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# Lead And Associated Heavy Metal Distribution In Ciudad Juarez, Mexico

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# Dedication

I dedicate this work to my beloved parents, all members of my family. Their support, encouragement helped me overcome the difficulties and eased the pressure that I faced during my PhD study.

To my adorable husband, without his inspiration, assistance, encouragement, support, I would never have gone this far and succeed without his concerns in my study and my entire life.

# LEAD AND ASSOCIATED HEAVY METAL DISTRIBUTION

# IN CIUDAD JUARAZ, MIXECO

by

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# Abstract

Concern over the extent and sources of heavy metals exposure has arisen worldwide since their significant effects have been discovered in the environment. There is general agreement that research is needed to examine the residual lead and its association to heavy metals contamination in soil and quantify the health hazards. This research was directed to quantify and document the geographic distribution of lead and associated heavy metals concentration in Ciudad Juarez, Mexico. Lead, cadmium, chromium, zinc, and copper were selected to analysis. The soil samples used in this research were collected during a previous Encountors Binational Community Lead Study (RO1ES 11367; 2001-2006. The composite surface soil samples were taken from municipal blocks around 50 strata that were randomly selected. Within each stratum, 10 blocks were randomly selected. The samples were prepared for analysis by X-ray fluorescence. The general procedures of EPA method 6200 for field portable XRF were followed for preparation of the samples, with slight modification. These included grinding, mixing, pressing, and homogenization. 496 soil samples were analyzed in this study. Statistical analyses were conducted to explore the relationship between lead and associated heavy metals. Additionally, geographic information system techniques (GIS) were used to create a detailed colored map of metals concentration. The soil lead concentration levels were recorded, ranging from 12.6 to 550.3 ppm, with the mean concentration values recorded for lead was 42.8 ppm. Soil chromium concentration levels recorded for chromium ranged from 1.8 to 75.6 ppm; with mean concentration values recorded for chromium was 32.1 ppm. Soil copper concentration levels recorded for Cu ranged from 6.3 to 547.3 ppm; with mean concentration values recorded for Cu was 22.3 ppm. Soil zinc concentration levels recorded for chromium ranged from 20.7 to

415.8 ppm; with mean concentration values recorded for chromium was 83.7 ppm. Soil cadmium concentration levels recorded for cadmium ranged from 0.1 to 6.2 ppm; with mean concentration values recorded for cadmium was 1.9 ppm. Soil antimony concentration levels recorded for antimony ranged from 2.7 to 28.8 ppm; with mean concentration values recorded for Sb was 5.8 ppm.

## Table of Contents

# List of Tables

## List of Figures

# Chapter 1: Introduction

## 1.1 Background

Residual contamination by heavy metals is one of the most important local and global environmental health concerns. This is due to the negative effects and significant consequences that heavy metals create on the ecosystem and human health. Heavy metals contamination is largely a legacy of the human industry revolution, which started in 18$^{th}$ century Europe, before expanding in later centuries to the rest of the world. During the industrial revolution, waste materials from industrial and agricultural application were disposed in various environments without any concern (Chernet, 2009).

The disasters that happened around the world caused by heavy metals contamination have drawn attention to the damage of the environment, and human health. Examples of some major disasters include the Minamata disaster. The Minamata disaster occurred in Japan (1950s – 60s) in Minamata City Kumamoto prefecture – due to mercury pollution. The Chisso Corporation Company dumped an estimated 27 tons of mercury compounds into the bay. The mercury accumulated in seafood stores and eventually led to mercury poisoning in the population. In 1952, the first incidents of mercury poisoning appeared in the population of Minimata Bay. Over 3,000 victims have been recognized as having "Minamata Disease". Hundreds of children around the bay were born with horrific birth defects after their mothers ate seafood contaminated with mercury compounds (Jaj, 2005; Horsfall, 2011).

Another disaster happened in Japan involving cadmium poisoning in Toyama Prefecture (1912 -32) when cadmium was released by mining companies into the Jinzu River and its tributaries. The river was used mainly for the irrigation of rice fields, but also for drinking water,

washing, fishing, and other uses, by downstream populations. Due to the cadmium poisoning, the fish in the river started to die, and the rice irrigated with river water did not grow well. The cadmium accumulated in the people eating

contaminated rice. The cadmium poisoning caused softening of the bones and kidney failure, and severe pain, “Itai-Itai disease,” to the population (Horsfall, 2011).

In 1998, Spain's largest nature reserve bird sanctuary Europe’s largest was contaminated by toxic chemicals, resulting from large amounts of mud spilled into the Rio Guadimer River. The waste contained sulphur, lead, copper, zinc and cadmium, which flowed into the Rio Guadimer. Spain’s agriculture and fisheries suffered permanent damage from the pollution (Kaur, 2006; Jaj, 2005).

In the 1980s, in U.S., environmental damage was caused by the leakage of mining by-products. A large amount of copper, cadmium, manganese, zinc, lead, nickel, aluminum, iron and cyanide, on site and in the acid mine drainage contamination leaked into Wightman Fork and the Alamosa River in the San Juan Mountains of Colorado from Summitville gold mining, 25 miles south of Del Norte in Rio Grande County, Colorado (Plumlee, 1995). Adverse effects to agriculture and livestock resulted from regular use of Alamosa River water. The disaster killed fish and other aquatic life along 17-mile downstream stretch of river to Terrance Reservoir. Farmers have reported water quality problems on land irrigated by the Alamosa River. Human exposure to these contaminants is limited, since no one lives on site or within two miles, and site groundwater is not used for human and animal drinking (EPA, 2012; Williams, 1996).

The effect of lead and other heavy metals deposits in the ecosystem may manifest in human health, food safety, soil ecosystems, quality of ground water, animals and plant growth (Roychowdhury et al., 2001; Adegok et al., 2009; Florescu, 2011). Between 1850 and 1990, production of metals increased nearly 10 fold (WRI, 1998).

Lead is a typical example of heavy metals pollutants that have a wide of effect on the environment and human health. Although dominant sources of lead have significantly

diminished, and despite concurrent reductions in pediatric blood lead levels, lead exposure remains in the 21$^{th}$ century Post-industrial era (Amaya et al., 2010), as it is still continually used in a wide range of industrial and agricultural applications.

The most significant release of lead to the environment occurred during the 20$^{th}$ century when lead began being added to gasoline in the 1920s in order to help reduce engine knocking, boost octane ratings, and help with wear and tear on valve seats within the motor. Leaded gasoline created a high lead exposure condition in urban areas with a risk for lead poisoning (Jamison et al., 2006). Urban population groups are at greater risk from soil lead contamination than other population (WHO, 2010). The addition of lead to gasoline led to emissions of a variety of reactive lead and halogen compounds (Amaya et al., 2010). The small particles of lead emitted into the air remain there for extended periods. These lead particles will eventually fall out into the soil and dust, creating a large amount of lead, which will continue to poison future generations unless the soil is cleaned up (Diaz-Barriga et al., 1997).

The environmental media contamination by lead or other heavy metals is not regarded as the product solely of modern technological development; it began with human discovery of mining. Metal working techniques have been used into variety of ways for at least 2 millennia (WRI, 1998). The industrial activities and urbanization in recent centuries have spread the lead and other heavy metals in all parts of the world. Mexico is one of countries that experienced lead contamination.

Mexico is the sixth largest lead-producing country in the world, and 40% of its production is used locally in different industrial processes (Romieu et al., 1994). In 2009, the production of lead reached 143,838 metric tons, (USGS, 2013). The major sources and pathways of lead exposure among the Mexican population are glazed ceramics containing lead oxide,

gasoline emissions, leaded paint, and lead in canned foods and beverages (Mexico's Secretariat of Health, 2005). Cultural sources can also play a role in lead exposure to children. Three common sources of lead are Mexican clay pottery used to cook and serve foods, home remedies, and Mexican candies (Aguirre & Hernandez, 2003). Mexican children have higher average blood lead levels than children in the U.S., and in some cases more than five times higher the action level of 10 μg/dl (Mexico's Secretariat of Health, 2005).

Ciudad Juarez, Chihuahua, is one of Mexico's cities that experienced lead and other heavy metals contamination. The major pervasive 20$^{th}$ century sources of environmental lead in the city were the use of leaded gasoline, smelting, lead based paint and lead plumbing materials, and burning of various items such as wood, paper, tiers (Mackey et al., 1997). Gasoline in Ciudad Juarez continued to contain lead for a full decade after 1980 and it was not until 1990 that leaded gasoline started to phase-out in Mexico (Diaz-Barriga et al., 1997).

Ciudad Juarez experienced rapid population and economic growth during the last several decades due to immigration flow. Population growth, poverty and industrialization have resulted in pressure in the utilization of land for residential and industrial purposes (Blackman et al., 2004).

The population and economic growth associated with the urban sprawl has had serious environmental consequences, particularly for air quality. The maquiladora industry, brick-making procedures, vehicle emission, dust from unpaved roads, industrial pollution, tire burning, and open air fires, combined with extremely dry climate, often windy weather, topography, scarcity of vegetation, and prevalence of unpaved streets and roads, are all sources of air pollution, including heavy metals, affecting the city. These environmental sources of pollution emit their pollutants directly into the air of the city (Blackman & Bannister, 1996; Blackman et al., 2004),

which  has caused numerous health problems in resident populations, such as high lead blood levels and asthma (Ganster et al., 2004; Pinigtore et al., 2005; Espino et al., 2005).

The cities of El Paso and Juarez are tied together not only by culture and economy but also through a common environment, particularly an air-shed linking Ciudad Juarez and El Paso, Texas. Therefore, they share the same common environmental problem. Studies conducted in El Paso del Norte have found a link between lead and other heavy metals found in soil and air resulting from the American Smelting and Refinery Company (ASARCO) emissions in both cities. This research analyzed and correlated concentrations of Pb, Cr, Cu, Zn, Cd and Sb in Juarez soils.

## 1.2 Statement of problem

Soil concentration of Pb, Cr, Cu, Zn, Cd and Sb in Ciudad Juarez needed documentation and analysis. The data were available but had not been previously examined. Indeed, there are few studies that have documented concentrations of residual heavy metals. This study is important because the area of interest was located near areas ASARCO smelter in El Paso, Texas. The ASARCO smelter was located on the west side of El Paso, directly across the U.S. - Mexico border, south of the Rio Grande. The smelter is considered potential a source for metal contamination throughout El Paso, and the nearby area of Ciudad Juarez (Gardea -Toresday et al., 1996; The Senate of State of Texas, 2008; TDH, 2001; Thomson et al., 2007). The smelter was demolished in 2013, and remediation of the site is under way.

A previous study (RO1ES 11367; 2001-2006) had collected block composite soil from 10 blocks in each of 50 population-based strata in Juarez. The geographic distribution of Pb had been analyzed, but Cr, Cu, Zn, Cd and Sb needed analysis. Examining lead and heavy metals contamination would be a first step to quantify health hazards. Knowledge of the concentration

levels of heavy metals in the soil can protect the residents from the dangerous hazards of heavy metals exposure. To these ends, the researcher investigated the concentration of heavy metals in Ciudad Juarez by using XRF.

## 1.3 Research objectives

This study is an outgrowth from the provisory mentioned *Encountors Binational Community Lead Study*. This study attempts to quantify and document the geographic distribution of heavy metal concentrations in Ciudad Juarez. The result of this investigation will provide a database for establishing the degree of potential human health risk in the study area. The specific aims of the study are:

1. To determine and evaluate the average concentration of lead and associated heavy metal contamination in the soil of Ciudad Juarez;
2. To document the geographic distribution of heavy metals, and establish the causes of those distributions;
3. To evaluate the degree of potential human health concerns and risks associated with those concentrations;
4. To produce detailed maps of lead and associated heavy metals distribution and concentration.

## 1.4 Significance of the study

There are few studies in the literature that addressed the concentration and geographic distribution of lead and associated heavy metals in the study area. This study seeks to address the gap in studies of heavy metals, and establish a database for heavy metals distribution and degree of contamination.

The results of this study could provide valuable information that could help environmental specialists, local authorities, planners, and decision makers develop appropriate polices to protect the environment and increase the awareness of the population as to the negative effects of heavy metals contamination in human health.

## 1.5 Dissertation organization

The balance of this dissertation is organized as follows:

The introduction of the study is given in chapter one, which provides background information of heavy metals contamination in the environment.

Extensive relevant literature to the study is reviewed in chapter two, including physical and chemical of properties of target heavy metals, the behavior of metals in the soil, and their health effect in human followed by previous studies of heavy metals in the study area.

Chapter three introduces the information of the study area including a description of methods used in sample procedure and preparation. Procedures of soil collection, preparation and laboratory method used to analyze the soil samples.

Chapter four presented the result and discussion of the study. The summary of major findings that include the conclusions and recommendation to extend the future works related to this study are presented in chapter five, followed by references and appendices, which are inserted at the end.

# Chapter 2: Literature Review

## 2.1 Heavy metals in the environment

Heavy metals are a very heterogeneous group of elements widely varied in their chemical properties, and biological functions. A unifying quality of heavy metals, however, is that they do not decompose or break down easily. Heavy metals exhibit metallic properties, which mainly include the transition metal, some metalloids, lanthanides and actinides (Ibrahim et al., 2011; Raikwar et al., 2008), and have characteristic bioaccumulation through the food chain. Heavy metals become toxic if an increased concentration rate exceeds permissible limits (Ghiyasi et al., 2011). These metals exist in a number of different soluble and particle forms (Adegok et al., 2011). Heavy metals are also a major source for the production of free radicals, and have the ability to lose an electron to form cations, which strongly interact with soil matrix (Ghiyasi et al., 2011).

## 2.2 Definition of heavy metals

Heavy metal is a loosely defined term. There is no clear single identification for this group of elements. Many terms are used, including heavy metal, trace element, toxic metal, etc. (Issa, 2008). Many attempts at definitions have been proposed for heavy metals, some based on density, some on atomic number or atomic weight, and some on chemical properties or toxicity (Duffus, 2002). The common definition of heavy metals is a subset of chemical elements with specific gravity that is at least 5 times that of water (Suciu et al., 2009; Lide, 1992; Bone, 2004).

## 2.3 Classification of heavy metals

90 metallic elements occupy the bulk of the periodic table of elements. 35 of these are of concern to us because of occupational or residential exposure. 23 of these elements are described as heavy metals (Horsfall, 2011), which include antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium, and zinc (Glanze, 1996).

Heavy metals are classified into the following groups according to their function and toxicity (Lin et al., 2011; Lee et al., 2001; Adegoke et al., 2011; Iordache et al., 2010; Suciu et al., 2008):

(I) - Essential: this group of heavy metals has biological functions at low concentrations. They are essential to health function and the reproduction of microorganisms and plants and animals. Essential heavy metals include cobalt, chromium, copper, manganese, molybdenum, nickel, selenium, and zinc. Exceeding the limit of these metals is either carcinogenic or toxic.

(II) - Non-Essential: these groups of heavy metals have no biological function, and cause toxicity above certain tolerance level to plants and animal. They are difficult to metabolize and thus can easily accumulate in organisms. Arsenic and lead are typical non-essential heavy metals.

(III) - High toxic metals: such as mercury, and cadmium.

## 2.4 Sources of heavy metals in the environment

Heavy metals deposits in the environment are associated with a wide range of sources. Annually, at the global level, thousands of tons of heavy metals are released into the environmental ecosystem, including soil, air, and water from verity and widespread sources (MIRA, 2007). The presences of heavy metals are mainly related to geological processes, "natural activities" or through anthropogenic "human activities" (Flores et al., 2009).

### 2.4.1 Natural sources

Heavy metals accumulation may occur through chemical and physical weathering of high background parent rocks, and metal deposits, or may occur through geographical phenomena like volcanic eruptions, earthquakes, and sand storms (Adegoke et al., 2009; Jung, 2008). In addition, limited amounts of heavy metals are found in plant and animal bodies (Dube et al., 2001; Lin, 2011).

### 2.4.2 Anthropological sources

Heavy metals have a wide range of application in industry and agriculture (Adegoke et al., 2011). Mining producers and smelting operations are important sources of heavy metal contamination (Adegoke, 2009; Li et al., 2007). Activities such as mineral excavation, ore transportation, disposal of tailings, and wastewater disposal around mines are the most important sources of heavy metal in soil (Adegoke, 2009; Zhuang et al., 2009; Tetteh, 2010). Contamination can also occur due to heavy metals derived from metallurgical industries, the use of synthetic products (i.e. pesticides, paints, batteries and land application of industrial or domestic sludge) and burning of various items such as wood, paper, tires, waste incineration, and

traffic emission (Ghiyasi et al., 2011; USAD-NRCS, 2000; Ibrahim et al., 2011; Mackay et al., 1997).

## 2.5 Soil contamination by heavy metals

Soil is a dynamic part of the terrestrial environment; it plays many important roles in the environment. It provides a habitat for the growth of living organisms and provides essential ecosystem services (Sdepanian, 2011; Zovko & Romic, 2011).

Soil is formed through the decomposition of rock and organic matter by physical and chemical weathering, over many years, in a continuous process (Shayler et al., 2009), which consists of liquid, gaseous and solid components. Typically, soil consists of a porous mix of silt, sand, clay, and organic matter (Bone, 2004).

Topsoil serves as a sink or a filter in which metal contaminants are accumulated rapidly, including heavy metals, due to their high metal retention capacities (Scholitz, 2006). Heavy metals in soil can have significant deleterious consequences for an ecosystem (Florescu et al., 2011). They can dramatically change the soil composition and organization (Sherametic et al., 2009).

The soil becomes contaminated if the concentration of the heavy metals exceeds the specified limit of concentration that can negatively affect the quality of the soil, leading to the loss of its structure, biological and chemical properties. Soil contamination affects the health of plants, animals and humans that live with and within it (UNEP, 2008). The most important heavy metals concerning potential hazards and occurrence in contaminated soil are cadmium, chromium, lead, zinc, mercury, arsenic and copper (Alloway, 1995). Theoretically, every 1000-

kilo grams of normal soil contains 200 grams chromium, 80 grams nickel, 16 grams lead, 0.5 grams mercury and 0.2 grams cadmium (IOCCC, 1996; Adegok et al., 2011).

## 2.6 Sources of heavy metals in contaminated soils

Most heavy metals released to the environment are eventually deposited in soil (Sobolev & Begonia, 2008; Wuana & Okieimen, 2011). The concentration of heavy metals in soil may be derived from various sources. Activities such as mining, smelting, refining, wastewater, traffic emission disposal of high metal wastes, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals and atmospheric deposition are the most important causes of heavy metal in soil (Adegoke, 2009; Zhuang et al., 2009; Tetteh, 2010; Ghiyasi et al., 2011; Wuana & Okieimen, 2011).

The large quantities of heavy metals are the legacy of human industrialization particularly in the 19$^{th}$ and 20$^{th}$ centuries. Many studies have shown that soil in urban areas is more heavily contaminated than suburban and rural spaces, reflecting the anthropogenic activity of urbanization (Tahir et al., 2007). Some studies in China, South Korea, and the United States showed that areas near mining and smeltering plants are vulnerable to contamination by heavy metals (Zhuang et al., 2009).

The United States-Environment Public Authority (EPA) provides typical background levels for non-contamination soil of heavy metals Table 1.1

Table 2.1: Typical safe heavy metals soil level

| Heavy Metal | Typical Background Levels for Non-contaminated Soil |
|---|---|
| Arsenic | 3 to 12 ppm |
| Cadmium | 1.0 ppm |
| Copper | 1 to 50 ppm |
| Lead | 10 to 70 ppm |
| Zinc | 10 to 300 ppm |
| Antimony | 1.0 ppm |
| Selenium | 9 to 125 ppm |

## 2.7 Benefits of heavy metals

Historically, humans have used metals in many activities for thousands of years. The demand and use of metals by humans has increased since the eighteenth century, when the world established the industrial era, which led to massive use of metals in many applications in industrial and agriculture applications, resulting in distribution and increasing the levels of these pollutants in all environment components (Pundyte et al., 2011).

Due to their properties, such as strength, malleability, and conductivity of heat and electricity, some metals are used in a wide variety of industrial and agricultural applications. For example, industrial applications include automobiles, appliances, tools, computers and other electronic devices, as well as infrastructure (e.g. highways, bridges, railroads, and electrical

utilities). In agricultural applications, metals are used to increase food production through the manufacture of pesticides, and herbicides. Other applications of heavy metals in human needs include medicine and treatment (Sparks, 2005). Some heavy metals are used in diagnostic medical applications, such as the direct injection of gallium during radiological procedures, the use of lead as a radiation shield around x-ray equipment and the use of silver and mercury amalgam for tooth filling (Horsfall, 2011).

In addition, some heavy metals (copper, chromium, zinc) play an important role in biological systems; they are essential for good health life, normal health growth, and reproduction by plants and animals in small trace amounts (Iordache et al., 2010).

## 2.8 Toxicity of heavy metals

Heavy metals are generally toxic to living organisms at excessive concentrations, even metals that are essential to plant, and animal growth (Bone et al., 2004; Adegoke et al., 2009). High concentrations of heavy metals are toxic to cell and tissues of living organisms. Heavy metals exhibit toxic effects towards soil biota by affecting key microbial processes and decreasing the number and activity of soil microorganisms (Jiwan & Kalamdhad, 2011).

Plants absorb and accumulate heavy metals from the soil and water in soluble form as salts by uptake from the roots. Heavy metals can influence the physiological activities of plants such as photosynthesis, gaseous exchange, and nutrient absorption (Fagbote & Olanipekun, 2010). Absorption and accumulation of heavy metals in plant tissue depend upon many factors, which include temperature, moisture, organic matter, pH and nutrient availability (Jiwan & Kalamdhad, 2011).

In human heavy metals affect the body and psychophysical development (Szyczewski et al., 2009). The toxicity of heavy metals for humans is mainly caused through their persistence in the environment and hinges strongly upon the chemical form in which they are ingested. There are a number of different factors that can influence metals toxicity; these factors are (Zukowska & Biziuk, 2008):

- Physical and chemical properties of the metal
- Element interaction
- Formation of compounds or complexes among metal and other metalloids
- Interchange of metal bounds to protein
- Sources and sinks, environmental transport, and transformation
- Influence of concentration and other exposure variables (for example: time, route, pattern of exposure, bioavailability)
- Nutritional status
- Taking drugs such as alcohol and nicotine

Heavy metals enter the human body through inhalation, or intestinal absorption, or through the skin contact in manufacturing, agriculture, pharmaceutical, or residential settings (Martin, 2011; Issa, 2008). Heavy metals contamination in the body plays a major pathological role in many diseases; it can damage or reduce mental and central nervous function, lower energy levels, and inspire damage to blood composition, lungs, kidneys, livers, and other vital organs (WHO,1974; Heavy Metal Detox, 2011). The World Health Organization estimates that 80% of all chronic diseases can be attributed to heavy metals contamination, which reduces the efficacy of medical treatment up to 60 % (WHO, 1974).

The toxicity of heavy metals in soil depends on the heavy metal concentration, soil texture, organic matter, and pH (Shayler et al., 2009; Dube et al., 2001).

## 2.9 Description of target heavy metals

### 2.9.1 Lead

Lead (Pb) has been used since the prehistoric era; it has been mined and used by humans for 6,000 years. The history of lead poisoning is nearly 2,500 years old. Lead has been documented from ancient Rome, Greece, and China (Lesser, 1988). It is one of the most common of the heavy metals contaminants as well as one of the most widely studied.

Lead is one of the naturally occurring elements, usually found in combination with other elements to form different minerals (Kinder, 1997). Its abundance ranges from 2 to 200 mg/ kg in the soil surface (EPA, 2006). The total metal content in unpolluted soils for lead is below 20 mg/kg in remote or recently settled areas, and between 3 -100 mg/kg in soils that experience low-level pollution (Sanchez & Ayuso, 2008). Lead is used in a wide variety of products including paint, ceramic, pipes, solders, batteries, and cosmetic (NIEHS, 2013).

The element is in period 6 and group 14 of the periodic table. Lead is a malleable metal with the following chemical and physical properties: it is bluish-white, silvery, or gray and lustrous. It is very soft, ductile with atomic number 82. The melting point of lead is 621.3°F, and its boiling point is 3,180 to 3,190°F. Its density is 11.34 g/ $cm^{-3}$ (Wuana & Okieimen, 2011; EPA, 1997).

Lead is released to environmental components from natural phenomena and human activities. It is dispersed into air, soil, water, and transferred continuously between them through physical and chemical processes. Atmospheric deposition is the largest source of lead found in

soils. Soils and sediments in particular appear to be important sinks for lead. Most lead that enters the soil forms insoluble compounds and results in most soil lead being found in the surface soil (ATSDR, 2007). Natural sources of lead include the weathering of rocks, and volcanic activities. The main anthropogenic sources of lead include: smelting and the processing of lead ore, secondary metals production, lead battery manufacturing, production of ceramic, fire retardants, additives, medicine, pigments, and semiconductors, gun and ammunition factories, and lead-contaminated wastes (UNDP, 2010; Evanko & Dzombak, 1997).

Lead is known to be toxic to plants, animals and microorganisms. Indeed, lead has a wide range of toxic effects on multiple body systems. Its compounds are variably toxic, bioavailable, and biodegradable. It is number 2 on the ATSDRS “Top 20 list”.

Lead poisoning occurs when a human being absorbs contaminants of the metal through breathing or by ingestion. The affected organs of lead poisoning are the bones, brain, blood, kidney, and thyroid gland (ATSDR Tox FAQ for lead, 2007; Haroun, 2009).

It is a heavy metal that is toxic at very low exposure levels and has acute and chronic effects on human health. It is a multi-organ system toxicant that can cause neurological, cardiovascular, renal, gastrointestinal, hematological and reproductive effects. The type and severity of effects depend on the level, duration and timing of exposure. Lead is accumulated in bone and may serve as a source of exposure later in life. Organolead compounds, such as tri-alkyl-lead and tetra-alkyl-lead compounds, are more toxic than inorganic forms of lead (UNEP, 2010; EPA, 2005).

Absorbed lead enters the blood stream and accumulates in body tissue, particularly the kidneys, bones and nervous system. In children, lead poisoning occurs at lower blood lead levels than in adults. The age range of 1-5 years is the most critical (CDC, 2012).

Acute exposure to high levels of lead causes severe intoxication and can lead to encephalopathy. Chronic exposure produces a more subtle and variable range of symptoms and a heightened risk of neuropsychological disorders, neuropathy, and peripheral neuropathy. Lead can cause a wide range of health effects over the long term, including chronic anemia, slow mental and physical development, and altered normal behavior (ATSDR, 2007).

### 2.9.2 Antimony

Antimony (Sb) and its compounds have been known by humans since ancient times. It has been used in beads, vases, and other glassware (Winship, 1987). Antimony is used to make alloys with other t metals; their compounds are used in the manufacture of flame retardant material. Antimony is also used in lead storage batteries, solder, sheet and pipe metal, bearings, castings, and pewter (ATSDR, 1992).

The metal is one of the naturally occurring elements; it exists in very low concentration in surface soils. It usually occurs as a compound as trivalent (III) and pentavalent (V). Its abundance is less than 1 to 4 mg/ kg in the soil surface (EPA, 2006). The total metal content in unpolluted soils for antimony is below < 1 mg/kg (Sanchez & Ayuso, 2008). Concentration above 31 mg/kg in soil may be hazardous to human beings (EPA, 2006).

Antimony is a semi-metallic element in period 5 and group 12 of the periodic table, with the following chemical and physical properties: antimony is a moderately active, moderately hard, silvery-white, shiny metal. The melting point of antimony is 1,170°F and its boiling point is 2,980°F. Its density is 6.68 g/ $cm^{-3}$ (Wuana & Okieimen, 2011).

Antimony is released into environment components from natural phenomena and human activities and is dispersed into air, soil, and water. Natural sources include volcanoes, while antimony oxides are common component of both coal and petroleum (Alloway, 2013). The main

anthropogenic sources of antimony include the production of ceramic, fire retardants, additives, medicine, pigments, and semiconductors (WHO, 2008; Chen, 2011).

Antimony and its compounds are hazardous to human health. It is number 232nd on most hazardous substances (SPL). The organs affected by antimony are the stomach, kidney, respiratory system, and skin system (ATSDR Tox FAQ for Antimony, 1992).

Antimony poisoning occurs when a human absorbs contaminants of the metal through breathing or by ingestion. It can cause a variety of adverse health effects at low levels of exposure, including eye irritation, stomach pain, diarrhea, vomiting, and lung, and stomach ulcers. Acute toxicity inspire: irritation of tissues, respiratory system, heart, liver and kidney damage, and may cause death (ATSDR, 1992).

### 2.9.4 Cadmium

Cadmium (Cd) was discovered in 1817 by the German chemist Friedrich Stromeyer from an impurity in some samples of zinc carbonate (Thornton, 1986). Cadmium is produced mainly as a by-product from the processing of zinc, lead and copper extraction ores (EPA, 1997). Cadmium compounds are currently mainly used in rechargeable nickel-cadmium batteries. It is also used in pigments, coatings and plating, the manufacture of plastic products, alloys, PVC, plastic, paint pigments, letches tanning, and, wood treatment (Morrison, 2000; Mudgal et al., 2010).

Cadmium is a natural occurring element that exists in low concentration in surface soils. It is found most commonly in ores of zinc. Its abundance ranges from 0.6 to 1.1 mg/kg in soil surfaces (EPA, 2006). The total metal content in unpolluted soils for cadmium is below 1 mg/kg

(Sanchez & Ayuso, 2008). Concentrations that exceeded 37 mg/kg may result in adverse health effects in humans (EPA, 2006).

Cadmium is a transition element in period 5 and group 12 of the periodic table with the following chemical and physical properties: cadmium is a bluish-white, soft, ductile metal, non-corrosive with atomic weight 112.4, its melting point is 610°, and its boiling point is 1,410°F. The density of cadmium is 8.65 g/ $cm^{-3}$ (Wuana & Okieimen, 2011).

Cadmium is released to environment components from natural phenomena, and human activities, and is dispersed into air, soil, and water. Natural sources of cadmium include weathering of rocks, volcanic activity, and spray from oceans, biogenic material and forest fires (ATSDR, 2007; COWI, 2003). Anthropogenic sources are responsible for increases in the concentration of cadmium in the environment media, these sources include batteries, fertilizers, plastic, steel industries, and coal utilization for energy production (Chen, 2011).

Cadmium is one of the most toxic metals with a major carcinogenic impact in humans. It is number 7 on the ATSDR "Top 20 list". Cadmium poisoning occurs when a human being absorbs contaminants of the metal through breathing or through ingestion. Food intake and tobacco smoking are the main routes by which Cadmium enters the body (Wuana & Okieimen, 2011; ATSDR, 2012).

Target organs of cadmium toxicity are mainly the kidneys, liver, kidney, placenta, lungs, brain, and bone systems (ATSDR Tox FAQ for Cadmium, 2010; Haroun, 2009). Cadmium concentrations can cause epigastria pain, nausea, vomiting, severe diarrhea and hemorrhage (Geiger & Cooper, 2010). Low levels of cadmium cause nausea, vomiting, and diarrhea. Inhaled, cadmium dust causes dryness of the throat, choking, headache, and pneumonia like symptoms. Long-term occupational exposure to cadmium at excess concentrations can cause a wide variety

of acute and chronic effects in humans. It can cause depressed growth, high blood pressure, kidney damage, cardiac enlargement, hypertension, fetal deformity, erythrocyte destruction, muscular cramps, nausea, renal degradation, salivation, and skeletal deformity (Chen, 2011; Amid, 2006).

### 2.9.5 Chromium

Chromium (Cr) was discovered in 1797 by the French chemist N. L. Vauquelin. Chromium is used in many manufacturing application such as the production of stainless steel, electro planting, and refractory bricks, in furnaces, tanning leather, and wood preservation. Chromium has also been used to make dyes and pigments for paints (Krebs, 2006).

Chromium is a naturally occurring element; it exists in low concentrations in surface soils. It occurs only in compounds in several forms such as chromium (0), trivalent (III) and hexavalent (VI) (Jalali, 2007; Wuana & Okieimen, 2011). Its abundance ranges from 1 to 1,000 mg/kg in soil surface (EPA, 2006). Concentrations of hexavalent above 30 mg/kg, and above 10,000 for trivalent may result in adverse health effects in humans (EPA, 2006).

Chromium is a transition element in period 5 and group 12 of the periodic table, having both properties of a metal and nonmetal, with the following chemical and physical properties: Chromium is a fairly active metal. It is a steel-gray, lustrous, hard, brittle metal; and it can be highly polished. Chromium has an atomic number of 24, atomic mass of 52, melting point of 1503°F, and boiling point of 1137°F. The density of chromium is 8.65 $g/cm^3$ (Wuana & Okieimen, 2011).

Chromium is released into environment components from natural phenomena and human activities and is dispersed into air, soil, and water. Natural sources of chromium include the continental dust flux, volcanic eruption, sea spray, forest fires, and biogenic sources (Krebs,

2006). The main anthropogenic sources of chromium include chrome tanning, electroplating, dye paints, and paper industries and, aluminum manufacturing (Jacobs & Testa, 2004).

Chromium is an essential micronutrient for human beings. Chromium (III) is a micronutrient essential for the health of humans, as it a plays a role in normal body functions, and helps the body in regulating sugar, protein, fat, and the digestion of food.

Chromium can also be toxic; it is number 78$^{th}$ most hazardous substances (SPL). Chromium poisoning occurs when a human being absorbs contaminants of the metal through breathing or through ingestion or by skin contact with chromium or its compounds. Food is the major source of chromium intake (WHO, 2008).

Chromium is an accumulative poison in large amounts or high concentration and causes various health effects in the human body. Target organs are the liver, kidney, blood, and lungs (ATSDR Tox FAQ for Chromium, 2012; Chen, 2011). It is reported that chromium’s hexavalent form is more toxic compared to the trivalent species. Studies also concluded that chromium (III) has low toxicity and has a low tendency to be adsorbed into the gastrointestinal tract. Exposure to chromium (VI) can cause allergic contact dermatitis, digestive and lung carcinoma as well as irritation and corrosion of skin and respiratory tract Chromium ingestion may cause epigastric pain, nausea, vomiting, severe diarrhea and hemorrhage (Chen, 2011).

### 2.9.6 Zinc

Zinc (Zn) has been in use since ancient times. It was reportedly known in Asia, most notably in India, China, and Palestine, before it was discovered in Europe. Zinc was rediscovered and described later in Europe by Swiss physician Paracelsus (1493-1541) and by Andreas Marggraft in 1746 in Germany (Krebs, 2006).

Zinc is used to galvanize other metals and make alloys; zinc is also used as coating for iron or other metals, used in preserving wood and in manufacturing and dyeing fabrics. Zinc compounds are used by drug industries as ingredients in some common products such as sun blocks, diaper rash ointments, automobile parts, roofing, gutters, batteries, organ pipes, electrical fuses, type metal, household utensils, and building materials (Jalali, 2007).

Zinc is a naturally occurring element found in soil surfaces combined with other elements in the form of sulfide, carbonate, silicate and oxide. It is found most commonly in ores of zinc. Its abundance ranges from 10 to 300 mg/kg in soil surfaces (EPA, 2006). The total metal content in unpolluted soils for zinc is between 10 - 300 mg/kg (Sanchez & Ayuso, 2008). Concentrations above 23,000 mg/kg may result in adverse health effects in humans (EPA, 2006).

Zinc is a fairly active transition element in period 4 and group 12 of the periodic table, with the following chemical and physical properties: zinc is an inorganic substance, fairly soft, lustrous, bluish-white metal with a shiny surface. Zinc has an atomic number of 30, with melting point of 787.1°F and its boiling point of 1,670°F. Its density is 7.14 g/cm$^3$ (Wuana & Okieimen, 2011).

Zinc is released into environment components from natural phenomena and human activities and is dispersed into air, soil, and water. Natural sources of zinc include sea salt, the movement of soil dust particles in the air, forest fires and volcanoes (UNEP, 2010). The main anthropogenic sources of zinc include mining, purification of zinc, lead, and cadmium ore (Wilson, 2013; UNEP, 2010).

Zinc is an essential micronutrient for human health, necessary in small amounts. It is number 75$^{th}$ most hazardous substances (SPL). Zinc is found in foodstuffs, and plays an essential role in the manufacture of many important chemicals in the human body. Zinc poisoning occurs

when a human being absorbs contaminants of the metal through breathing or by ingestion. Target organs are the liver, kidney, blood, and lungs (ATSDR Tox FAQ for Zinc, 2010; Chen, 2011).

In excess, concentrations of zinc can cause health problem such as dryness of the throat, coughing, nausea, general weakness, aching, chills, fever, and vomiting. In high concentrations, zinc can cause respiratory distress syndrome, acute renal tubular necrosis, chemical pneumonitis, interstitial nephritis (ATSDR, 2005).

### 2.9.7 Copper

Humans have known of copper (Cu) since earliest ancient times. It has been used by humans since the Bronze Age. Copper was used in north Iraq, China, and the Roman Empire (Krebs, 2006).

Copper is used to make alloys; the most important application of copper metal is electric wiring, used in construction. Copper is also used as a coloring agents in paints, ceramic, inks, varnishes, and enamels (NTP/NIH, 2011).

Furthermore, copper is a naturally occurring element found in surface soils. It is found most commonly in ores of zinc. Its abundance ranges from 2 to 100 mg/kg in soil surface (EPA, 2006). The total metal content in unpolluted soils for copper is around 20-30 mg/kg (Sanchez & Ayuso, 2008). Concentrations greater than 3,100 mg/kg may result in adverse health effects in humans (EPA, 2006).

Copper is a moderately active malleable transition metal, in period 4 and group 29 of the periodic table, with the following chemical and physical properties: pure copper is usually a fairly soft and ductile, reddish-brown or red-orange metal. It has a melting point of 1,982°F and a boiling point of 4,703°F. Its density is 8.96 g/cm$^3$ (Wuana & Okieimen, 2011).

Copper is released into environment components from natural phenomena and human activities and is dispersed into air, soil, and water. Natural sources of copper include windblown dust, decaying vegetation, forest fires, and sea spray. The main anthropogenic sources of copper include metal plating, mining, smelting, fertilizers, and sewage sludge (WHO, 2008).

Copper can enter soil mainly from atmospheric deposits, tailings of mines and mills, agricultural use, and solid waste and sludge disposal. In soil, copper can become strongly attached to the organic material and other components (in the top layers of soil) and may not move very far when it is released (ATSDR, 2004).

Copper is an essential micronutrient for human growth, it helps in the production of blood hemoglobin, and is needed in small amounts. It is number 125$^{th}$ on most hazardous substance (SPL).

Copper poisoning occurs when a human being absorbs contaminants of the metal through breathing or by ingestion. Target organs of copper toxicity are primarily liver or kidney (ATSDR Tox FAQ for Copper, 2004).

Inhalation of high levels of copper can cause irritation to the nasal passage. Ingestion of high levels can cause nausea and vomiting. Exposure to very high levels can cause anemia damage to the liver and kidneys, stomach and intestinal irritation and may lead to death (Sharma et al, 2009; Greanly, 2005).

## 2.10 Heavy metals behavior in soil

The study of the presence of heavy metals and their behavior in soil is of significant concern due to the negative consequences of metallic toxicity in soil environment. Some heavy metals can be transferred through soil profile down to ground water, or uptake by plants, hence creating a toxicological impact on human health and other living organisms in the soil.

Generally, heavy metals in soils can be found in a variety of forms: i) dissolved in the soil solution; ii) occupying exchange sites on inorganic soil constituents; iii) specifically adsorbed on inorganic soil constituents; iv) associated with insoluble soil organic matter; v) precipitated as pure or mixed solids; vi) present in the structure of secondary minerals; vii) present in the structure of primary minerals (EPA, 1992; Issa, 2008).

The soil's reaction to contamination depends on their chemical and physical properties and the nature of the contaminant. The total concentration of heavy metals in soils persists for a long time after their introduction (Bone, 2004). Once heavy metals are incorporated into the soil surface, a series of complex chemical and biological interactions occur. They are adsorbed by initial fast reactions, followed by slow adsorption reactions. This reaction takes from minutes to years. Following adsorption reactions, the heavy metals are redistributed into different chemical forms with varying bioavailability, mobility and toxicity (Wuana & Okieimen, 2011). Some of these metals can persist for a long time because of their immobile nature, while others are more mobile (Violante et al., 2010).

The mobility of heavy metals depends on the interaction between physio chemical soil and soil solution properties such as contents of organic matter, carbonates, oxides as well as soil structure and profile development (EPA, 1992; Dube, 2002). Heavy metals can be found in the liquid phase of the soil as free cations or complexed with inorganic and organic ligands, and in

the solid phase retained at exchange sites or at specific sites of oxides, organic matter and in structures of primary or secondary minerals (Chernet, 2009; Altaher, 2001).

The interaction of heavy metals with the soil includes precipitation/dissolution, sorption/desorption and the formation of organic complexion / decomplexion (David & Leventhal, 1995; Violante etal., 2010). These interactions are controlled by many factors, which determine the bioavailability, leaching, and toxicity of heavy metals in the soil. These factors are: the chemical bonding form, pH value, redox potential, conductivity and ionic strength, presence of free oxides of iron, and aluminum, clay content,  cation exchange capacity, organic matter content and hydrothermal condition of soil, nature of sorbents, presence and concentration of organic and inorganic ligands, including humic and folic acids, root exudates, microbial ties and nutrient. In addition, heavy metal mobility is influenced by seasonal fluctuations induced by climate such as temperature, precipitation, and influences by biological activity (Violante et al., 2010; Matranga, 2012).

The brief description of mobility of target heavy metals is summarized below:

### 2.10.1 Lead

Lead in the environment is mainly particulate bound with relatively low mobility and bioavailability in soil. Most lead that is released to the environment binds strongly to soil particles (ATSDR, 2007).

Ionic lead, lead (II), lead oxides, hydroxides, and lead-metal oxyanion complexes are the general forms of lead that are released into the soil, surface waters, and groundwater. Only a very small portion of the lead in soil is present in the soil solution. The primary processes influencing

the content and mobility of lead in soil include adsorption, ion exchange, precipitation, complexation with sorbed organic matter, and soil pH (Evanko, & Dzombak, 1997).

The sorbed lead is in forms of carbonate, sulfate, halides and oxide. Soluble lead reacts with clay, phosphates, sulfate, carbonates, hydroxides and organic matters. Lead is absorbed on clay surface or forms lead carbonates at a pH less than 6. Soil acidification will lead to increased mobility and bioavailability of lead (European Commission, 2002; Amid, 2006).

### 2.10.2 Chromium

Chromium can exist in soil in two possible oxidation states: the trivalent chromium, Cr (III) and the hexavalent chromium, Cr (VI), depending on pH and redox potential (Stanin & Pirni, 2004). Chromium in soil is not very mobile as it does not dissolve easily in water and can attach strongly to soil particles (ATSDR, 2012). Chromium mobility depends on sorption characteristics of the soil, including clay content, iron oxide content, the amount of organic matter present, pH, and redox potential (Evanko& Dzombak, 1997; Field, 2011). Chromium (VI) is more mobile than Cr (III). The mobility of Cr (III) is decreased by adsorption to clays and oxide minerals below pH 5 and low solubility above pH 5 (EPA, 1997; Stanin & Pirni, 2004; Field, 2011).

