906	.0843463425	.999	-.208385059	.3110880406
	3	-.113588297	.0721035059	.764	-.335624195	.1084476001
	4	.2225389046	.0754416622	.071	-.009776528	.4548543373
	5	-.045052369	.0699362927	.998	-.260414539	.1703098014
	6	.1839397026	.0862420026	.400	-.081634353	.4495137578
	8	.1094657175	.0862420026	.909	-.156108338	.3750397727
8	1	.0318004670	.0790693710	1.000	-.211686151	.2752870845
	2	-.058114227	.0862420026	.998	-.323688282	.2074598284
	3	-.223054015	.0743121328	.062	-.451891169	.0057831394
	4	.1130731871	.0775552830	.828	-.125750940	.3518973143
	5	-.154518086	.0722112356	.395	-.376885727	.0678495548
	6	.0744739852	.0880968816	.990	-.196811994	.3457599638
	7	-.109465717	.0862420026	.909	-.375039773	.1561083378

*. The mean difference is significant at the 0.05 level.



Log Concentration

Tukey HSD[a,b]

Site	N	Subset for alpha = 0.05		
		1	2	3
4	20	1.803716458		
6	11	1.842315660	1.842315660	
1	18	1.884989178	1.884989178	
8	11	1.916789645	1.916789645	1.916789645
2	12	1.974903872	1.974903872	1.974903872
7	12	2.026255362	2.026255362	2.026255362
5	32		2.071307731	2.071307731
3	26			2.139843659
Sig.		.066	.052	.065

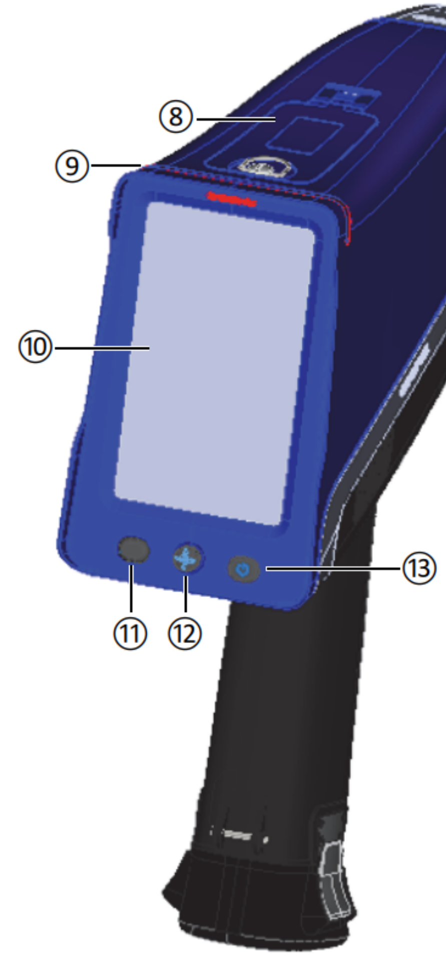
Means for groups in homogeneous subsets are displayed.

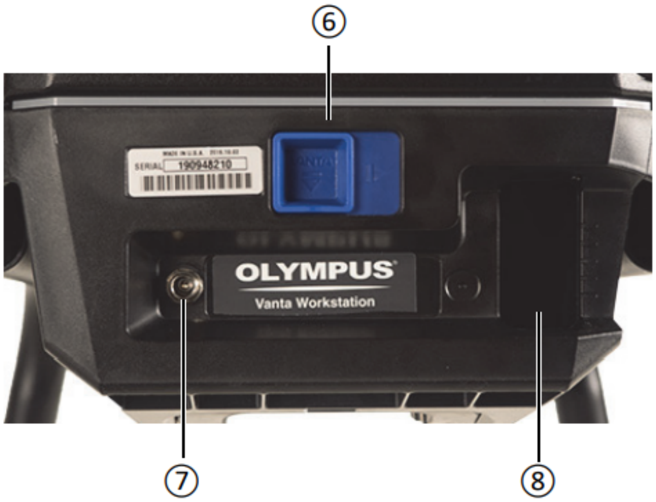
a. Uses Harmonic Mean Sample Size = 15.274.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