### 2.10.3 Copper

Interactions of copper with the environment are complex. Research shows that most of copper introduced into the environment becomes stable (Kiaune & Singhasemanon, 2011; Wuana & Okieimen, 2011). Copper is strongly adsorbed to soil particles and therefore has very little mobility relative to other trace metals, and tends to accumulate in soil (CCME, 1999). Copper mobility in soil depends on pH, cation exchange capacity, organic matter content, and

presence of oxides of iron, manganese, aluminum, and redox potential (Evanko & Dzombak, 1997).

The capacity of soil to adsorb copper increases with increasing pH, with a maximum holding capacity at neutral to slightly alkaline conditions (pH 6.7–7.8). Furthermore, soils with alkaline conditions tend to favor the precipitation of copper; thus, copper is more mobile under acidic than alkaline conditions (CCME, 1999).

### 2.10.4 Antimony

Our understanding of the environmental behavior of antimony in soil is underdeveloped compared to most other metals. Its mobility is not clearly understood; some studies indicate that antimony is highly mobile while others indicate that it is strongly absorbed into soil (EPA, 1992). Antimony is considered relatively or moderately mobile in the soil under oxidizing conditions and/or with low available contents in soils. It attaches strongly to particles that contain iron, manganese or aluminum (Sanchez & Ayuso, 2008; Krupka & Serne, 2002). Soluble fraction is probably present as antimonate, especially under oxidizing and basic conditions, and could be adsorbed by the same soil constituent that bind phosphate and arsenate (Adriano, 2001).

### 2.10.5 Cadmium

In soil, cadmium usually takes the form of cadmium carbonate and cadmium sulfide or sulphate (IARC, 2007; ATSDR, 2007). Cadmium is relatively water-soluble; therefore making it more mobile in the soil compared to other heavy metals. Cadmium also tends to bioaccumulate (WHO, 2003).

Cadmium mobility in soil depends on Soil pH and redox potential (EPA, 1992). The more acidic the soil is, the more mobile the cadmium becomes. In acidic soil conditions, amorphous colloids and organic matters can absorb very little of cadmium, clay mineral carbonates or hydrous oxides of iron and manganese may absorb cadmium. In addition, cadmium may precipitate as cadmium carbonate, hydroxide, and phosphate (European Commission, 2002; Amid, 2006; EPA, 1992).

### 2.10.6 Zinc

In soil, zinc is relatively mobile, does not dissolve in water, and adsorbs strongly onto soil particles. Zinc is readily adsorbed by clay minerals, carbonates, or hydrous oxides (ATSDR, 2005). Zinc mobility in soil depends upon the concentration of zinc and other ions in the soil solution, the type and amount of adsorption sites associated with the solid phase of the soil, the concentration of all ligands capable of forming organo-zinc complexes and pH and redox potential of the soil. A very small proportion of the total zinc content of a soil is present in the soil solution (Alloway, 2008).

## 2.11 Previous studies of heavy metals in the study area

The study of heavy metals in Ciudad Juarez is associated with the heavy metals in El Paso. The relevant studies conducted in El Paso del North region indicated that there are high levels of some elements in Ciudad Juarez, especially the area nearby the ASARCO smelter. Summaries of these studies can be found below.

In 2006, Ketterer conducted a study for the Sierra Club. The purpose of this study was to characterize the possible contributions of ASARCO's inactive El Paso smelters to the burden of lead and other hazardous substances in the soils of three locations near the plant: residential areas

in Ciudad Juarez, Chihuahua, Mexico; residential areas in Anapra, New Mexico; and areas near the facility in El Paso, Texas. The top 10 cm of soil from 97 locations in three areas were collected to investigate concentrations of elements lead, copper, zinc, arsenic, silver, cadmium, indium, antimony, thallium, and bismuth.

The study revealed a probable link between the smelting activities of ASARCO and soil contamination in El Paso and the nearby communities of Anapra, New Mexico and Ciudad Juarez, Chihuahua, Mexico. This study concludes that the major source of soil contamination is the ASARCO smelter. The major findings of this study are the presence of elevated levels of hazardous substances such as lead and arsenic, which were also strongly correlated with smelter association. In sampled locations where lead and arsenic were present, the contaminants were always present at correspondingly high levels.

In 2001, the National Institute of Environmental Health Sciences funded a five-year study (Encountors: Binational Community Lead Project) conducted by researchers at the University of Texas at El Paso and the Texas Tech University Health Sciences Center of lead exposure risks in El Paso, Ciudad Juarez, and the surrounding communities. As part of this project, the researchers are conducting a comprehensive survey of lead levels in soil throughout Ciudad Juarez. A total of 500 superficial soil samples from Juarez were collected from municipal city blocks. The results of the study are produced in a uniquely detailed map of lead soil concentration (UTEP Press Release, 2004).

In 1974, the Secretariat de Salud (Secretariat of Health in Mexico) performed a study in Ciudad Juarez. The study involved the analysis of blood samples, and glazed pottery for lead soils for gardens and courtyards and household dust for lead, copper, zinc, and cadmium. Dust

and soils were found to have higher concentration of these metals in soils within distance from ASARCO smelter (Srivivas, 1994).

# Chapter 3: Material & Method

## 3.1 Study area description

### 3.1.1 Location

Ciudad Juarez is in the state of Chihuahua, Mexico. Juarez shares boundaries with Texas and New Mexico Figure 3.1, and is located in the Rio Grande/Bravo basin in in the northern Chihuahuan Desert, at latitude between the coordinates 31º 07' 38" and 31º 44' 22" north latitude and longitude between the coordinates 106º 06' 57" and 106º 26' 29" west longitude, within the Paso Del Norte region (PdN), directly south of the Rio Grande River and El Paso, Texas, in midpoint of the 2,000 mile long U.S.-Mexico border (Grineskia et al., 2012; Lougheed et al., 2008).


Figure 3.1: Study area

Ciudad Juarez and El Paso are linked in a long history of emigration and immigration, as well as the interchanging of culture, goods, and services. They also share air, watersheds, and other biophysical attributes that unite them environmentally (Heyman, 2007).

### 3.1.2 Population

Ciudad Juarez has grown substantially in recent decades as migrants arrive in search of job opportunities in the manufacturing sector. It is the 5th largest city in Mexico with approximately 1.5 million residents (Grineski & Collins, 2010).

### 3.1.3 Climate

Due to its location in the Chihuahuan Desert, Ciudad Juarez has an arid climate, with a wide range of seasonal conditions. Seasons are distinct, with hot summers, cool springs and autumns, and cold winters. The summer average high is 95 °F with lows of 70 °F. Winter highs average 57 °F, with lows of 32 °F. An average annual rainfall ranges from 8.7 inches to 40.3 inches, which occurs mostly during brief thunderstorms from July through September (Thomson et al., 2007).3.1.4 Topography

Juarez rests between two mountain ranges and the flat riverbanks of the Rio Grande. The local topography is classified as complex terrain because of the moderately sized mountain. The area is surrounding by the southwest trending Sierra del Juarez mountain ranges that lie north, south, and west of the central Ciudad Juarez (Li et al., 1999), rising to 5,413 feet above the valley floor. The Sierra de Juarez on the other hand, is composed mainly of Cretaceous sedimentary rocks deformed by folding and thrust faulting during the Paleocene or Eocene age (Drewes, 1993). In a large scale, the Sierra de Juarez structures form a small synclinorium, or a

composite syncline, of older Cretaceous rocks, which was thrust faulted northeastward over younger Cretaceous rocks (Avila, 2011).

The Chihuahua Plateau lies to the south of Ciudad Juarez and is characterized by relatively flat terrain, gradually increasing in altitude above the valley floor moving south (Rincon et al., 2005).

The soil in the area is high in calcisols, cambisols, luvisols (cl), soils dominated by calcium carbonate as powdery lime or concretions.

### 3.1.5 Vegetation

Flora is mostly dominated by desert shrub and native plants typical of the northern extreme of Mexico's Chihuahuan Desert, such as creosote bushes on the lower slopes, and by cactus, grasses, some juniper, and a few pines at the higher elevations. Narrow ribbons of riparian forest and scrub run along stream channels and springs, such as cottonwood and sycamore. Agaves are typically found on hill slopes, along with ocotillo, yucca, cancholla and prickly pear (lougheed et al., 2008; Cotera et al., 2004).

## 3.2 Sample preparation and procedure

### 3.2.1 Soil Sample

The soil samples used in this study were a composite of samples collected during Encountors bi-national community lead study. The samples were collected from public areas around selected municipal blocks in the city of Ciudad Juarez.

The city area was divided into 50 strata Figure 3.2, with each stratum defined by uniform population size. IMIP/ INEGI data were utilized to define strata. Each stratum had approximately 24,000 ± 2,000 individuals (Amaya, 2003).

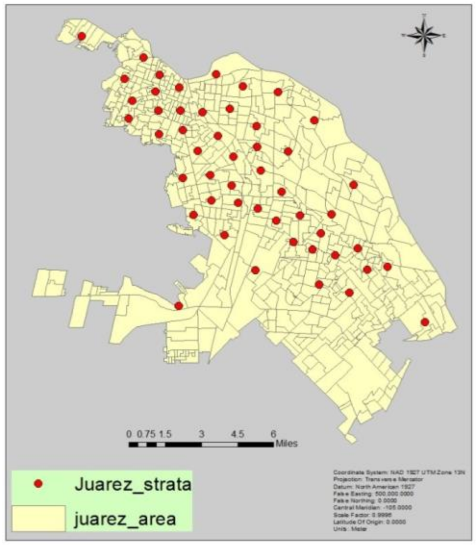


Figure 3.2: Juarez strata

The samples were taken from the land in front of individual houses, or structures around the blocks. A total of 500 composite surface sample soils were collected Figure 3.3.

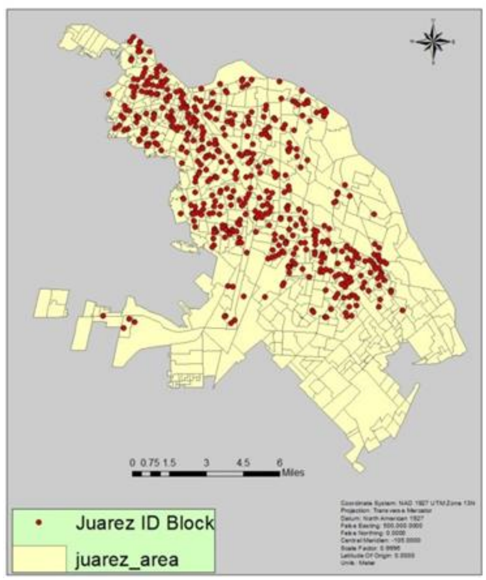


Figure 3.3: Study area collection soil samples from city blocks

To create a single composite sample to characterize each 500-block region, a mixture was created of equal volume samples taken from a single block from every other parcel on the block.

The composite sample was taken with a10 ml cup that was emptied into sealable plastic bags (Pingitore et al., 2005), and stored in the lab for the next subsequent laboratory procedure.

### 3.2.2 Soil Sample Procedure

The X-ray fluorescence analytical spectroscopic method requires samples in the form of round, flat surface discs. The general procedures of EPA method 6200 for field portable XRF, and PAN analytical article by the analytical x-ray company, with slight modification were followed for preparation samples. These included grinding, mixing, and homogeneity to achieve uniform particle grain size ≤ 40 µm.

#### 3.2.2.1 Grinding

The samples were mixed thoroughly to achieve homogeneity. The samples were ground in a PQ-T 04 gear-drive planetary ball mill. The following steps were utilized:

1. Weigh 9.8 grams (±0.1) of sample in balance.
2. Transfer the weighted sample into 100 ml jar with 24-10 mm mill balls.
3. Grind the sample in the mill for an operational time of 10 minutes at speeds of 350 rpm with bidirectional interval time.
4. Transfer sample to a watch glass using a plastic strainer to separate the balls, scrape the sample off the wall and bottom of jar with Teflon spatula.
5. Transfer the sample into sealed plastic bag with identification number for next subsequent laboratory procedure.

#### 3.2.2.2 Mixing

The following steps were utilized for mixing the samples:

1. Transfer 9.2 grams of ground soil sample (±0.005) to an 8 oz. translucent container.

2. Add 1.15 (±) grams of cellulose binder (particle size ≤ 30 µm), and 1.15 (±) grams of paraffin binder (particle size ≤ 20 µm) to the sample, followed by the addition of 7 ml of methanol.

3. Close the container and place it in the mill for an operational time of 4 minutes at 350 rpm with bidirectional interval time.

4. Remove the container from the mill; open it, to allow the sample to dry, and evaporate the methanol by replacing it in the hood for 24 hours.

5. Transfer the sample to a watch glass, and then transfer it to a sealed plastic bag with identification number for the next subsequent laboratory procedure.

#### 3.2.2.3 Pressing

The samples were prepared in the form of a pressed pellet. The samples were pressed into pre –flared XRF spec-cap, 31 mm diameter by using RIIC, C- 30 manual 30 tons hydraulic lab press. The following steps were followed for pressing the samples:

1. Weigh 11 g (±0.005) in the balance, and empty into the die set for pressing. The sample is then pressed into the die bore between the polished steel pellet surfaces at 20 tons for 30 seconds.

2. Allow the pressure to be released within 15 seconds (bleed time).

3. Remove the die set from the press, takes out the sample pellet, and label it by identification number.

#### 3.2.2.4 Homogenization of the sample soil

To monitor homogenization, two methods in this study were utilized:

The researchers weighed 10 grams of sample, and then added 1.15 grams of cellulose binder, and 1.15 grams of paraffin binder. We then added 0.5 gram of sodium fluorescein dye in the jar, and ground the mixture in the planetary mill for 2 minutes at 350 rpm.

The first method then calls for a transfer of approximately 2 grams of the sample to weighing paper, allowing examination under the microscope. When the dye is evenly distributed in the sample and no visible white spots appears, homogenization is considered complete.

The second method examines the same mixture as above under ultraviolet light to assess the distribution of sodium florescence dye through the sample. If the dye is evenly distributed in the sample, and no visible white spots appear, homogenization is considered complete (Spex Certiprep handbook, 1997; IAEA, 2004).

#### 3.2.2.5 Standard and blank procedure

The same methods for soil procedure have been used to prepare the standards, which include grinding and mixing. In addition, to verify the results and to calibrate the instrument, the following standards from the National Institute of Standards and Technology (NIST), and U.S Geological Survey (USGS) were utilized:

USGS standards are BR-1, NOD-A-1, SDC-1, GLO-1, SRG--1, SCO-1, MAG-1, RGM-1

NIST standards are 2586, 2711, 2710, 2709 a.

The blanks used are silica oxide, and Teflon (Polytetrafluoroethylene).

### 3.2.3 Cleaning procedure

All apparatus used in this study were cleaned by cleaning solution. These include jars, mill balls, plastic spoons, watch glass, Teflon spatulas, die set, translucent containers, plastic strainer, and steel spatula. The cleaning solution used in this study is Citranox (10-20 ml /l).

The jars and mill balls are cleaned after every run off sample with the following procedure:

1. Wash with tap water.
2. Wash with cleaning solution.
3. Rinse with tap water
4. Dry with tissues, followed by blow dryer.

The jars were also cleaned after every 50 run off the samples. The following steps were adapted:

1. Grind 10 grams of silicon oxide (99.5 %) for 5 minutes in the mill.
2. Rinse with tap water.
3. Grind 1-teaspoon silicon oxide with cleaning solution, and hot water in the jar for 10 minutes at 350 rpm.
4. Rinse the jar with tap water.
5. Dry the jar with the blow dryer.

### 2.2.3 Instrumentation (XRF)

Metal concentrations were quantitatively determined using the x-ray fluorescence (XRF) spectrometer. The (XRF) spectrometer is an x-ray instrument used for material analysis in a broad range of industries and applications including, research in igneous, sedimentary, and metamorphic petrology, soil surveys, measuring the grade of ore, cement production, ceramic and glass manufacturing and quality control in metallurgy.

The XRF method depends on fundamental principles that are common to several other instrumental methods involving interactions between electron beams and x-rays with samples. When materials are excited with high energy, short wavelength radiation (e.g., X-rays), they can become ionized. If the energy of the radiation is sufficient to dislodge a tightly held inner electron, the atom becomes unstable and an outer electron replaces the missing inner electron.

When this happens, energy is released due to the decreased binding energy of the inner electron orbital compared with the outer electron. The emitted radiation is of lower energy than the primary incident X-rays and is termed fluorescent radiation. Because the energy of the emitted photon is characteristic of a transition between specific electron orbitals in a particular element, the resulting fluorescent X-rays can be used to detect the abundances of elements that are present in the sample (EPA, 2006; Wirth & Barth, 2012).

In this study, the Epsilon5 instrument is used to analyze the soil samples. The Epsilon5 is an X-Ray Fluorescence Spectrometer (XRF) consisting of spectrometer, X-Y sample handler and software. The measuring program was set up in the software using the Epsilon5 wizard.  It works on wavelength-dispersive spectroscopic principles that are similar to an electron microprobe. Samples analyzed under this technique were utilized with samples prepared as compressed powder pellets.

The soil sample size for the city of Juarez is 501. For each sample the concentration of the metals lead (Pb), chromium (Cr), copper (Cu), zinc (Zn), cadmium (Cd), and antimony (Sb) were analyzed and measured by parts per million (ppm), via XRF. The data obtained was statistically analyzed by Minitab software. The maps for distribution of these metals were created and produced by using ESRI, Arc GIS Info (Ver. 10.1).  The metal level values for each sample that were collected from blocks were symbolized by a four-colored symbol: white, blue, green and dark brown.

# Chapter 4: Results & Discussion

## 4.1 Results on Juarez Data

### 4.1.1 Juarez

The results of the soil sample analysis are given in (Appendix A). The data obtained was statistically analyzed Table 4.1.

Table 4.1: Descriptive statistics for the variables (metals) - Juarez

| Variable | N | Mean | StDev | Minimum | Q1 | Median | Q3 | Maximum |
|---|---|---|---|---|---|---|---|---|
| Pb | 501 | 42.8 | 40.8 | 12.6 | 21.4 | 30.3 | 50.9 | 550.3 |
| Cr | 501 | 32.1 | 12.9 | 1.8 | 23.3 | 33.1 | 40.9 | 75.6 |
| Cu | 501 | 22.3 | 30.6 | 6.3 | 12.3 | 16.4 | 23.7 | 547.3 |
| Zn | 501 | 83.7 | 59.9 | 20.7 | 43.9 | 63.5 | 104.9 | 415.8 |
| Cd | 501 | 1.9 | 0.9 | 0.1 | 1.3 | 1.8 | 2.4 | 6.2 |
| Sb | 501 | 5.9 | 1.8 | 2.7 | 5.1 | 5.7 | 6.4 | 28.8 |

#### 4.1.1.1 Lead

Soil lead concentration Table 4.1 shows the resulting concentration levels, ranging from 12.6 to 550.3 ppm. In addition, the results indicated that the mean concentration values recorded for lead was 42.8 ppm. The concentration of lead in the soil samples is represented in the blocks of Figure 4.1.

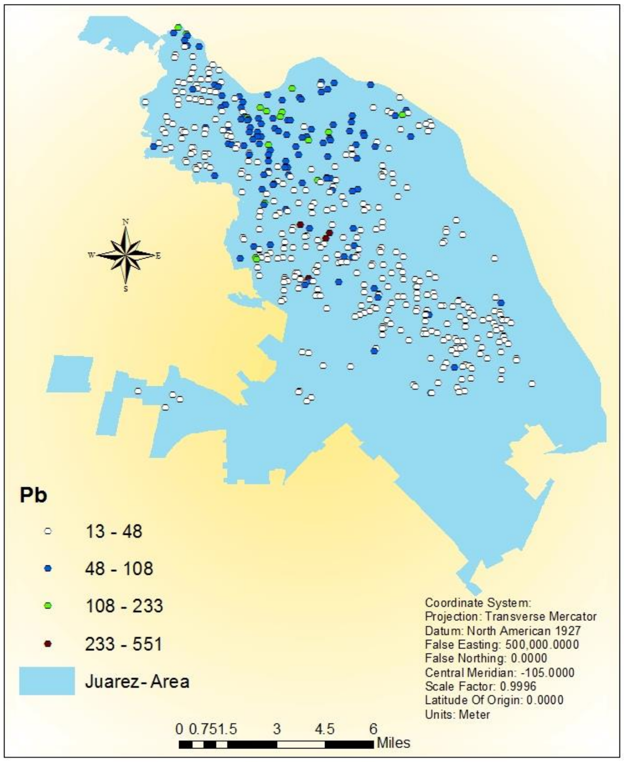


Figure 4.1: Lead concentration in composite samples from blocks in Juarez

The lowest values (between 13 ppm to 48 ppm; white dots) of lead are mostly encountered in the central and surrounding area of Juarez. Most of the blocks have concentrations that fall under this level. However, white dots are scattered all over, except the old town area, indicating lower soil lead levels.

Blocks with 48 ppm to 108 ppm lead are indicated with the color blue in Figure 4.1. Therefore, the concentrations between 48 ppm to 108 ppm for lead are recorded mostly from the old town and the surrounding area of Juarez. However, a few blue dots can be found in other areas. Only a few blocks have lead levels between 108 ppm to 233 ppm (green dots). Most of them are in the old town area.

There are only three blocks that have the highest values, between 233 ppm and 551 ppm; these values are depicted in brown. This block of concentrations is in the east side. When it goes from central area to old town, the concentration of lead gradually increases.

In comparison, lead abundance ranges from 2 to 200 mg/ kg in the soil surface, and the total metal content in unpolluted soils for lead ranges between 10 and 70 ppm (EPA, 2006). The results obtained in this work indicated that the lead concentration is above-mentioned limits; therefore, the soil is highly polluted, and may pose threats to the environment and the residents living in it.

The concentration of lead in the soil of study area probably constitutes a major health hazard, and poses a threat to local population. Young children and infants are the higher risk for adverse health effect of lead. Figure 4.2 illustrates the potential risk hazardous of lead levels in soil samples to the children age 1-5 living in Juarez area.

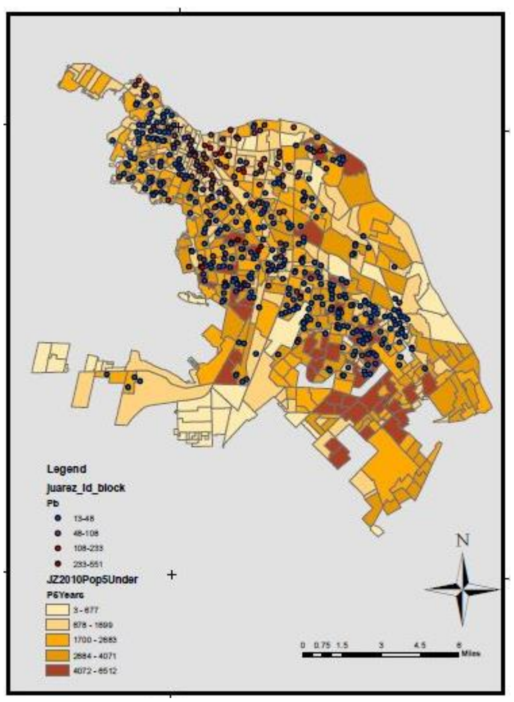


Figure 4.2: Potential population density and lead soil in Juarez

Figure 4.3 illustrates the risk areas for the children, the risk areas is ranked from the highest; number 1 to t 7, which represent low or no risk area.

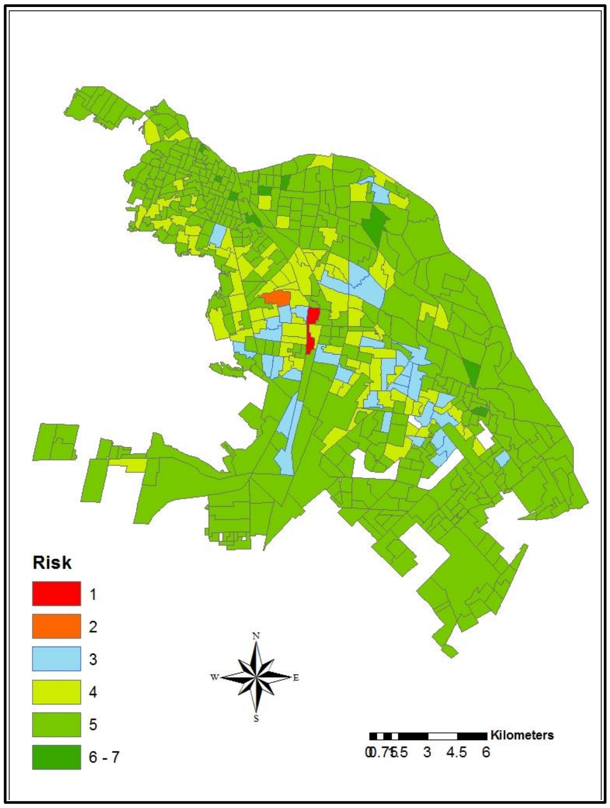


Figure 4.3: Risk lead in Juarez areas

#### 4.1.1.2 Chromium

Soil chromium concentration Table 4.1 indicates that the resulting concentration levels recorded for chromium ranged from 1.8 to 75.6 ppm. In addition, the results indicate that the mean concentration values recorded for chromium was 32.1 ppm. The concentration of chromium in soil samples is represented in the blocks in Figure 4.4.

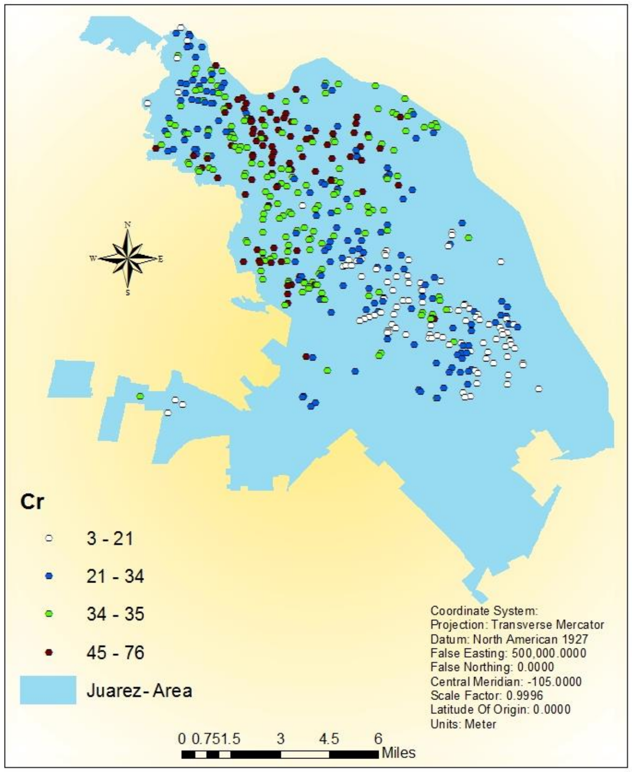


Figure 4.4: Chromium concentration in composite samples from blocks in Juarez

The lowest values (between 3 ppm and 21ppm; white dots) of chromium are mainly encountered in central and southern central areas. None of the blocks in the new town and old town areas shows chromium concentrations in this range.

Blocks with 21 ppm to 34 ppm chromium, are seen in blue in Figure 4.4, are scattered all over the map. Blocks having chromium levels between 34 ppm to 45 ppm (green dots), are encountered mainly in old town, new town and east areas. Only a few blocks having chromium concentration in between 34 ppm to 45 ppm are situated outside these areas.

Blocks with the highest value between 45 ppm and 76 ppm are depicted in brown. Most of these blocks are situated in old town, new town and east areas. Only a few blocks, having

chromium concentrations between 45 ppm to 76 ppm, are situated outside these areas. The level of concentrations seems higher in old town, new town and east areas, with compared to others.

In comparison, the chromium abundance ranges from 1 to 1,000 mg/kg in soil surface (EPA, 2006). The results obtained from the present work indicate that the chromium is considered within the background level; therefore, the soil is not contaminated by chromium, and exhibits no environmental effect.

#### 4.1.1.3 Copper

Table 5.1, indicates that the resulting concentration levels recorded for Cu ranged from 6.3 to 547.3 ppm. In addition, the results indicated that the mean concentration values recorded for Cu was 22.3 ppm. The concentration of copper in soil samples are represented in the blocks in Figure 4.5.

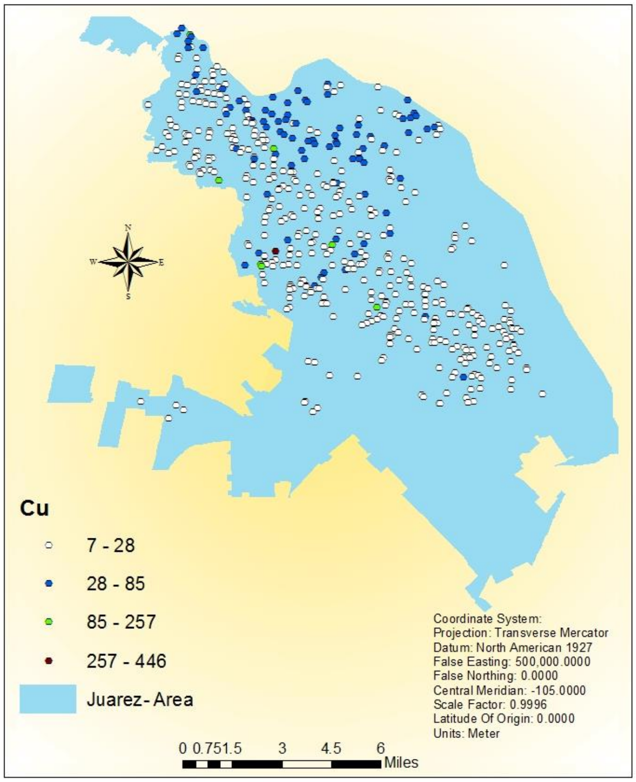


Figure 4.5: Copper concentration in composite samples from blocks in Juarez

The lowest values (between 7 ppm and 28 ppm white dots) of copper are spread out all over the city. However, the majority of these blocks can be found in east and the central areas. Most of the blocks in Juarez fall under this level of concentration. In green are all the blocks that have concentrations between 7 ppm and 28 ppm.

Blocks with 28 ppm to 85 ppm copper, are seen in blue in Figure 4.4, and are mainly found in the old town area and few in other areas. However, old town and new town areas show more blocks with this level of concentration.

Blocks having copper levels between 85 ppm to 257 ppm (green dots) are encountered only in a few blocks. Only one bloc has highest value between 257 ppm - 446 ppm and it is depicted in brown. This block is situated in the east area of Juarez.

The level of concentrations seems to be gradually increasing from the southern area of Juarez to the old town area. In the old town area, the left most section contains blocks with lower concentrations than the right side.

Copper abundance ranges from 2 to 100 mg/kg in the soil surface (EPA, 2006) and the total metal content in unpolluted soils for copper is around 20-30 mg/kg (Sanchez & Ayuso, 2008).

The concentration of cadmium recorded is higher than the background levels when compared with the result obtained. Therefore, we can be considering the soil contaminated by copper, and may pose hazards to the environment and residential health.

#### 4.1.1.4 Zinc

Table 4.1 indicates that the resulting concentration levels recorded for chromium ranged from 20.7 to 415.8 ppm. In addition, the results indicate that the mean concentration values recorded for chromium was 83.7 ppm. The concentration of zinc in soil samples are represented in the blocks in Figure 4.6.

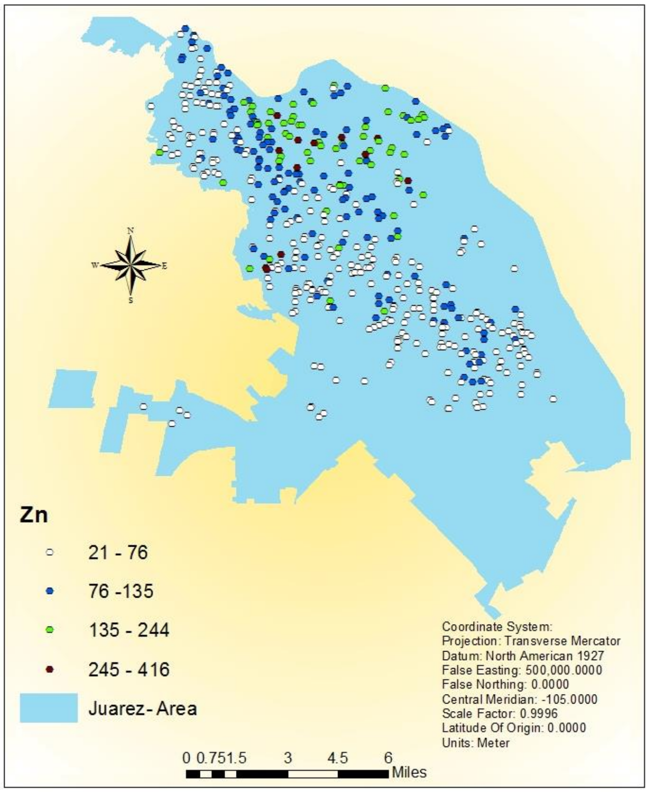


Figure 4.6: Zinc concentration in composite samples from blocks in Juarez

Figure 4.6 shows that the lowest values (between 21 ppm and 76 ppm; white dots) of zinc are mainly encountered in central, southern central, east and zone 6 areas. Most of the blocks in Juarez fall under this level of zinc concentration.

Blocks with 76 ppm to 135 ppm zinc, seen in blue in Figure 4.5, are scattered all over the map. However, these blocks can be mainly found in old town and the surrounding area. Blocks having zinc levels between 135 ppm to 244 ppm (green dots) are encountered prominently in old town and new town areas. Only a few blocks with zinc concentration in between 135ppm to 244 ppm are situated outside these areas.

Only one block has highest values between 244 ppm and 416 ppm. These blocks are depicted in brown. Most of these blocks are situated in old town and new town areas. Only a few blocks have zinc concentrations between 244 ppm - 41 6 ppm are in east side. However, none of the blocks in central, zone 6 or green area have blocks with this level of concentration.

The level of concentrations seems to be gradually increasing from south area of Juarez to old town, new town area. In old town area, left most section contains blocks with lower concentrations than the right side.  Furthermore, left side of old town is shows lower zinc concentrations compared to the right side.

For comparison, zinc abundance ranges from 10 to 300 mg/kg in soil surfaces (EPA, 2006). The total metal content in unpolluted soils for zinc is between 10 - 300 mg/kg (Sanchez & Ayuso, 2008). The result obtained from this work shows that the concentration of zinc in some area is above-mentioned limits. Therefore, we can consider the soil contaminated by zinc, and may pose hazards to the environment and residential health in this particular area in the city.

#### 4.1.1.5 Cadmium

Table 4.1 shows that the resulting concentration levels recorded for cadmium ranged from 0.1 to 6.2 ppm. In addition, the results indicate that the mean concentration values recorded for cadmium was 1.9 ppm. The concentration of cadmium in soil samples are represented in the blocks in Figure 4.7.

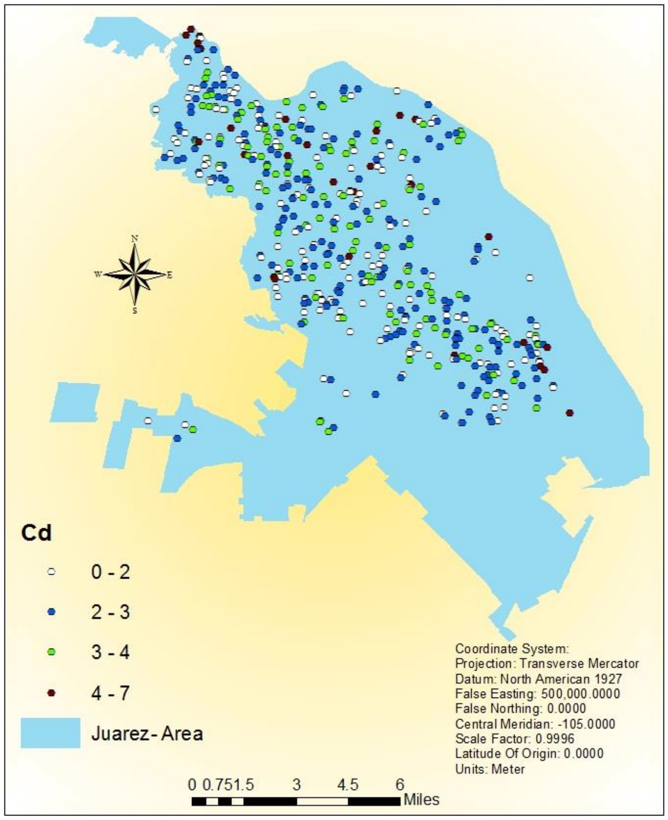


Figure 4.7: Cadmium concentration in composite samples from blocks in Juarez

The concentration of cadmium in soil samples are represented in the blocks in Figure 4.7. The lowest values (between 0 ppm to2 ppm; white dots) of cadmium are spread out all over the city.

Blocks with 2 ppm to 3 ppm cadmium are shown in blue in Figure 4.7. Therefore, the concentrations between 2 ppm to 3 ppm for cadmium are recorded all over. Most of the blocks in Juarez fall under this category.

Blocks with cadmium levels between 3 ppm to 4 ppm (green dots) are encountered all over the city except green area. Blocks with the highest values between 4 ppm and 7 ppm are

depicted in brown. At least one block having the highest concentration is recorded from each area. The brown blocks in the central area are situated more to south.

According to this map, no specific pattern can be observed between the concentrations and the area.

For comparison, cadmium abundance ranges from 0.6 to 1.1 mg/kg in soil surfaces (EPA, 2006). The total metal content in unpolluted soils for cadmium is below 1 mg/kg (Sanchez & Ayuso, 2008). The result obtained for cadmium showed high levels of cadmium above background level in the soil samples. Therefore, the study area is considered contaminated by cadmium and may result in adverse health through soil cadmium concentration.

#### 4.1.1.6 Antimony

Table 4.1, shows that the resulting concentration levels recorded for antimony ranged from 2.7 to 28.8 ppm. In addition, the results indicate that the mean concentration values recorded for lead was 5.8 ppm. The concentration of antimony in soil samples are represented in the blocks in Figure 4.8.

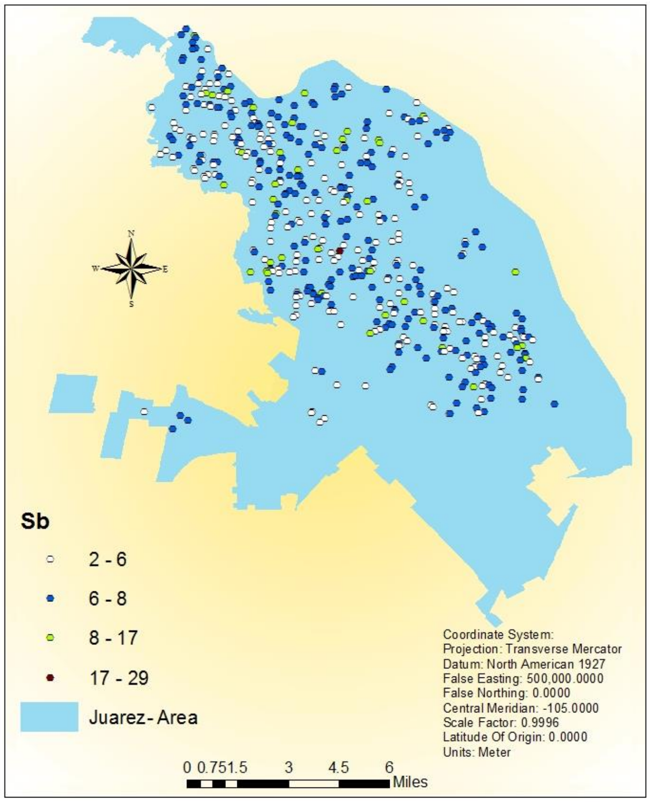


Figure 4.8: Antimony concentration in composite samples from blocks in Juarez

The lowest values (between 2 ppm and 6 ppm; white dots) of antimony are scattered all over the city. Blocks with 6 ppm to 8 ppm antimony, seen in are scattered. The majority of the blocks in Juarez show the concentration of antimony within this range.

Blocks having antimony levels between 8 ppm to 17 ppm (green dots) are encountered in all the blocks except zone 6. Only one type of block has highest values between 17 ppm and 29 ppm. That is depicted in brown. This block is situated in the east area of Juarez.

According to this map, no specific pattern can be observed between the concentration of antimony and the area.

For comparison, antimony abundance is less than 1 to 4 mg/ kg in the soil surface (EPA, 2006). The total metal content in unpolluted soils for antimony is below < 1 mg/kg (Sanchez & Ayuso, 2008). The concentration of cadmium recorded is higher than the background levels. Therefore, the soil is contaminated by antimony, and may pose hazards to the environment and residential health.

As seen from Table 5.1, the highest mean concentration value is recorded for the metal Pb and the minimum concentration is recorded for Cd, which is more than 40 times less than Cd. However, the standard deviation relevant to Zn is also high which is not favorable to the accuracy of the interpretation. A higher standard deviation indicates that the observations are scattered. However, all of the five number summaries (minimum, Q1, median, Q3, maximum) are also high for the variable Zn as compared to all the others. This provides a hint to believe that in the Juarez soil samples the highest concentration is recorded for Zn. However, it is advisable to consider the presence of outliers as well.

By considering all of the above statistics, we can conclude that the concentration of the soil samples taken from Juarez differs in the following order: Zn >Pb> Cr > Cu >Sb> Cd.

### 4.1.2 Correlation between variables (metals)

In this section, the correlation or the relationship between variables (metals) is studied. For this purpose, the Pearson correlation coefficient (r), and scatter plots have been used. In order to increase the readability of the scatter plots, log transformations have been used.

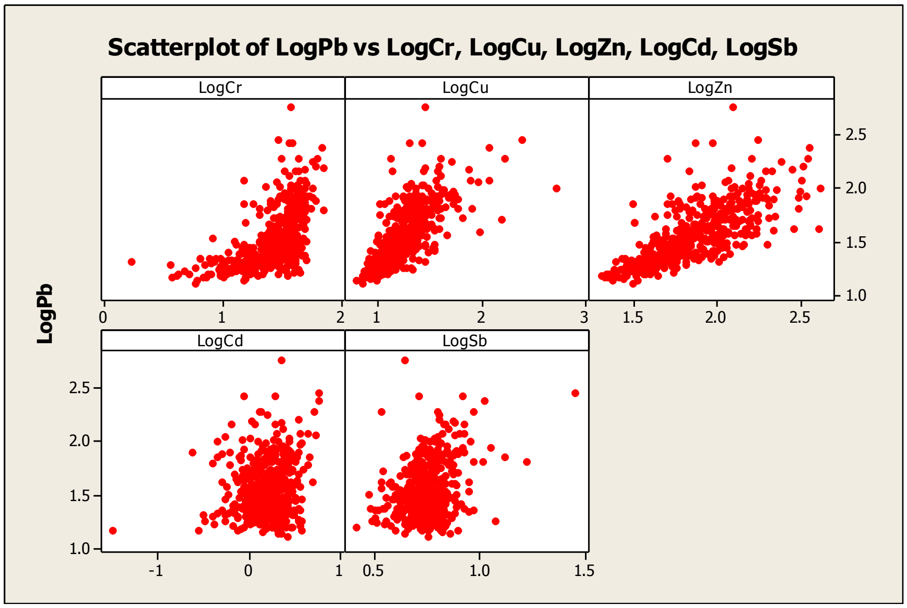


Figure 4.9: Scatter plots of Pb with other metals

From the above Figure, it can be observed that the variable Pb shows a slight positive correlation with the three variables Cr, Cu and Zn.

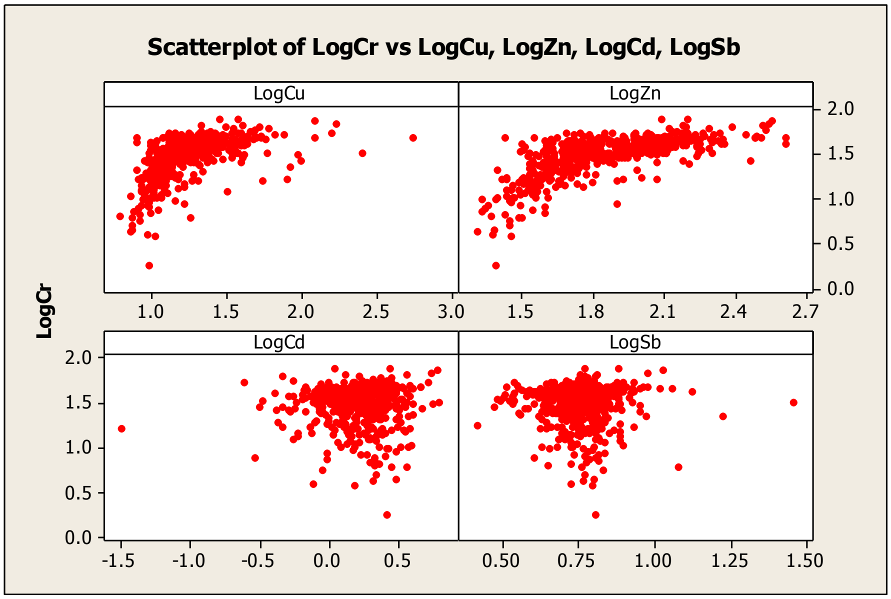


Figure 4.10: Scatter plots of Cr with other metals

From the above Figure 4.10, it can be observed that the variable Cr does not show a significant correlation with the other variables. However, it shows a minor relationship with Cu and Zn.

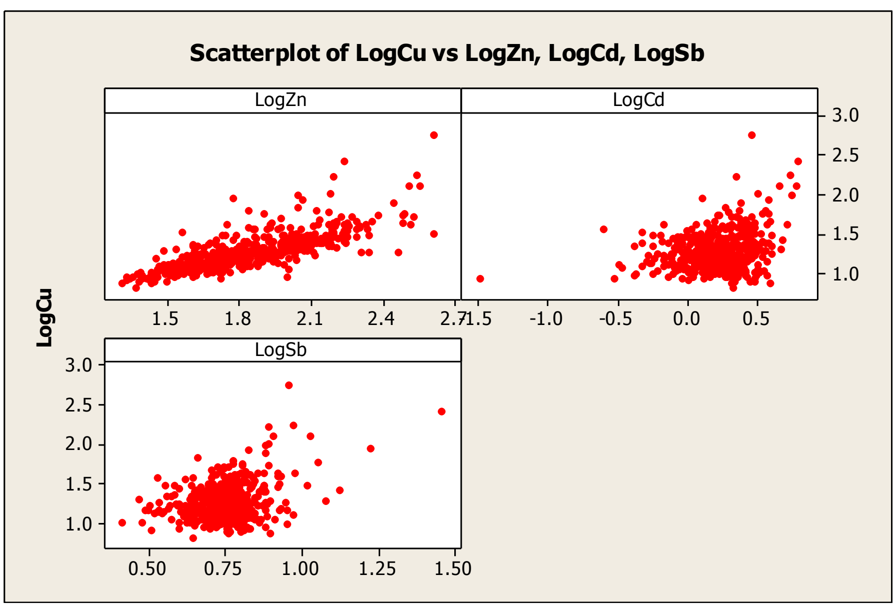


Figure 4.11: Scatter plots of Cu with other metals

From the above Figure 4.11, it can be observed that the variable Cu exhibits a positive correlation with Zn.

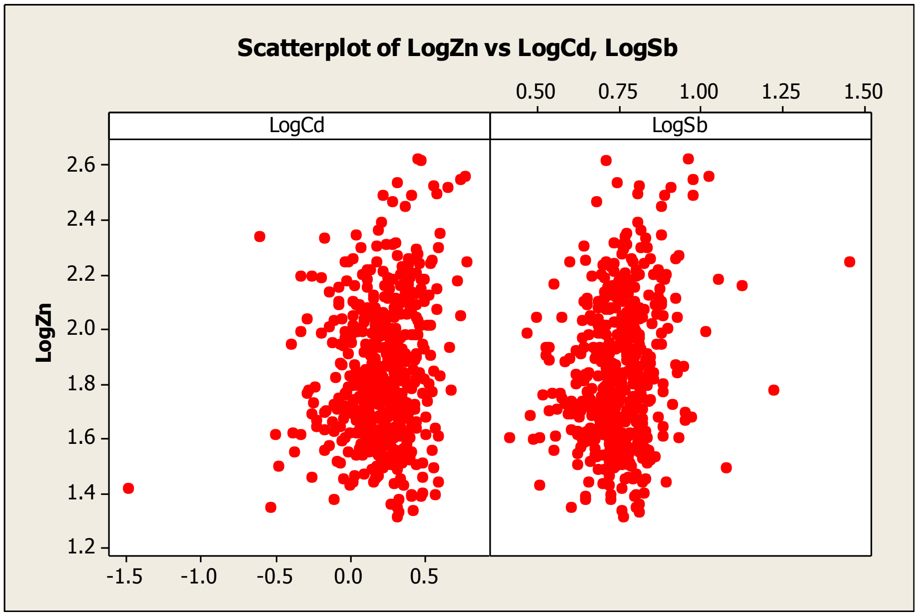


Figure 4.12: Scatter plots of Zn with other metals

From the above Figure 4.12, it can be observed that the variable Zn does not exhibit a significant relationship with Cd and Sb.

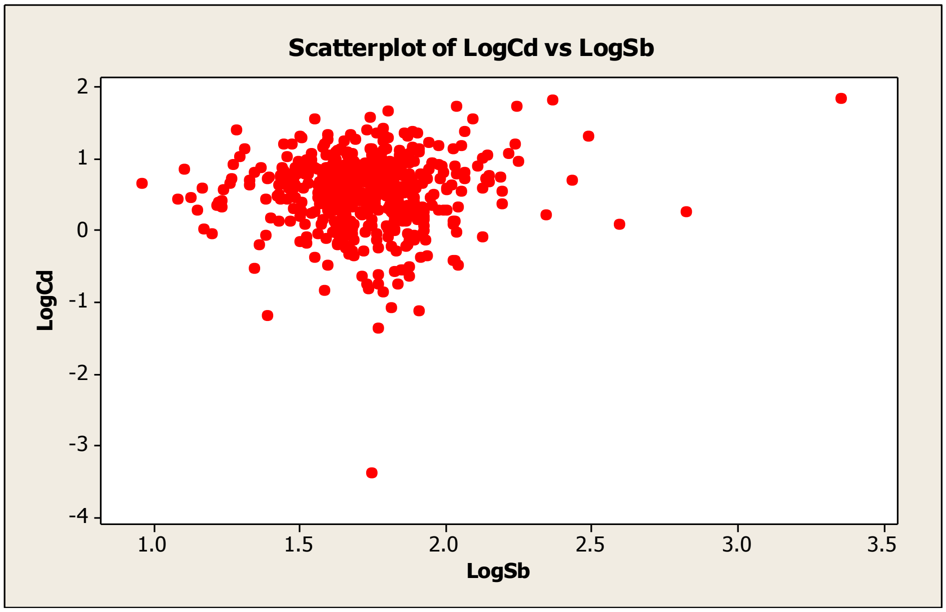


Figure 4.13: Scatter plots of Cd with other metals

As shown in Figure 4.13, it can be observed that the variable Cd does not exhibit a significant correlation with the other variables.

To emphasize the observed results from the above scatter plots, a correlation matrix was implemented.

Table 4.2: Correlation matrix between variables (metals)

**Correlations: Pb, Cr, Cu, Zn, Cd, Sb**

| | Pb | Cr | Cu | Zn | Cd |
|---|---|---|---|---|---|
| Cr | 0.420 | | | | |
| | 0.000 | | | | |
| Cu | 0.378 | 0.270 | | | |
| | 0.000 | 0.000 | | | |
| Zn | 0.517 | 0.590 | 0.554 | | |
| | 0.000 | 0.000 | 0.000 | | |
| Cd | 0.217 | 0.094 | 0.304 | 0.274 | |
| | 0.000 | 0.036 | 0.000 | 0.000 | |
| Sb | 0.323 | 0.017 | 0.430 | 0.238 | 0.208 |
| | 0.000 | 0.698 | 0.000 | 0.000 | 0.000 |

Cell Contents: Pearson correlation
P-Value

From the above Table, the following observations can be made.

- The correlation between Pb and Cr is 0.420
- The correlation between Pb and Cu is 0.378
- The correlation between Pb and Zn is 0.517
- The correlation between Pb and Cd is 0.217
- The correlation between Pb and Sb is 0.323
- The correlation between Cr and Cu is 0.270
- The correlation between Cr and Zn is 0.590
- The correlation between Cr and Cd is 0.094
- The correlation between Cr and Sb is 0.017
- The correlation between Cu and Zn is 0.554
- The correlation between Cu and Cd is 0.304
- The correlation between Cu and Sb is 0.430
- The correlation between Zn and Cd is 0.274
- The correlation between Zn and Sb is 0.238
- The correlation between Cd and Sb is 0.208

According to these observations, it is noticeable that the correlation between Cr and Zn is the highest correlation ($r = 0.590$).

## 4.3 Checking the normality of the data

To check the normality of the data, histograms were utilized.

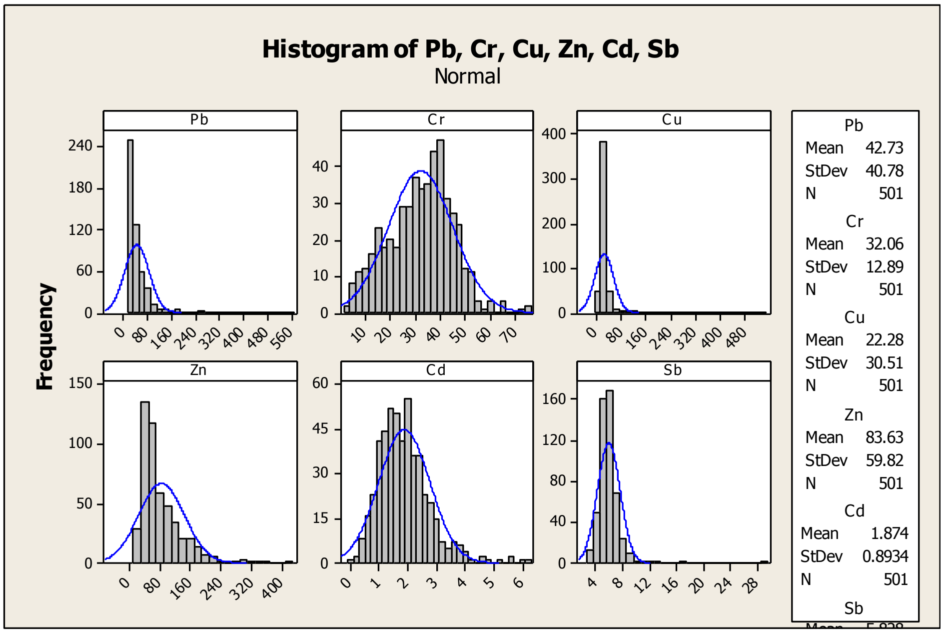


Figure 4.14: Histograms for the metals

The above Figure 4.14 shows the histograms for the variables. From the figure, it can be observed that the variable Cr fits to approximately normal data. Further, the variables Zn, Cd and Sb show slightly normal data.

### 4. 1.3 Checking for the outliers in the data

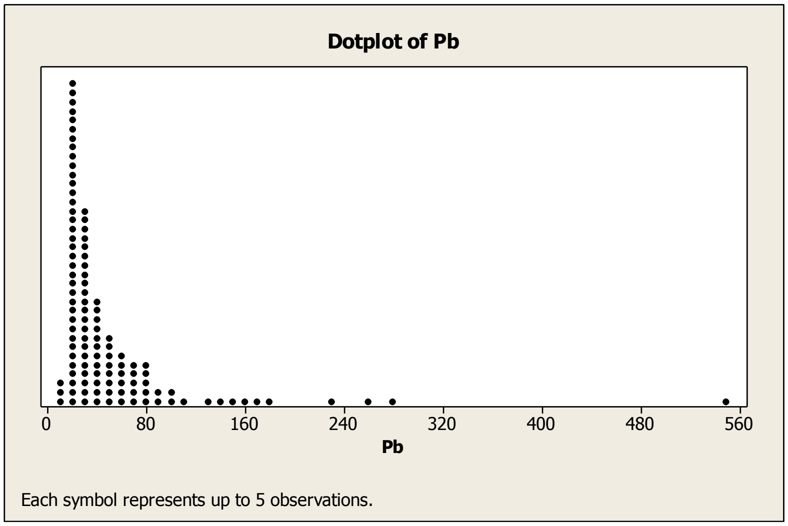


Figure 4.15: Dot Plot of Pb

According to the above dot plot, it can be noticed that the data is positively skewed. Further, there are some outliers in the upper end.

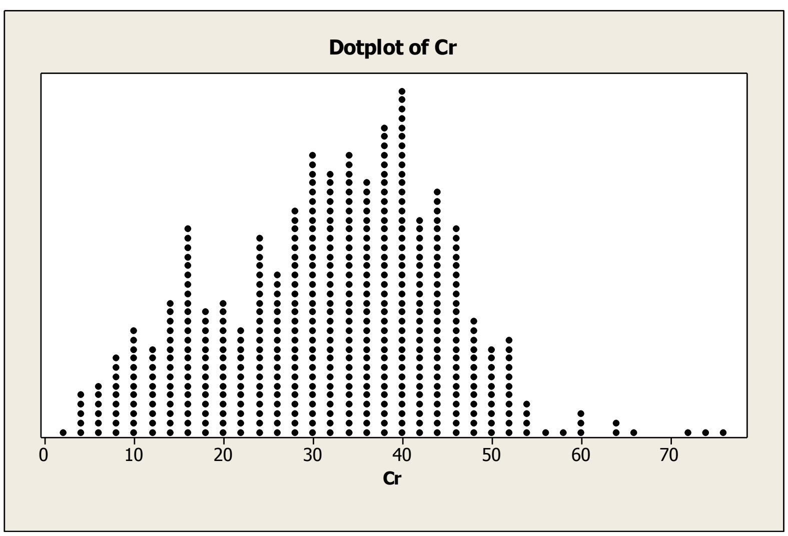


Figure 4.16: Dot Plot of Cr

Figure 4.16: the data is slightly symmetric. Further, there are no significant outliers.

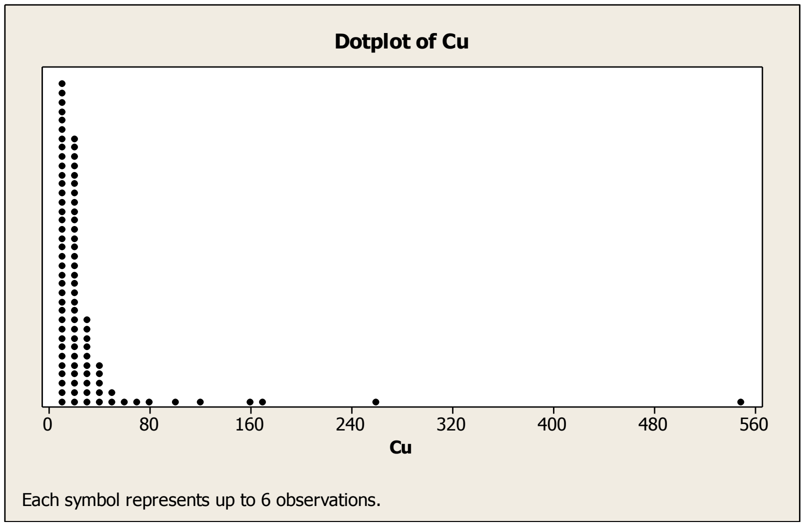


Figure 4.17: Dot Plot of Cu

Figure 5.17, the data is positively skewed. Further, there are some outliers in the upper end.

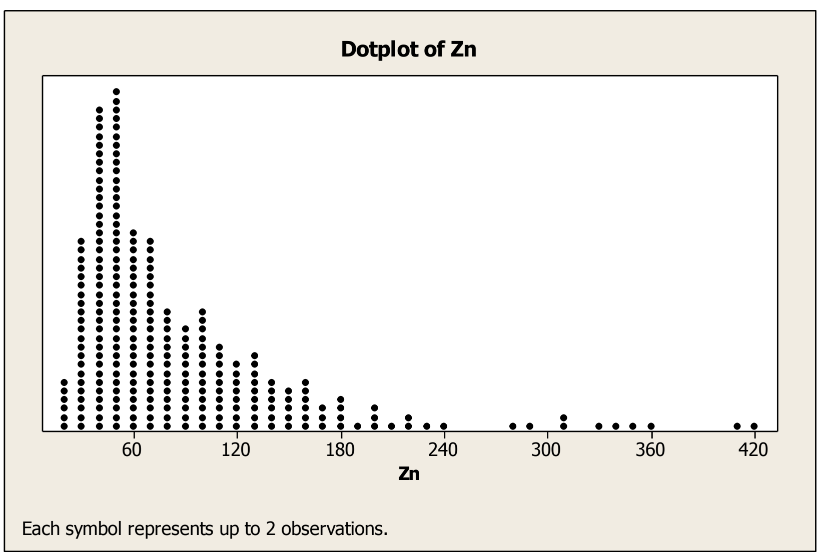


Figure 4.18: Dot Plot of Zn

Figure 4.18, it can noticed that the data is positively skewed. Further, there are some outliers appear in the upper end.

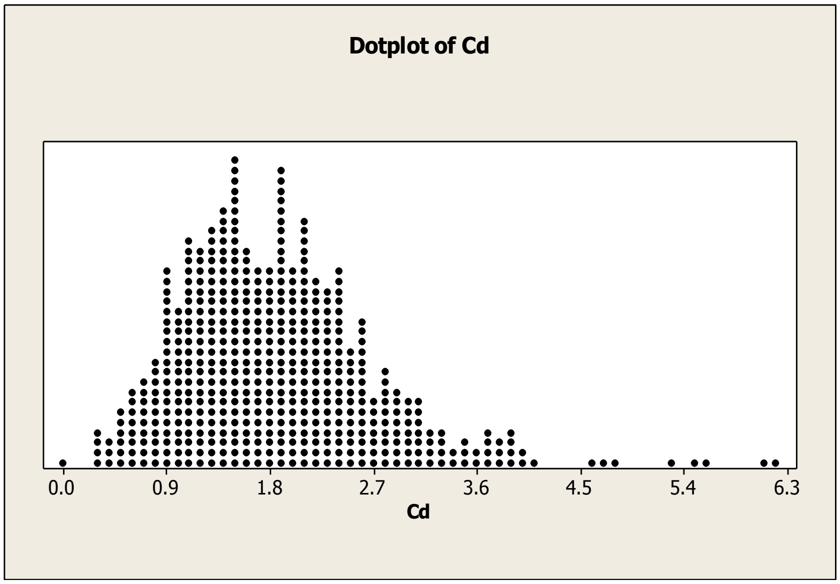


Figure 1: Dot Plot of Cd

Figure 4.19, it can be noticed that some outliers in the upper end, the data is approximately symmetric.

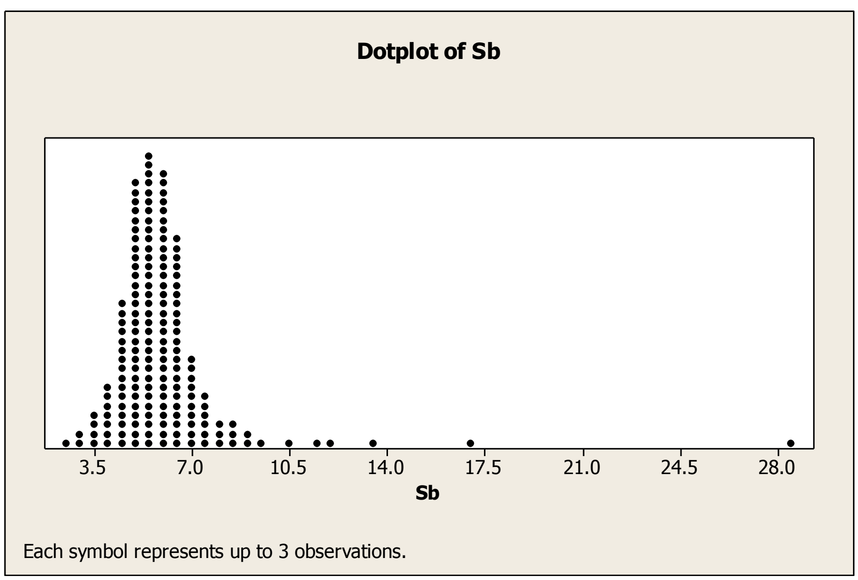


Figure 2: Dot Plot of Sb

Figure 4.20, it can be noticed that some outliers appear in the upper end, the data is approximately symmetric.

### 4.1.4 Ciudad Juarez – region (sides) data analysis

The study area was divided into six regions Figure 4.21. There are no geological characters to divide study area. The study area divided in 6 regions depending on population density, industrial activity, and agricultural and green areas. Divided the area in regions helps in comparison of concentration of heavy metals in each region and determination which region have high levels of metal content in soil.

For each region, the concentrations of metals was determined and recorded. Maps were also created.

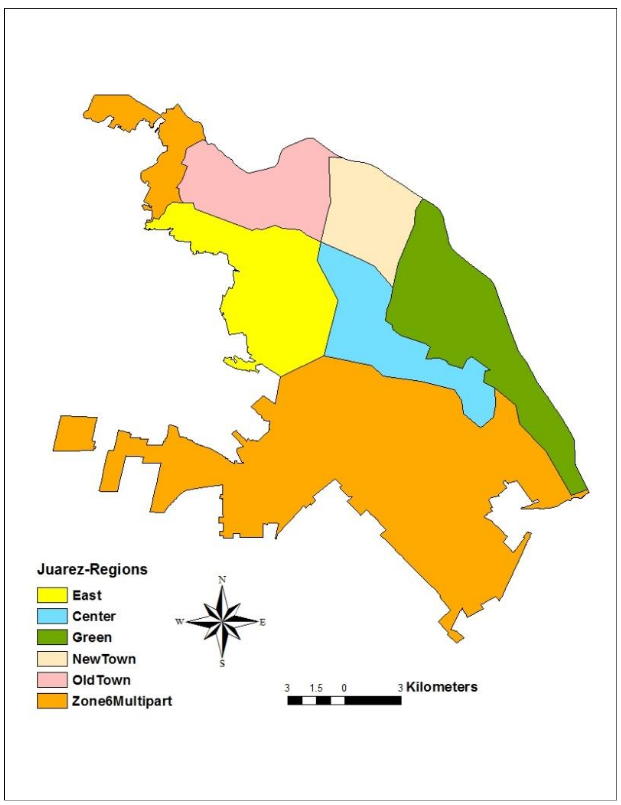


Figure 4.21: Study area regions (sides)

#### 4.1.4.1 Old Town

The sample size for old town is 99. The data obtained was statistically analyzed as shown in Table 4.3, and maps for distribution and concentrations of the metals were also created Figures 4.22 - 4.27.

Table 4.3: Descriptive statistics for the variables (metals) old town

| Variable | N | Mean | StDev | Minimum | Q1 | Median | Q3 | Maximum |
|---|---|---|---|---|---|---|---|---|
| Pb | 99 | 62.8 | 34.5 | 15.2 | 36.5 | 57.7 | 78.2 | 181.9 |
| Cr | 99 | 40.2 | 9.8 | 21.5 | 32.8 | 39.6 | 46.6 | 75.6 |
| Cu | 99 | 27.9 | 16.4 | 9.9 | 18.2 | 23.9 | 35.4 | 122.6 |
| Zn | 99 | 120.1 | 65.9 | 36.4 | 70.8 | 107.5 | 152.5 | 341.6 |
| Cd | 99 | 1.9 | 0.9 | 0.5 | 1.4 | 1.9 | 2.6 | 4.7 |
| Sb | 99 | 5.9 | 1.6 | 3.1 | 5.2 | 5.8 | 6.5 | 16.9 |

The above Table 4.3 displays, the descriptive statistics obtained for the old town soil samples. From the table, the following observations can be made.

##### 4.1.4.1.1 Lead

The resulting concentration levels recorded for lead ranged from 15.2 to 181.9 ppm, with mean concentration values 62.8 ppm.

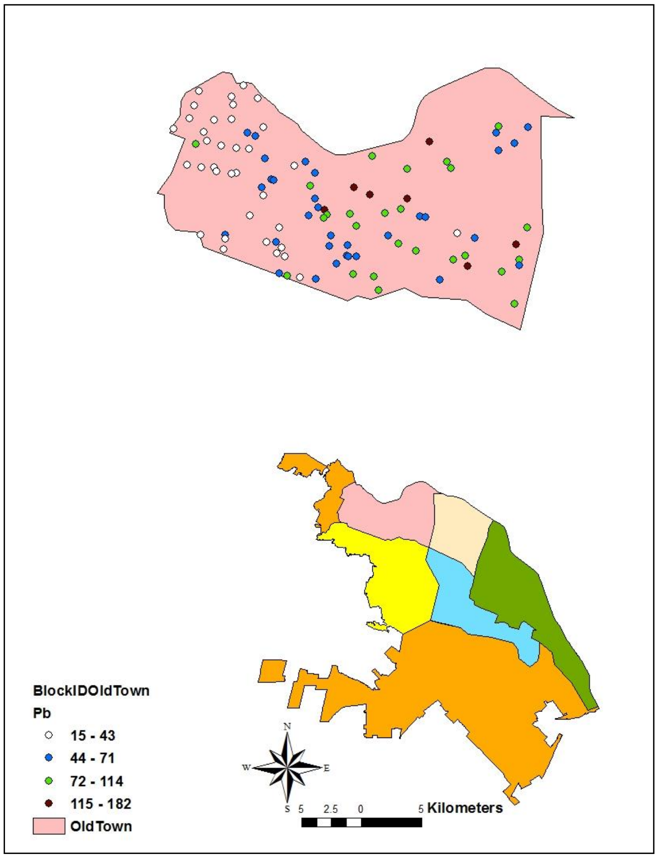


Figure 4.22: Lead concentration in composite samples from blocks in old town

The lowest values (between 15 ppm and 43 ppm; white dots) of lead are mostly encountered in the west side of old town in Juarez. However, there is one white block in the east side of the map. Blocks with 44 ppm to 71 ppm lead, seen in blue in Figure 4.22. Therefore, the concentrations between 44 ppm to 71 ppm for lead are recorded mostly from the central area of old town. Furthermore, most of the blocks in old town have this level of lead concentration in the soil samples

Blocks having lead levels between 72 ppm to 114 ppm (green dots) are encountered mostly from the east and the central area of old town in Juarez. There is only few blocks having

highest value between 115 ppm and 182 ppm and depicted in brown. These blocks are situated in east and the central area of old town in Juarez.

In general, the lead concentration is higher in the east side than the west side of old town in Juarez.

Figure 4.23, illustrates the concentration of lead levels in soil samples with correlation of children age 1-5 in old town Juarez.

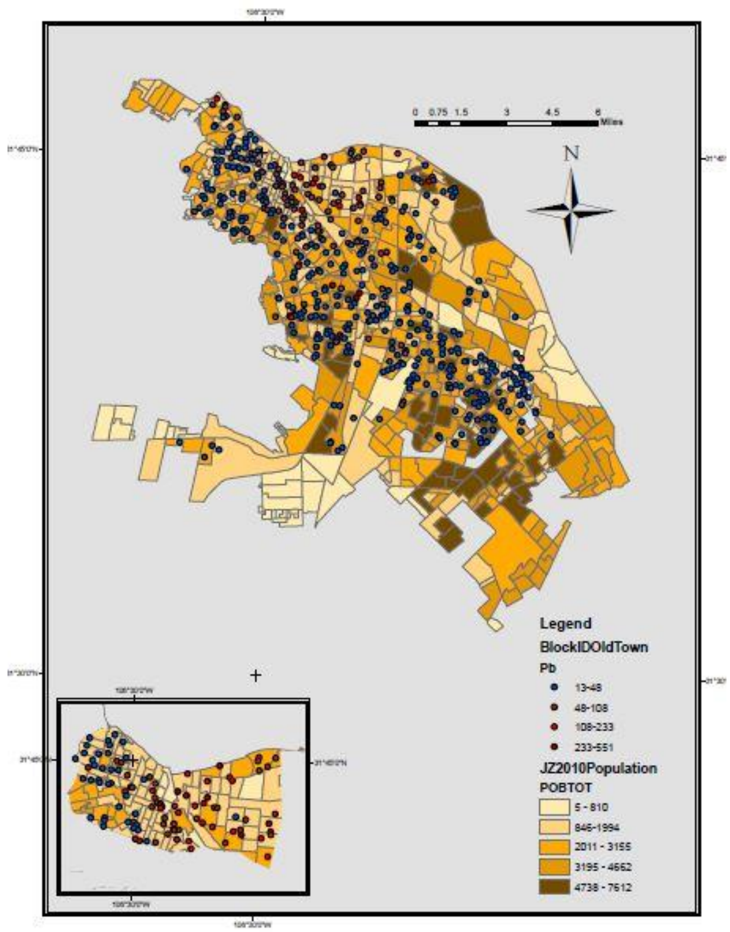


Figure 4.23: Potential population density of children and lead soil in old town

#### 4.1.4.1.2 Chromium

Soil concentrations levels recorded for Cr ranged from 21.5 to 75.6 ppm, with mean concentration values 40.2 ppm.

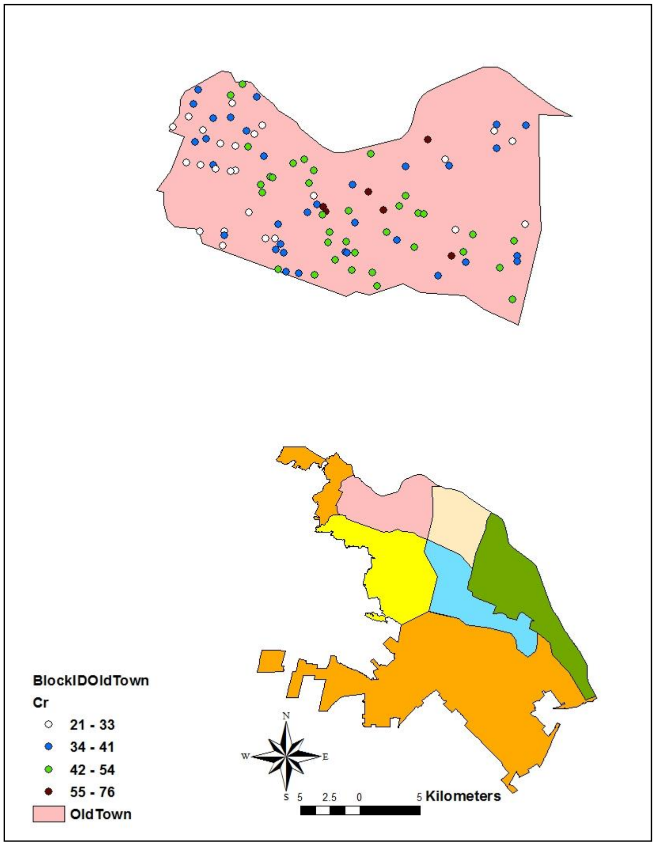


Figure 4.24: Chromium concentration in composite samples from blocks in old town

The lowest values (between 21 ppm and 33 ppm; white dots) of chromium are mainly encountered to the west side of the old town area. However, there are a few blocks in the east side, having this level of chromium concentration. Blocks with 34 ppm to 41 ppm chromium, seen in blue in Figure 4.24, are scattered all over the map of old town.

Chromium levels between 42 ppm to 54 ppm (green dots), are encountered mainly in the central part of old town. Although the density of green dots is higher for the central area, there is considerable number of green blocks in west and east sides.

Blocks having highest value between 55 ppm and 76 ppm are depicted in brown. Most of these blocks are situated in central to east area of old town.

#### 4.1.4.1.3 Copper

Soil copper concentration levels recorded for Cu ranged from 9.9 to 122.6 ppm, with mean concentration values 27.9 ppm

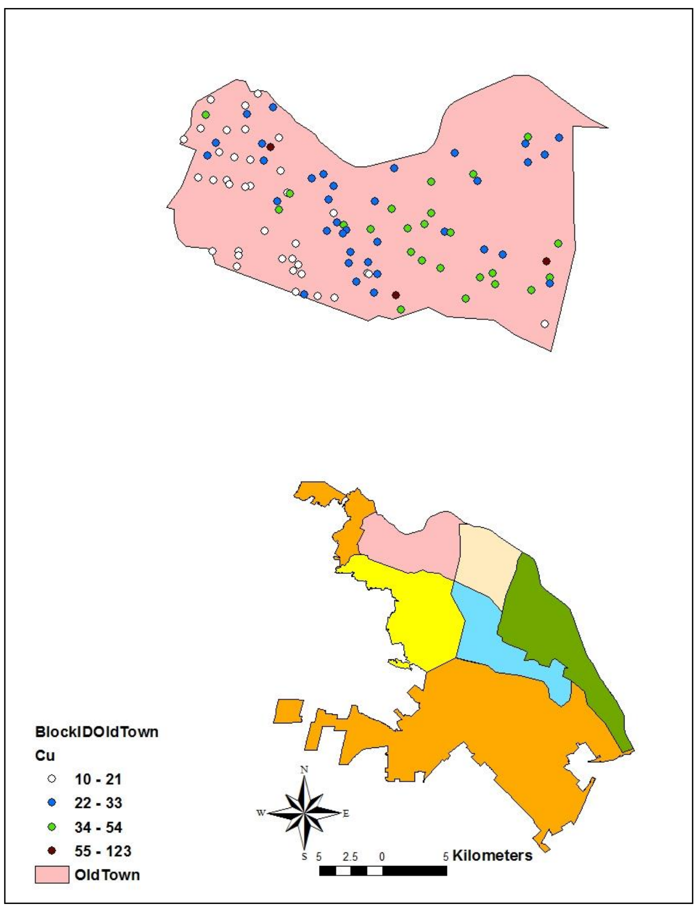


Figure 4.25: Copper concentration in composite samples from blocks in old town

The lowest values (between 10 ppm to 21 ppm; white dots) of copper are scattered mostly in the west side of old town area. However, few blocks with this concentration are situated in the east and the central areas.

Blocks with 22 ppm to 33 ppm copper, seen in blue in Figure 4.25 are mainly found in all over old town are. However, the density of blue dots is higher for the central part of old town area. Blocks having copper levels between 34 ppm to 54 ppm (green dots), are encountered mainly in central to east side of old town area. However, there are few green blocks situated in the west side.

Only three blocks are found to have highest value between 55 ppm and 123 ppm and it is depicted in brown. These blocks are scattered the in west, central and east sides of old town. However in general, the east side of old town area contains higher copper concentrations that in the east side.

#### 4.1.4.1.4 Zinc

Soil zinc concentration levels recorded for Zn ranged from 36.4 to 341.6 ppm, with mean concentration values 120.1 ppm.

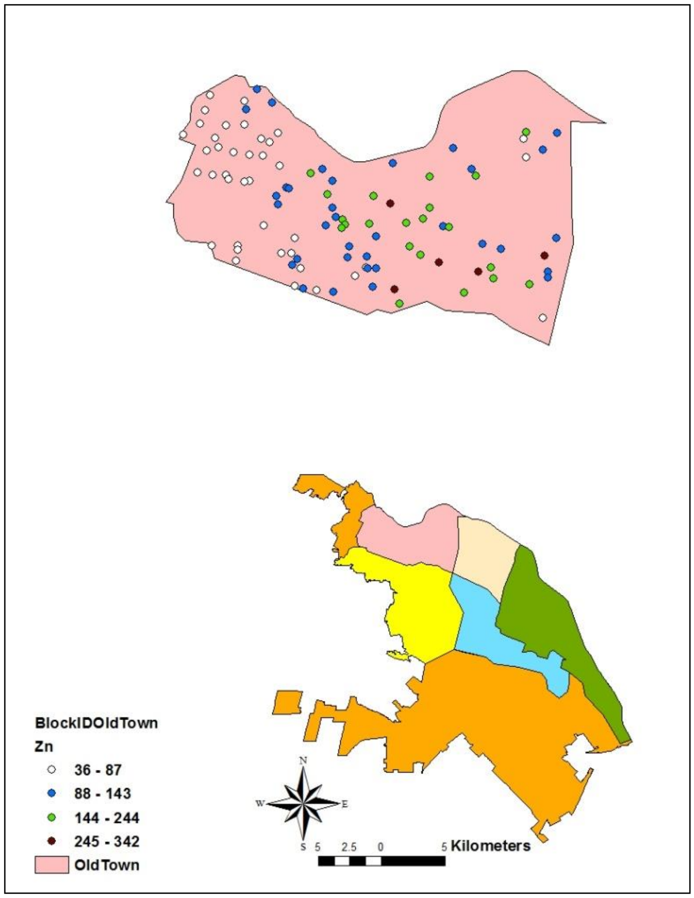


Figure 4.26: Zinc concentration in composite samples from blocks in old town

The lowest values (between 36 ppm and 87 ppm; white dots) of zinc are mainly encountered in the west side of the old town area. However, there are few white blocks in the east side.

Blocks with 88 ppm to 143 ppm zinc, seen in blue in Figure 4.26, are scattered all over the map. However, the density of the blue dots is higher in central to east area. Blocks having zinc levels between 144 ppm to 244 ppm (green dots), are encountered prominently in the central and east side of old town area. Few blocks having highest value between 245 ppm and 342 ppm

are encountered in the old town area and those are depicted in brown. All of them are situated in central and east side of old town.

In general, it can be observed that the east side contains more zinc concentrations in the soil samples than the west side, in old town.

#### 4.1.4.1.5 Cadmium

Soil cadmium concentration levels recorded for Cd ranged from 0.5 to 4.7 ppm, with mean concentration values1.9 ppm.

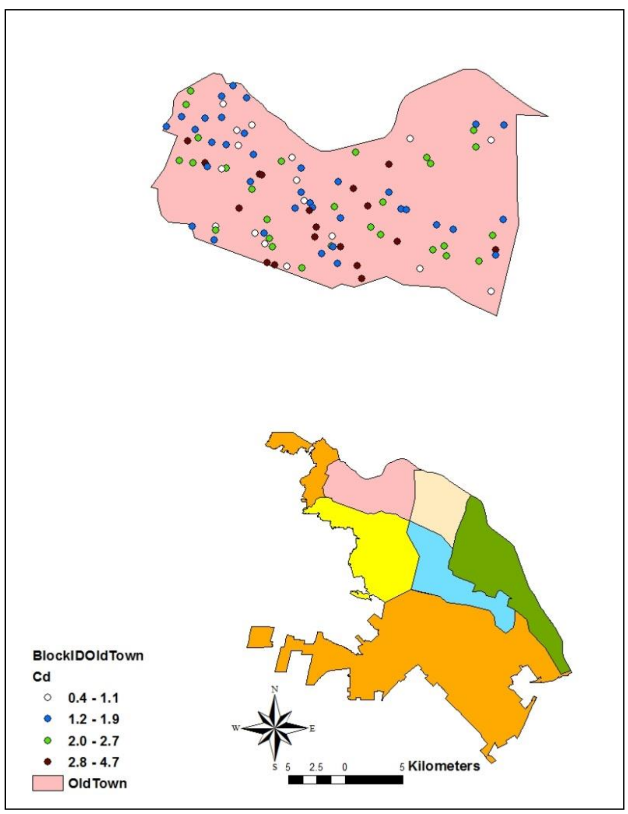


Figure 4.27: Cadmium concentration in composite samples from blocks in old town

The lowest values (between 0.4 ppm and 1.1 ppm; white dots) of cadmium are scattered all over the old town area. Blocks with 1.2 ppm to 1.9 ppm cadmium, shown in blue in Figure 4.27. Therefore, the concentrations between 1.2 ppm to 1.9 ppm for cadmium are recorded all over the map. However, the density of the blue dots is higher in the west side. Blocks having cadmium levels between 2.0 ppm to 2.7 ppm (green dots), are encountered all over the area.

Blocks having highest value between 2.8 ppm and 4.7 ppm are depicted in brown. The majority of these blocks are situated in the central area.

According to this map, no specific pattern can be observed between the concentration and the sides in old town.

#### 4.1.4.1.6 Antimony

Soil concentration levels recorded for antimony ranged from 3.1 to 16.9 ppm, with mean concentration values 5.9 ppm.

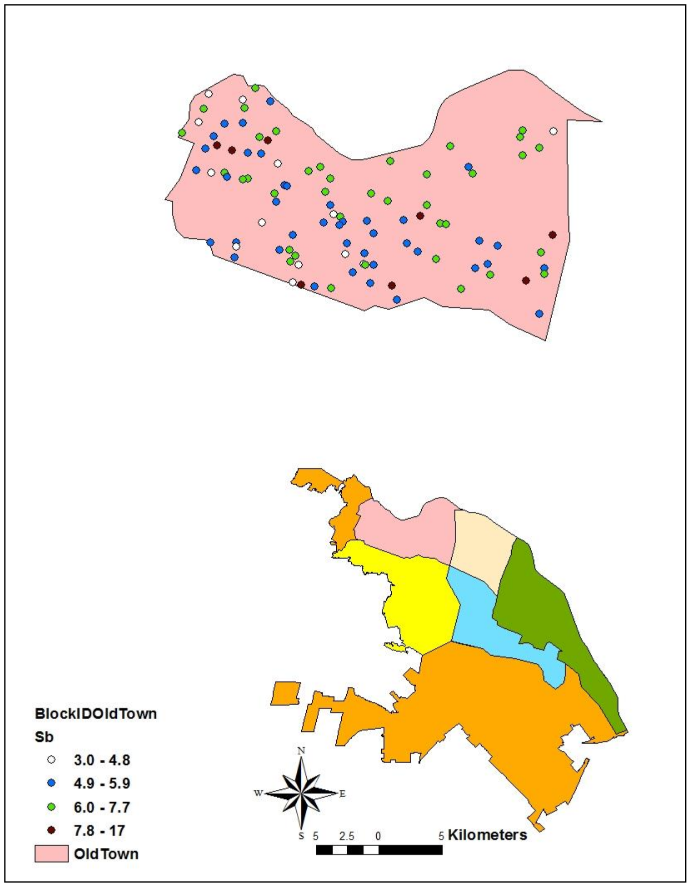


Figure 4.28: Antimony concentration in composite samples from blocks in old town

Only a few blocks having the lowest values (between 3.0 ppm and 4.8 ppm; white dots) of antimony are in the old town. The majority of these gray dots are encountered in the west side of old town area.