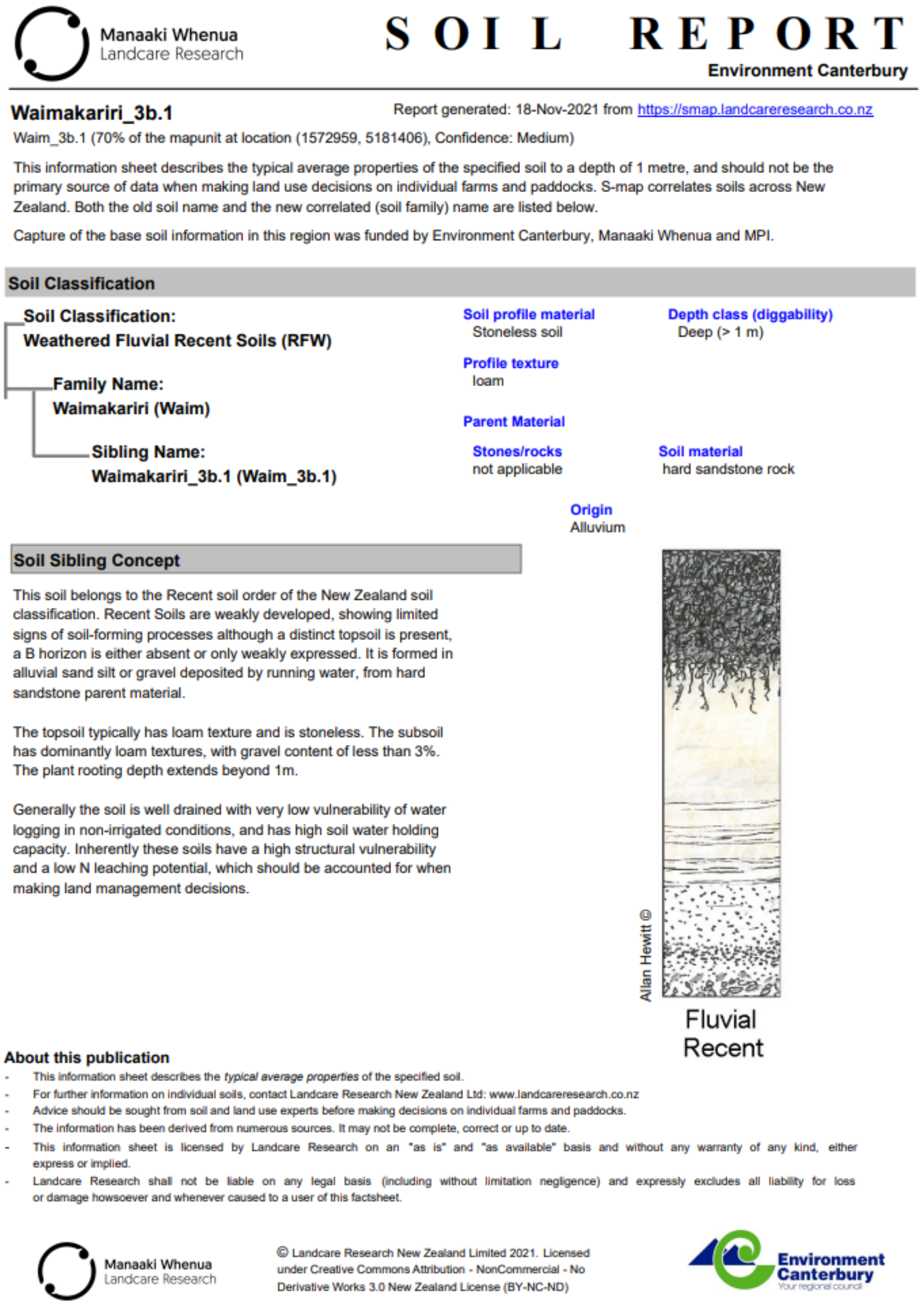
Appendix D: Equipment components

<table>
<tr><th colspan="2">Component key</th><th>Vanta XRF analyzer</th></tr>
<tr><td>1</td><td>Probe</td><td rowspan="8">
</td></tr>
<tr><td>2</td><td>Measurement window</td></tr>
<tr><td>3</td><td>Window plate</td></tr>
<tr><td>4</td><td>Docking connector (not on the Vanta Element Series)</td></tr>
<tr><td>5</td><td>Trigger</td></tr>
<tr><td>6</td><td>Handle</td></tr>
<tr><td>7</td><td>Battery</td></tr>
<tr><td></td><td></td></tr>
</table>

Component key		Vanta XRF analyzer
8	Connector access cover	
9	X-ray warning indicator	
10	User interface touch screen	
11	Back button	
12	Joystick	
13	Power button	

	Component key	**Vanta Work Station**
1	Lid handle	
2	Chamber interior	
3	Stand locking lever	
4	Lid locking lever	
5	Stand	
Rear panel:		
6	Analyzer release lever	
7	DC power connector	
8	Battery receptacle	

Appendix E: Soil characteristics



Manaaki Whenua
Landcare Research

SOIL REPORT

Environment Canterbury

Waimakariri_3b.1

Report generated: 18-Nov-2021 from https://smap.landcareresearch.co.nz

Waim_3b.1 (70% of the mapunit at location (1572959, 5181406), Confidence: Medium)

This information sheet describes the typical average properties of the specified soil to a depth of 1 metre, and should not be the primary source of data when making land use decisions on individual farms and paddocks. S-map correlates soils across New Zealand. Both the old soil name and the new correlated (soil family) name are listed below.

Capture of the base soil information in this region was funded by Environment Canterbury, Manaaki Whenua and MPI.

Soil Classification

Soil Classification:
Weathered Fluvial Recent Soils (RFW)

Family Name:
Waimakariri (Waim)

Sibling Name:
Waimakariri_3b.1 (Waim_3b.1)

Soil profile material
Stoneless soil

Depth class (diggability)
Deep (> 1 m)

Profile texture
loam

Parent Material

Stones/rocks
not applicable

Soil material
hard sandstone rock

Origin
Alluvium

Soil Sibling Concept

This soil belongs to the Recent soil order of the New Zealand soil classification. Recent Soils are weakly developed, showing limited signs of soil-forming processes although a distinct topsoil is present, a B horizon is either absent or only weakly expressed. It is formed in alluvial sand silt or gravel deposited by running water, from hard sandstone parent material.

The topsoil typically has loam texture and is stoneless. The subsoil has dominantly loam textures, with gravel content of less than 3%. The plant rooting depth extends beyond 1m.

Generally the soil is well drained with very low vulnerability of water logging in non-irrigated conditions, and has high soil water holding capacity. Inherently these soils have a high structural vulnerability and a low N leaching potential, which should be accounted for when making land management decisions.

Allan Hewitt ©

Fluvial
Recent

About this publication

- This information sheet describes the *typical average properties* of the specified soil.
- For further information on individual soils, contact Landcare Research New Zealand Ltd: www.landcareresearch.co.nz
- Advice should be sought from soil and land use experts before making decisions on individual farms and paddocks.
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Your regional council

SOIL REPORT

Environment Canterbury

Waimakariri_4b.1

Report generated: 18-Nov-2021 from https://smap.landcareresearch.co.nz

Waim_4b.1 (30% of the mapunit at location (1572959, 5181406), Confidence: Medium)

This information sheet describes the typical average properties of the specified soil to a depth of 1 metre, and should not be the primary source of data when making land use decisions on individual farms and paddocks. S-map correlates soils across New Zealand. Both the old soil name and the new correlated (soil family) name are listed below.

Capture of the base soil information in this region was funded by Environment Canterbury, Manaaki Whenua and MPI.

Soil Classification

Soil Classification:
Weathered Fluvial Recent Soils (RFW)

Family Name:
Waimakariri (Waim)

Sibling Name:
Waimakariri_4b.1 (Waim_4b.1)

Soil profile material
Moderately deep soil

Depth class (diggability)
Moderately deep (45 - 90 cm)

Profile texture
loam

Parent Material

Stones/rocks
hard sandstone rock

Soil material
hard sandstone rock

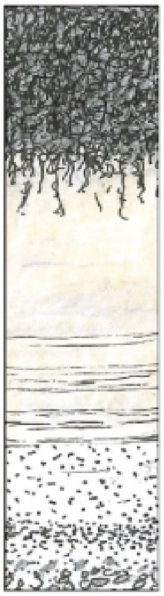
Origin
Alluvium

Soil Sibling Concept

This soil belongs to the Recent soil order of the New Zealand soil classification. Recent Soils are weakly developed, showing limited signs of soil-forming processes although a distinct topsoil is present, a B horizon is either absent or only weakly expressed. It is formed in alluvial sand silt or gravel deposited by running water, from hard sandstone parent material.