Blocks with 4.9 ppm to 5.9 ppm antimony, seen in blue are scattered all over the map of old town area. The majority of the blocks in this area show the concentration of antimony within this range. Blocks having antimony levels between 6.0 ppm to 7.7 ppm (green dots), are encountered in all over old town area. Few blocks having highest value between 7.8 ppm and 17 ppm are found and they are depicted in brown. These blocks are scattered all over the old town area.

According to this map, no specific pattern can be observed between the concentration of antimony and the area.

In old town, the results indicate that the metal zinc has the highest concentration level 341.6 ppm, and Cd has the lowest level 0.5 ppm. The highest mean concentration value is recorded for the metal Zn. However, the standard deviation relevant to Zn is also high which is not favorable to the accuracy of the interpretation. Higher standard deviation indicates that the observations are scattered. However all of the five number summaries (minimum, Q1, median, Q3, maximum) are also high for the variable Zn when compared to all others. This provides a hint to believe that in the old town soil samples, the highest concentration is recorded for Zn. However, it is advisable to consider the presence of outliers as well.

The minimum concentration is recorded for Cd, which is more than 60 times less than Zn. By considering the mean concentration, we can conclude the concentration of the soil samples taken from old town differs in the following order: Zn>Pb> Cr > Cu>Sb> Cd.

#### 4.1.4.2 Correlation between metals

Correlations and scatter plots have been used to observe the relationship between the metal components. In order to increase the readability of the scatter plots, log transformations have been used.

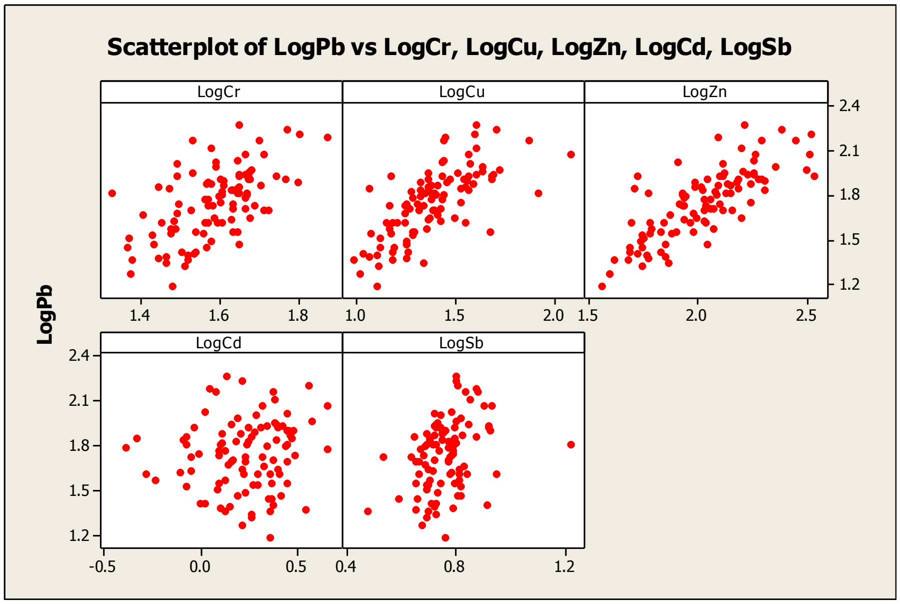


Figure 4.29: Correlation of Pb with other variables (metals) – old town

From the above Figure, it can be observed that the variable Pb shows a positive correlation with the three variables Cr, Cu and Zn.

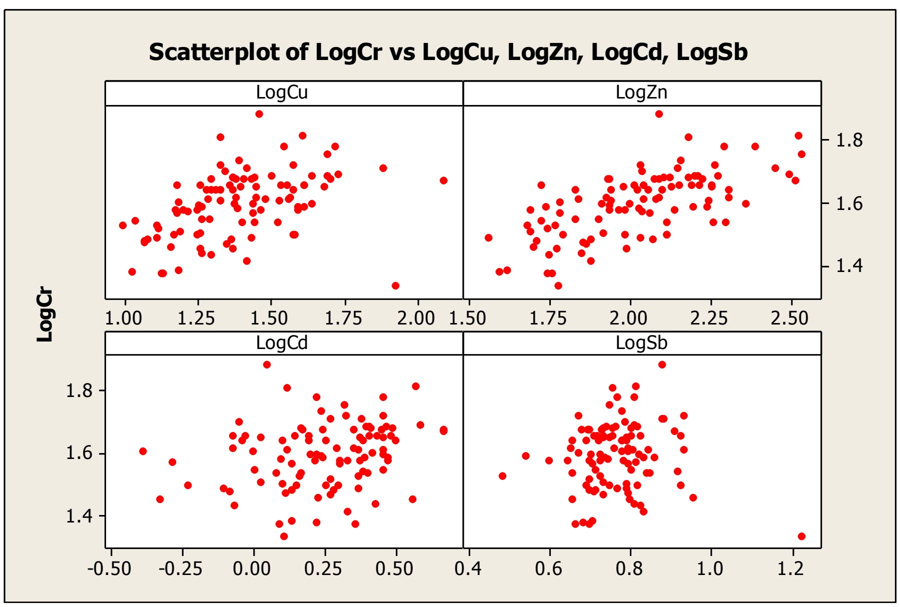


Figure 4.30: Correlation of Cr with other variables – old town

From the above Figure 4.30, it can be observed that the variable Cr shows a correlation with the Cu and Zn variable.

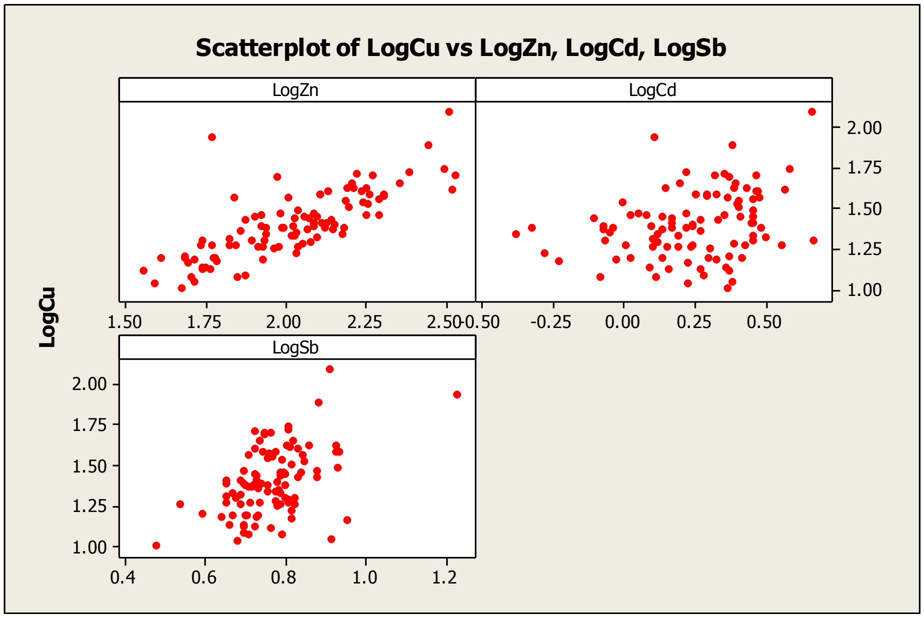


Figure 4.31: Correlation of Cu with other variables – old town

By examining the above Figure 4.31, it can be observed that the variable Cu exhibits a positive correlation with Zn and a slight positive relationship with Cd and Sb.

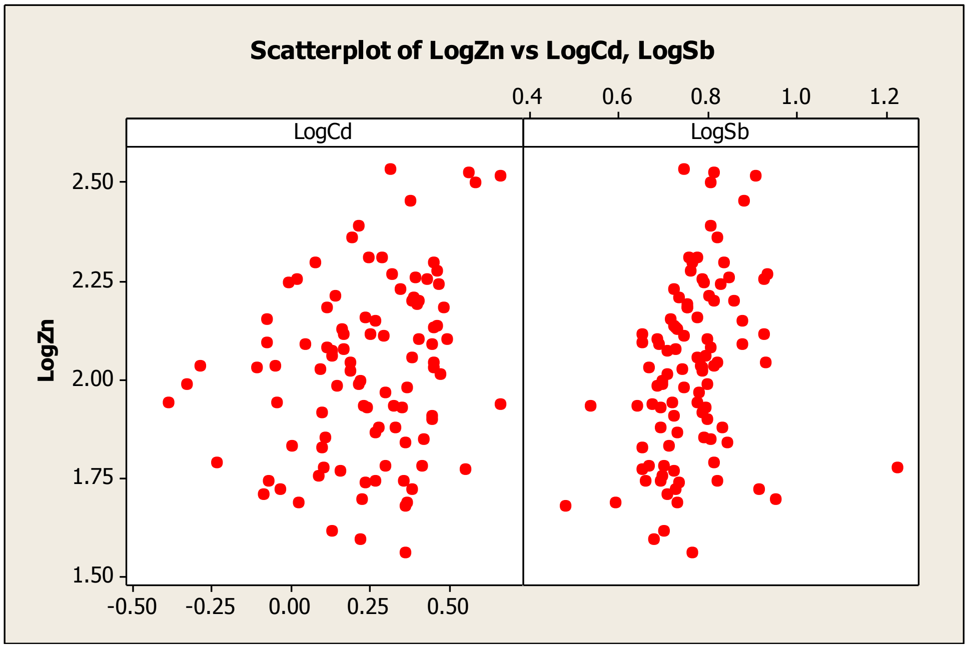


Figure 4.32: Correlation of Zn with other variables – old town

It can be observed that the variable Zn exhibits no considerably high correlation with other variables.

To emphasize the observed results from the above scatter plots, a correlation matrix will used.

Table 4.4: Correlation matrix between metals- old town

**Correlations: Pb, Cr, Cu, Zn, Cd, Sb**

| | Pb | Cr | Cu | Zn | Cd |
|---|---|---|---|---|---|
| Cr | 0.576 | | | | |
| | 0.000 | | | | |
| Cu | 0.577 | 0.316 | | | |
| | 0.000 | 0.001 | | | |
| Zn | 0.709 | 0.600 | 0.707 | | |
| | 0.000 | 0.000 | 0.000 | | |
| Cd | 0.153 | 0.244 | 0.368 | 0.342 | |
| | 0.132 | 0.015 | 0.000 | 0.001 | |
| Sb | 0.278 | -0.022 | 0.515 | 0.186 | -0.012 |
| | 0.005 | 0.828 | 0.000 | 0.065 | 0.909 |

Cell Contents: Pearson correlation
P-Value

Except for the variable pairs Pb and Cd, Cr and Sb, Sb and Zn, Sb and Cd, all other variable pairs have significant correlations with a 5% level of significance. Furthermore, these pairs have the lowest correlation values.

From the above figure, the following statistics can be obtained:

- The correlation between Pb and Cr is 0.576
- The correlation between Pb and Cu is 0.577
- The correlation between Pb and Zn is 0.709
- The correlation between Pb and Cd is 0.153
- The correlation between Pb and Sb is 0.278
- The correlation between Cr and Cu is 0.316
- The correlation between Cr and Zn is 0.6

- The correlation between Cr and Cd is 0.244
- The correlation between Cr and Sb is - 0.022
- The correlation between Cu and Zn is 0.707
- The correlation between Cu and Cd is 0.368
- The correlation between Cu and Sb is 0.515
- The correlation between Zn and Cd is 0.342
- The correlation between Zn and Sb is 0.186
- The correlation between Cd and Sb is -0.012

According to these observations, it is noticeable that the correlation between Pb and Zn is the highest correlation (r = 0.709).

#### 4.1.4.3 Check the normality of the data – old town

To check the normality of the data, this study has employed histograms.

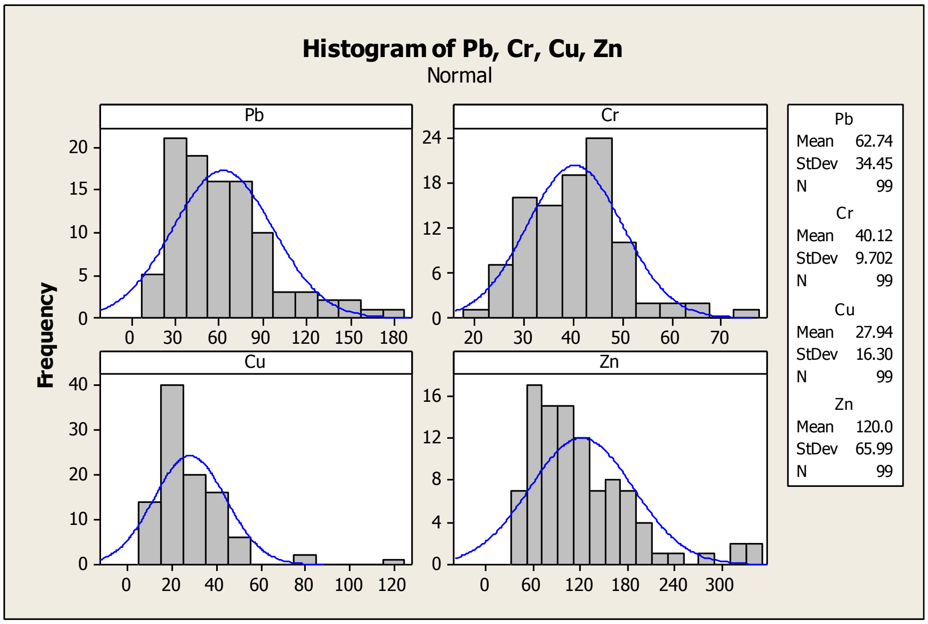


Figure 4.33: Histograms for the variables – old town

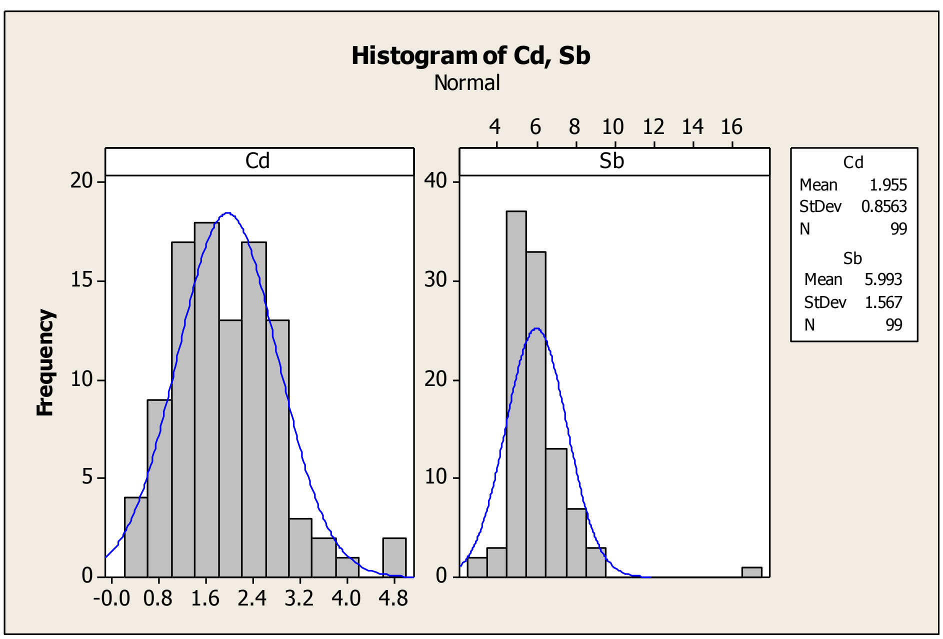


Figure 4.34: Histograms for the variables – old town

Figure 4.33 and 4.34, exhibits the histograms for the variables. From the figures, it can be observed that the variable Cr fits to approximately normal data. Further, the variable Zn and Cd also shows slightly normal data.

#### 4.1.4.4 Checking for the outlying observations – old town

It is important to check for the outlying observations. For this purpose box plots have been used.

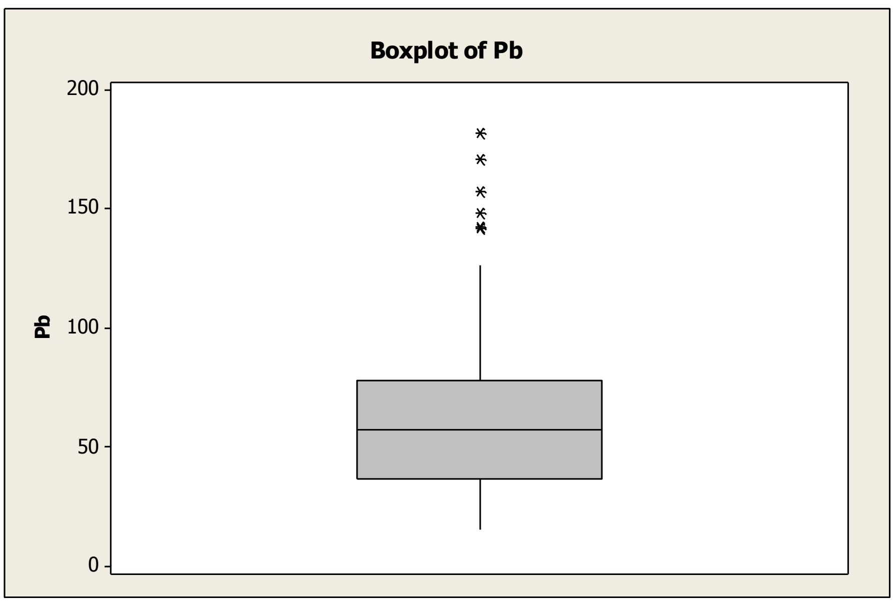


Figure 4.35: Box plot for Pb – old town

From the above plot, it is noticeable that there are some outliers in the upper end.

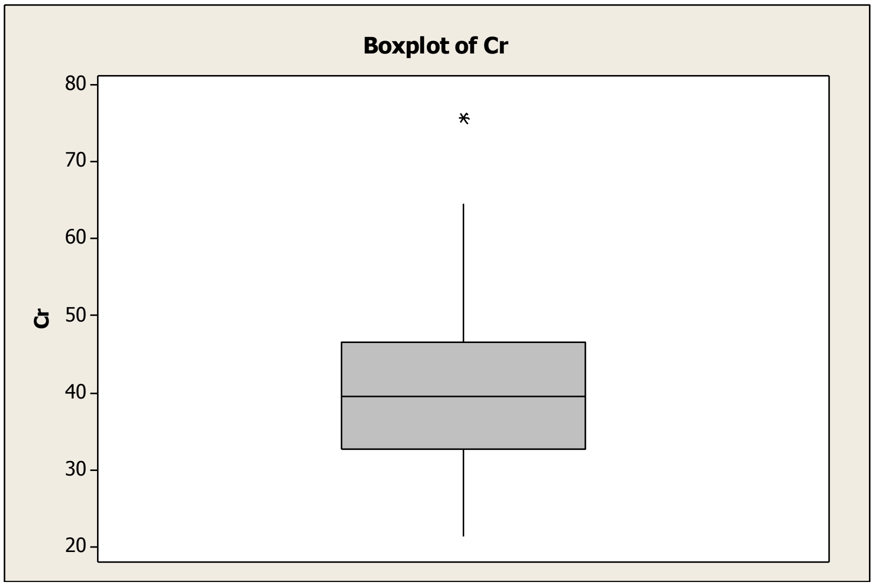


Figure 3: Box plot for Cr – old town

From the above plot, it is noticeable that the data are approximately symmetric. However, there are some significant outliers.

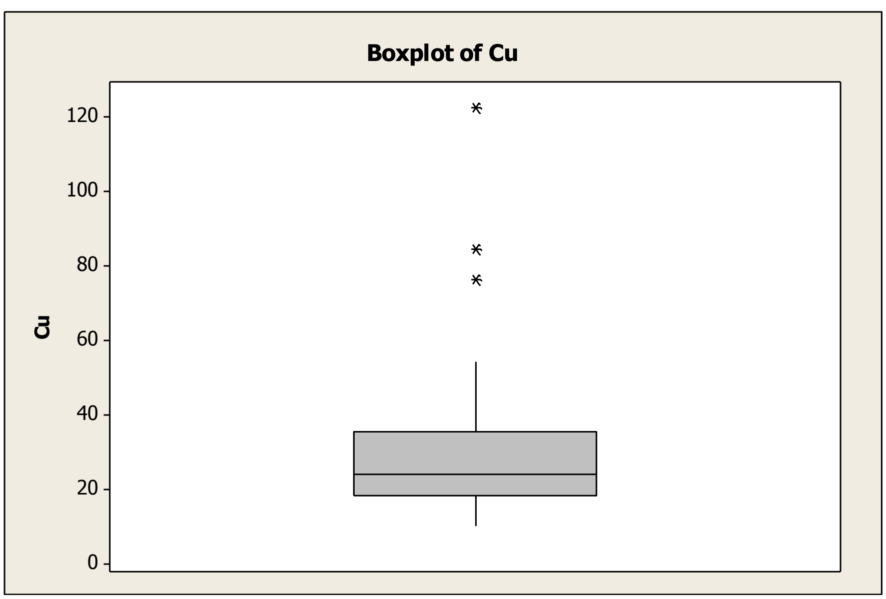


Figure 4: Box plot for Cu – old town

From the above plot, it is noticeable that the data is positively skewed. Further, there are some outliers in the upper end.

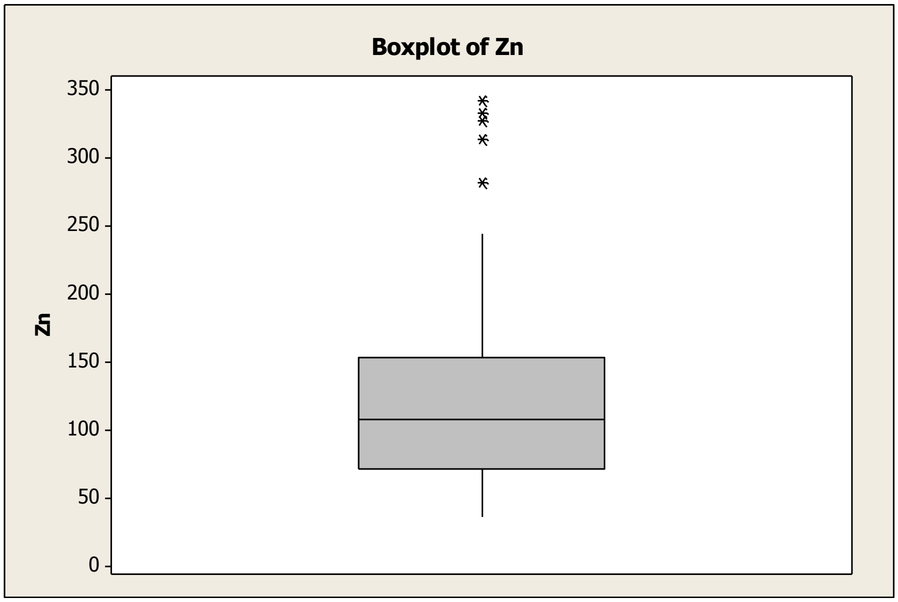


Figure 5: Box plot for Zn – old town

Figure 4.38, shows that the data is positively skewed. Further, there are some outliers in the upper end.

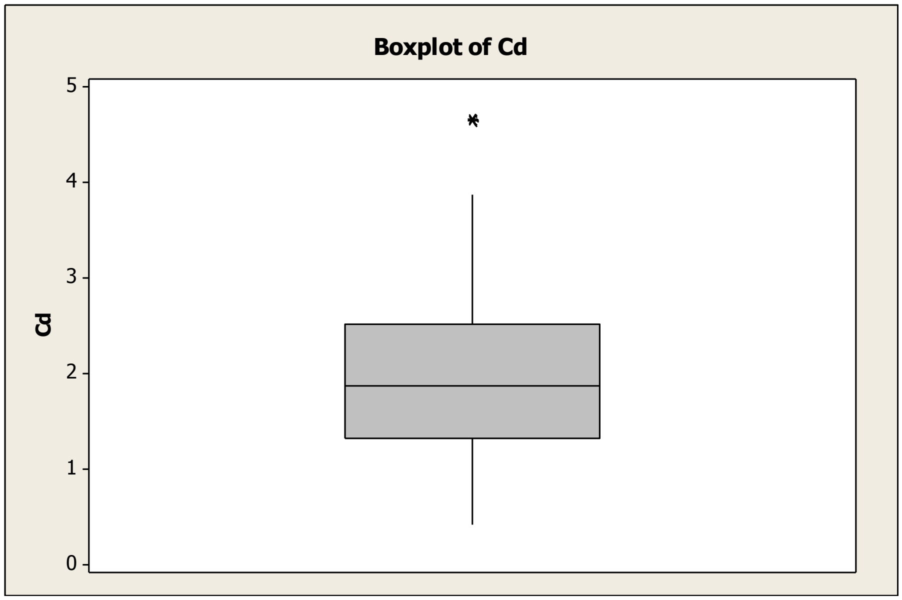


Figure 4.39: Box plot for Cd – old town

From Figure 4.39, it is noticeable there are some outliers in the upper end. With the ignorance of the outliers, it shows slightly symmetric distribution.

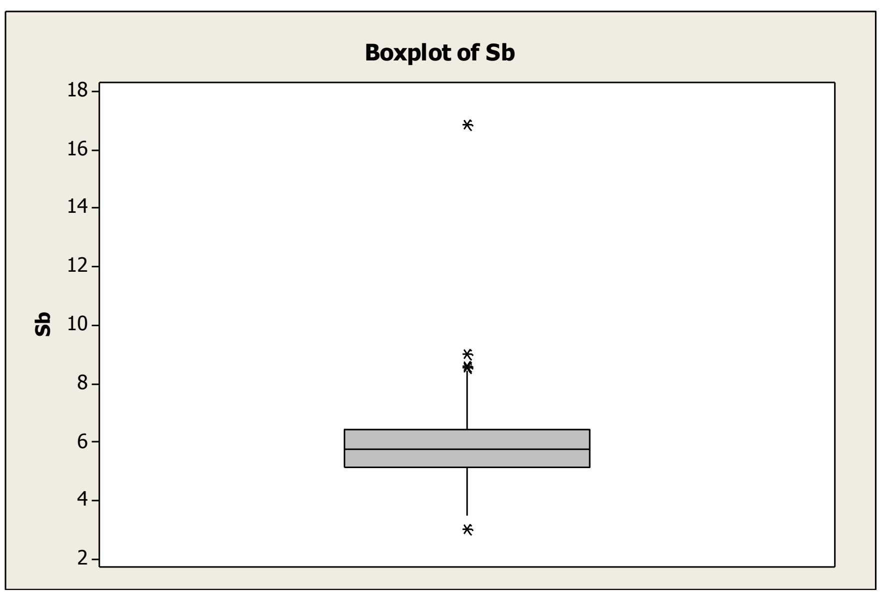


Figure 4.40: Box plot for Sb – old town

The above plot shows that there are some noticeable outliers.

#### 4.1.4.5 New Town

The sample size for new town is 39. For each sample, the concentration of metals was determined and recorded. The data obtained was statistically analyzed, as shown in Table 4.5. Maps for distribution and concentrations of the metals were also created Figure 4.41 to 4.49.

Table 4.5: Descriptive statistics for the variables (metals) - new town

| Variable | N | Mean | StDev | Minimum | Q1 | Median | Q3 | Maximum |
|---|---|---|---|---|---|---|---|---|
| Pb | 39 | 50.1 | 26.2 | 18.2 | 34.5 | 40.8 | 63.9 | 139.8 |
| Cr | 39 | 40.4 | 10.2 | 23.8 | 32.6 | 39.3 | 44.6 | 74.4 |
| Cu | 39 | 27.6 | 9.3 | 12.1 | 20.8 | 25.7 | 34.8 | 53.4 |
| Zn | 39 | 146.8 | 73.1 | 42.5 | 102.9 | 142.3 | 173.6 | 414.2 |
| Cd | 39 | 1.9 | 1.1 | 0.3 | 1.4 | 1.7 | 2.7 | 5.3 |
| Sb | 39 | 5.9 | 1.7 | 3.4 | 5.2 | 5.9 | 6.4 | 13.5 |

The above table displays the descriptive statistics obtained for the new town soil samples.

##### 4.1.4.5.1 Lead

Soil lead concentration Table 4.5, the resulting concentration levels recorded for lead ranged from18.2 to 139.8 ppm.

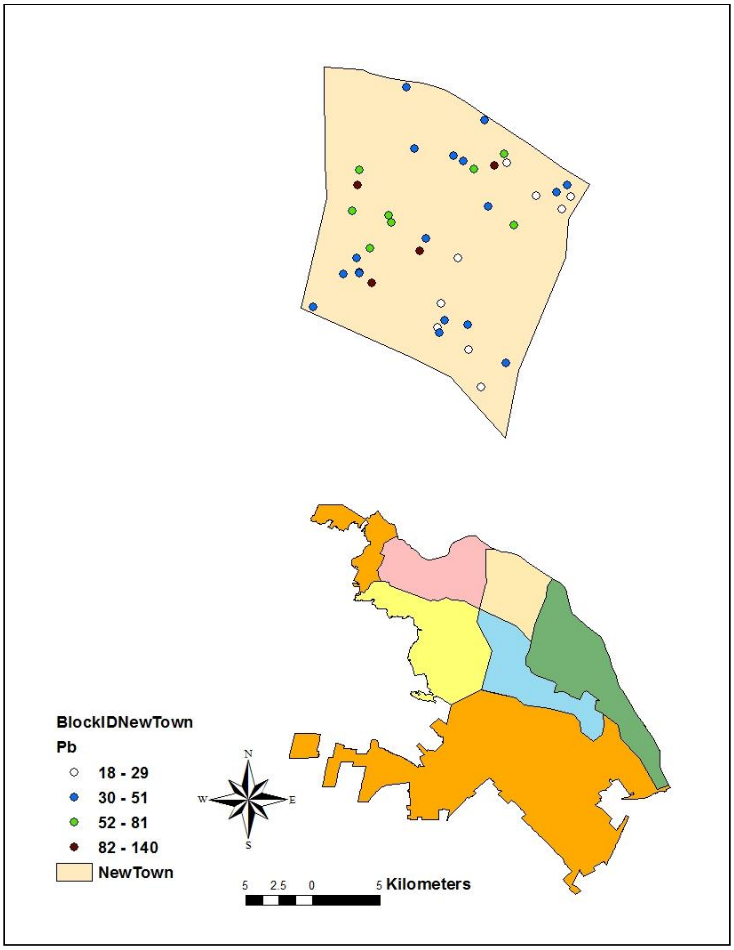


Figure 4.41: Lead concentrations in composite samples from blocks in new town

The lowest values (between 18 ppm to 29 ppm; white dots) of lead are mostly encountered in the east and the south areas of new town in Juarez.

Blocks with 30 ppm to 51 ppm lead, seen in blue in Figure 4.41. Therefore, the concentrations between 30 ppm to 51 ppm for lead are recorded all over new town area. Furthermore, most of the blocks in new town have this level of lead concentration in the soil samples. Blocks having lead levels between 52 ppm to 81 ppm (green dots) are encountered more to the north of new town in Juarez. There are only a few blocks having highest value between 82 ppm and 140 ppm and depicted in brown.

In general, the lead concentration is higher in the west side than the east side and in the north area than the southern area of new town in Juarez.

Figure 4.42, illustrates the concentration of lead levels in soil samples with correlation of children age 1-5 in new town Juarez.

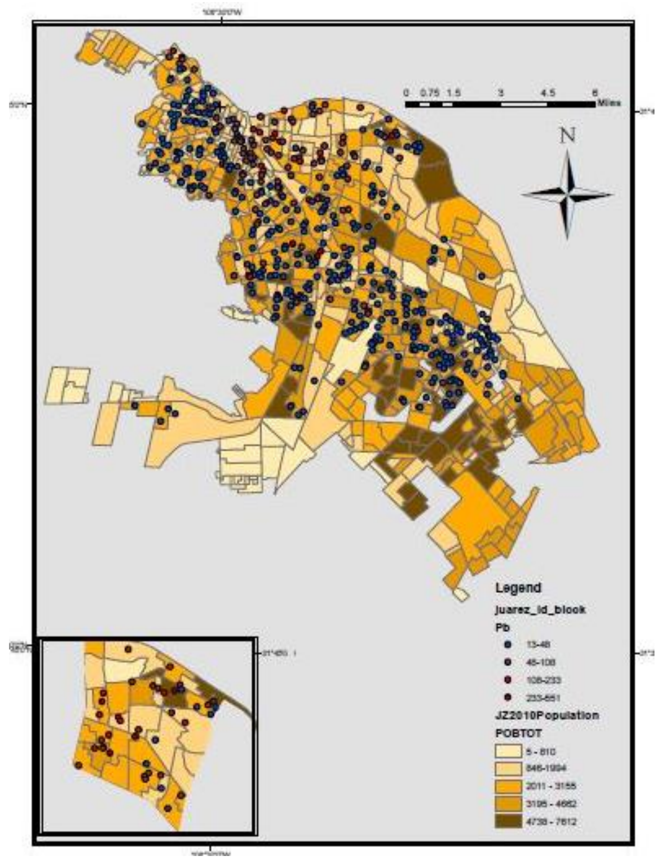


Figure 4.42: Population density of children and lead soil in new town

#### 4.1.4.5.2 Chromium

Soil chromium concentration Table 4.5, the resulting concentration levels recorded for Cr ranged from 23.8 to 74.4 ppm.

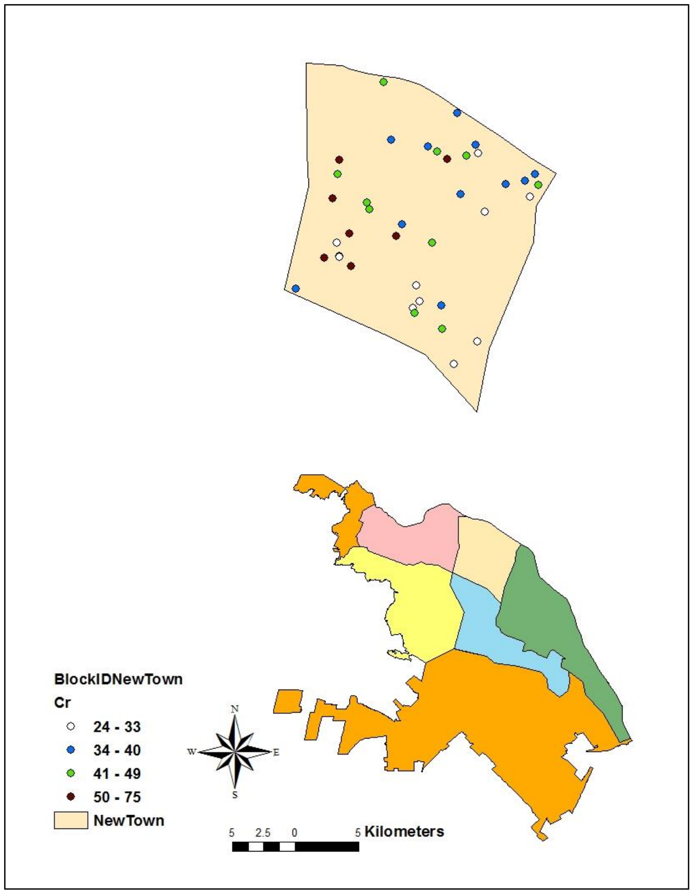


Figure 4.43: Chromium concentrations in composite samples from blocks in new town

The lowest values (between 24 ppm and 33 ppm; white dots) of chromium are mainly encountered in peripheral areas new town. Blocks with 34 ppm to 40 ppm chromium, seen in blue in Figure 4.43, are scattered all over the map of new town. However, the density of the blue dots is higher in the east side.

Chromium levels between 41 ppm to 49 ppm (green dots) are scattered all over the new town area. However, the concentration of green dots is lower in the west side. Blocks having highest value between 50 ppm and 75 ppm are depicted in brown. Most of these blocks are situated in central to west and the central sides of new town.

#### 4.1.4.5.3 Copper

Soil copper concentration Table 4.5, the resulting concentration levels recorded for Cu ranged from 12.1 to 53.4 ppm.

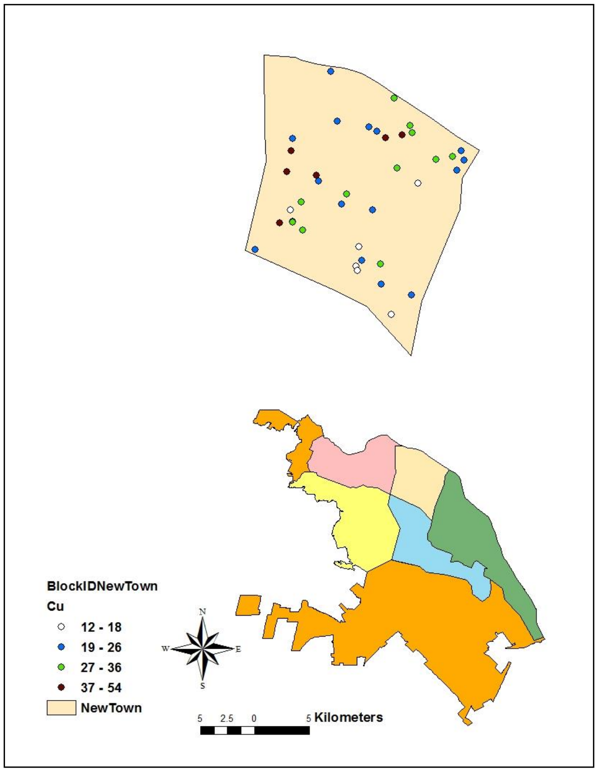


Figure 4.44: Copper concentrations in composite samples from blocks in new town

There are only few lowest values (between 12 ppm and 18 ppm; white dots) of copper are scattered areas except central and north. Blocks with 19 ppm to 26 ppm copper, seen in blue in Figure 4.44, are mainly found in all over new town area. Most of the blocks in new town area have this level of copper concentrations.

Blocks having copper levels between 27 ppm to 36 ppm (green dots), are encountered in both east and west sides of new town area. Only three blocks are found having highest value

between 37 ppm and 54 ppm and it is depicted in brown. These blocks are scattered in north part of new town.

However, in general, the north part of new town area contains higher copper concentrations than in the southern part.

#### 4.1.4.5.4 Zinc

Soil zinc concentration Table 4.5, the resulting concentration levels recorded for Zn ranged from 42.4 to 414.1 ppm.

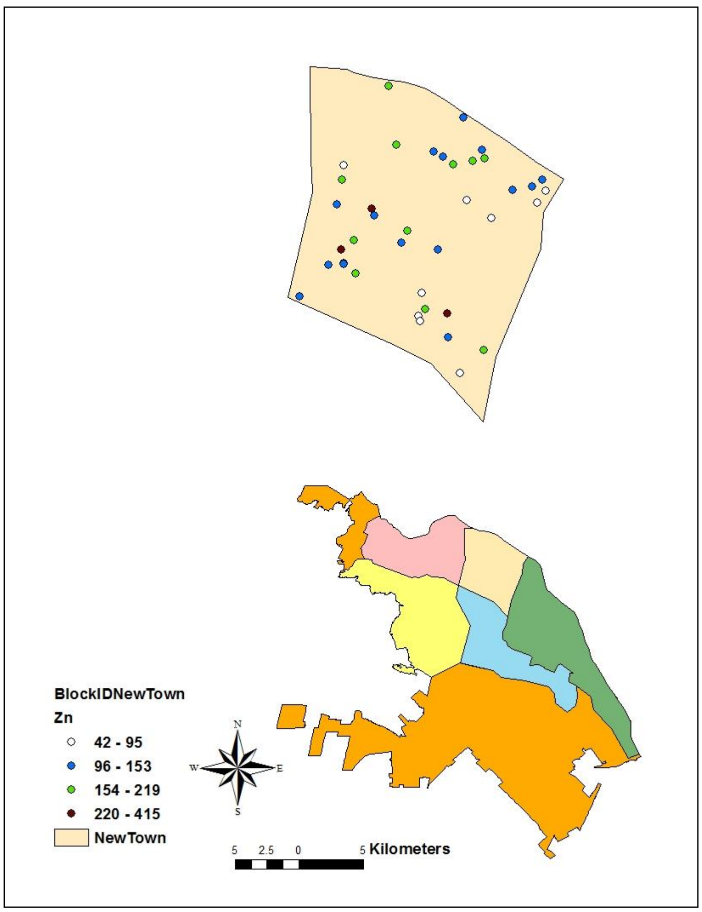


Figure 4.45: Zinc concentrations in composite samples from blocks in new town

The lowest values (between 42 ppm to 95 ppm; white dots) of zinc are mainly encountered close to the peripheral areas of new town area. Blocks with 96 ppm to 153 ppm zinc, seen in blue in Figure 4.45, are scattered all over the map.

Blocks having zinc levels between 154 ppm to 219 ppm (green dots) are also encountered all over the new town area. Few blocks having highest value between 220 ppm - 415 ppm are encountered in the new town area and those are depicted in red. All of them are situated more closely to the west side.

In general, it can be observed that the west side contains more zinc concentrations in the soil samples than the east side, in new town.

#### 4.1.4.5.5 Cadmium

Soil cadmium concentration Table 4.5, the resulting concentration levels recorded for Cd ranged from 0.3 to 5.3 ppm.

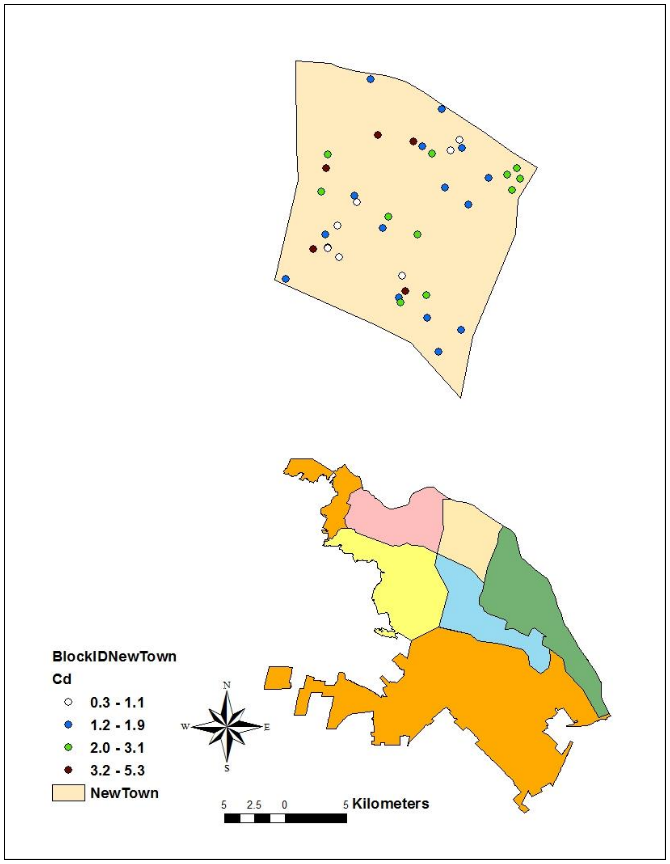


Figure 4.46: Cadmium concentrations in composite samples from blocks in new town

The lowest values (between 0.3 ppm to 1.1 ppm; white dots) of cadmium are scattered mostly in the west side of new town area.  However, there are few white blocks in the east side.

Blocks with 1.2 ppm to 1.9 ppm cadmium, shown in blue in Figure 4.46. The concentrations between 1.2 ppm to 1.9 ppm for cadmium are recorded all over the map. Blocks having cadmium levels between 2.0 ppm to 3.1 ppm (green dots) are encountered all over the area except the far west. Blocks having highest value between 3.2 ppm and 5.3 ppm are depicted in brown. There are only a few blocks having between 3.2 ppm and 5.3 ppm cadmium concentrations.

According to this map, no specific pattern can be observed between the concentration and the sides in new town.

### 4.1.4.5.6 Antimony

Soil antimony concentration Table 4.5, the resulting concentration levels recorded for Sb ranged from 3.32 to 13.41 ppm.

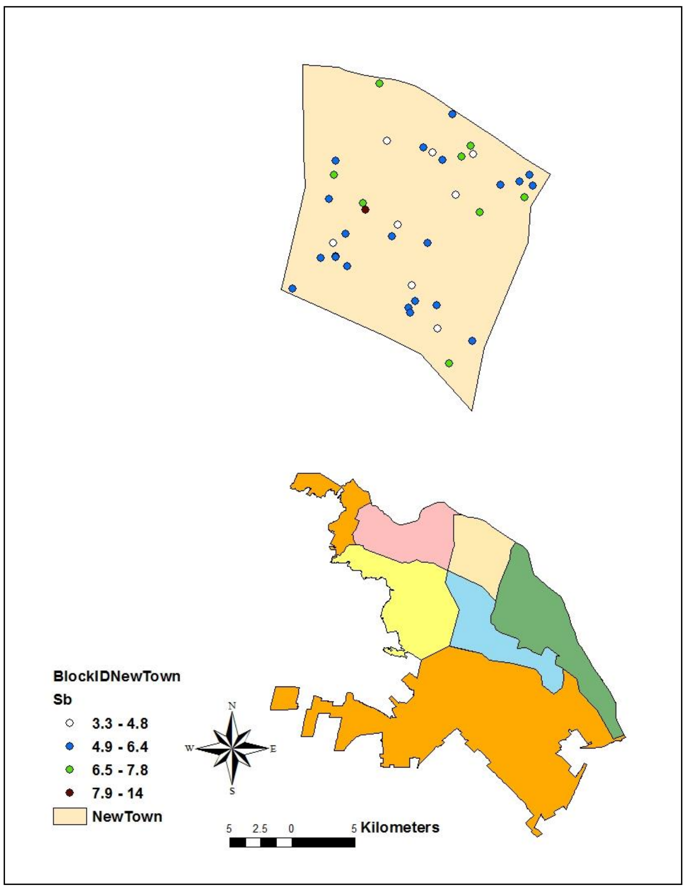


Figure 4.47: Antimony concentrations in composite samples from blocks in new town

Blocks having the lowest values (between 3.3 ppm to 4.8 ppm; white dots) of antimony are scattered in new town. Blocks with 4.9 ppm to 6.4 ppm antimony, seen in blue, are scattered

all over the map of new town area. The majority of the blocks in this area show the concentration of antimony within this range.

Blocks having antimony levels between 6.5 ppm to 7.8 ppm (green dots) are encountered mostly from the east side of new town area. There is only one block having highest value between 7.9 ppm and 14 ppm and it is depicted in brown. This block is situated in the central area of new town.

According to this map, no specific pattern can be observed between the concentration of antimony and the area.

The results indicate that the metal lead has the highest concentration level 414.2 ppm, and Cd has the lowest level 0.3 ppm. The highest mean concentration value is recorded for the metal Zn, and the minimum concentration is recorded for Cd, which is almost 70 times less than Zn. However, the standard deviation relevant to Zn is also high which is not favorable to the accuracy of the interpretation. A higher standard deviation indicates that the observations are scattered. However, all five of number summaries (minimum, Q1, median, Q3, maximum) are also high for the variable Zn when compared to all others. This provides a hint to believe that in the New town soil samples, the highest concentration is recorded for Zn. However, it is advisable to consider the presence of outliers.

By considering the all above statistics, we can conclude the concentration of the soil samples taken from Juarez new town differs in the following order: Zn >Pb> Cr > Cu >Sb> Cd.

#### 4.1.4.6 Correlation between metals

In this section, the correlation between the variables is studied. For this purpose, correlations and the scatter plots are utilized. As well, log transformations have been used in order to increase the readability of scatter plots.

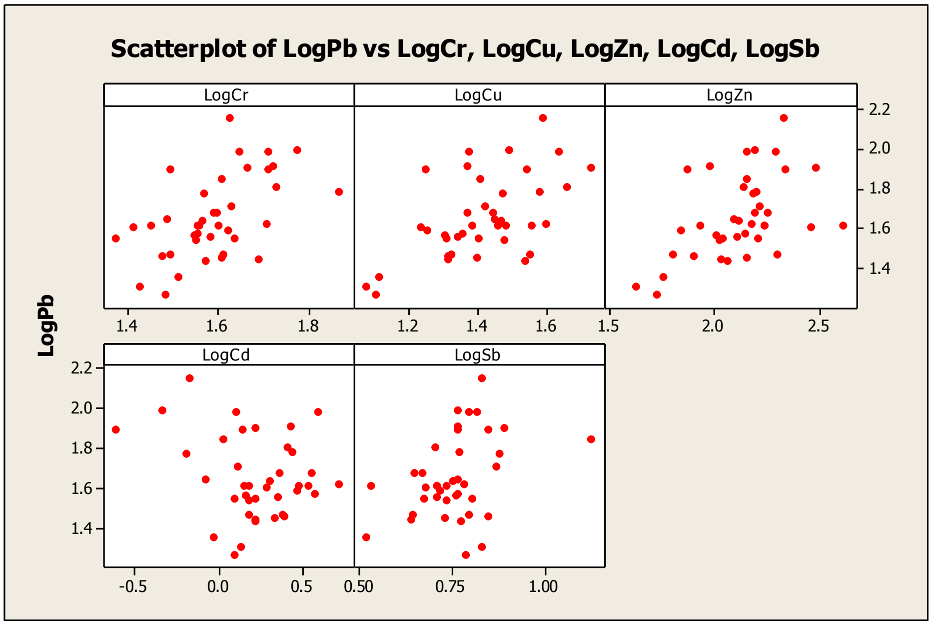


Figure 4.48: Correlation of Pb with other variables - new town

The variable Pb shows a slight positive correlation with the three variables Cr, Cu and Zn.

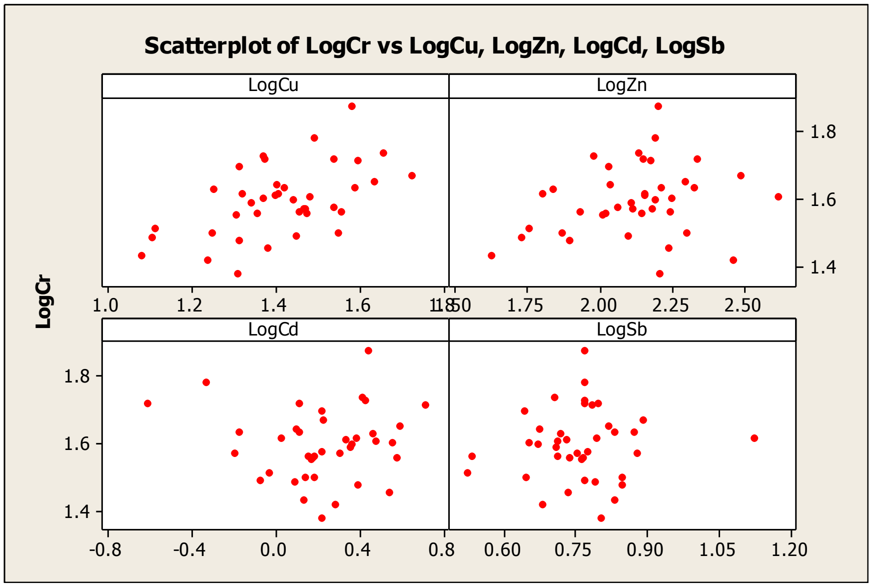


Figure 4.49: Correlation of Cr with other variables - new tow

From the above Figure 4.49, it can be observed that the variable Cr shows a correlation with the Cu and Zn variable.

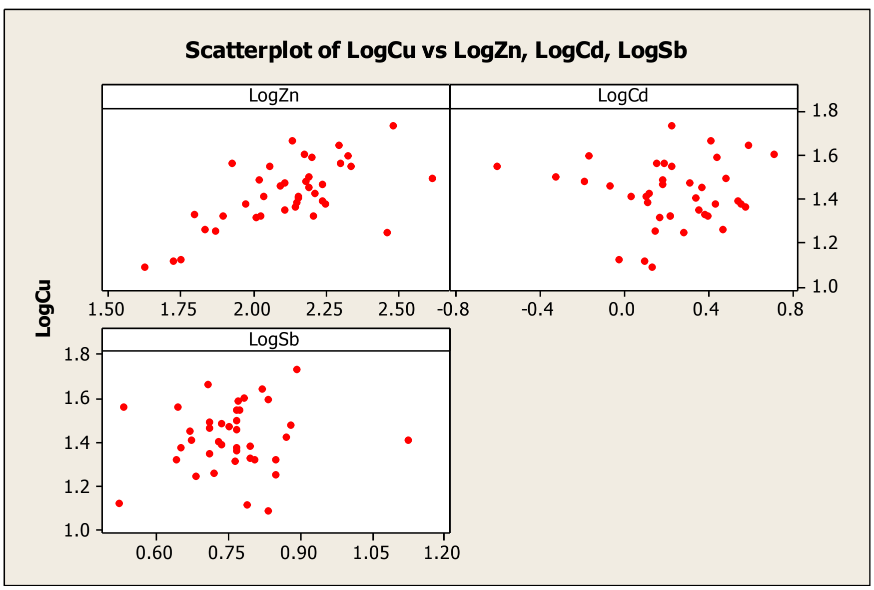


Figure 4.50: Correlation of Cu with other variables - new town

From the above Figure 4.50, it can be observed that the variable Cu exhibits a positive correlation with Zn.

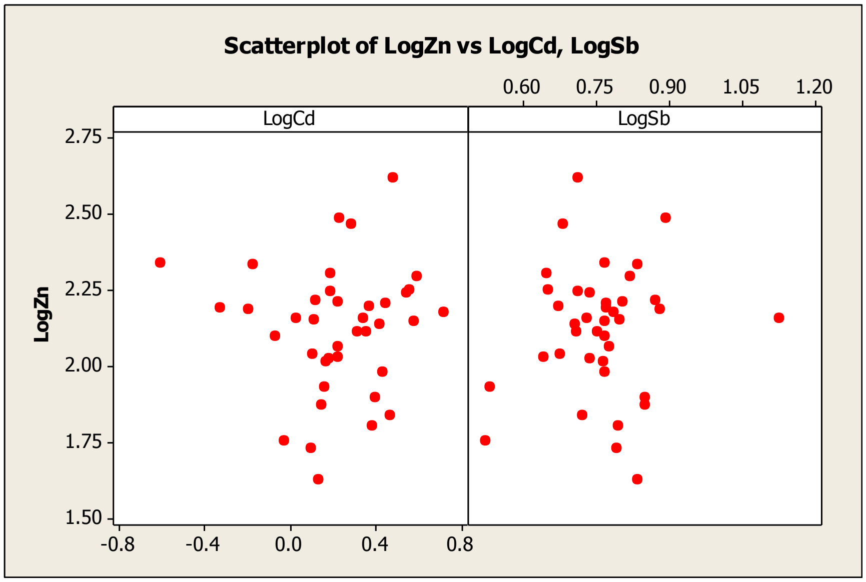


Figure 4.51: Correlation of Zn with other variables - new town

From the above Figure 4.51, it can be observed that the variable Zn does not exhibit a significant relationship with the Cd and Sb.

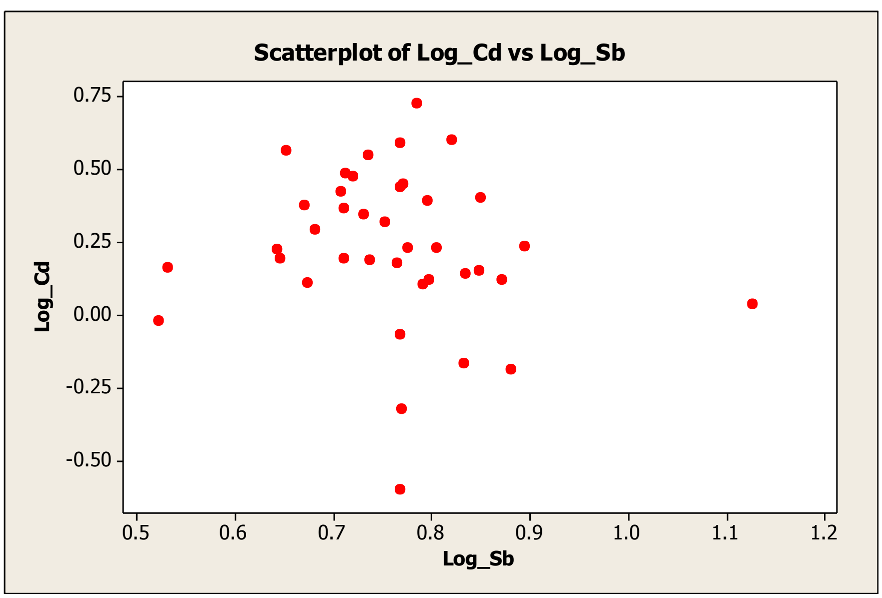


Figure 4.52: Correlation of Cd with other variables - new town

From the above Figure 4.52, it can be observed that the variable Cd does not exhibit a significant correlation with the other variables.

To emphasize the observed results from the above scatter plots, correlation matrix can be used.

Table 4.6: Correlation between variables (metals) – new town

**Correlations: Pb, Cr, Cu, Zn, Cd, Sb**

| | Pb | Cr | Cu | Zn | Cd |
|---|---|---|---|---|---|
| Cr | 0.486 | | | | |
| | 0.002 | | | | |
| Cu | 0.486 | 0.504 | | | |
| | 0.002 | 0.001 | | | |
| Zn | 0.318 | 0.121 | 0.492 | | |
| | 0.049 | 0.462 | 0.001 | | |
| Cd | -0.167 | 0.127 | 0.142 | 0.126 | |
| | 0.308 | 0.441 | 0.389 | 0.446 | |
| Sb | 0.340 | 0.042 | 0.079 | 0.039 | -0.154 |
| | 0.034 | 0.800 | 0.635 | 0.816 | 0.348 |

Cell Contents: Pearson correlation
P-Value

According to above Table 4.6, only the variable pairs Pb and Cr, Pb and Cu, Cr and Cu, Pb and Zn, Cu and Zn, Pb and Sb are not significant at 5%. Therefore, out of 16 variable pairs, 6 pairs are insignificant implying there is no significant correlation.

From the above Figure, the following observations can be made:

- The correlation between Pb and Cr is 0.486
- The correlation between Pb and Cu is 0.486
- The correlation between Pb and Zn is 0.318
- The correlation between Pb and Cd is - 0.167
- The correlation between Pb and Sb is 0.340

- The correlation between Cr and Cu is 0.504
- The correlation between Cr and Zn is 0.121
- The correlation between Cr and Cd is 0.127
- The correlation between Cr and Sb is 0.042
- The correlation between Cu and Zn is 0.492
- The correlation between Cu and Cd is 0.142
- The correlation between Cu and Sb is 0.079
- The correlation between Zn and Cd is 0.126
- The correlation between Zn and Sb is 0.039
- The correlation between Cd and Sb is - 0.154

According to these observations, it is noticeable that the correlation between Cr and Cu is the highest correlation (r =0.504).

### 4.1.4.7 Checking the normality of the data - new town

To check the normality of the data, histograms can be used.

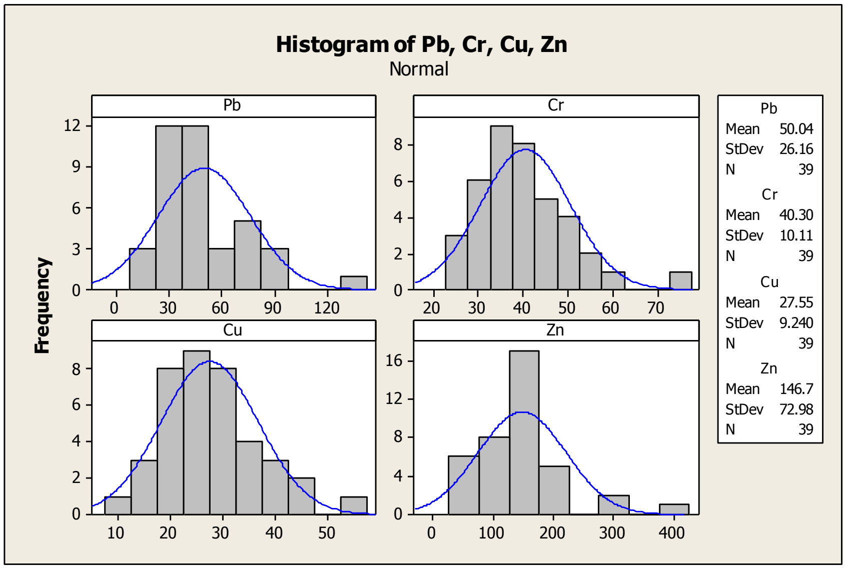


Figure 4.53: Histograms for the variables - new town

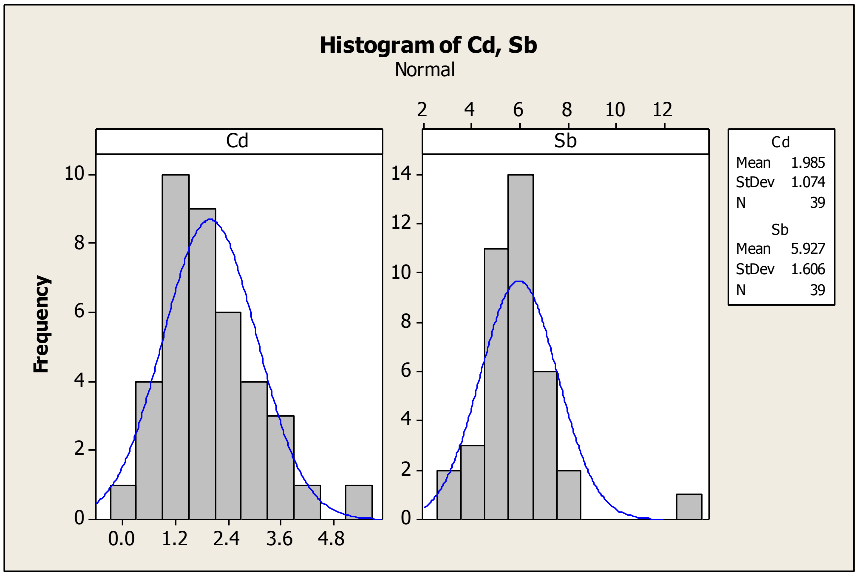


Figure 4.54: Histograms for the variables - new town

Figures 4.53 and 4.54 provide the histograms for the variables. The variable Cr fits to approximately normal data. Further the variables Cr, Cu and Cd shows slightly normal data.

#### 4.1.4.8 Checking for the outliers in the data

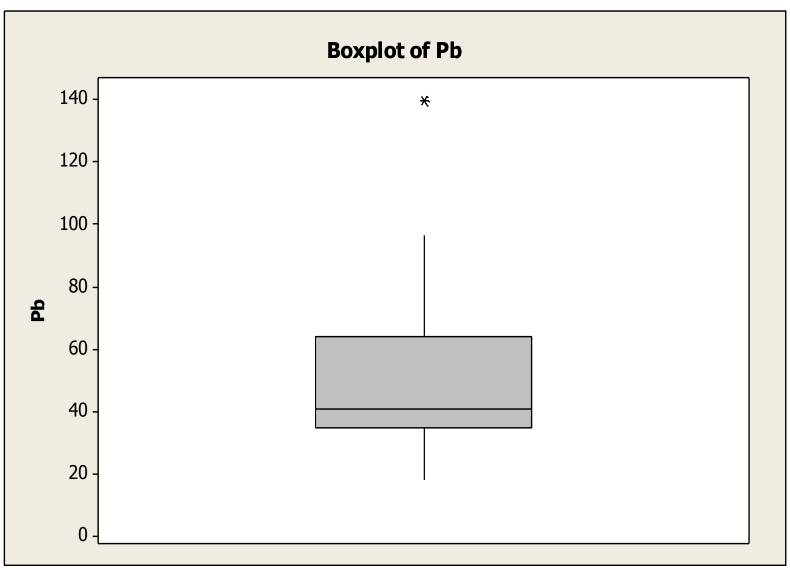


Figure 4.55: Box plot of Pb - new town

Figure 4.55: The data is positively skewed. Further, there are some outliers in the upper end.

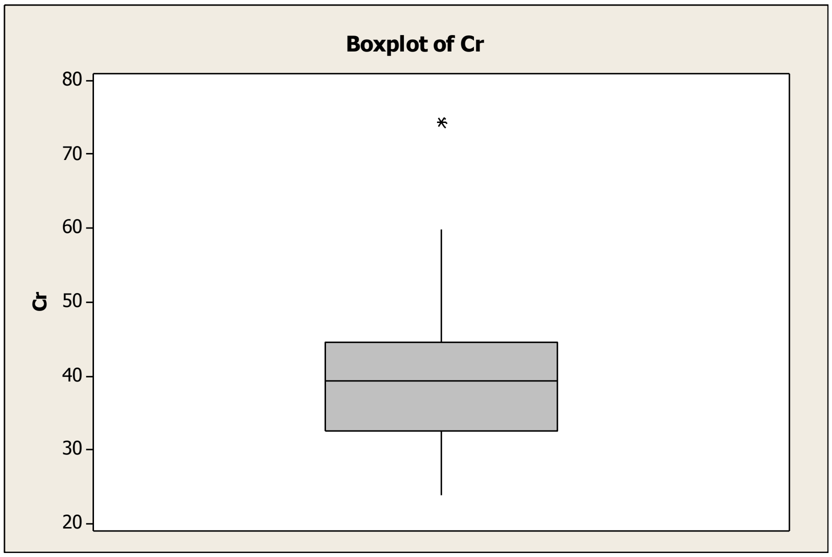


Figure 4.6: Box plot of Cr - new town

According to the above box plot Figure 4.56, the data is negatively skewed. Further, there are outliers in the upper end.

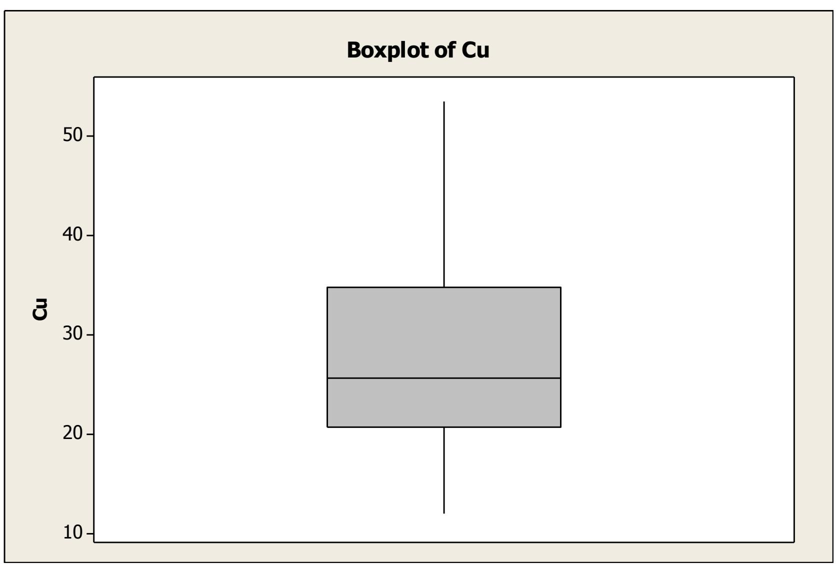


Figure 4.57: Box plot of Cu - new town

Studying the above Box plot, we noticed that the data is positively skewed. Further, there are no outliers shown.

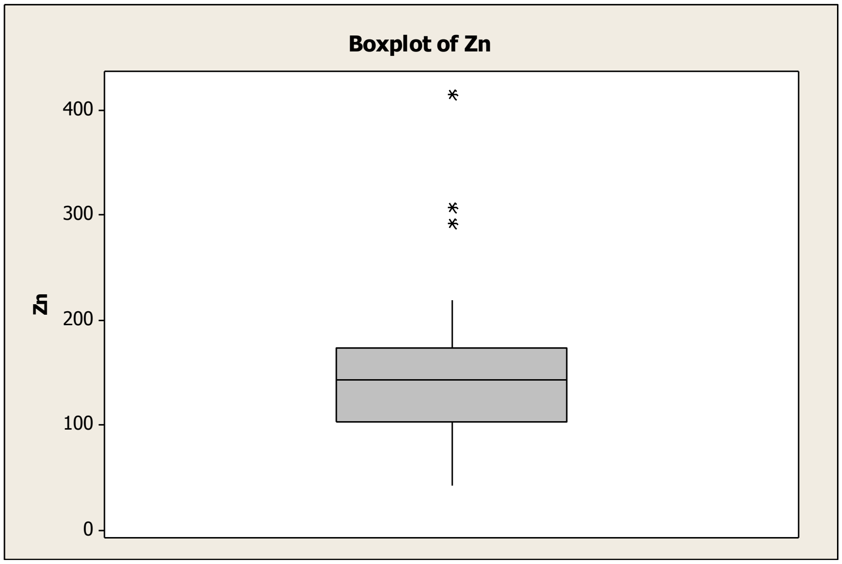


Figure 4.7: Box plot of Zn - new town

The above Box plot, we noticed that the data is negatively skewed. Further, there are some outliers in the upper

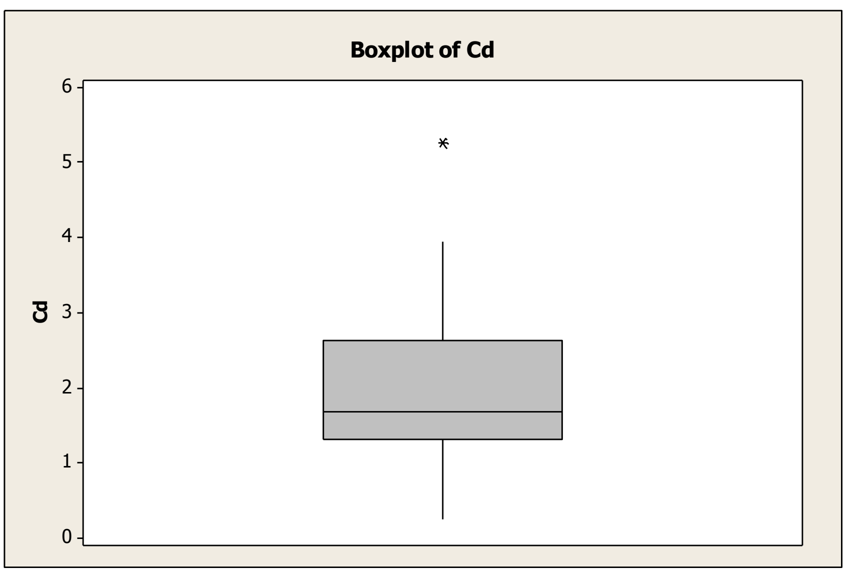


Figure 4.8: Box plot of Cd - new town

According to the above Box plot, it can be noticed that there are some outliers in the upper end.

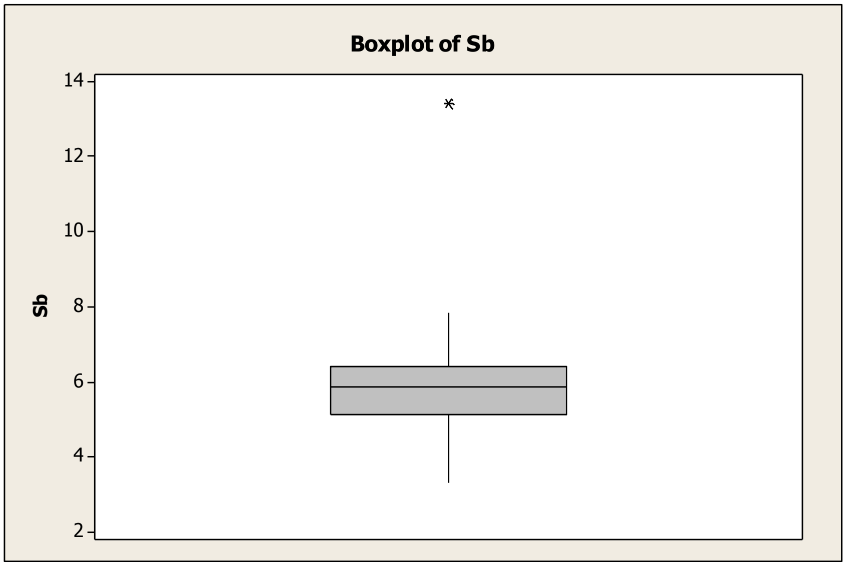


Figure 4.60: Box plot of Sb - new town

Studying the above Box plot, it can be noticed that some outliers in the upper end.

#### 4.1.4.9 East side

The sample size for east side is 137. For each sample, the concentration of the metals was determined and recorded. The data obtained was statistically analyzed, as shown in Table 4.7. Maps for distribution and concentrations of the metals were also created.

Table 4.7: Descriptive statistics for metals - east side

| Variable | N | Mean | StDev | Minimum | Q1 | Median | Q3 | Maximum |
|---|---|---|---|---|---|---|---|---|
| Pb | 137 | 49.1 | 62.7 | 15.9 | 23.2 | 31.7 | 48.2 | 550.3 |
| Cr | 137 | 39.1 | 8.5 | 11.6 | 34.2 | 39.6 | 44.3 | 71.6 |
| Cu | 137 | 26.9 | 53.5 | 8.1 | 13.9 | 16.5 | 21.7 | 547.3 |
| Zn | 137 | 82.9 | 60.6 | 33.6 | 50.6 | 62.8 | 94.9 | 415.8 |
| Cd | 137 | 1.9 | 0.9 | 0.4 | 1.3 | 1.8 | 2.3 | 6.2 |
| Sb | 137 | 5.9 | 2.5 | 3.3 | 4.9 | 5.6 | 6.4 | 28.8 |

The above Table 4.7, display the descriptive statistics obtained for the east side soil samples. From the table the following observations can be made.

#### 4.1.4.9.1 Lead

The resulting concentration levels recorded for lead ranged from 15.9 to 550.3 ppm.

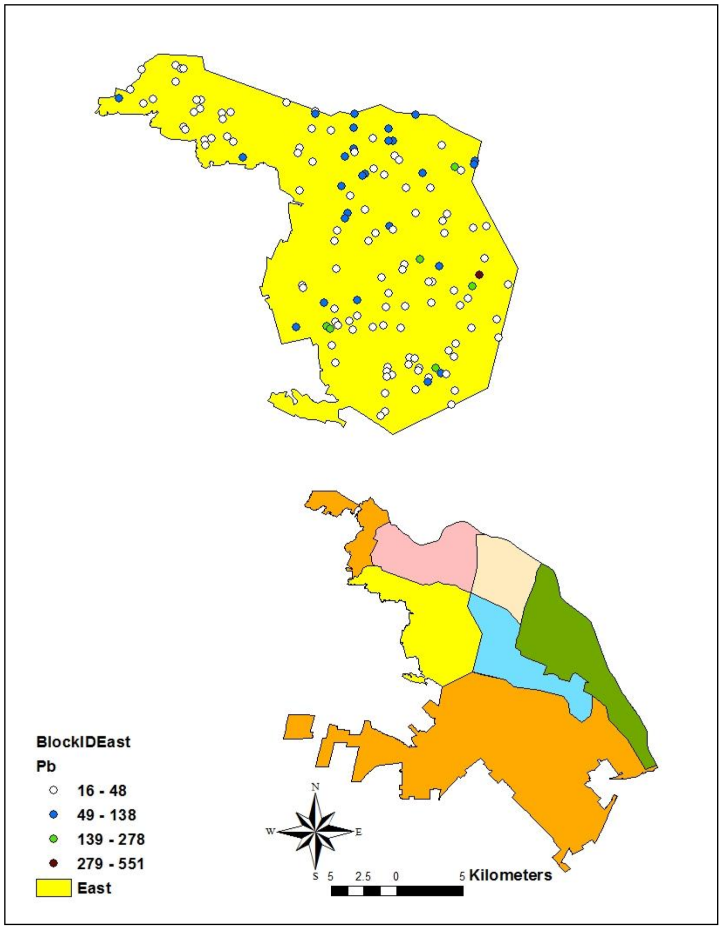


Figure 4.61: Lead concentrations in composite samples from blocks in east Juarez

The lowest values (between 16 ppm to 48 ppm; white dots) of lead are encountered all over the east area in east region of Juarez. Blocks with 49 ppm to 138 ppm lead, are shown in blue in Figure 4.61. Therefore, the concentrations between 49 ppm and 138 ppm for lead are recorded all over the map. However, the density of the blue dots is higher in the northeast area.

Only a few blocks having lead levels between 139 ppm to 278 ppm (green dots) are encountered in east region of Juarez. There is only one block having highest value between 279 ppm and 551 ppm and depicted in brown. This block is situated in the east side of east Juarez region.

Figure 4.62, illustrates the concentration of lead levels in soil samples with correlation of children age 1-5 in east Juarez.

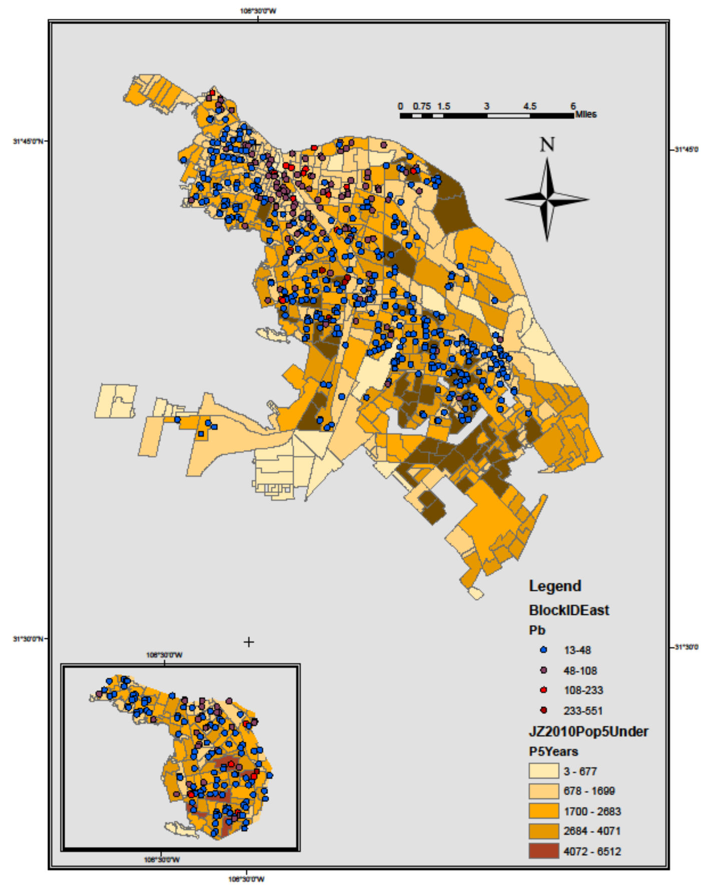


Figure 4.62: Population density of children and lead soil in east region of Juarez

#### 4.1.4.9.2 Chromium

The resulting concentration levels recorded for chromium ranged from 11.6 ppm to 71.6 ppm.

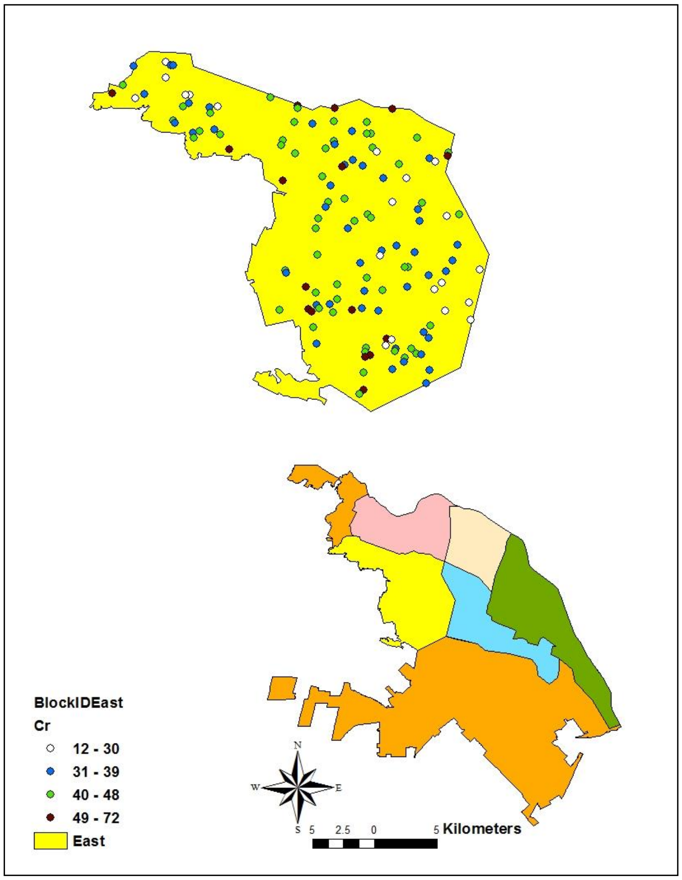


Figure 4.63: Chromium concentrations in composite samples from blocks in east Juarez

The lowest values (between 12 ppm to 30 ppm; white dots) of chromium are mainly encountered in west side of east area. Blocks with 31 ppm to 39 ppm chromium, seen in blue, are scattered all over the map of east area.

Chromium levels between 40 ppm to 48 ppm (green dots), are encountered all over the east area. Blocks having highest value between 49 ppm and 72 ppm are depicted in brown. These blocks are scattered all over.

No specific pattern can be observed in the spread of chromium concentrations in the east area of Juarez.

#### 4.1.4.9.3 Copper

The resulting concentration levels recorded for copper ranged from 8.1 ppm to 547.3 ppm.

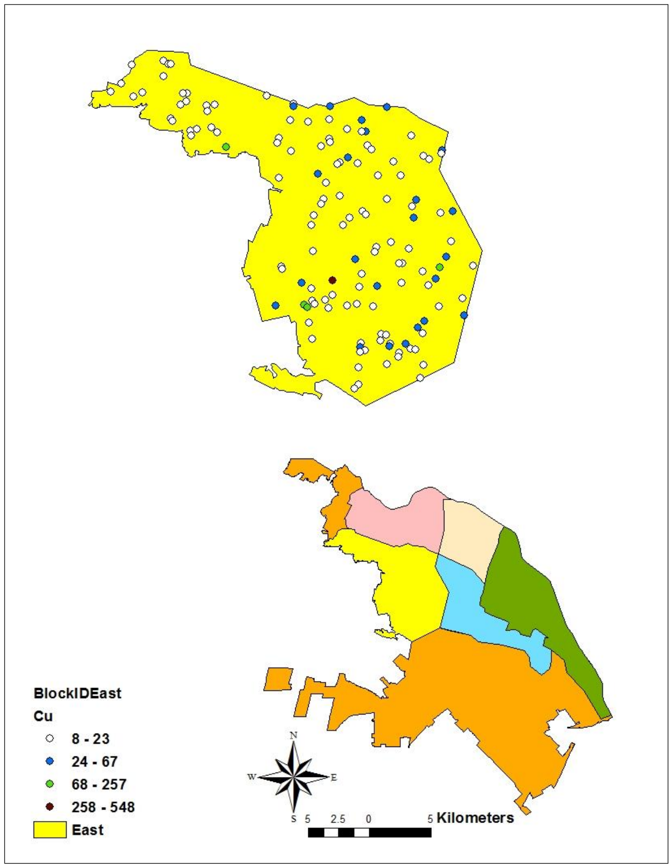


Figure 4.64: Copper concentrations in composite samples from blocks in east Juarez

The lowest values (between 8 ppm and 23 ppm; white dots) of copper are scattered all over the east area. Blocks with 24 ppm to 67 ppm copper, seen in blue, are mainly found east side of east area of Juarez. However, the density of blue dots is higher for the central part of east area. Blocks having copper levels between 68 ppm to 257 ppm (green dots), are encountered mainly in central to east side of east area. Only one block is found having highest value between

258 ppm and 548 ppm and it is depicted in brown. However, in general, no specific pattern of the spread of the copper concentrations can be identified.

#### 4.1.4.9.4 Zinc

The resulting concentration levels recorded for copper ranged zinc ranged from 33.6 ppm to 415.8 ppm.

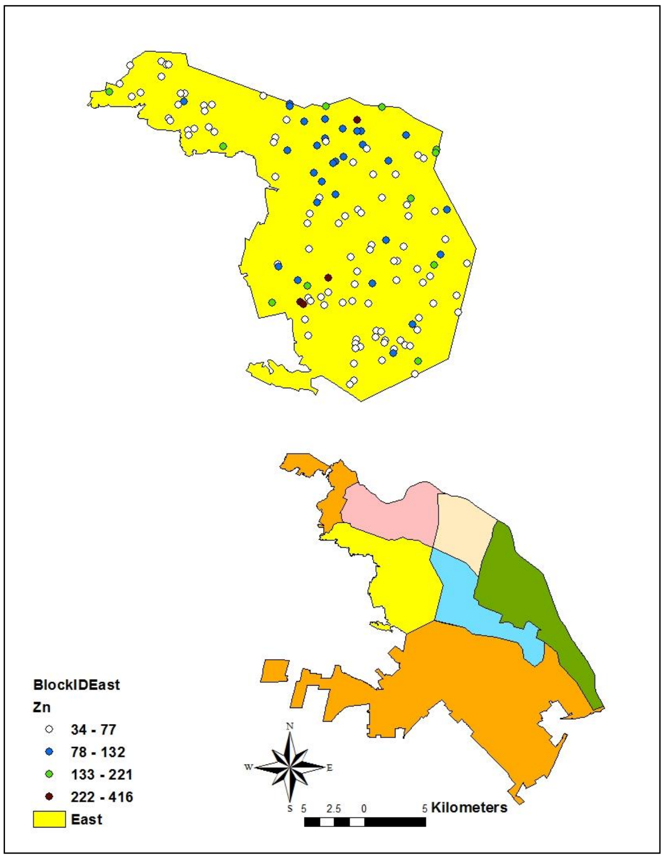


Figure 4.65: Zinc concentrations in composite samples from blocks in east Juarez

The lowest values (between 34 ppm to 77 ppm; white dots) of zinc are encountered in all over east area. The majority of the blocks in east area have zinc concentration in this range. Blocks with 78 ppm to 132 ppm zinc are shown in blue in Figure 4.65. Blue dots are scattered

mostly in the northeast part of the map. Blocks having zinc levels between 133 ppm to 221 ppm (green dots) are encountered from the peripheral areas of east area. However, there are only a few green dots in the map. Few blocks having highest value between 222 ppm to 416 ppm are encountered in the east area and those are depicted in brown.