The topsoil typically has loam texture and is stoneless. The subsoil has dominantly loam textures, with a very gravelly layer that starts at or below 45 cm soil mineral depth and extends continuously to 100 cm. The plant rooting depth extends beyond 1m.

Generally the soil is well drained with very low vulnerability of water logging in non-irrigated conditions, and has high soil water holding capacity. Inherently these soils have a high structural vulnerability and a low N leaching potential, which should be accounted for when making land management decisions.



Fluvial Recent

About this publication

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SOIL REPORT

Environment Canterbury

Kaiapoi_17a.1

Report generated: 18-Nov-2021 from https://smap.landcareresearch.co.nz

Kaia_17a.1 (60% of the mapunit at location (1572895, 5182016), Confidence: Medium)

This information sheet describes the typical average properties of the specified soil to a depth of 1 metre, and should not be the primary source of data when making land use decisions on individual farms and paddocks. S-map correlates soils across New Zealand. Both the old soil name and the new correlated (soil family) name are listed below.

Capture of the base soil information in this region was funded by Environment Canterbury, Manaaki Whenua and MPI.

Soil Classification

Soil Classification:
Mottled-weathered Fluvial Recent Soils (RFMW)
  Family Name:
  Kaiapoi (Kaia)
    Sibling Name:
    Kaiapoi_17a.1 (Kaia_17a.1)

Soil profile material
Stoneless soil

Depth class (diggability)
Deep (> 1 m)

Profile texture
loam

Parent Material

Stones/rocks
not applicable

Soil material
hard sandstone rock

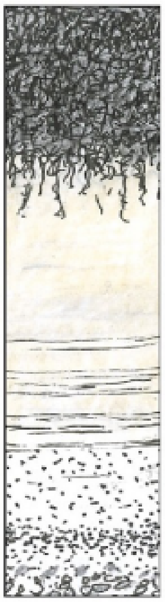
Origin
Alluvium

Soil Sibling Concept

This soil belongs to the Recent soil order of the New Zealand soil classification. Recent Soils are weakly developed, showing limited signs of soil-forming processes although a distinct topsoil is present, a B horizon is either absent or only weakly expressed. It is formed in alluvial sand silt or gravel deposited by running water, from hard sandstone parent material.

The topsoil typically has loam texture and is stoneless. The subsoil has dominantly loam textures, with gravel content of less than 3%. The plant rooting depth extends beyond 1m.

Generally the soil is imperfectly drained with low vulnerability of water logging in non-irrigated conditions, and has high soil water holding capacity. Inherently these soils have a high structural vulnerability and a low N leaching potential, which should be accounted for when making land management decisions.



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Fluvial
Recent

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SOIL REPORT

Environment Canterbury

Kaiapoi_16a.1

Report generated: 18-Nov-2021 from https://smap.landcareresearch.co.nz

Kaia_16a.1 (40% of the mapunit at location (1572895, 5182016), Confidence: Medium)

This information sheet describes the typical average properties of the specified soil to a depth of 1 metre, and should not be the primary source of data when making land use decisions on individual farms and paddocks. S-map correlates soils across New Zealand. Both the old soil name and the new correlated (soil family) name are listed below.

Capture of the base soil information in this region was funded by Environment Canterbury, Manaaki Whenua and MPI.

Soil Classification

Soil Classification:
Mottled-weathered Fluvial Recent Soils (RFMW)
- **Family Name:**
  Kaiapoi (Kaia)
  - **Sibling Name:**
    Kaiapoi_16a.1 (Kaia_16a.1)

Soil profile material
Moderately deep soil

Depth class (diggability)
Moderately deep (45 - 90 cm)

Profile texture
loam

Parent Material

Stones/rocks
hard sandstone rock

Soil material
hard sandstone rock

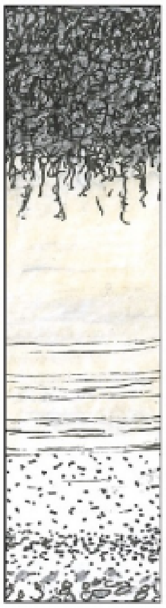
Origin
Alluvium

Soil Sibling Concept

This soil belongs to the Recent soil order of the New Zealand soil classification. Recent Soils are weakly developed, showing limited signs of soil-forming processes although a distinct topsoil is present, a B horizon is either absent or only weakly expressed. It is formed in alluvial sand silt or gravel deposited by running water, from hard sandstone parent material.

The topsoil typically has loam texture and is stoneless. The subsoil has dominantly loam textures, with a very gravelly layer that starts at or below 45 cm soil mineral depth and extends continuously to 100 cm. The plant rooting depth extends beyond 1m.

Generally the soil is imperfectly drained with low vulnerability of water logging in non-irrigated conditions, and has high soil water holding capacity. Inherently these soils have a high structural vulnerability and a low N leaching potential, which should be accounted for when making land management decisions.