#### 4.1.4.9.5 Cadmium

Cadmium in the soil samples ranged from 0.4 ppm to 6.2 ppm.

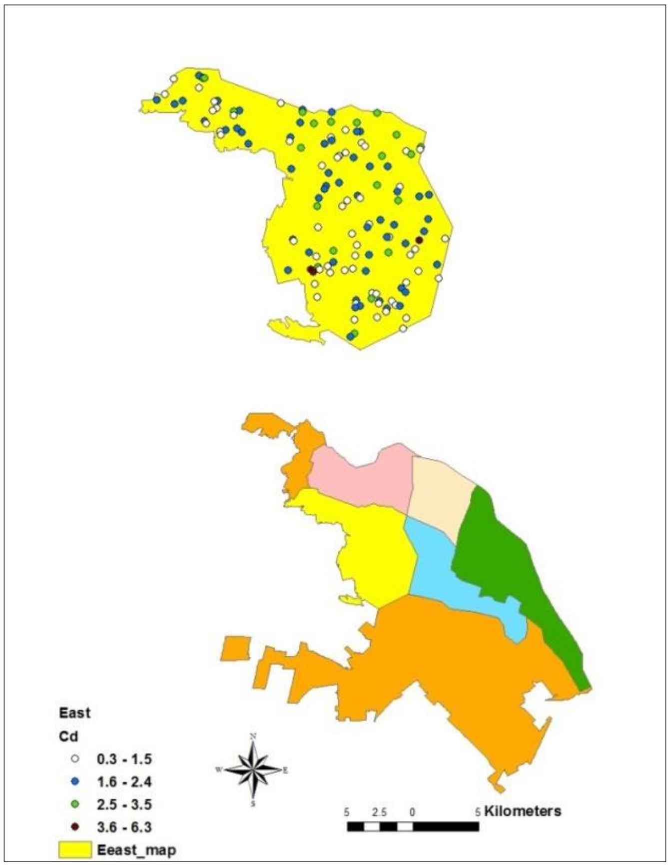


Figure 4.66: Cadmium concentrations in composite samples from blocks in east Juarez

The lowest values (between 0.3 ppm to 1.5 ppm; white dots) of cadmium are scattered all over the east area. Blocks with 1.6 ppm to 2.4 ppm cadmium, shown in blue in Figure 4.66.

Therefore, the concentrations between 2ppm to 3ppm for cadmium are also recorded all over the map.

Blocks having cadmium levels between 2.5 ppm to 3.5 ppm (green dots), are encountered all over the area. However, majority of them can be found from the far east. Blocks having highest value between 3.6 ppm to 6.3 ppm are depicted in brown. There are only a few blocks in east area show this level of cadmium concentrations.

According to this map, no specific pattern can be observed between the concentration and the sides in east.

#### 4.1.4.9.6 Antimony

Antimony in the soil samples ranged from 3.3 ppm to 28.8 ppm.

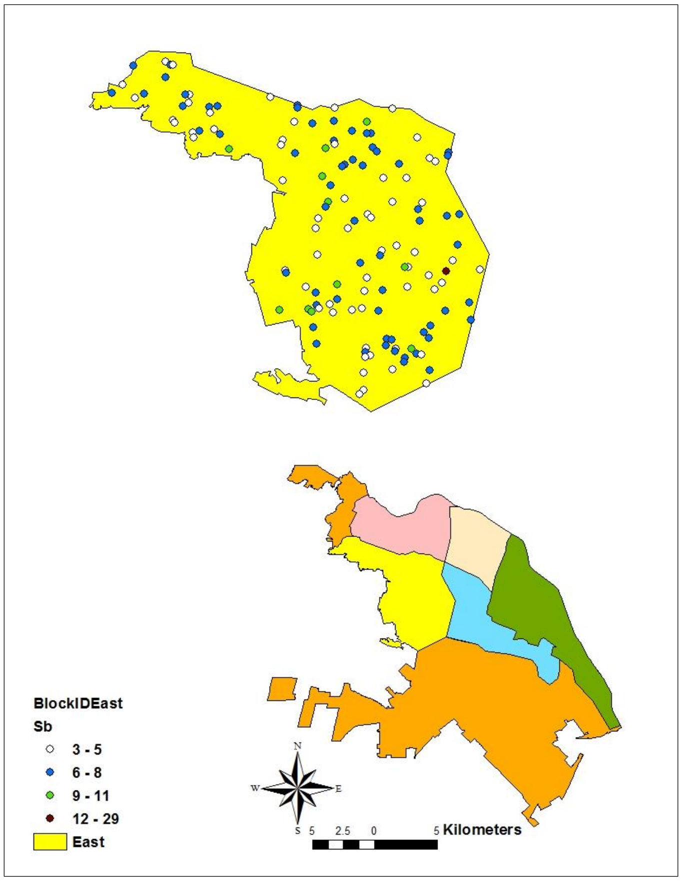


Figure 4.67: Antimony concentrations in composite samples from blocks in east Juarez

Blocks having the lowest values (between 3 ppm to 5 ppm; white dots) of antimony are found from the east area. These white dots are scattered all over the map. Blocks with 6 ppm to 8 ppm antimony, seen in blue, are scattered all over the map of east area. The majority of the blocks in this area show the concentration of antimony within this range.

There are a few blocks having antimony levels between 9 ppm to 11 ppm (green dots) encountered in east area. Only one block having highest value between 12 ppm and 29 ppm is found and it is depicted in brown. That block is situated in the west side of east Juarez.

According to this map, no specific pattern can be observed between the concentration of antimony and the area.

The highest mean concentration value is recorded for the metal Pb, and the minimum concentration is recorded for Cd, which is approximately 50 times less than Zn. However, the standard deviation relevant to Zn is also high which is not favorable to the accuracy of the interpretation. A higher standard deviation indicates that the observations are scattered. However all of the five number summaries (minimum, Q1, median, Q3, maximum) are also high for the variable Zn when compared to all others. This provides a hint to believe that in the east side soil samples the highest concentration is recorded for Zn. By considering the all above statistics, we can conclude that the concentration of the soil samples taken from East side differs in the following order: Zn >Pb> Cr > Cu >Sb> Cd.

#### 4.1.4.10 Correlation between metals

For this purpose, correlations and scatter plots have been used. In order to increase the readability of the scatter plots, log transformations have been employed.

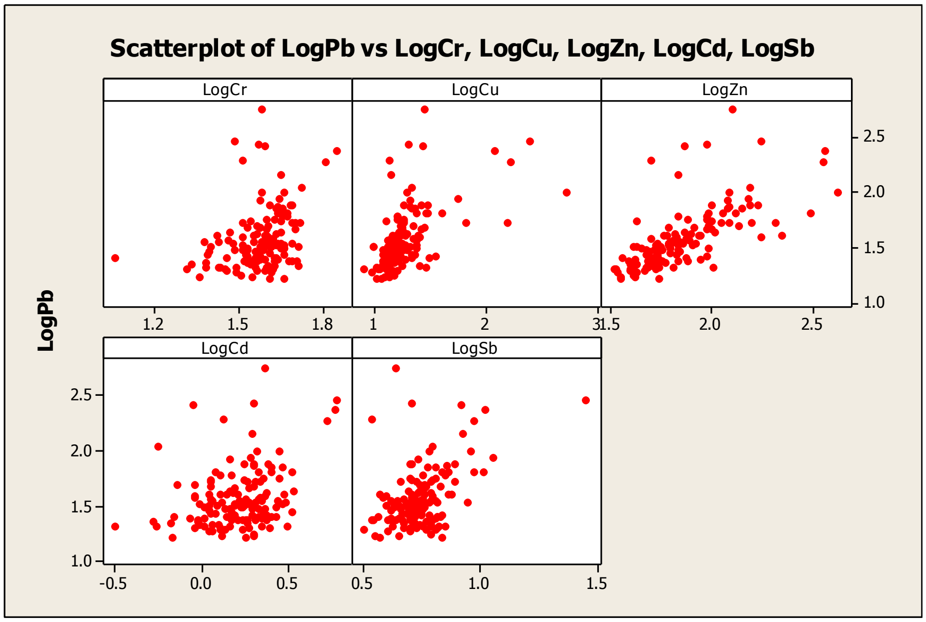


Figure 4.68: Correlation of Pb with other variables - east side

From Figure 4.68, it can be observed that the variable Pb shows a slight positive correlation with the tow variables Cu and Zn.

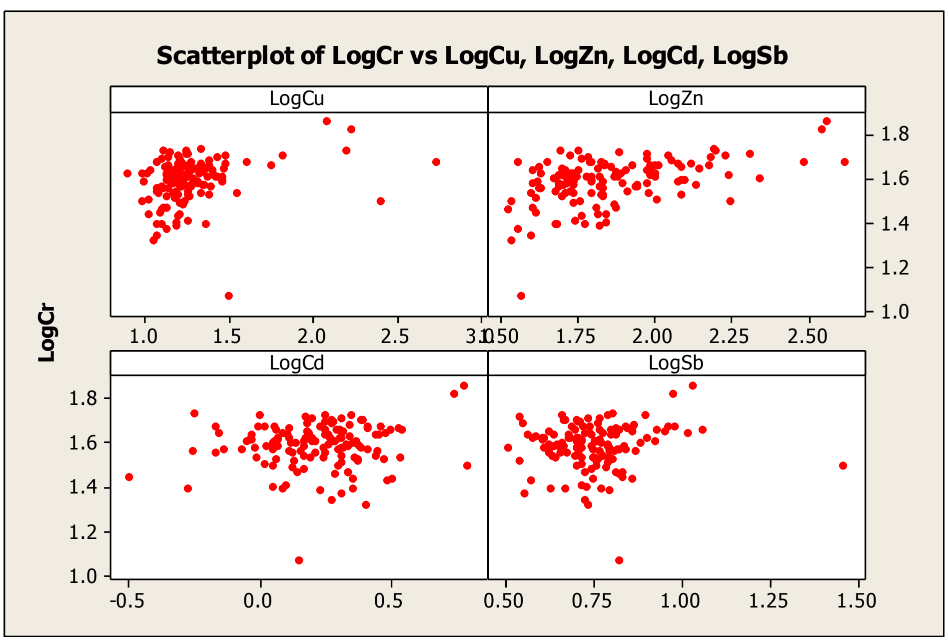


Figure 4.69: Correlation of Cr with other variables - east side

Figure 4.69, shows that the variable Cr shows a correlation with Zn.

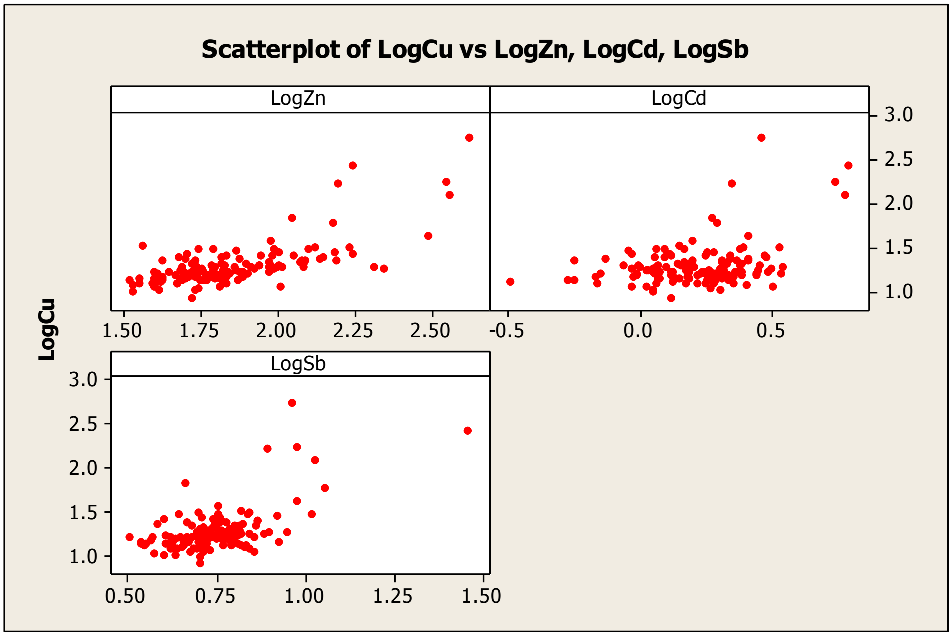


Figure 4.70: Correlation of Cu with other variables - east side

From Figure 4.70 it can be observed that the variable Cu does not exhibit a significant relationship with the Zn, Cd, and Sb.

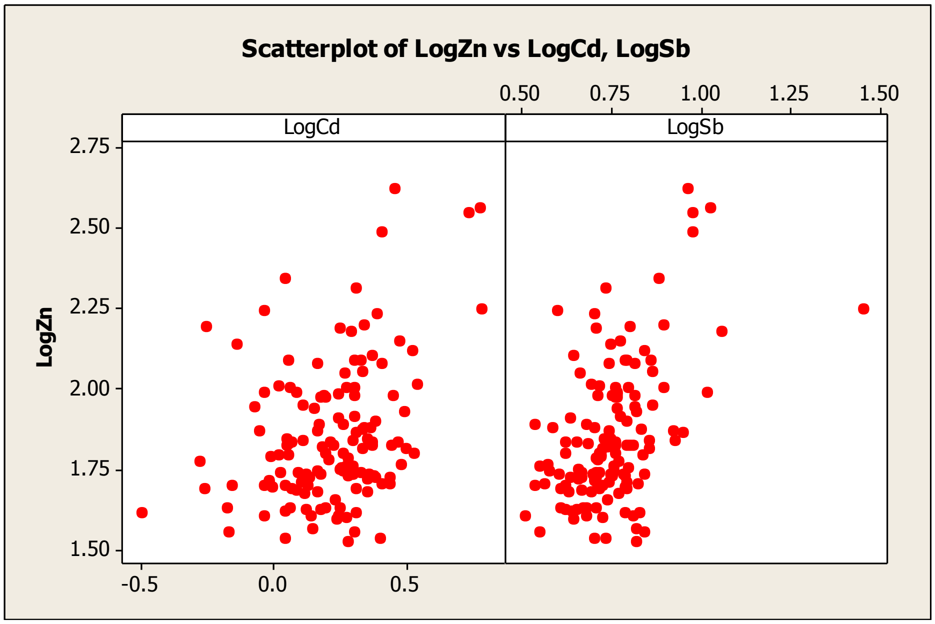


Figure 4.71: Correlation of Zn with other variables - east side

From Figure 4.71, it can be observed that the variable Zn does not exhibit a significant correlation with the Cd, Sb.

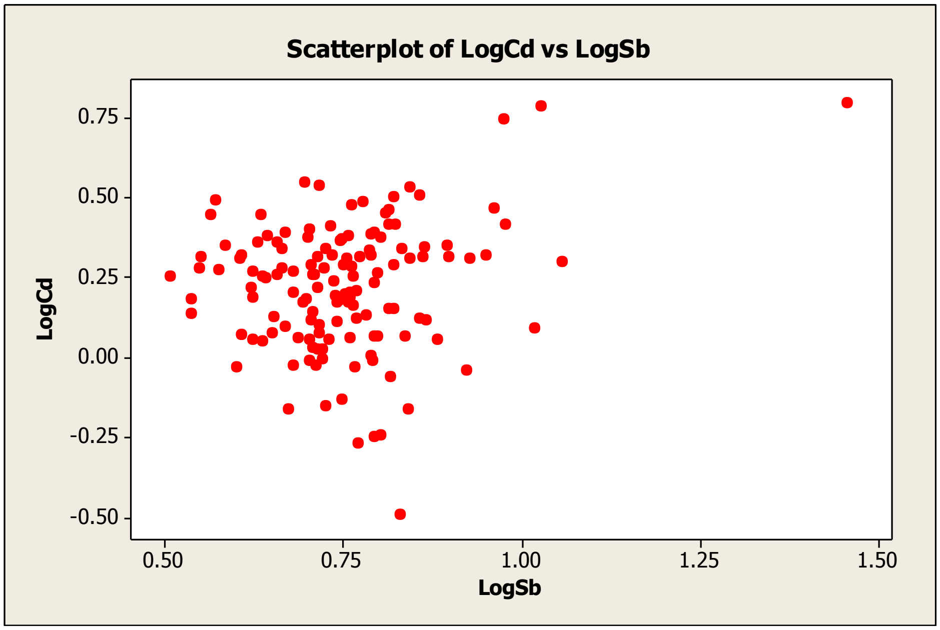


Figure 4.72: Correlation of Cd with other variables - east side

From Figure 4.72, it can be observed that the variable Cd does not exhibit a significant correlation with Sb.

To emphasize the observed results from the above scatter plots, a correlation matrix has been used.

Table 9: Correlation between the variables – east side

**Correlations: Pb, Cr, Cu, Zn, Cd, Sb**

| | Pb | Cr | Cu | Zn | Cd |
|---|---|---|---|---|---|
| Cr | 0.210 | | | | |
| | 0.014 | | | | |
| Cu | 0.295 | 0.215 | | | |
| | 0.000 | 0.012 | | | |
| Zn | 0.423 | 0.498 | 0.683 | | |
| | 0.000 | 0.000 | 0.000 | | |
| Cd | 0.363 | 0.209 | 0.412 | 0.483 | |
| | 0.000 | 0.014 | 0.000 | 0.000 | |
| Sb | 0.382 | 0.084 | 0.509 | 0.428 | 0.474 |
| | 0.000 | 0.328 | 0.000 | 0.000 | 0.000 |

Cell Contents: Pearson correlation
P-Value

Save for Cr and Sb, all variable pairs show significant correlations with a 5% significance level.

- The correlation between Pb and Cu is 0.295
- The correlation between Pb and Zn is 0.423
- The correlation between Pb and Cd is 0.363
- The correlation between Pb and Sb is 0.382
- The correlation between Pb and Cr is 0.210
- The correlation between Cu and Zn is 0.683
- The correlation between Cu and Cd is 0.412

- The correlation between Cu and Sb is 0.509
- The correlation between Cu and Cr is 0.215
- The correlation between Zn and Cd is 0.483
- The correlation between Zn and Sb is 0.428
- The correlation between Zn and Cr is 0.498
- The correlation between Cd and Sb is 0.474
- The correlation between Cd and Cr is 0.209
- The correlation between Sb and Cr is 0.084

According to these observations, it is noticeable that the correlation between Zn and Cu is the highest correlation.

### 4.1.4.11 Check the normality of the data – east side

To check the normality of the data, we employed histograms.

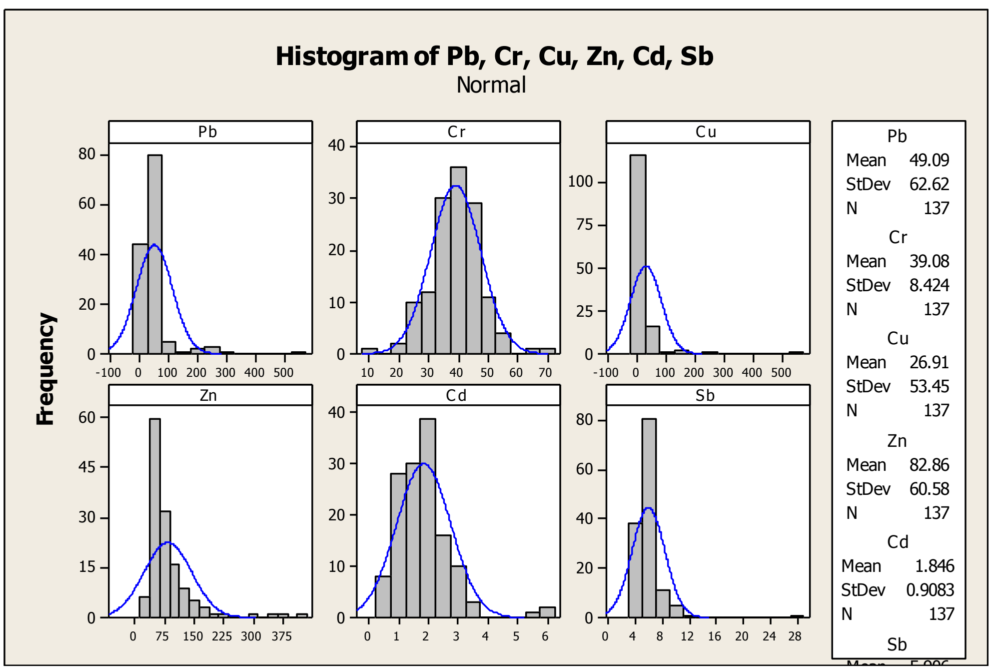


Figure 4.73: Histograms for the variables - east side

Figure 4.73 provide the histograms for the variables. From the figure, it can be observed that only the variable Cr fits to approximately normal data.

### 4.1.4.12 Checking for the outliers in the data

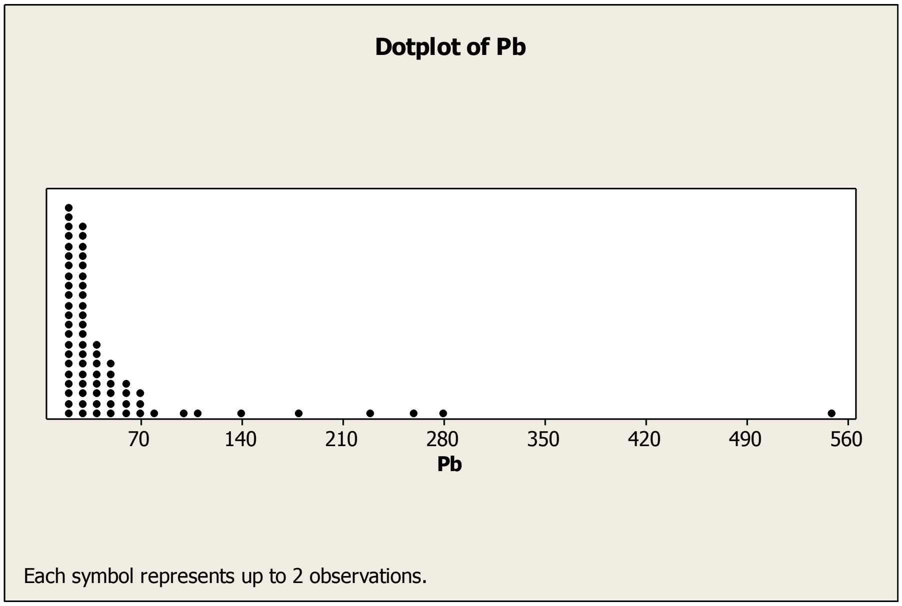


Figure 4.74: Dot plot for Pb - east side

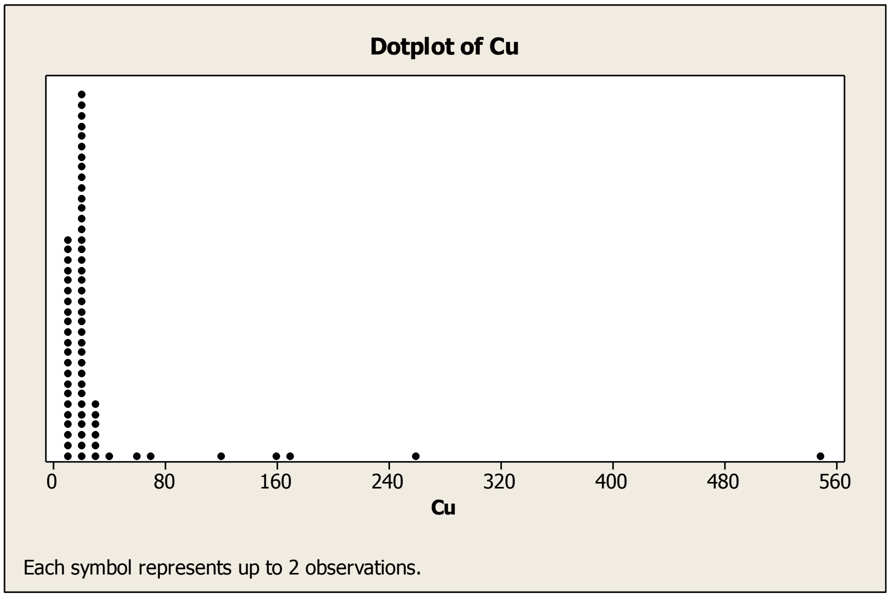


Figure 4.75: Dot plot for Cu - east side

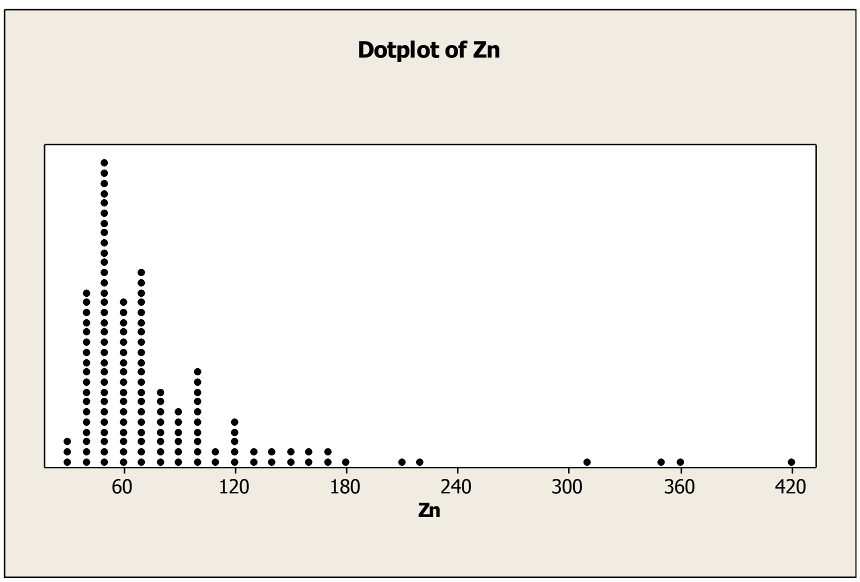


Figure 4.76: Dot plot for Zn - east side

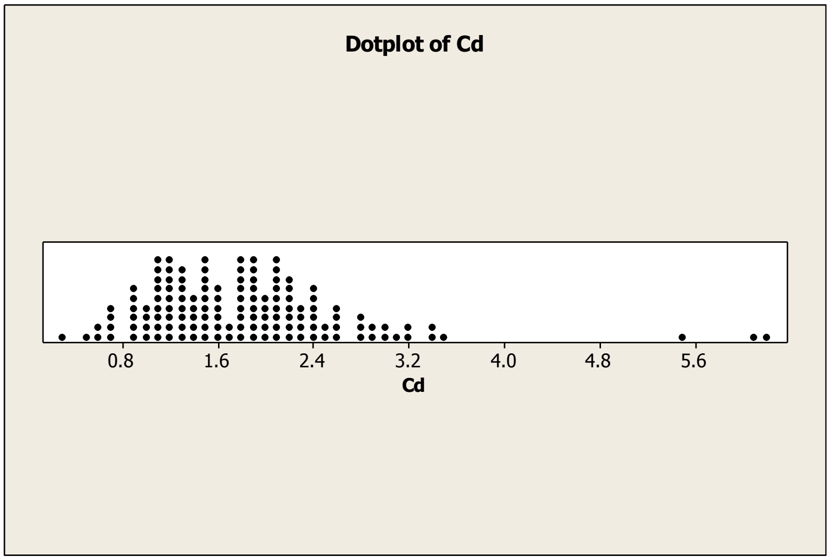


Figure 4.77: Dot plot for Cd - east side

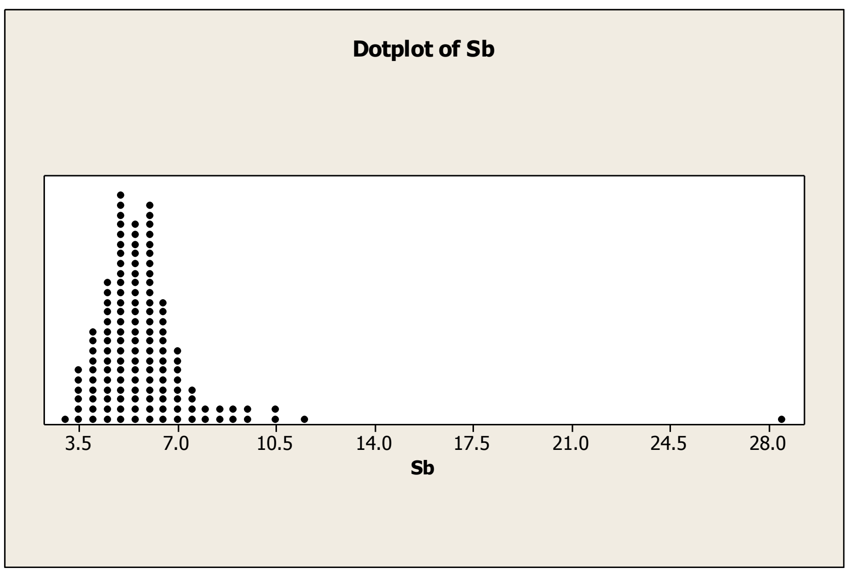


Figure 4.78: Dot plot for Sb - east side

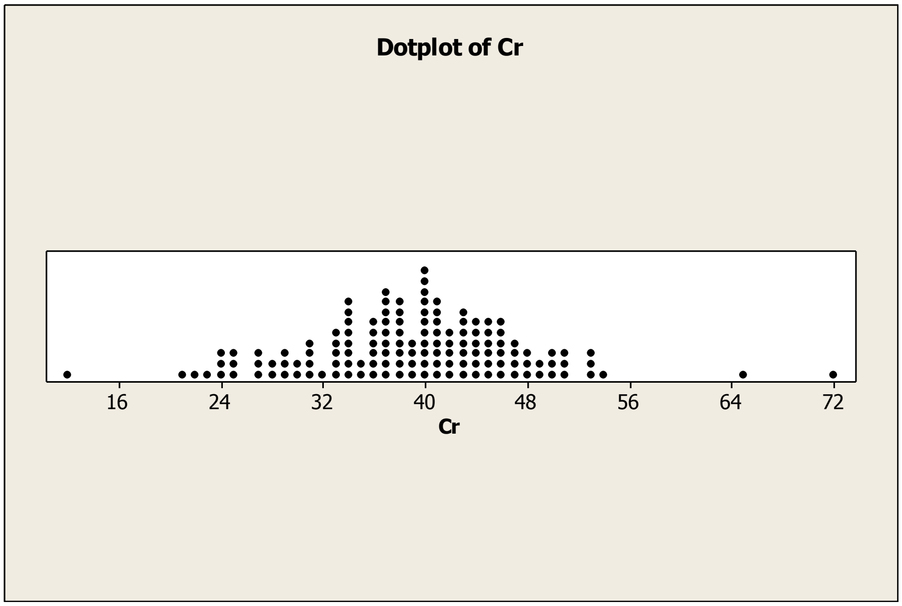


Figure 4.79: Dot plot for Cr - east side

From the set of Figures (4.74 - 4.79), the dot-plots are represented. By examining all of them, it can be concluded that except for Cr and Sb all other variables are highly skewed and have significant outliers.

#### 4.1.1.13 Ciudad Juarez – Center

The sample size for the city center is 104. For each sample, the concentration of the metals was determined and recorded. The data obtained was statistically analyzed, as shown in Table 4.9. In addition, maps for distribution and concentrations of the metals were created.

Table 4.9: Descriptive statistics for the metals - center

| Variable | N | Mean | StDev | Minimum | Q1 | Median | Q3 | Maximum |
|---|---|---|---|---|---|---|---|---|
| Pb | 104 | 30.4 | 16.6 | 14.1 | 20.1 | 24.4 | 33.7 | 100.4 |
| Cr | 104 | 23.2 | 11.2 | 3.8 | 14.7 | 22.1 | 32.7 | 57.7 |
| Cu | 104 | 15.2 | 7.5 | 7.6 | 10.6 | 13.4 | 18.3 | 60.7 |
| Zn | 104 | 63.1 | 35.7 | 21.7 | 37.8 | 48.9 | 83.7 | 222.5 |
| Cd | 104 | 1.9 | 0.9 | 0.5 | 1.3 | 1.8 | 2.4 | 4.2 |
| Sb | 104 | 5.7 | 1.3 | 2.9 | 4.9 | 5.6 | 6.3 | 12.1 |

The above table display the descriptive statistics obtained for the center soil samples. From Table 4.9, the following observations can be made.

#### 4.1.4.13.1 Lead

The resulting concentration levels recorded for lead ranged from 14.1 to 100.4 ppm.

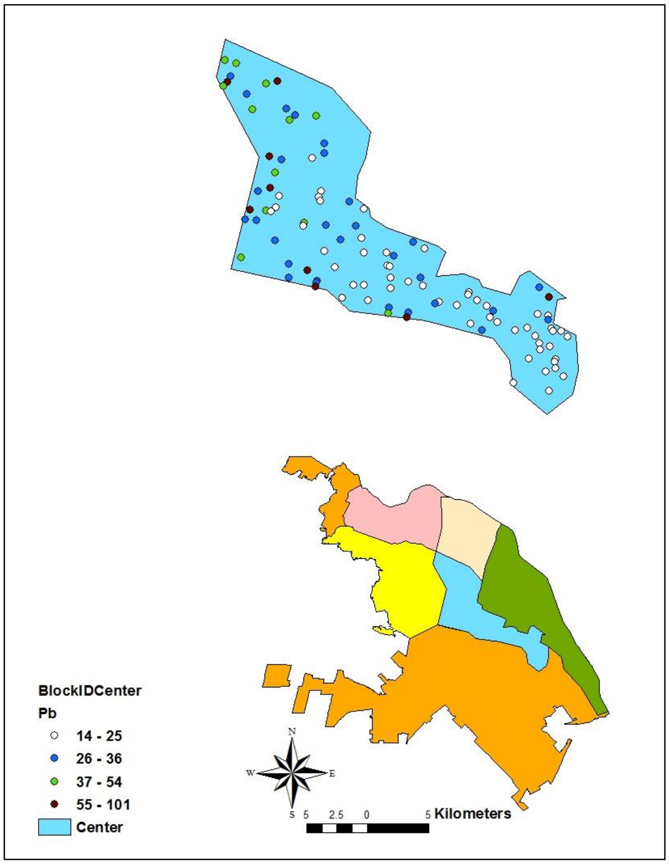


Figure 4.80: Lead concentrations in composite samples from blocks in center Juarez

The lowest values (between 14 ppm to 25 ppm; white dots) of lead are mostly encountered in the southern area of center in Juarez. The density of the white dots increases from north to south.

Blocks with 26 ppm to 36 ppm lead, seen in blue in Figure 4.80. Therefore, the concentrations between 26 ppm and 36 ppm for lead are recorded all over center area. However, most of them are found in the central and the north part of central area. Blocks having lead levels between 37 ppm to 54 ppm (green dots) are encountered only in the north of center in Juarez.

There are only a few blocks having highest value between 55 ppm and 101 ppm and depicted in brown. These blocks are mostly found in the peripheral areas.

In general, the lead concentration is higher in the north are than the south area in center region in Juarez.

Figure 4.81, illustrates the concentration of lead levels in soil samples with correlation of children age 1-5 in center Juarez.

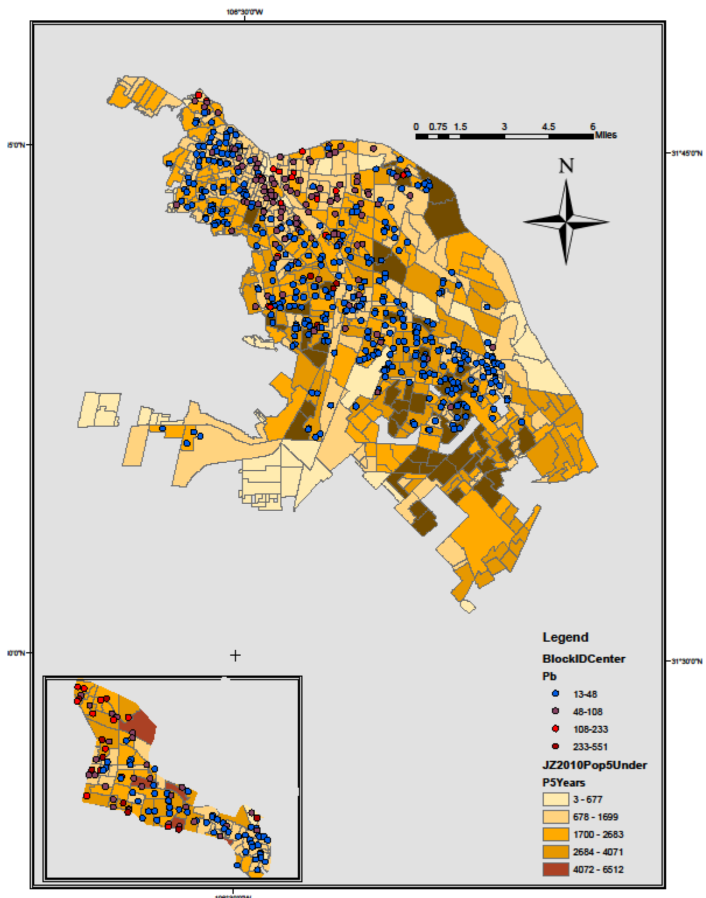


Figure 4.81: Population density of children and lead soil in center Juarez

#### 4.1.4.13.2 Chromium

The resulting concentration levels recorded for chromium ranged from 3.8 to 57.7 ppm.

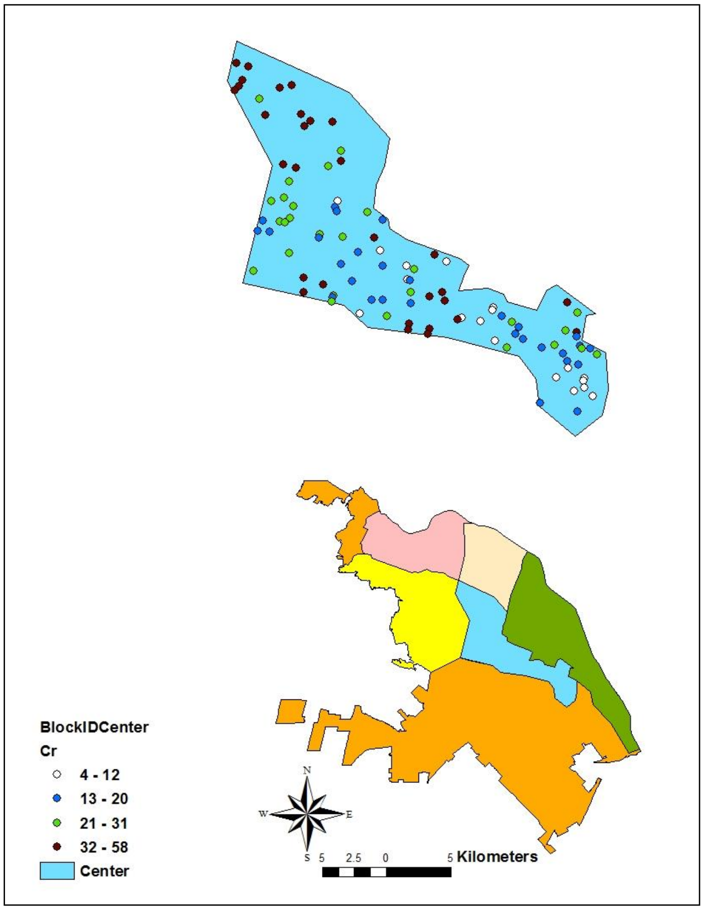


Figure 4.82: Chromium concentrations in composite samples from blocks in center Juarez

The lowest values (between 4 ppm and 12 ppm, white dots) of chromium are mainly encountered in southern areas of center region in Juarez.

Blocks with 13 ppm to 20 ppm chromium concentrations, seen in blue in Figure 4.82, are scattered all over the map of center except the far north area. Chromium levels between 21 ppm to 31 ppm (green dots) are scattered all over the center area. Blocks having highest value between 32 ppm and 58 ppm are depicted in brown. The brown blocks are scattered all over the center area. However, the density of brown dots is higher in the north part.

In general, the chromium concentrations in the north part are higher than the southern part.

#### 4.1.4.13.3 Copper

Soil concentrations levels recorded for Cu ranged from 7.6 to 60.7 ppm.

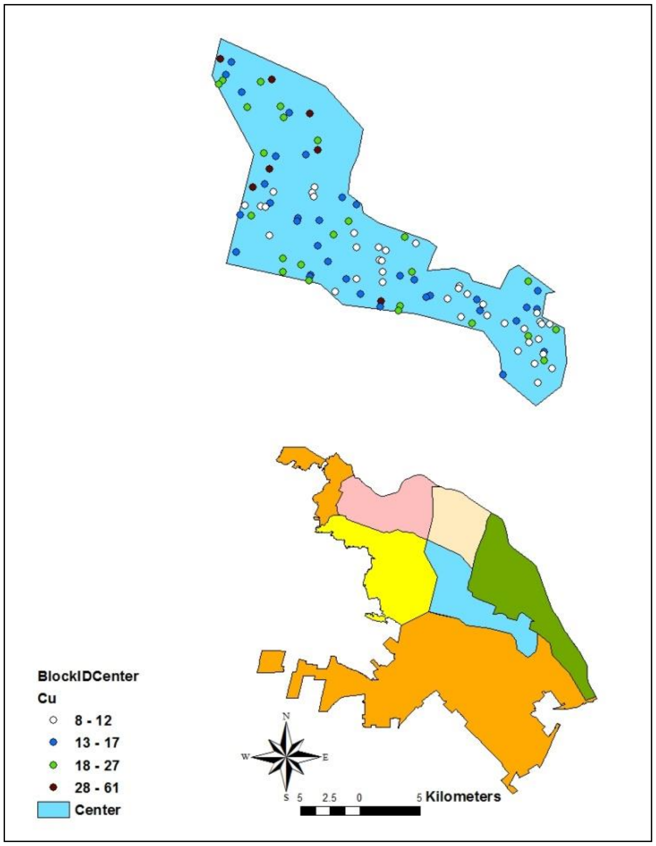


Figure 4.83: Copper concentrations in composite samples from blocks in center Juarez

The lowest values (between 8 ppm to 12 ppm; white dots) of copper are scattered areas except central and north. Blocks with 13 ppm to 17 ppm copper, seen in blue in Figure 4.83, are mainly found in all over center area. However, most of these blocks are found in the central and

the southern areas. The majority of the blocks in center area have this level of copper concentrations.

Blocks having copper levels between 18 ppm to 27 ppm (green dots) are encountered in all over the center area of Juarez. Only three blocks are found having highest value between 28 ppm and 61 ppm and it is depicted in brown. These blocks are scattered in north part of center. However, in general, the north part of center area contains higher copper concentrations than in the southern part.

#### 4.1.4.13.4 Zinc

Soil concentrations levels recorded Zn ranged from 21.7 ppm to 222.5 ppm.