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Fluvial Recent

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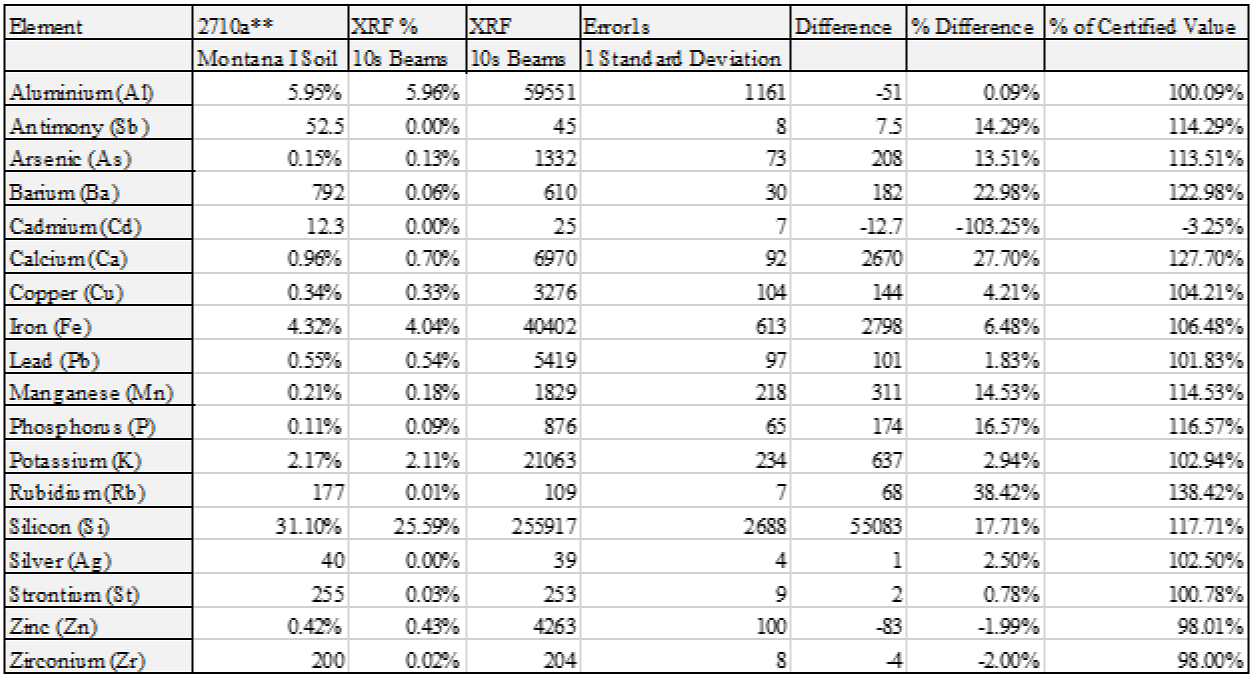
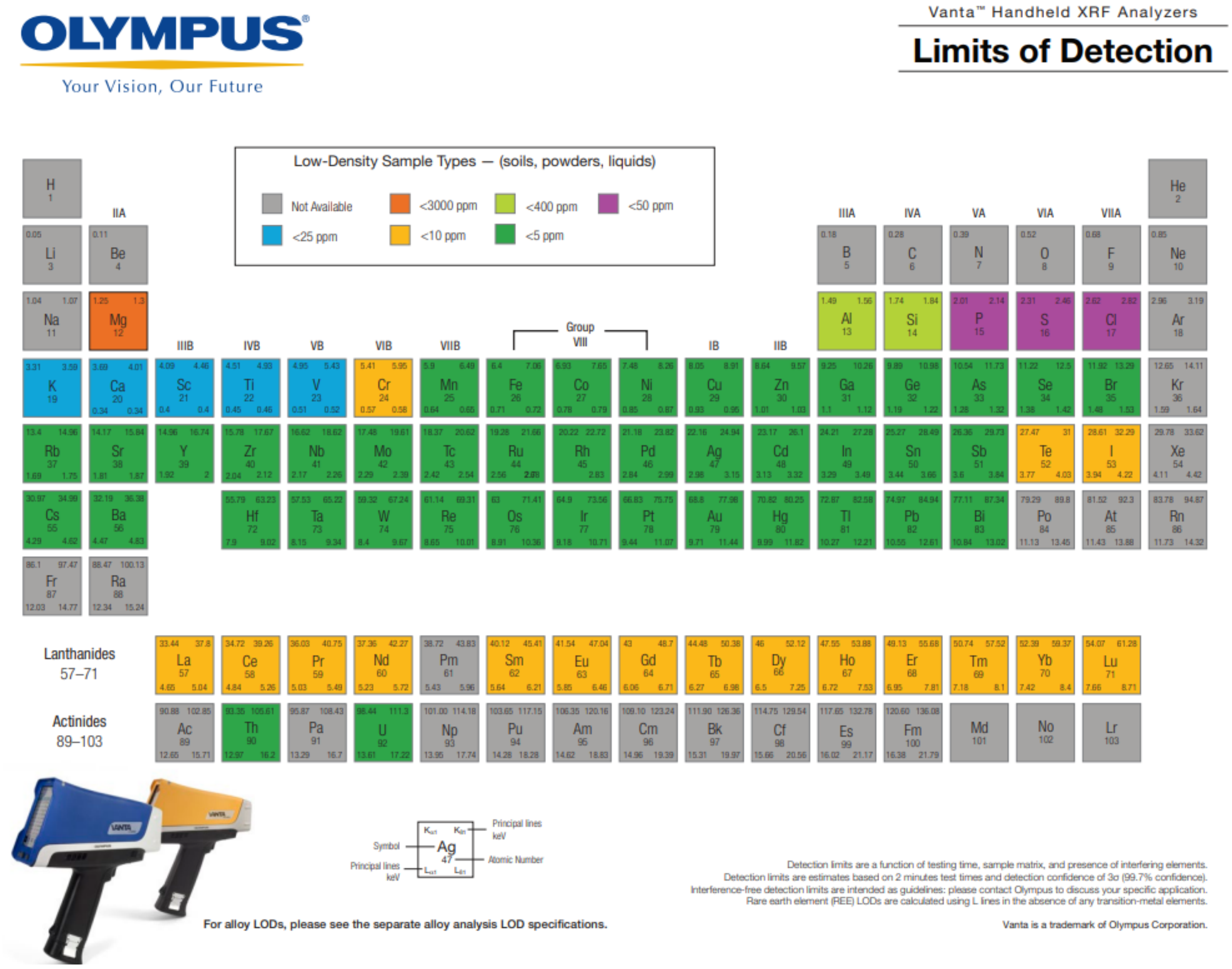
Appendix F: Calibration data



Element	2710a**	XRF %	XRF	Error 1s	Difference	% Difference	% of Certified Value
	Montana I Soil	10s Beams	10s Beams	1 Standard Deviation			
Aluminium (Al)	5.95%	5.96%	59551	1161	-51	0.09%	100.09%
Antimony (Sb)	52.5	0.00%	45	8	7.5	14.29%	114.29%
Arsenic (As)	0.15%	0.13%	1332	73	208	13.51%	113.51%
Barium (Ba)	792	0.06%	610	30	182	22.98%	122.98%
Cadmium (Cd)	12.3	0.00%	25	7	-12.7	-103.25%	-3.25%
Calcium (Ca)	0.96%	0.70%	6970	92	2670	27.70%	127.70%
Copper (Cu)	0.34%	0.33%	3276	104	144	4.21%	104.21%
Iron (Fe)	4.32%	4.04%	40402	613	2798	6.48%	106.48%
Lead (Pb)	0.55%	0.54%	5419	97	101	1.83%	101.83%
Manganese (Mn)	0.21%	0.18%	1829	218	311	14.53%	114.53%
Phosphorus (P)	0.11%	0.09%	876	65	174	16.57%	116.57%
Potassium (K)	2.17%	2.11%	21063	234	637	2.94%	102.94%
Rubidium (Rb)	177	0.01%	109	7	68	38.42%	138.42%
Silicon (Si)	31.10%	25.59%	255917	2688	55083	17.71%	117.71%
Silver (Ag)	40	0.00%	39	4	1	2.50%	102.50%
Strontium (St)	255	0.03%	253	9	2	0.78%	100.78%
Zinc (Zn)	0.42%	0.43%	4263	100	-83	-1.99%	98.01%
Zirconium (Zr)	200	0.02%	204	8	-4	-2.00%	98.00%

Appendix G: XRF handheld analyzer Limits of Detection



Your Vision, Our Future

Vanta™ Handheld XRF Analyzers

Limits of Detection

Low-Density Sample Types — (soils, powders, liquids)

⬜ Not Available	🟥 <3000 ppm	🟨 <400 ppm	🟪 <50 ppm	🟦 <25 ppm	🟧 <10 ppm	🟩 <5 ppm

	IIA	IIIB	IVB	VB	VIB	VIIB	Group VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	
⬜ H 1																	⬜ He 2
⬜ 0.05 Li 3	⬜ 0.11 Be 4											⬜ 0.18 B 5	⬜ 0.28 C 6	⬜ 0.39 N 7	⬜ 0.52 O 8	⬜ 0.68 F 9	⬜ 0.85 Ne 10
⬜ 1.04 1.07 Na 11	🟥 1.25 1.3 Mg 12											🟨 1.49 1.56 Al 13	🟨 1.74 1.84 Si 14	🟪 2.01 2.14 P 15	🟪 2.31 2.46 S 16	🟪 2.62 2.82 Cl 17	⬜ 2.96 3.19 Ar 18
🟦 3.31 3.59 K 19	🟦 3.69 4.01 Ca 20 0.34 0.34	🟦 4.09 4.46 Sc 21 0.4 0.4	🟦 4.51 4.93 Ti 22 0.45 0.46	🟦 4.95 5.43 V 23 0.51 0.52	🟧 5.41 5.95 Cr 24 0.57 0.58	🟩 5.9 6.49 Mn 25 0.64 0.65	🟩 6.4 7.06 Fe 26 0.71 0.72	🟩 6.93 7.65 Co 27 0.78 0.79	🟩 7.48 8.26 Ni 28 0.85 0.87	🟩 8.05 8.91 Cu 29 0.93 0.95	🟩 8.64 9.57 Zn 30 1.01 1.03	🟩 9.25 10.26 Ga 31 1.1 1.12	🟩 9.89 10.98 Ge 32 1.19 1.22	🟩 10.54 11.73 As 33 1.28 1.32	🟩 11.22 12.5 Se 34 1.38 1.42	🟩 11.92 13.29 Br 35 1.48 1.53	⬜ 12.65 14.11 Kr 36 1.59 1.64
🟩 13.4 14.96 Rb 37 1.69 1.75	🟩 14.17 15.84 Sr 38 1.81 1.87	🟩 14.96 16.74 Y 39 1.92 2	🟩 15.78 17.67 Zr 40 2.04 2.12	🟩 16.62 18.62 Nb 41 2.17 2.26	🟩 17.48 19.61 Mo 42 2.29 2.39	🟩 18.37 20.62 Tc 43 2.42 2.54	🟩 19.28 21.66 Ru 44 2.56 2.68	🟩 20.22 22.72 Rh 45 2.83	🟩 21.18 23.82 Pd 46 2.84 2.99	🟩 22.16 24.94 Ag 47 2.98 3.15	🟩 23.17 26.1 Cd 48 3.13 3.32	🟩 24.21 27.28 In 49 3.29 3.49	🟩 25.27 28.49 Sn 50 3.44 3.66	🟩 26.36 29.73 Sb 51 3.6 3.84	🟧 27.47 31 Te 52 3.77 4.03	🟧 28.61 32.29 I 53 3.94 4.22	⬜ 29.78 33.62 Xe 54 4.11 4.42
🟩 30.97 34.99 Cs 55 4.29 4.62	🟩 32.19 36.38 Ba 56 4.47 4.83		🟩 55.79 63.23 Hf 72 7.9 9.02	🟩 57.53 65.22 Ta 73 8.15 9.34	🟩 59.32 67.24 W 74 8.4 9.67	🟩 61.14 69.31 Re 75 8.65 10.01	🟩 63 71.41 Os 76 8.91 10.36	🟩 64.9 73.56 Ir 77 9.18 10.71	🟩 66.83 75.75 Pt 78 9.44 11.07	🟩 68.8 77.98 Au 79 9.71 11.44	🟩 70.82 80.25 Hg 80 9.99 11.82	🟩 72.87 82.58 Tl 81 10.27 12.21	🟩 74.97 84.94 Pb 82 10.55 12.61	🟩 77.11 87.34 Bi 83 10.84 13.02	⬜ 79.29 89.8 Po 84 11.13 13.45	⬜ 81.52 92.3 At 85 11.43 13.88	⬜ 83.78 94.87 Rn 86 11.73 14.32
⬜ 86.1 97.47 Fr 87 12.03 14.77	⬜ 88.47 100.13 Ra 88 12.34 15.24																

Lanthanides 57–71	🟧 33.44 37.8 La 57 4.65 5.04	🟧 34.72 39.26 Ce 58 4.84 5.26	🟧 36.03 40.75 Pr 59 5.03 5.49	🟧 37.36 42.27 Nd 60 5.23 5.72	⬜ 38.72 43.83 Pm 61 5.43 5.96	🟧 40.12 45.41 Sm 62 5.64 6.21	🟧 41.54 47.04 Eu 63 5.85 6.46	🟧 43 48.7 Gd 64 6.06 6.71	🟧 44.48 50.38 Tb 65 6.27 6.98	🟧 46 52.12 Dy 66 6.5 7.25	🟧 47.55 53.88 Ho 67 6.72 7.53	🟧 49.13 55.68 Er 68 6.95 7.81	🟧 50.74 57.52 Tm 69 7.18 8.1	🟧 52.39 59.37 Yb 70 7.42 8.4	🟧 54.07 61.28 Lu 71 7.66 8.71
Actinides 89–103	⬜ 90.88 102.85 Ac 89 12.65 15.71	🟩 93.35 105.61 Th 90 12.97 16.2	⬜ 95.87 108.43 Pa 91 13.29 16.7	🟩 98.44 111.3 U 92 13.61 17.22	⬜ 101.00 114.18 Np 93 13.95 17.74	⬜ 103.65 117.15 Pu 94 14.28 18.28	⬜ 106.35 120.16 Am 95 14.62 18.83	⬜ 109.10 123.24 Cm 96 14.96 19.39	⬜ 111.90 126.36 Bk 97 15.31 19.97	⬜ 114.75 129.54 Cf 98 15.66 20.56	⬜ 117.65 132.78 Es 99 16.02 21.17	⬜ 120.60 136.08 Fm 100 16.38 21.79	⬜ Md 101	⬜ No 102	⬜ Lr 103