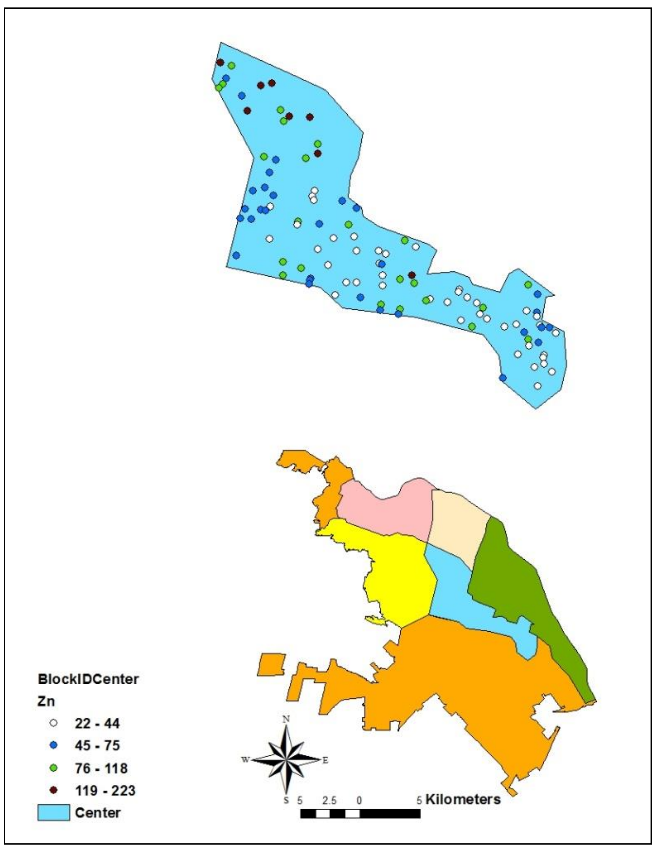


Figure 4.84: Zinc concentrations in composite samples from blocks in center Juarez

The lowest values (between 22 ppm to 44 ppm; white dots) of zinc are mainly encountered in the central and the southern parts of center area. Blocks with 45 ppm to 75 ppm zinc, seen in blue in Figure 4.84, are scattered all over the map. However, the density of the blue dots is higher in the peripheral areas. Blocks having zinc levels between 76 ppm to 118 ppm (green dots), are also encountered all over the center area.

Few blocks having highest value between 119 ppm to 223 ppm are encountered in the center area and those are depicted in brown. Most of them are situated more in the north area.

In general, it can be observed that the north area contains more zinc concentrations in the soil samples than the southern area, in center region of Juarez.

#### 4.1.4.13.5 Cadmium

Soil concentrations levels recorded for Cd ranged from 0.9 ppm to 4.2 ppm.

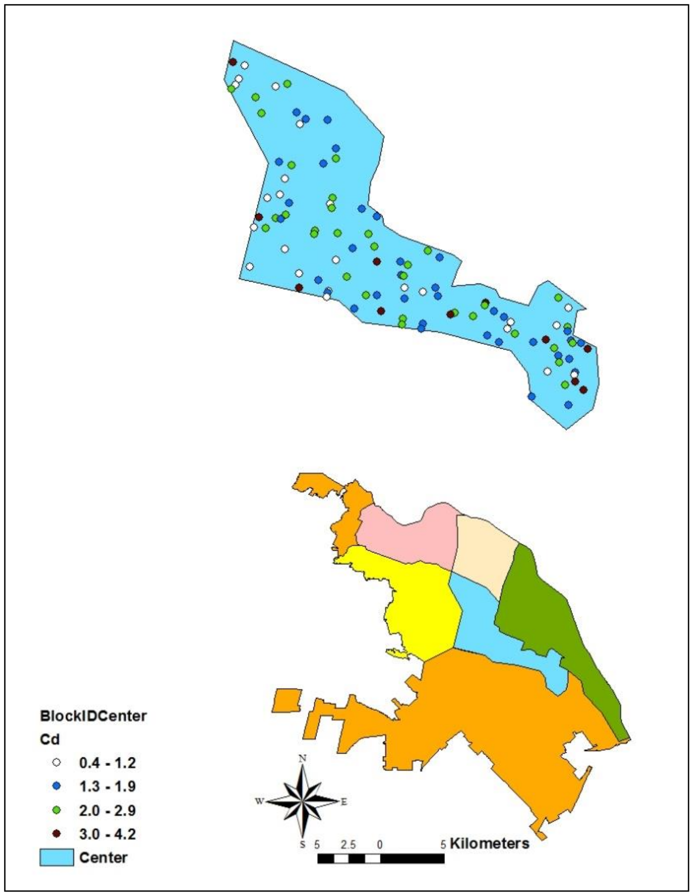


Figure 4.85: Cadmium concentrations in composite samples from blocks in center Juarez

The lowest values (between 0.4 ppm to1. 2 ppm; white dots) of cadmium are scattered all over the center area of Juarez. Blocks with 1.3 ppm to 1.9 ppm cadmium are shown in blue in Figure 4.85. Therefore, the concentrations between 1.3 ppm to 1.9 ppm for cadmium are also recorded all over the map.

Blocks having cadmium levels between 2.0 ppm to 2.9 ppm (green dots), are encountered all over the area except the far west. Blocks having highest value between 3.0 ppm and 4.2 ppm are depicted in brown. These blocks are also scattered all over, however, the density of the red dots looks higher for the southern part of center region in Juarez.

According to this map, no specific pattern can be observed between the concentration and the sides in center.

#### 4.1.4.13.6 Antimony

Soil concentrations levels recorded for Sb ranged from 2.9 ppm to 12.1 ppm.

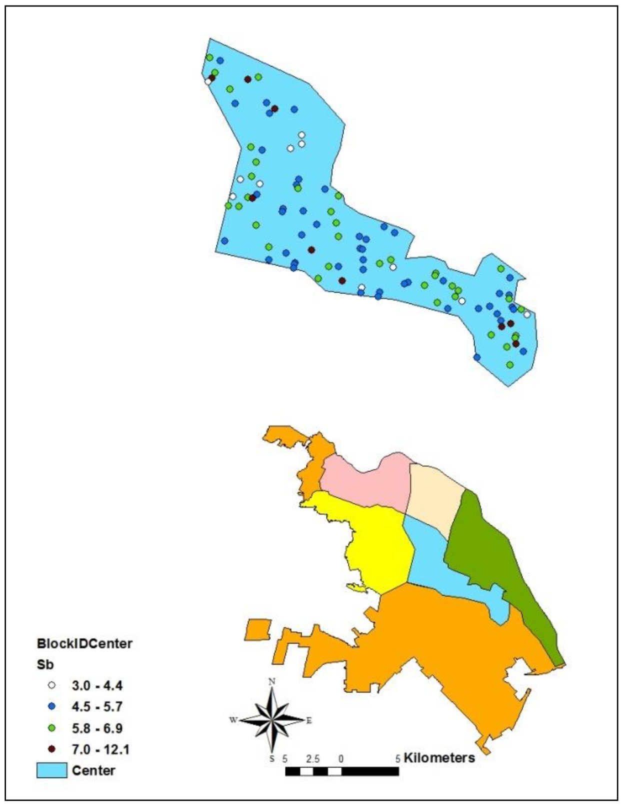


Figure 4.86: Antimony concentrations in composite samples from blocks in center Juarez

There are only a few blocks having the lowest values (between 3.0 ppm and 4.4 ppm; white dots) of antimony are found in central part of Juarez. Most of these gray dots are scattered in the north part. However, there are few gray dots situation in the southern part.

Blocks with 4.5 ppm to 5.7 ppm antimony, seen in blue, are scattered all over the map of center area. However, the density of blue dots is higher in the central and the southern part. The majority of the blocks in this area show the concentration of antimony within this range. Blocks having antimony levels between 5.8 ppm to 6.9 ppm (green dots), are encountered all over the center area.

There few blocks having highest value between 7.0 ppm and 12.1 ppm and these are depicted in brown. These blocks are scattered all over the center area.

The results in center area indicated that the metal Zn has the highest concentration level 222.5 ppm, and Cd has the lowest level 0.5 ppm. The highest mean concentration value is recorded for the metal Zn, and the minimum concentration is recorded for Cd, which is more than 15 times less than Zn. However, the standard deviation relevant to Zn is also high which is not favorable to the accuracy of the interpretation. A higher standard deviation indicates that the observations are scattered. However, all of the five number summaries (minimum, Q1, median, Q3, maximum) are also high for the variable Zn when compared to all others. This provides a hint to believe that in the center soil samples, the highest concentration is recorded for Zn. By considering the all above statistics, we can conclude the concentration of the soil samples taken from center differs in the following order: Zn >Pb> Cr > Cu >Sb> Cd.

#### 4.1.4.14 Correlation between metals

For this purpose, correlations and the scatter plots have been used. In order to increase the readability of the scatter plots, log transformations have also been employed.

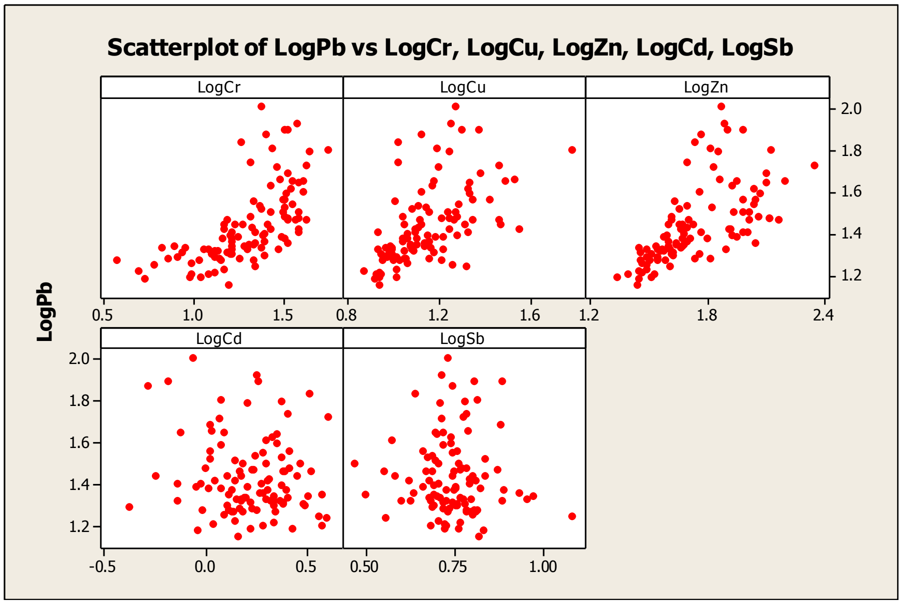


Figure 4.87: Correlation of Pb with other variables – center

From Figure 4.87, it can be observed that the variable Pb shows a positive correlation with the three variables Cr, Cu and Zn.

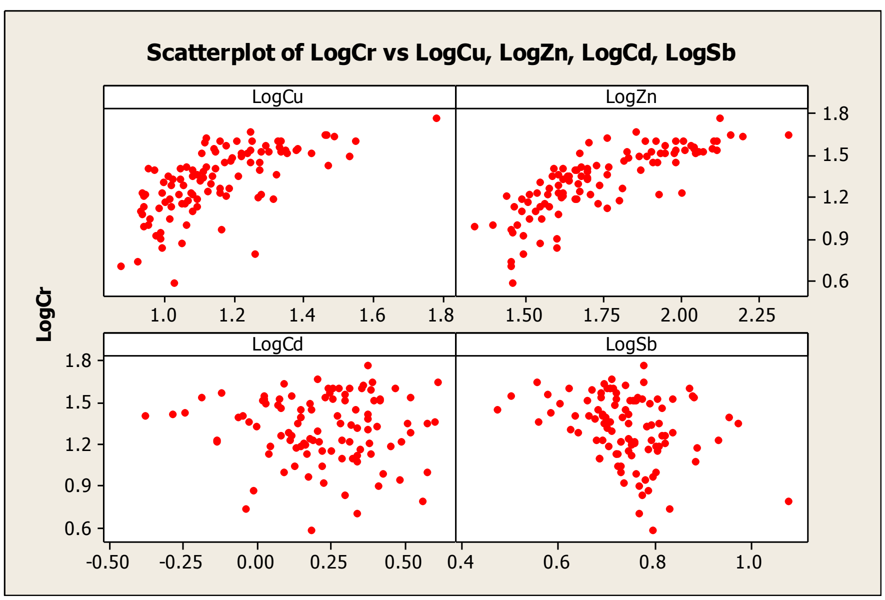


Figure 4.88: Correlation of Cr with other variables – center

From Figure 4.88, it can be observed that the variable Cr shows a correlation with the Zn variable.

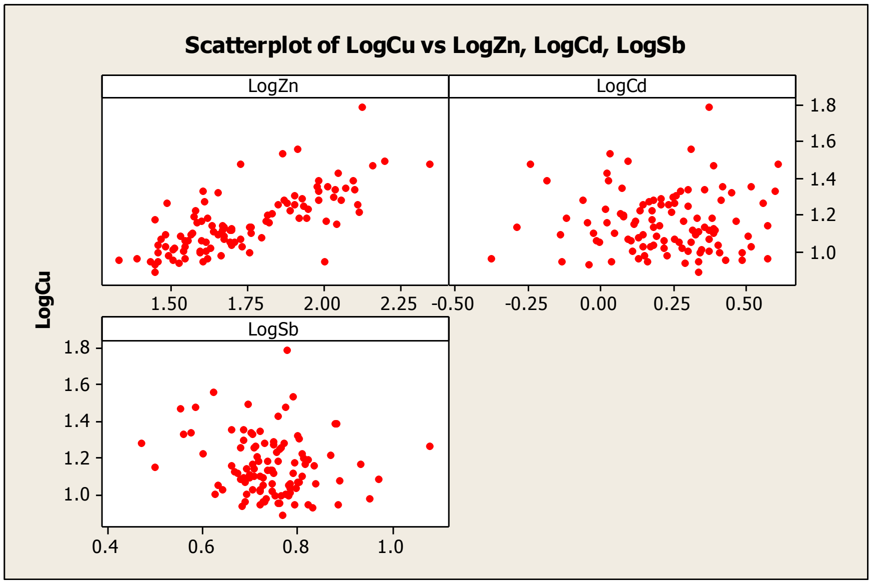


Figure 4.89: Correlation of Cu with other variables – center

Figure 4.89, show that the variable Cu exhibits a positive correlation with Zn.

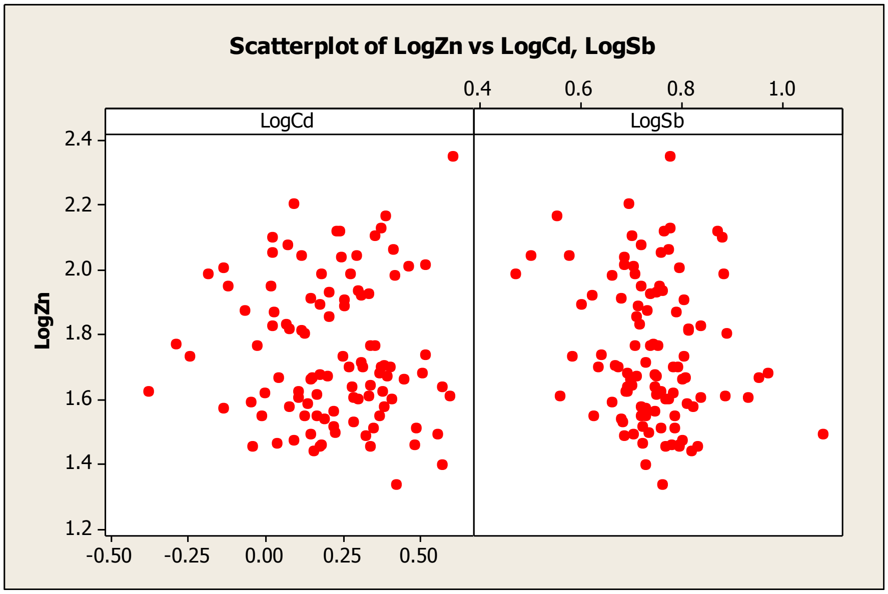


Figure 4.90: Correlation of Zn with other variables – center

By examining Figure 4.90, we can be observed that the variable Zn exhibits no significant correlation with Cd and Sb.

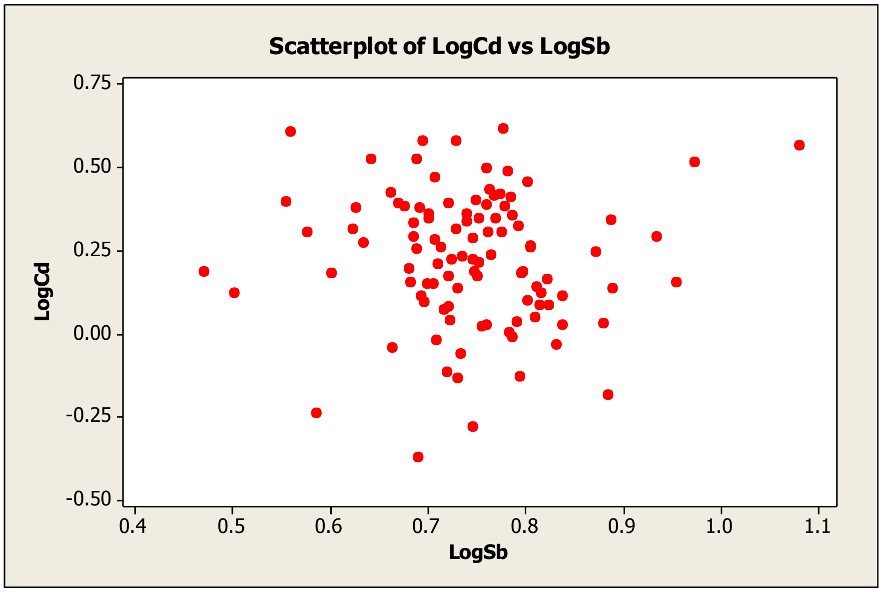


Figure 4.91: Correlation of Cd with other variables – center

By examining Figure 4.91, we can be observed that the variable Cd exhibits no significant correlation with Sb.

To emphasize the observed results from the above scatter plots, a correlation matrix were performed Table 4.10.

Table 4.10: Correlations between the variables – center

**Correlations: Pb, Cr, Cu, Zn, Cd, Sb**

| | Pb | Cr | Cu | Zn | Cd |
|---|---|---|---|---|---|
| Cr | 0.549 | | | | |
| | 0.000 | | | | |
| Cu | 0.427 | 0.687 | | | |
| | 0.000 | 0.000 | | | |
| Zn | 0.451 | 0.787 | 0.662 | | |
| | 0.000 | 0.000 | 0.000 | | |
| Cd | -0.117 | 0.002 | 0.045 | 0.038 | |
| | 0.236 | 0.984 | 0.648 | 0.700 | |
| Sb | -0.029 | -0.260 | -0.102 | -0.147 | 0.023 |
| | 0.772 | 0.008 | 0.304 | 0.136 | 0.818 |

Cell Contents: Pearson correlation
P-Value

Out of 15 variable pairs, three have significant correlations with a 5% significance level. Furthermore, these three pairs have the lowest correlation values.

From the above Table, the following statistics can be obtained.

- The correlation between Pb and Cu is 0.427
- The correlation between Pb and Zn is 0.451
- The correlation between Pb and Cd is - 0.117
- The correlation between Pb and Sb is - 0.029
- The correlation between Pb and Cr is 0.549
- The correlation between Cu and Zn is 0.662
- The correlation between Cu and Cd is 0.045
- The correlation between Cu and Sb is - 0.102

- The correlation between Cu and Cr is 0.687

- The correlation between Zn and Cd is 0.038

- The correlation between Zn and Sb is - 0.147

- The correlation between Zn and Cr is 0.787

- The correlation between Cd and Sb is 0.023

- The correlation between Cd and Cr is 0.002

- The correlation between Sb and Cr is - 0.26

According to these observations, it is noticeable that the correlation between Zn and Cr is the highest correlation.

#### 4.1.4.15 Checking the normality of the data – center

To check the normality of the data, histograms have been employed.

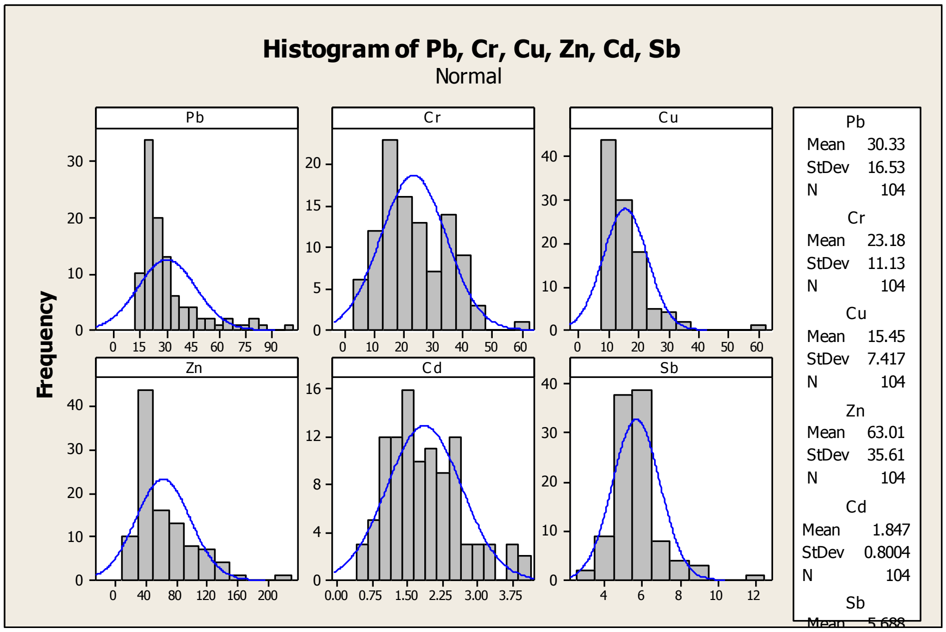


Figure 4.92: Histograms for the variables – center

Figure 4.92, provides the histograms for the variables. From the figure, it can be observed that the variables Cd and Sb show slightly normal data.

### 4.1.4.16 Checking for outlying observations – center

It is important to check for the outlying observations. For this purpose dot plots have been used.

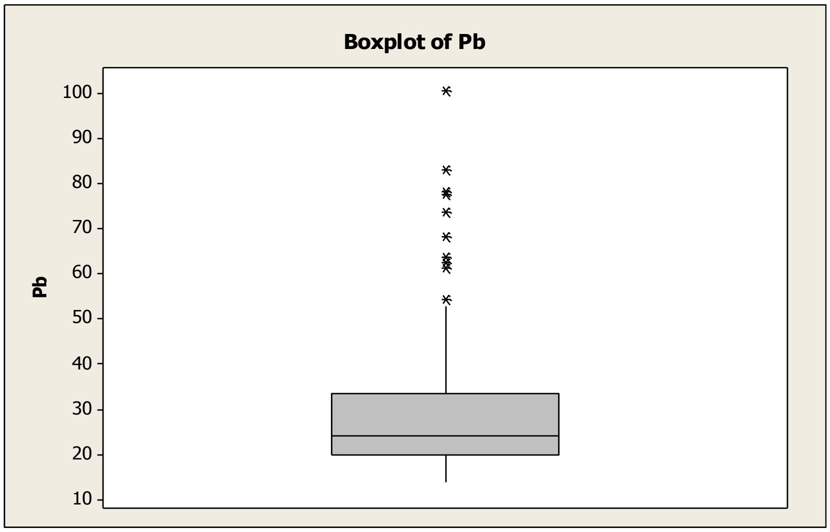


Figure 4.93: Box plot for Pb – center

From the above plot, it is noticeable that there are some outliers in the upper end and that the data seem to be positively skewed.

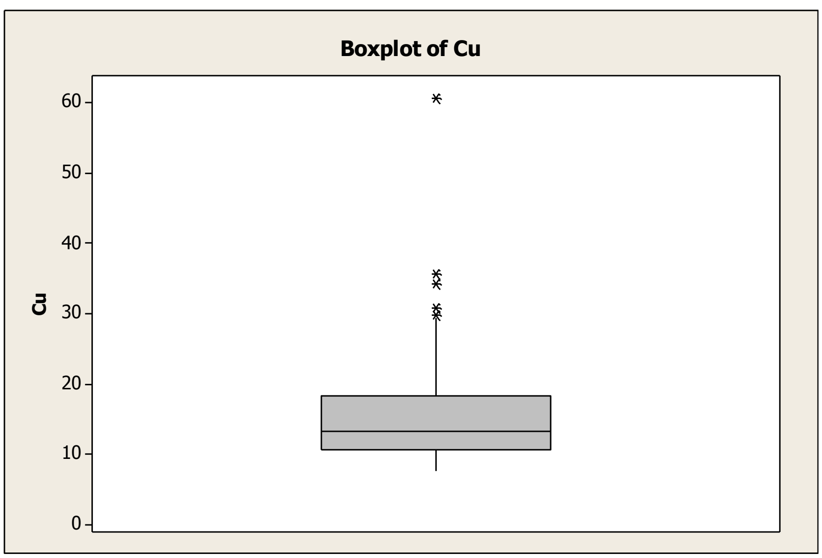


Figure 4.94: Box plot for Cu – center

According to the Figure 4.94, data is positively skewed with some outliers in the upper end.

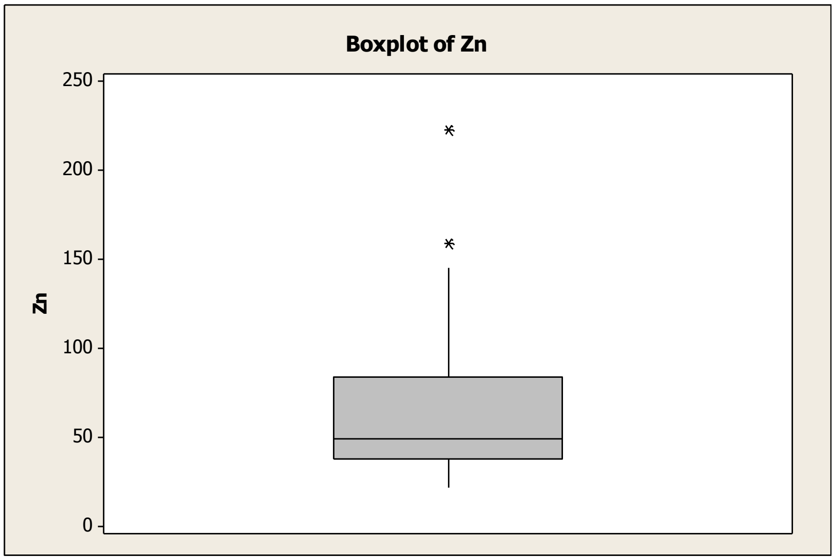


Figure 4.95: Box plot for Zn – center

Figure 4.95, suggests that the data is positively skewed and there are some outliers in the upper end.

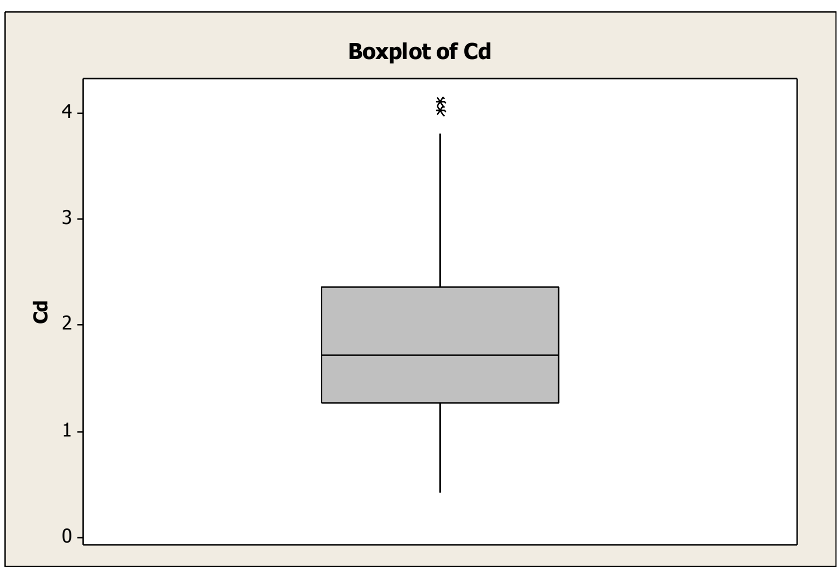


Figure 4.96: Box plot for Cd – center

Figure 4.96, shows some significant outliers in the upper end. Data seems to be slightly normal with the ignorance of the outliers.

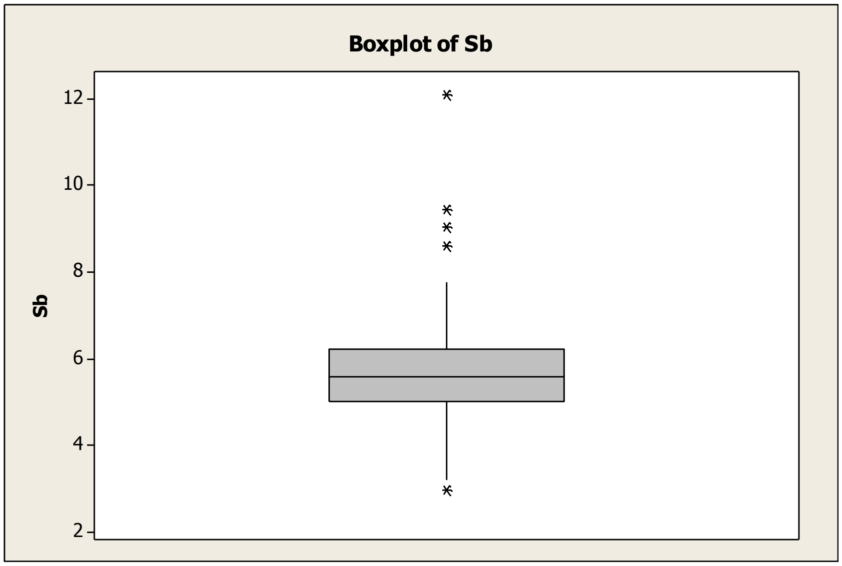


Figure 4.97: Box plot for Sb – center

According to the Figure 4.97, there are some significant outliers in the extremes. Data seems to be slightly normal with the ignorance of the outliers.

#### 4.1.4.17 Green region

The sample size for the city green is 7. For each sample, the concentration of the metals was determined and recorded. The data obtained was statistically analyzed, as shown in Table 4.11, and maps for distribution and concentrations of the metals were created.

Table 4.11: Descriptive statistics for the metals - green

| Variable | N | Mean | StDev | Minimum | Q1 | Median | Q3 | Maximum |
|---|---|---|---|---|---|---|---|---|
| Pb | 7 | 24.9 | 3.3 | 21.1 | 22.6 | 23.1 | 28.3 | 29.4 |
| Cr | 7 | 23.7 | 6.2 | 17.9 | 18.8 | 20.9 | 30.1 | 33.9 |
| Cu | 7 | 15.2 | 2.9 | 12.3 | 12.6 | 14.3 | 16.7 | 20.6 |
| Zn | 7 | 63.1 | 16.9 | 48.4 | 49.7 | 59.1 | 66.9 | 97.3 |
| Cd | 7 | 1.7 | 1.2 | 0.7 | 0.9 | 1.6 | 1.9 | 4.1 |
| Sb | 7 | 6.2 | 0.9 | 4.9 | 5.5 | 6.3 | 6.6 | 7.8 |

The above Table 4.11, display the descriptive statistics obtained for the green soil samples. From the above table, the following observations can be made.

#### 4.1.4.17.1 Lead

Soil lead concentration Table 4.11, indicates that the resulting concentration levels recorded for lead ranged from 21.1 ppm to 29.4 ppm.

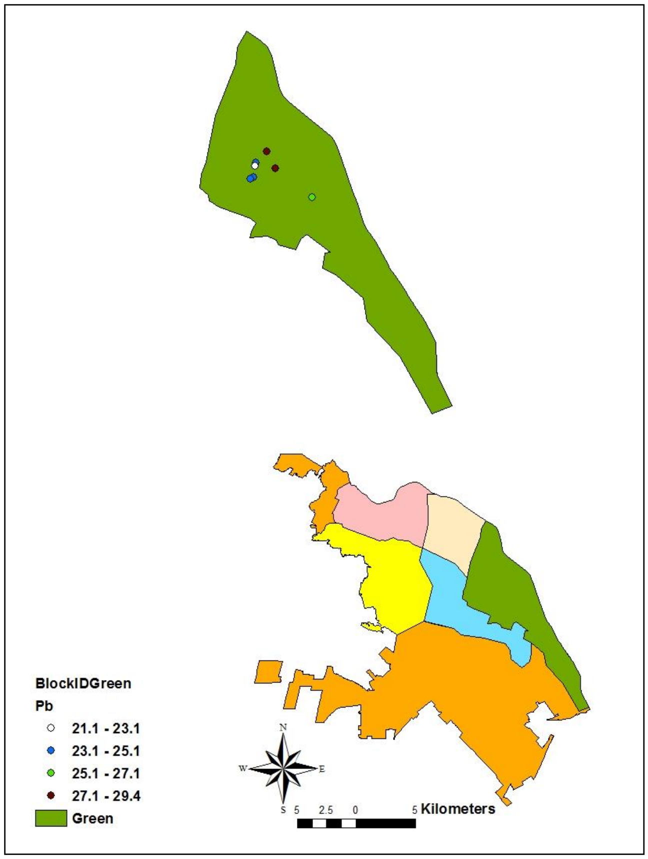


Figure 4.98: Lead concentrations in composite samples from blocks in green

There is only one block having the lowest values (between 21.1 ppm to 23.1 ppm; white dots) of lead is found from green Juarez.

Three blue blocks with 23.1 ppm to 25.1 ppm of lead have found in the green area of Juarez. Only one block having lead levels between 25.1 ppm to 27.1 ppm (green dots) is encountered from green area in Juarez. There are two blocks having highest value between 27.1 ppm to 29.4 ppm and depicted in brown.

Figure 4.99, illustrates the concentration of lead levels in soil samples with correlation of children age 1-5 in green Juarez.

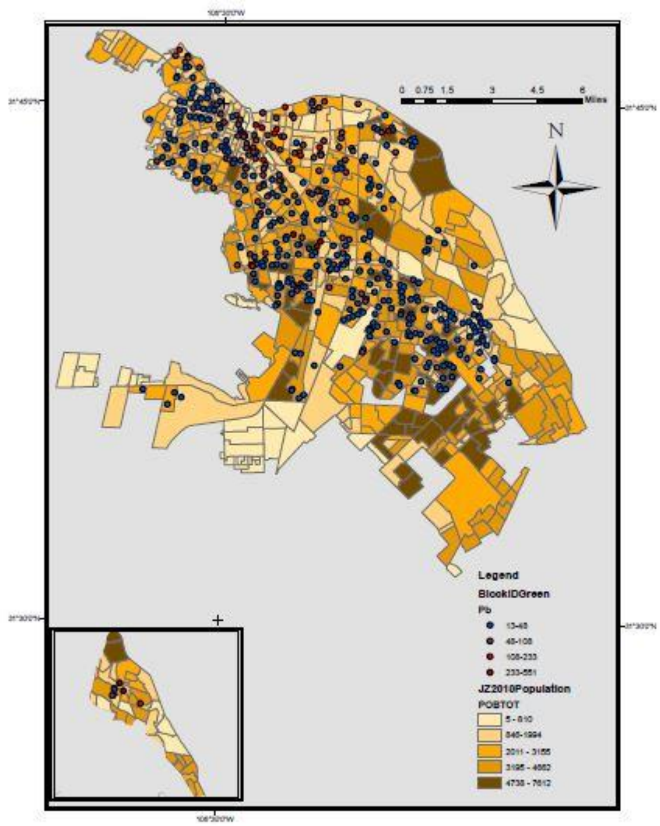


Figure 4.99: Population density of children and lead soil in green

There is only one block that has the lowest values (between 13 ppm to 48 ppm; white dots) of lead and it is found from green Juarez. Three blue blocks with 48 ppm to 108 ppm of lead have found in the green area of Juarez.

Only one block having lead levels between 108 ppm to 233 ppm (green dots) is encountered from green area in Juarez. There are two blocks having highest value between 233 ppm and 551 ppm and depicted in brown.

#### 4.1.4.17.2 Chromium

Soil chromium concentration Table 4.11, indicates that the resulting concentration levels recorded for chromium ranged from 17.9 ppm to 33.9 ppm.

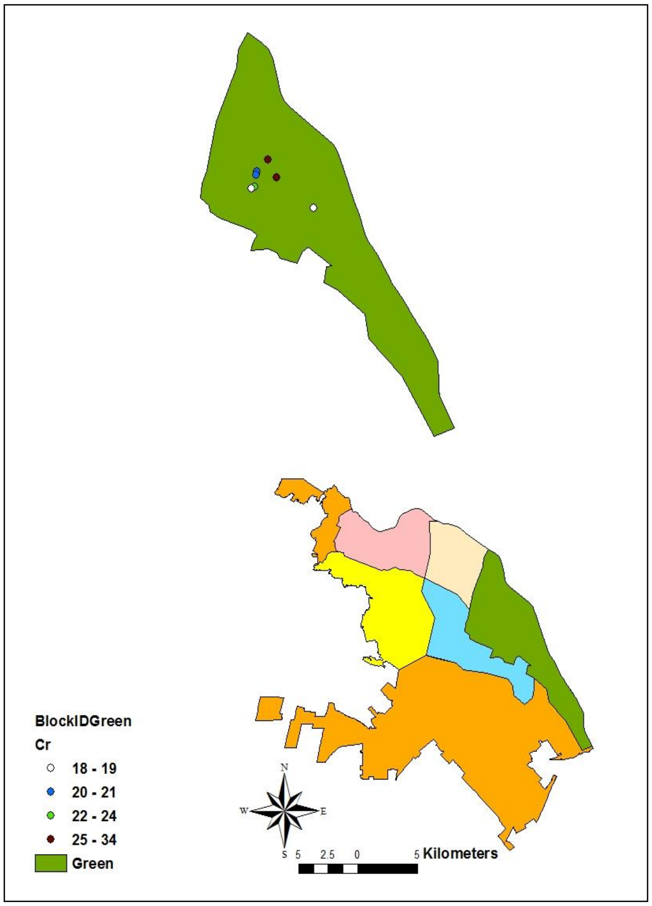


Figure 4.100: Chromium concentrations in composite samples from blocks in green

There are two blocks having the lowest values (between 18 ppm to 19 ppm; white dots) of chromium in the green area. Blocks with 20-21 ppm to 34 ppm chromium, are shown in blue in Figure 4.99. Hence, there is only one block shows this level of concentration.

Chromium levels between 22 ppm to 24 ppm (green dots), are encountered from only one block in the green area of Juarez. Blocks having highest value between 25ppm - 34 ppm are depicted in brown. There are two red blocks in the green area.

#### 4.1.4.17.3 Copper

Soil copper concentration Table 4.11, indicates that the resulting concentration levels recorded for Cu ranged from 12.3 ppm to 20.6 ppm.

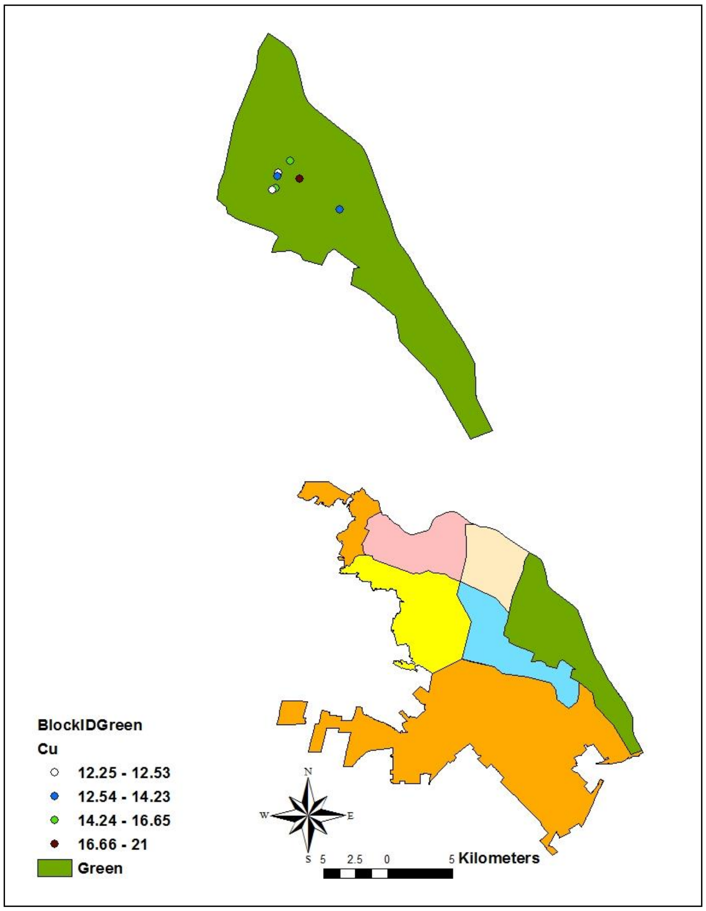


Figure 4.101: Copper concentrations in composite samples from blocks in green

There is only one block having the lowest values (between 12.25 ppm to 12.53 ppm; white dots) of copper in the green area of Juarez. Blocks with 12.54 ppm to 14.23 ppm copper are shown in blue in Figure 4.101. Most of the blocks in green area have these levels of concentrations.

Blocks having copper levels between 14.24 ppm to 16.65 ppm (green dots), are encountered from the green area. Blocks having highest value between 16.66 ppm to 21 ppm are depicted in brown. There is only one brown block is found in green area.

#### 4.1.4.17.4 Zinc

Soil zinc concentration Table 4.11, indicates that the resulting concentration levels recorded for Zn ranged from 48.4 ppm to 97.3 ppm.

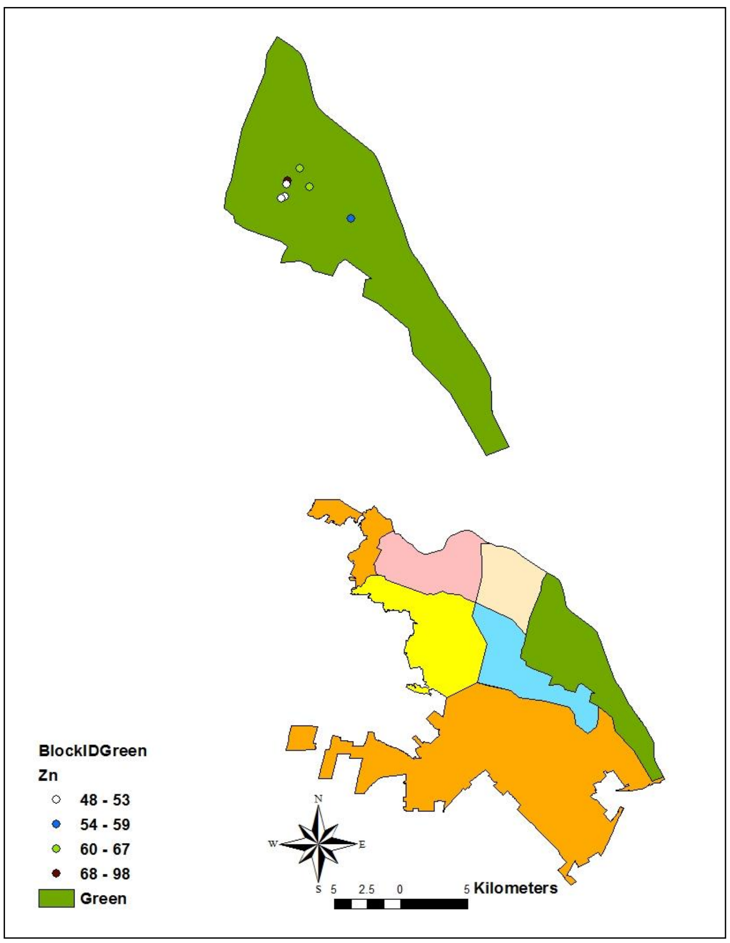


Figure 4.102: Zinc concentrations in composite samples from blocks in green

There are three blocks having the lowest values (between 48 ppm to53 ppm; white dots) of zinc in the green area. Only one block has the zinc concentration between 54 ppm to 59 ppm zinc, and is shown in blue in Figure 4.102.