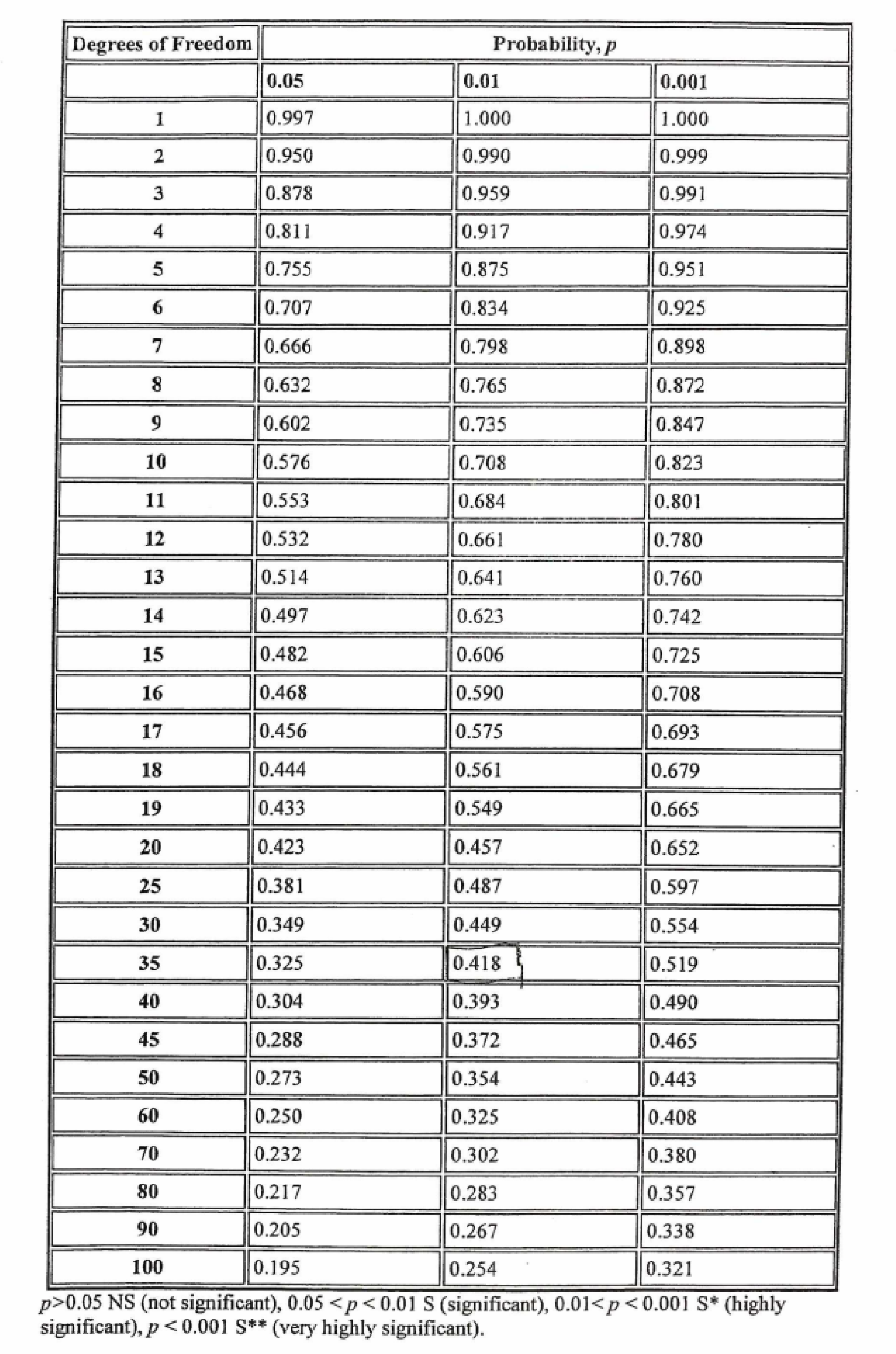
For alloy LODs, please see the separate alloy analysis LOD specifications.

Detection limits are a function of testing time, sample matrix, and presence of interfering elements.
Detection limits are estimates based on 2 minutes test times and detection confidence of 3σ (99.7% confidence).
Interference-free detection limits are intended as guidelines: please contact Olympus to discuss your specific application.
Rare earth element (REE) LODs are calculated using L lines in the absence of any transition-metal elements.

PHOTON ENERGIES, IN ELECTRON VOLTS, OF PRINCIPAL K- AND L-SHELL EMISSION LINES

Element	Symbol	Atomic #	$K_{\alpha1}$	$K_{\beta1}$	$L_{\alpha1}$	$L_{\beta1}$
Actinium	Ac	89	90.88	102.85	12.65	15.71
Aluminum	Al	13	1.49	1.56	0	0
Antimony	Sb	51	26.36	29.73	3.6	3.84
Argon	Ar	18	2.96	3.19	0	0
Arsenic	As	33	10.54	11.73	1.28	1.32
Astatine	At	85	81.52	92.3	11.43	13.88
Barium	Ba	56	32.19	36.38	4.47	4.83
Beryllium	Be	4	0.11	0	0	0
Bismuth	Bi	83	77.11	87.34	10.84	13.02
Boron	B	5	0.18	0	0	0
Bromine	Br	35	11.92	13.29	1.48	1.53
Cadmium	Cd	48	23.17	26.1	3.13	3.32
Calcium	Ca	20	3.69	4.01	0.34	0.34
Carbon	C	6	0.28	0	0	0
Cerium	Ce	58	34.72	39.26	4.84	5.26
Cesium	Cs	55	30.97	34.99	4.29	4.62
Chlorine	Cl	17	2.62	2.82	0	0
Chromium	Cr	24	5.41	5.95	0.57	0.58
Cobalt	Co	27	6.93	7.65	0.78	0.79
Copper	Cu	29	8.05	8.91	0.93	0.95
Dysprosium	Dy	66	46	52.12	6.5	7.25
Erbium	Er	68	49.13	55.68	6.95	7.81
Europium	Eu	63	41.54	47.04	5.85	6.46
Fluorine	F	9	0.68	0	0	0
Francium	Fr	87	86.1	97.47	12.03	14.77
Gadolinium	Gd	64	43	48.7	6.06	6.71
Gallium	Ga	31	9.25	10.26	1.1	1.12
Germanium	Ge	32	9.89	10.98	1.19	1.22
Gold	Au	79	68.8	77.98	9.71	11.44
Hafnium	Hf	72	55.79	63.23	7.9	9.02
Holmium	Ho	67	47.55	53.88	6.72	7.53
Indium	In	49	24.21	27.28	3.29	3.49
Iodine	I	53	28.61	32.29	3.94	4.22
Iridium	Ir	77	64.9	73.56	9.18	10.71
Iron	Fe	26	6.4	7.06	0.71	0.72
Krypton	Kr	36	12.65	14.11	1.59	1.64
Lanthanum	La	57	33.44	37.8	4.65	5.04
Lead	Pb	82	74.97	84.94	10.55	12.61
Lithium	Li	3	0.05	0	0	0
Lutetium	Lu	71	54.07	61.28	7.66	8.71
Magnesium	Mg	12	1.25	1.3	0	0
Manganese	Mn	25	5.9	6.49	0.64	0.65
Mercury	Hg	80	70.82	80.25	9.99	11.82
Molybdenum	Mo	42	17.48	19.61	2.29	2.39
Neodymium	Nd	60	37.36	42.27	5.23	5.72
Neon	Ne	10	0.85	0	0	0
Nickel	Ni	28	7.48	8.26	0.85	0.87
Niobium	Nb	41	16.62	18.62	2.17	2.26
Nitrogen	N	7	0.39	0	0	0
Osmium	Os	76	63	71.41	8.91	10.36
Oxygen	O	8	0.52	0	0	0
Palladium	Pd	46	21.18	23.82	2.84	2.99
Phosphorus	P	15	2.01	2.14	0	0
Platinum	Pt	78	66.83	75.75	9.44	11.07
Polonium	Po	84	79.29	89.8	11.13	13.45
Potassium	K	19	3.31	3.59	0	0
Praseodymium	Pr	59	36.03	40.75	5.03	5.49
Promethium	Pm	61	38.72	43.83	5.43	5.96
Protactinium	Pa	91	95.87	108.43	13.29	16.7
Radium	Ra	88	88.47	100.13	12.34	15.24
Radon	Rn	86	83.78	94.87	11.73	14.32
Rhenium	Re	75	61.14	69.31	8.65	10.01
Rhodium	Rh	45	20.22	22.72	2.7	2.83
Rubidium	Rb	37	13.4	14.96	1.69	1.75
Ruthenium	Ru	44	19.28	21.66	2.56	2.68
Samarium	Sm	62	40.12	45.41	5.64	6.21
Scandium	Sc	21	4.09	4.46	0.4	0.4
Selenium	Se	34	11.22	12.5	1.38	1.42
Silicon	Si	14	1.74	1.84	0	0
Silver	Ag	47	22.16	24.94	2.98	3.15
Sodium	Na	11	1.04	1.07	0	0
Strontium	Sr	38	14.17	15.84	1.81	1.87
Sulfur	S	16	2.31	2.46	0	0
Tantalum	Ta	73	57.53	65.22	8.15	9.34
Technetium	Tc	43	18.37	20.62	2.42	2.54
Tellurium	Te	52	27.47	31	3.77	4.03
Terbium	Tb	65	44.48	50.38	6.27	6.98
Thallium	Tl	81	72.87	82.58	10.27	12.21
Thorium	Th	90	93.35	105.61	12.97	16.2
Thulium	Tm	69	50.74	57.52	7.18	8.1
Tin	Sn	50	25.27	28.49	3.44	3.66
Titanium	Ti	22	4.51	4.93	0.45	0.46
Tungsten	W	74	59.32	67.24	8.4	9.67
Uranium	U	92	98.44	111.3	13.61	17.22
Vanadium	V	23	4.95	5.43	0.51	0.52
Xenon	Xe	54	29.78	33.62	4.11	4.42
Ytterbium	Yb	70	52.39	59.37	7.42	8.4
Yttrium	Y	39	14.96	16.74	1.92	2
Zinc	Zn	30	8.64	9.57	1.01	1.03
Zirconium	Zr	40	15.78	17.67	2.04	2.12

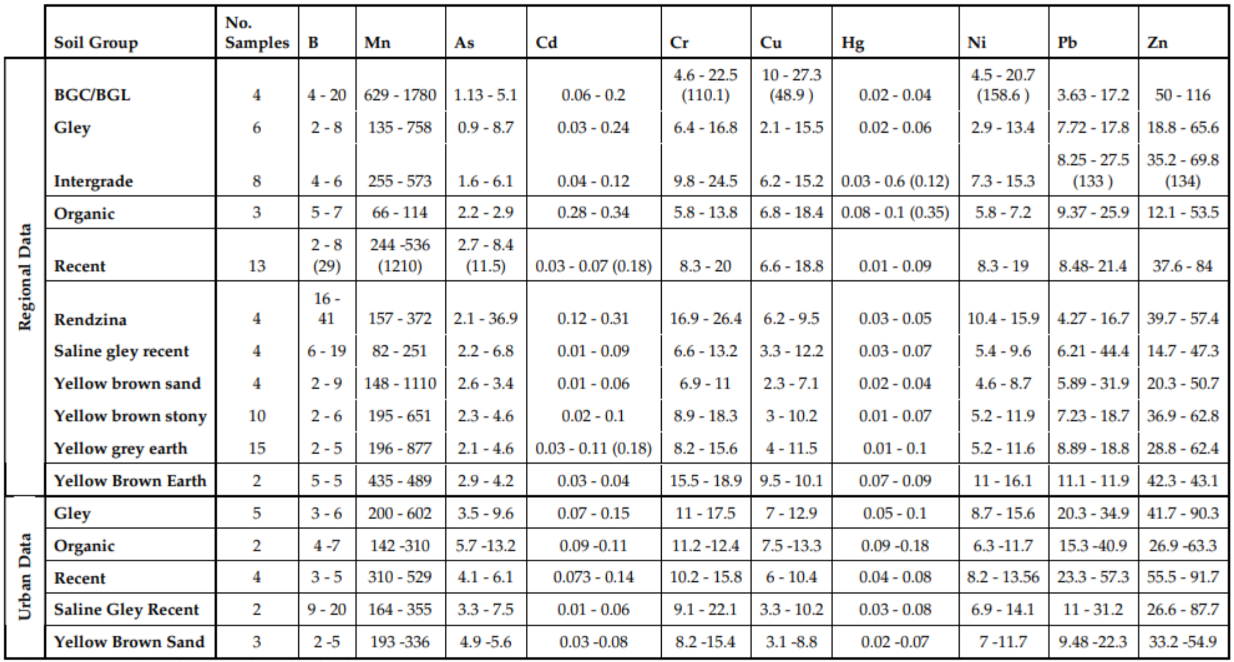
Appendix H: Table of significance



Degrees of Freedom	Probability, p		
	0.05	0.01	0.001
1	0.997	1.000	1.000
2	0.950	0.990	0.999
3	0.878	0.959	0.991
4	0.811	0.917	0.974
5	0.755	0.875	0.951
6	0.707	0.834	0.925
7	0.666	0.798	0.898
8	0.632	0.765	0.872
9	0.602	0.735	0.847
10	0.576	0.708	0.823
11	0.553	0.684	0.801
12	0.532	0.661	0.780
13	0.514	0.641	0.760
14	0.497	0.623	0.742
15	0.482	0.606	0.725
16	0.468	0.590	0.708
17	0.456	0.575	0.693
18	0.444	0.561	0.679
19	0.433	0.549	0.665
20	0.423	0.457	0.652
25	0.381	0.487	0.597
30	0.349	0.449	0.554
35	0.325	0.418	0.519
40	0.304	0.393	0.490
45	0.288	0.372	0.465
50	0.273	0.354	0.443
60	0.250	0.325	0.408
70	0.232	0.302	0.380
80	0.217	0.283	0.357
90	0.205	0.267	0.338
100	0.195	0.254	0.321

p>0.05 NS (not significant), 0.05 < p < 0.01 S (significant), 0.01< p < 0.001 S* (highly significant), p < 0.001 S** (very highly significant).

Appendix I: Canterbury soil background concentrations



	Soil Group	No. Samples	B	Mn	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Regional Data	**BGC/BGL**	4	4 - 20	629 - 1780	1.13 - 5.1	0.06 - 0.2	4.6 - 22.5 (110.1)	10 - 27.3 (48.9)	0.02 - 0.04	4.5 - 20.7 (158.6)	3.63 - 17.2	50 - 116
	Gley	6	2 - 8	135 - 758	0.9 - 8.7	0.03 - 0.24	6.4 - 16.8	2.1 - 15.5	0.02 - 0.06	2.9 - 13.4	7.72 - 17.8	18.8 - 65.6
	Intergrade	8	4 - 6	255 - 573	1.6 - 6.1	0.04 - 0.12	9.8 - 24.5	6.2 - 15.2	0.03 - 0.6 (0.12)	7.3 - 15.3	8.25 - 27.5 (133)	35.2 - 69.8 (134)
	Organic	3	5 - 7	66 - 114	2.2 - 2.9	0.28 - 0.34	5.8 - 13.8	6.8 - 18.4	0.08 - 0.1 (0.35)	5.8 - 7.2	9.37 - 25.9	12.1 - 53.5
	Recent	13	2 - 8 (29)	244 -536 (1210)	2.7 - 8.4 (11.5)	0.03 - 0.07 (0.18)	8.3 - 20	6.6 - 18.8	0.01 - 0.09	8.3 - 19	8.48- 21.4	37.6 - 84
	Rendzina	4	16 - 41	157 - 372	2.1 - 36.9	0.12 - 0.31	16.9 - 26.4	6.2 - 9.5	0.03 - 0.05	10.4 - 15.9	4.27 - 16.7	39.7 - 57.4
	Saline gley recent	4	6 - 19	82 - 251	2.2 - 6.8	0.01 - 0.09	6.6 - 13.2	3.3 - 12.2	0.03 - 0.07	5.4 - 9.6	6.21 - 44.4	14.7 - 47.3
	Yellow brown sand	4	2 - 9	148 - 1110	2.6 - 3.4	0.01 - 0.06	6.9 - 11	2.3 - 7.1	0.02 - 0.04	4.6 - 8.7	5.89 - 31.9	20.3 - 50.7
	Yellow brown stony	10	2 - 6	195 - 651	2.3 - 4.6	0.02 - 0.1	8.9 - 18.3	3 - 10.2	0.01 - 0.07	5.2 - 11.9	7.23 - 18.7	36.9 - 62.8
	Yellow grey earth	15	2 - 5	196 - 877	2.1 - 4.6	0.03 - 0.11 (0.18)	8.2 - 15.6	4 - 11.5	0.01 - 0.1	5.2 - 11.6	8.89 - 18.8	28.8 - 62.4
	Yellow Brown Earth	2	5 - 5	435 - 489	2.9 - 4.2	0.03 - 0.04	15.5 - 18.9	9.5 - 10.1	0.07 - 0.09	11 - 16.1	11.1 - 11.9	42.3 - 43.1
Urban Data	**Gley**	5	3 - 6	200 - 602	3.5 - 9.6	0.07 - 0.15	11 - 17.5	7 - 12.9	0.05 - 0.1	8.7 - 15.6	20.3 - 34.9	41.7 - 90.3
	Organic	2	4 -7	142 -310	5.7 -13.2	0.09 -0.11	11.2 -12.4	7.5 -13.3	0.09 -0.18	6.3 -11.7	15.3 -40.9	26.9 -63.3
	Recent	4	3 - 5	310 - 529	4.1 - 6.1	0.073 - 0.14	10.2 - 15.8	6 - 10.4	0.04 - 0.08	8.2 - 13.56	23.3 - 57.3	55.5 - 91.7
	Saline Gley Recent	2	9 - 20	164 - 355	3.3 - 7.5	0.01 - 0.06	9.1 - 22.1	3.3 - 10.2	0.03 - 0.08	6.9 - 14.1	11 - 31.2	26.6 - 87.7
	Yellow Brown Sand	3	2 -5	193 -336	4.9 -5.6	0.03 -0.08	8.2 -15.4	3.1 -8.8	0.02 -0.07	7 -11.7	9.48 -22.3	33.2 -54.9

NB Remaining outlier values are indicated by brackets