There are two blocks having zinc levels between 60 ppm to 67 ppm (green dots) in the green area. There is only one block having the highest value between 68 ppm to 98 ppm, which is found in the green area.

#### 4.1.4.17.5 Cadmium

Soil cadmium concentration Table 4.11, indicates that the resulting concentration levels recorded for Cd ranged from 0.7 ppm to 4.1 ppm.

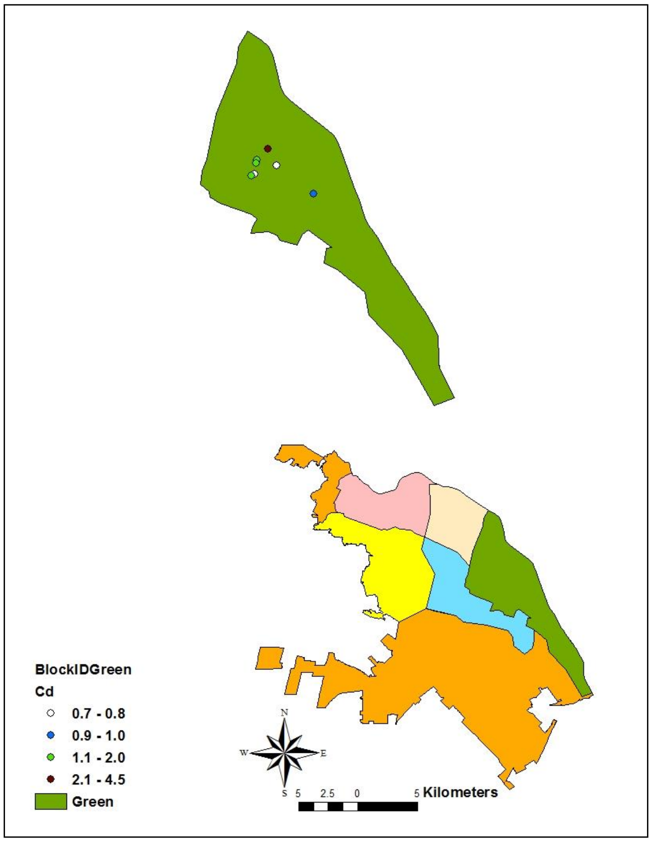


Figure 4.103: Cadmium concentrations in composite samples from blocks in green

There is only one block having the lowest values (between 0.7 ppm to 0.8 ppm; white dots) of cadmium in the green area of Juarez. Blocks with 2 ppm to 3 ppm cadmium, are shown in blue in Figure 4.103. Therefore, there is only one block having the concentrations between 0.9 ppm to 1.0 ppm for cadmium.

Blocks having cadmium levels between 1.1 ppm to 2.0 ppm (green dots), are encountered from the green area.  Most of the blocks in green area have these levels of concentrations. Blocks having highest value between 2.1 ppm to 4.5 ppm are depicted in brown. There is only one red block found in the green area.

#### 4.1.4.17.6 Antimony

Soil antimony concentration Table 4.11, indicates that the resulting concentration levels recorded for antimony ranged from 4.9 to 7.8 ppm.

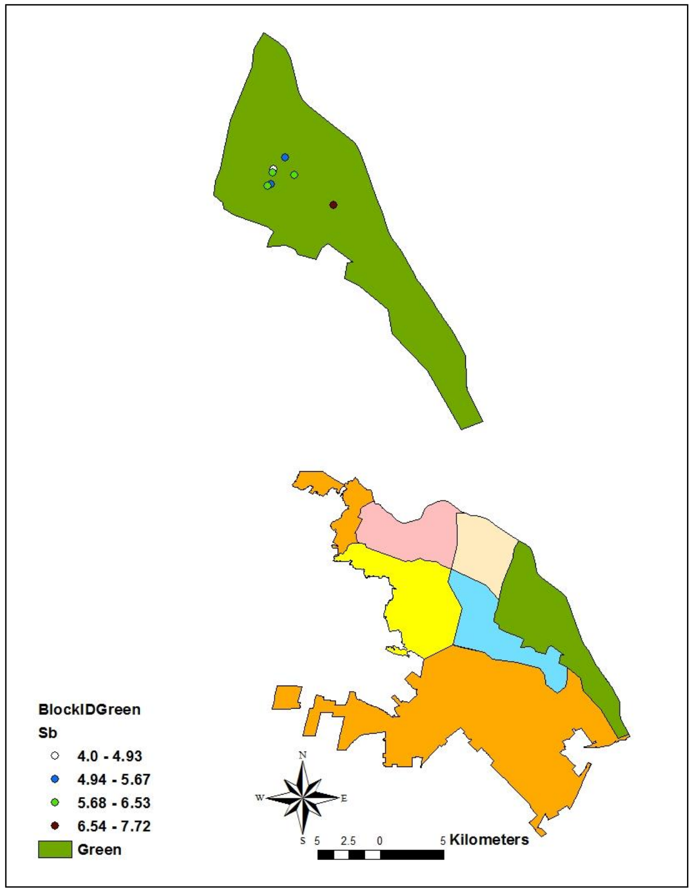


Figure 4.104: Antimony concentrations in composite samples from blocks in green

Only a few blocks having the lowest values (between 4.0 ppm to 4.93 ppm; white dots) of antimony are in the old town. The majority of these gray dots are encountered in the west side of old town area. Blocks with 4.94 ppm to 5.67 ppm antimony, seen in blue are scattered all over the map of old town area. The majority of the blocks in this area show the concentration of antimony within this range.

Blocks having antimony levels between 5.68 ppm to 6.53 ppm (green dots), are encountered in all over old town area. Few blocks having highest value between 6.54 ppm to

7.72 ppm are found and they are depicted in brown. These blocks are scattered all over the old town area.

According to this map, no specific pattern can be observed between the concentration of antimony and the area.

The results indicated that the metal lead has the highest concentration Zn 79.3 ppm, and Cd has the lowest level 0.7 ppm. The highest mean concentration value is recorded for the metal Zn, and  the minimum concentration is recorded for Cd which is almost 15 times less than Zn But the standard deviation relevant to Zn is also high - which is not favorable to the accuracy of the interpretation. Higher standard deviation indicates that the observations are scattered. However all of the five number summaries (minimum, Q1, median, Q3, maximum) are also high for the variable Zn when compared to all others. This provides a hint to believe that, in the Green soil samples; the highest concentration is recorded for Zn.

By considering the all above statistics, we can conclude the concentration of the soil samples taken from Green differs in the following order: Zn >Pb> Cr > Cu >Sb> Cd. Meaningful graphical analysis cannot be done since sample size is very small.

#### 4.1.4.18 Ciudad Juarez – Zone 6

The sample size for city zone 6 is 100. For each sample, the concentration of the metals was determined and recorded. The data obtained was statistically analyzed, as shown in Table 4.12, and maps for distribution of the metals were created.

Table 4.12: Descriptive statistics for the variables (metals) - zone 6

| Variable | N | Mean | StDev | Minimum | Q1 | Median | Q3 | Maximum |
|---|---|---|---|---|---|---|---|---|
| Pb | 100 | 28.4 | 18.4 | 13.6 | 17.5 | 21.9 | 31.9 | 114.9 |
| Cr | 100 | 23.7 | 9.2 | 7.5 | 15.9 | 24.3 | 29.9 | 51.3 |
| Cu | 100 | 17.4 | 15.9 | 7.4 | 10.6 | 12.7 | 16.6 | 98.8 |
| Zn | 100 | 52.6 | 23.9 | 22.2 | 36.1 | 44.7 | 63.5 | 151.8 |
| Cd | 100 | 1.9 | 0.9 | 0.1 | 1.2 | 1.9 | 2.2 | 5.7 |
| Sb | 100 | 5.7 | 1.1 | 2.7 | 4.9 | 5.7 | 6.6 | 7.9 |

The above Table displays the descriptive statistics obtained for the zone 6 soil samples. From the above Table 4.12, the following observations can be made.

#### 4.1.4.18.1 Lead

The resulting concentration levels for lead ranged from 13.6 ppm to 114.9 ppm.

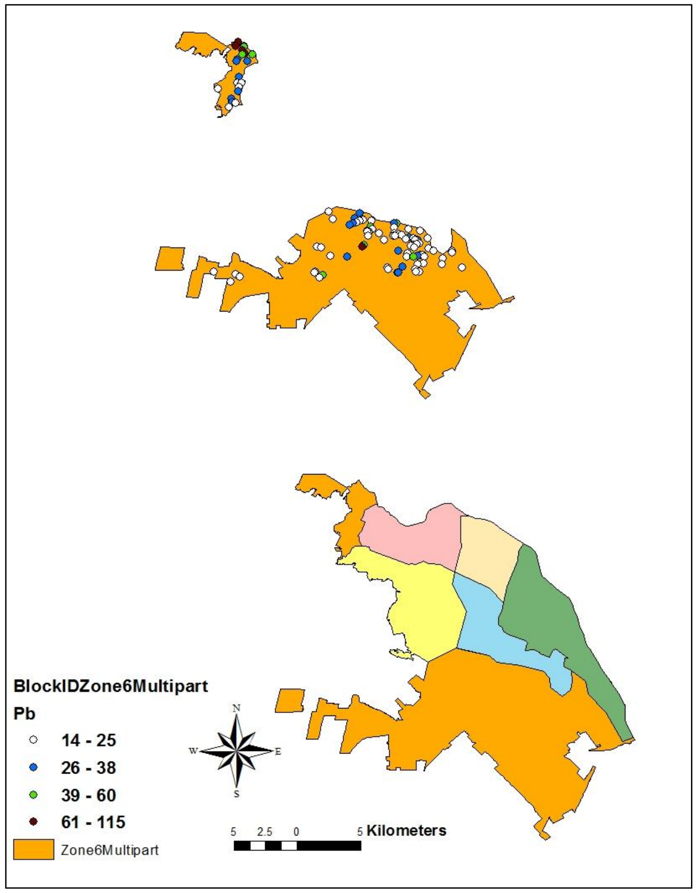


Figure 4.105: Lead concentration in composite samples from blocks in zone 6

The lowest values (between 14 ppm to 25 ppm; white dots) of lead are prominent in the bottom part of zone 6. Most of the blocks in zone 6 have lead concentrations between 14 ppm to 25 ppm. Blocks with 26 ppm to 38 ppm lead, are shown in blue in Figure 4. 105. Therefore, the concentrations between 26 ppm to 38 ppm for lead are recorded mostly from the central area of the bottom part of zone6. There are some blue blocks in the upper part of zone 6 also.

Only a few blocks having lead levels between 39 ppm to 60 ppm (green dots) are encountered in zone 6. In the upper part of zone 6, the green dots are scattered in the north area.

There is only few blocks having highest value between 61 ppm and 115 ppm and depicted in brown. These blocks are situated in the north area of upper part of zone 6 and the central area of bottom part of zone 6.

In general, the lead concentration is higher in the upper part of zone 6 than the bottom part. Furthermore, in the upper part of zone 6, the north area shows higher lead concentrations than the southern area.

Figure 4.106, illustrates the concentration of lead levels in soil samples with correlation of children age 1-5 in zone 6 Juarez.

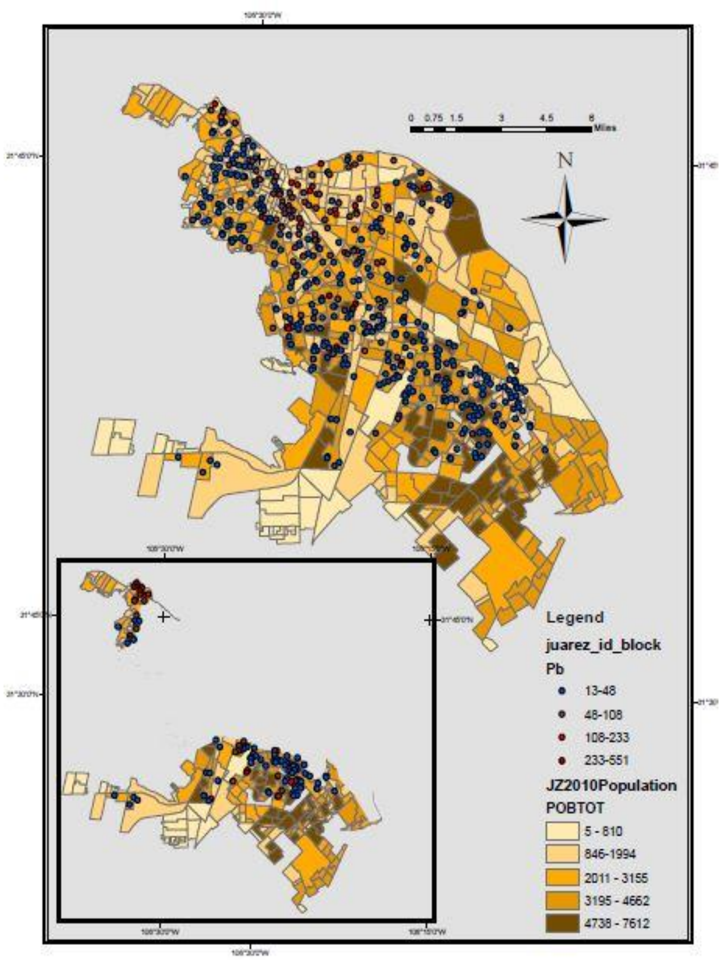


Figure 4.106: Population density of children and lead soil in zone 6

#### 4.1.4.18.2 Chromium

Soil chromium concentration Table 4.12, indicates that the resulting concentration levels recorded for Cr ranged from 23.7 ppm to 51.3 ppm.

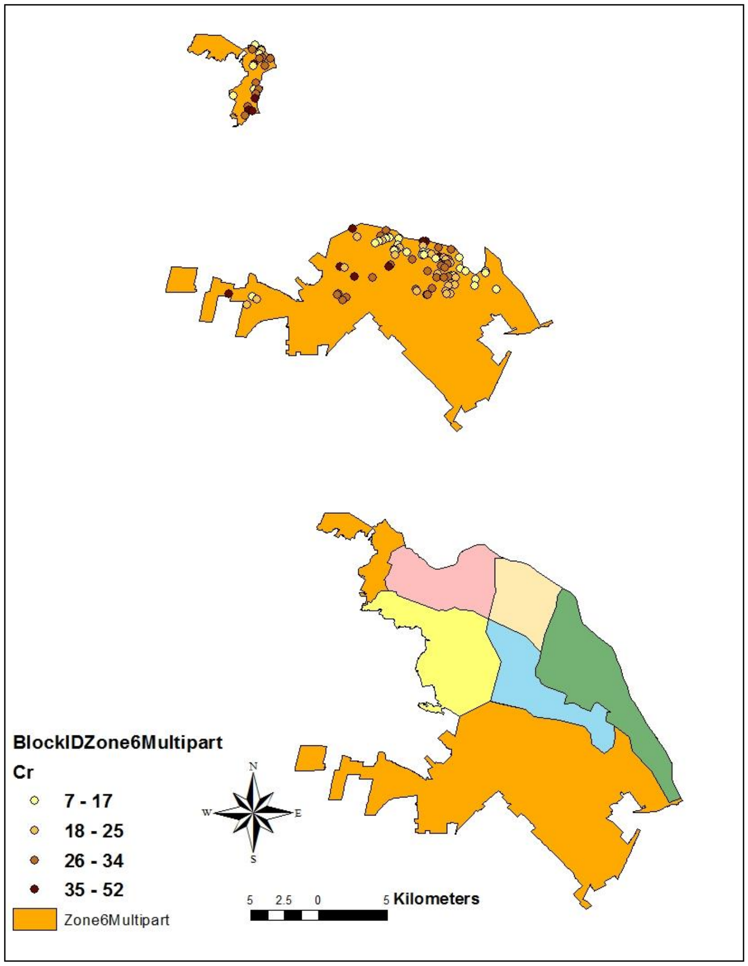


Figure 4.107: Chromium concentration in composite samples from blocks in zone 6

The lowest values (between 7 ppm to 17 ppm; white dots) of chromium are encountered in the peripheral area of the bottom part of zone 6 area. There are a few white dots in the upper part of zone 6 area.

Blocks with 18 ppm to 25 ppm chromium, are shown in blue in Figure 4.107. The blue dots in the bottom part of zone 6 are scattered all over. However, there are only few blue dots are found in the upper part of zone 6.

Chromium levels between 26 ppm to 34 ppm (green dots), are dominant in zone 6 area. These are encountered mainly in the central part of bottom part and all over the upper part of zone 6. Blocks having highest value between 35 ppm and 52 ppm are depicted in brown.

Most of these blocks are situated in central to east area of the bottom part and in the southern area of zone 6.

#### 4.1.4.18.3 Copper

Soil copper concentration Table 4.12, indicates that the resulting concentration levels recorded for Cu ranged from 17.4 ppm to 98.8 ppm.

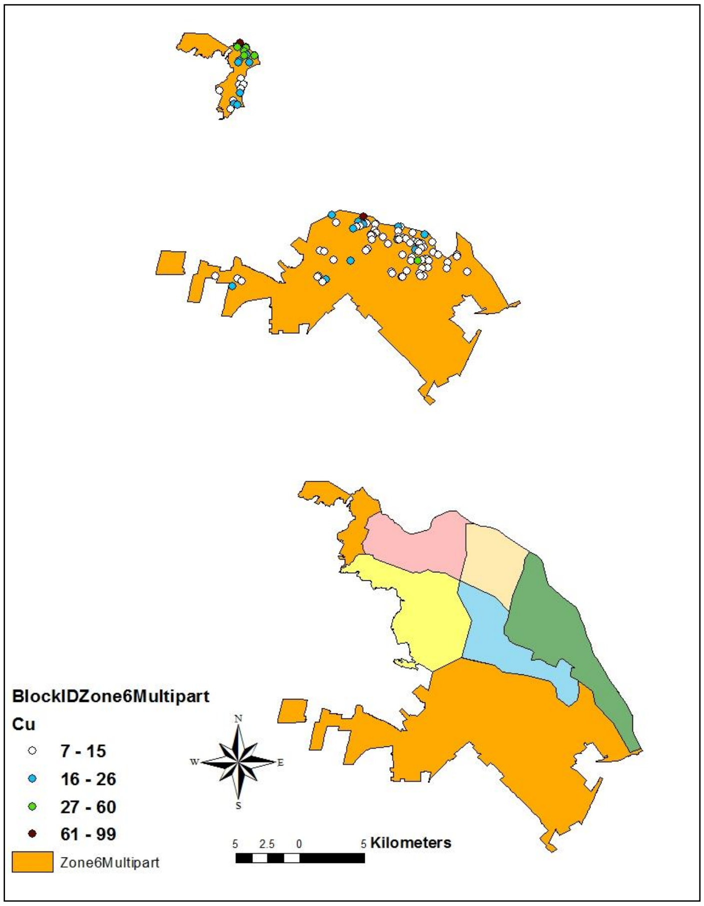


Figure 4.108: Copper concentration in composite samples from blocks in zone 6

The lowest values (between 7 ppm to 15 ppm; white dots) of copper are scattered all over the bottom part and the southern area of upper part of zone6. Blocks with 16 ppm to 26 ppm copper can be seen in blue dots in Figure 4.108. Blue blocks are mainly found more in the central and the west side of bottom part of zone 6 and all over the upper part of zone 6.

Only a few blocks having copper levels between 27 ppm to 60 ppm (green dots), are encountered in zone 6. Most of them are situated in the north area of the upper part of zone 6. Only two blocks are found having highest value between 61 ppm and 99 ppm and it is depicted in brown. One of these blocks is in the bottom part and the other one in the upper part of zone 6.

#### 4.1.4.18.4 Zinc

Soil zinc concentration Table 4.12, indicates that the resulting concentration levels recorded for Zn ranged from 52.6 ppm to 151.8 ppm.

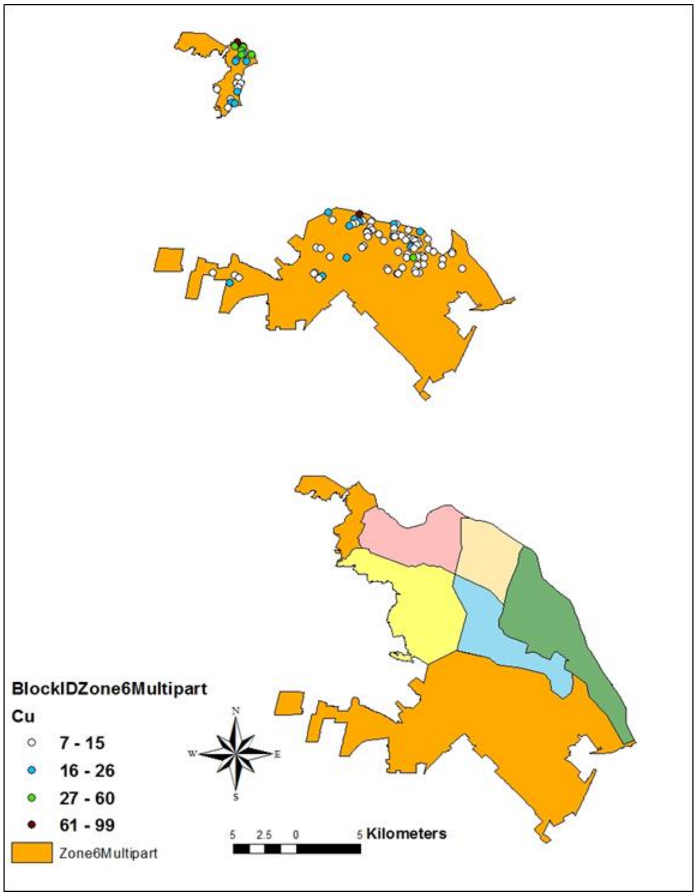


Figure 4.109: Zinc concentration in composite samples from blocks in zone 6

The lowest values (between 22 ppm to 40 ppm white dots) of zinc are mainly encountered all over the bottom part of zone 6 and from the southern part of upper part of zone 6. Blocks with 41 ppm to 62 ppm zinc, seen in blue in Figure 4.109 are also scattered all over the bottom part of zone 6 and from the southern part of upper part of zone 6. However, there are few blue blocks in the southern area of the upper part of zone 6.

Blocks having zinc levels between 63 ppm to 97 ppm (green dots), are encountered mainly in the north area of the upper part of zone 6 and in the central area of the bottom part of zone 6. Few blocks having highest value between 98 ppm to 152 ppm are encountered in the zone 6 area and those are depicted in brown.

In general, the central area of the bottom part of zone 6 contain higher zinc concentrations other areas of that part. Furthermore, the north area of the upper part of zone 6 has higher concentration levels of zinc than the southern area.

#### 4.1.4.18.5 Cadmium

Soil cadmium concentration Table 4.12, indicates that the resulting concentration levels recorded for Cd ranged from 1.9 ppm to 5.7 ppm.

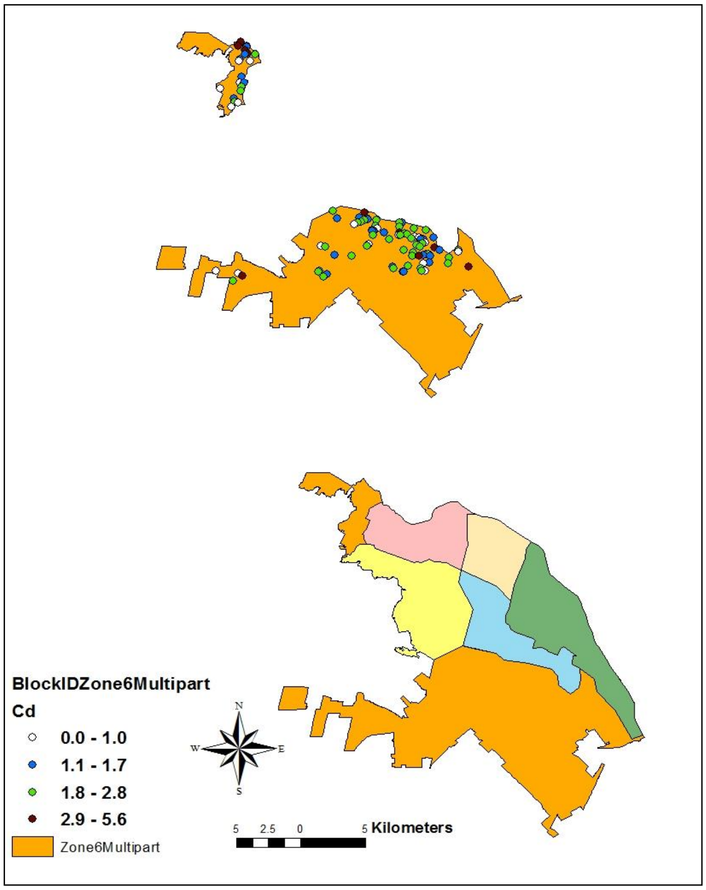


Figure 4.110: Cadmium concentration in composite samples from blocks in zone 6

The lowest values (between 0.0 ppm to 1.0 ppm; white dots) of cadmium are found in zone 6. There are only few gray dots in the bottom part of zone 6. However, the density of the gray dots in the upper part of zone 6 is much higher.

Blocks with 1.1 ppm to 1.7 ppm cadmium, are shown in blue in Figure 4.110. Therefore, the concentrations between 1.1 ppm to 1.7 ppm for cadmium are recorded mainly from the central area of the bottom part and the north area of the upper part of zone 6.

Blocks having cadmium levels between 1.8 ppm to 2.8 ppm (green dots), are dominant in the bottom part of the zone 6. However, only few green dots can be found in the upper part of zone 6.

There are few blocks having highest value between 2.9 ppm and 5.6 ppm and these are depicted in red. These red blocks are scattered in the east are of the bottom part and in the north area of the upper part of zone 6.

### 4.1.4.18.6 Antimony

Soil antimony concentration Table 4.12, indicates that the resulting concentration levels recorded for Sb ranged from 5.7 ppm to 7.9 ppm.

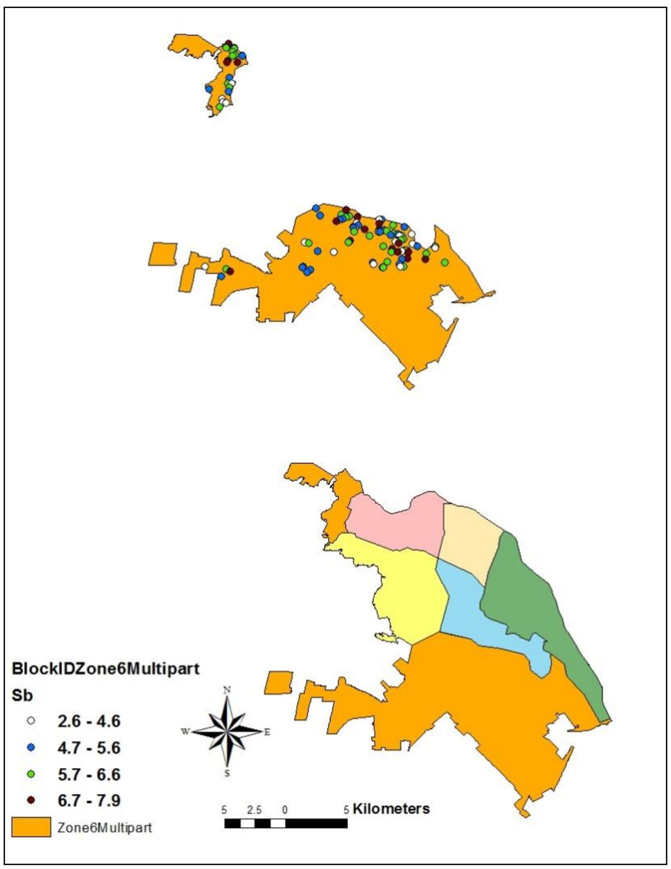


Figure 4.111: Antimony concentration in composite samples from blocks in zone 6

Only a few blocks having the lowest values (between 2.6 ppm and 4.6 ppm; white dots) of antimony can be found in the zone 6. The majority of these white dots are encountered all over the bottom part and in the southern area of the upper part of zone 6.

Blocks with 4.7 ppm to 5.6 ppm antimony, seen in blue are scattered all over in both upper and bottom parts of zone 6. Blocks having, antimony levels between 5.7 ppm to 6.6 ppm (green dots), are also encountered in both upper and bottom parts of zone 6.

There are blocks having highest value between 6.7 ppm and 7.9 ppm in zone 6 and they are depicted in brown. These blocks are scattered mainly in the central area of the bottom part and in the north part of the upper part of zone 6.

The results indicated that the metal Zn has the highest concentration level 151.8 ppm, and Cd has the lowest level 0.1 ppm. The highest mean concentration value is recorded for the metal Zn, and the minimum concentration is recorded for Cd, which is almost 30 times less than Zn. A higher standard deviation indicates that the observations are scattered. However, all of the five number summaries (minimum, Q1, median, Q3, maximum) are also high for the variable Zn, when compared to all others. This provides a hint to believe that in the Zone 6 soil samples the highest concentration is recorded for Zn.

By considering the mean concentration, we can conclude that the concentration of the soil samples taken from Zone 6 differs in the following order: Zn>Pb> Cr> Cu>Sb> Cd.

#### 4.1.4.19 Correlation between metals

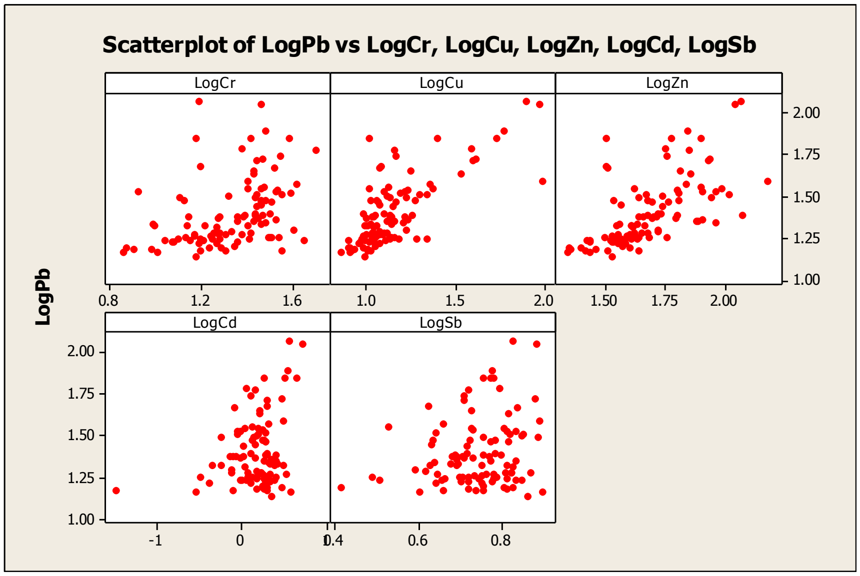


Figure 4.112: Correlation of Pb with other metals – zone 6

From Figure 4.112, it can be observed that the variable Pb shows a positive correlation with Cu and a slightly positive relationship with Zn.

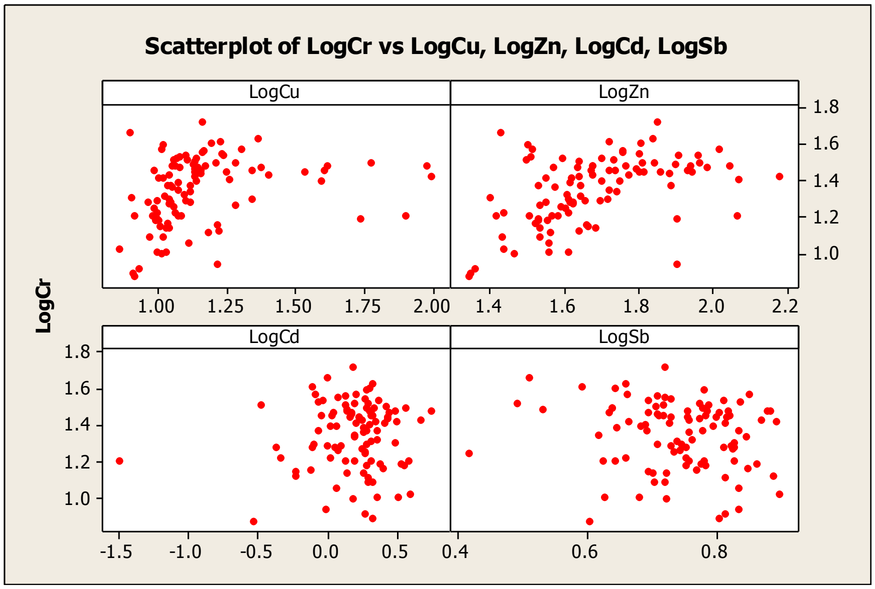


Figure 4.113: Correlation of Cr with other variables – zone 6

From Figure 4.113, it can be observed that the variable Cr does not show a significant correlation with the other variables. However, it shows a minor positive relationship with the variables Zn and Cu.

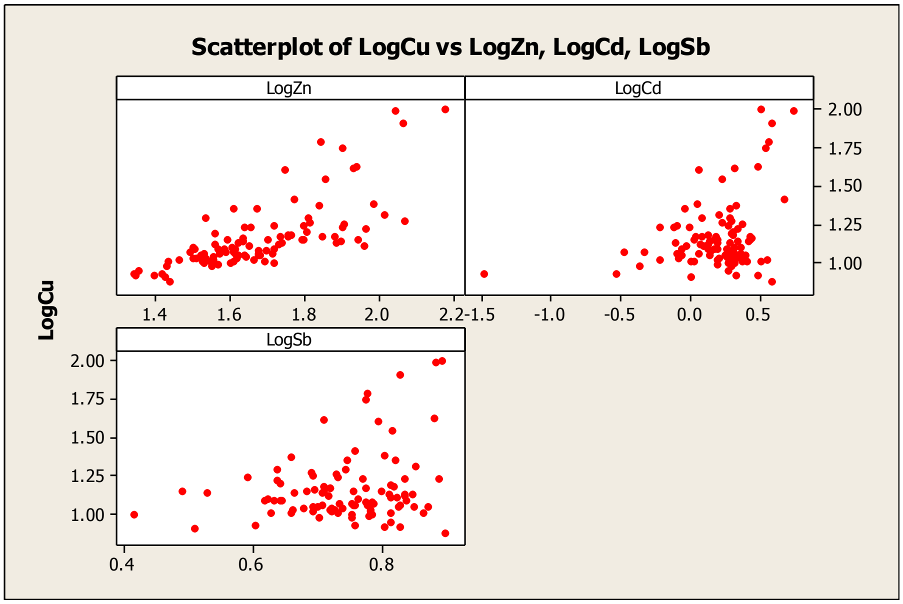


Figure 4.114: Correlation of Cu with other variables – zone 6

By examining Figure 4.114, it can be observed that the variable Cu exhibits a slight positive correlation with Zn.

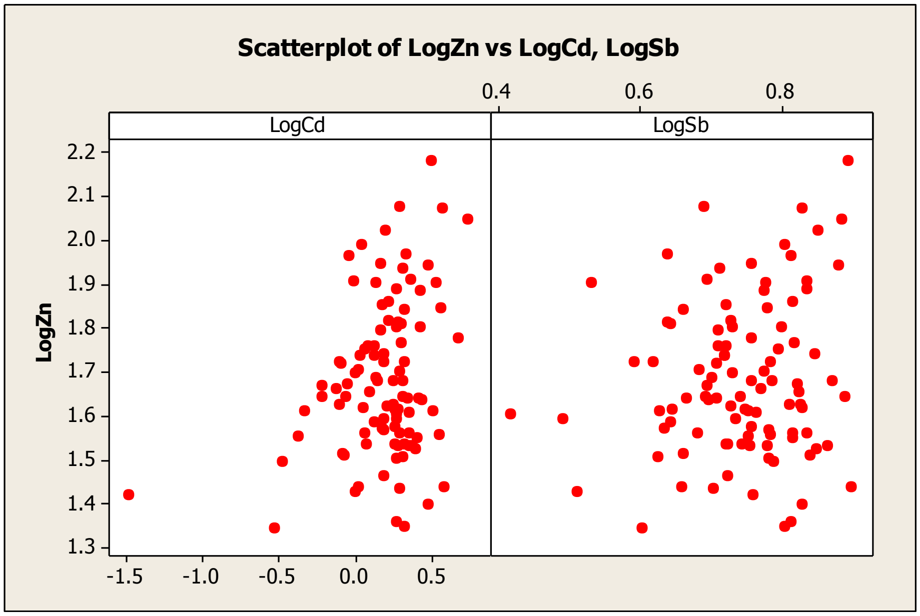


Figure 4.115: Correlation of Zn with other variables – zone 6

By examining Figure 4.115, we find that the variable Zn exhibits no considerably high correlation with other variables.

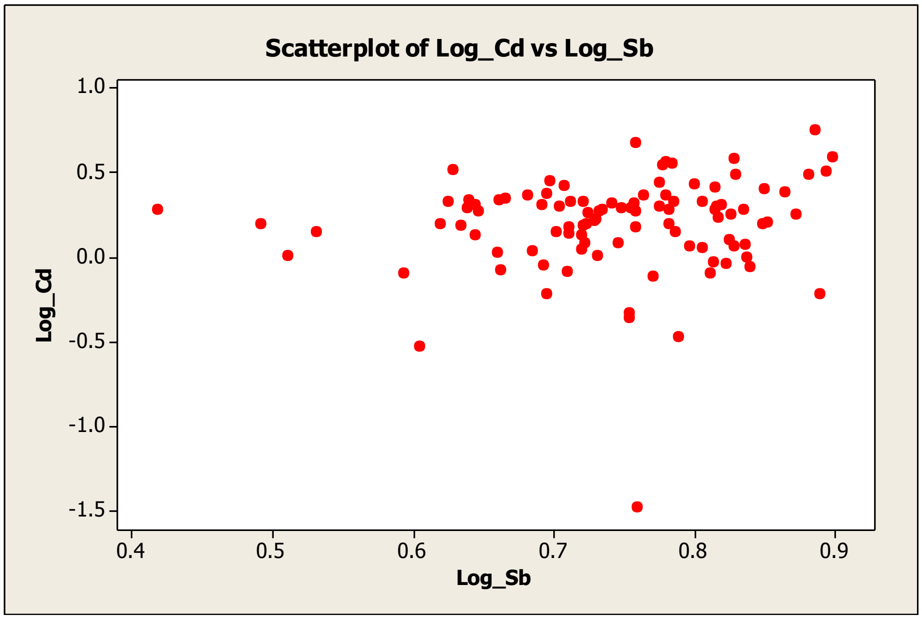


Figure 4.116: Correlation of Cd with other variables – zone 6

By examining Figure 4.116, we find that the variable Cd exhibits no significant correlation with Sb.

To emphasize the observed results from the above scatter plots, a correlation matrix was performed. Table 4.13 shows the correlation between the metals.

Table 4.13: Correlations between the metals – zone 6

**Correlations: Pb, Cr, Cu, Zn, Cd, Sb**

| | Pb | Cr | Cu | Zn | Cd |
|---|---|---|---|---|---|
| Cr | 0.280 | | | | |
| | 0.005 | | | | |
| Cu | 0.752 | 0.122 | | | |
| | 0.000 | 0.227 | | | |
| Zn | 0.549 | 0.366 | 0.699 | | |
| | 0.000 | 0.000 | 0.000 | | |
| Cd | 0.471 | -0.014 | 0.522 | 0.311 | |
| | 0.000 | 0.887 | 0.000 | 0.002 | |
| Sb | 0.227 | -0.190 | 0.315 | 0.197 | 0.246 |
| | 0.023 | 0.059 | 0.001 | 0.050 | 0.013 |

Cell Contents: Pearson correlation
P-Value

Except for the variable pairs Cu and Cr, Cd and Cr, Sb and Cr, all the other variable pairs have significant correlations with a 5% of level significance. Furthermore, these three pairs have the lowest correlation values.

From the above figure, the following statistics can be obtained:

- The correlation between Pb and Cr is 0.280
- The correlation between Pb and Cu is 0.752
- The correlation between Pb and Zn is 0.549
- The correlation between Pb and Cd is 0.471
- The correlation between Pb and Sb is 0.227
- The correlation between Cr and Cu is 0.122
- The correlation between Cr and Zn is 0.366
- The correlation between Cr and Cd is - 0.014
- The correlation between Cr and Sb is - 0.190
- The correlation between Cu and Zn is 0.699
- The correlation between Cu and Cd is 0.522
- The correlation between Cu and Sb is 0.315
- The correlation between Zn and Cd is 0.311
- The correlation between Zn and Sb is 0.197

- The correlation between Cd and Sb is 0.246

According to these observations, it is noticeable that the correlation between Pb and Cu is the highest correlation (r=0.699). Except for 6 pairs, all other variable pairs show less than 0.5 correlations. Further, it can be observed that the variables Pb and Cu have more influence or are more influenced by the other elements.

### 4.1.4.20 Check the normality of the data – zone 6

To check the normality of the data, histograms have been used.

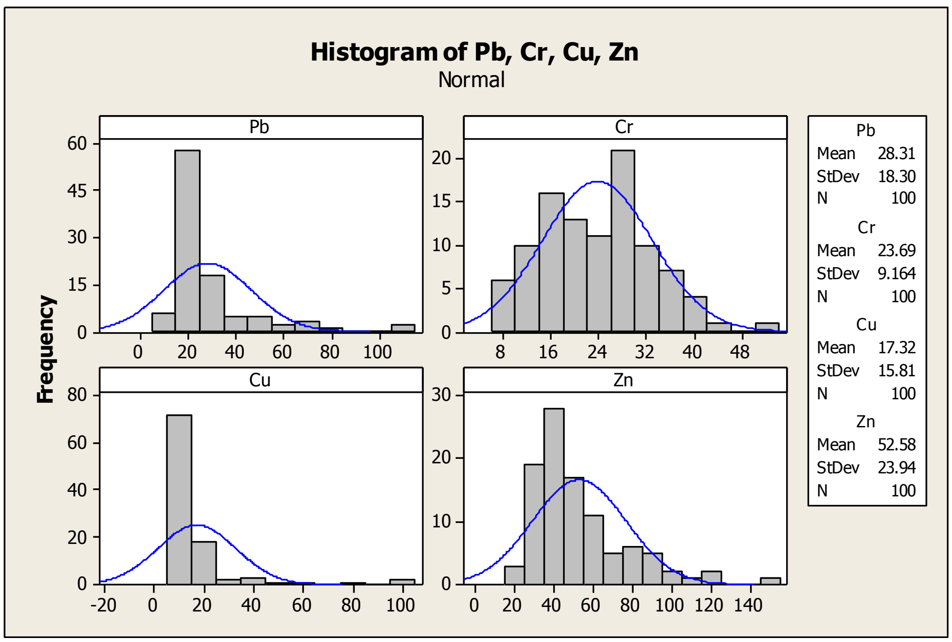


Figure 4.117: Histograms for the variables – zone 6

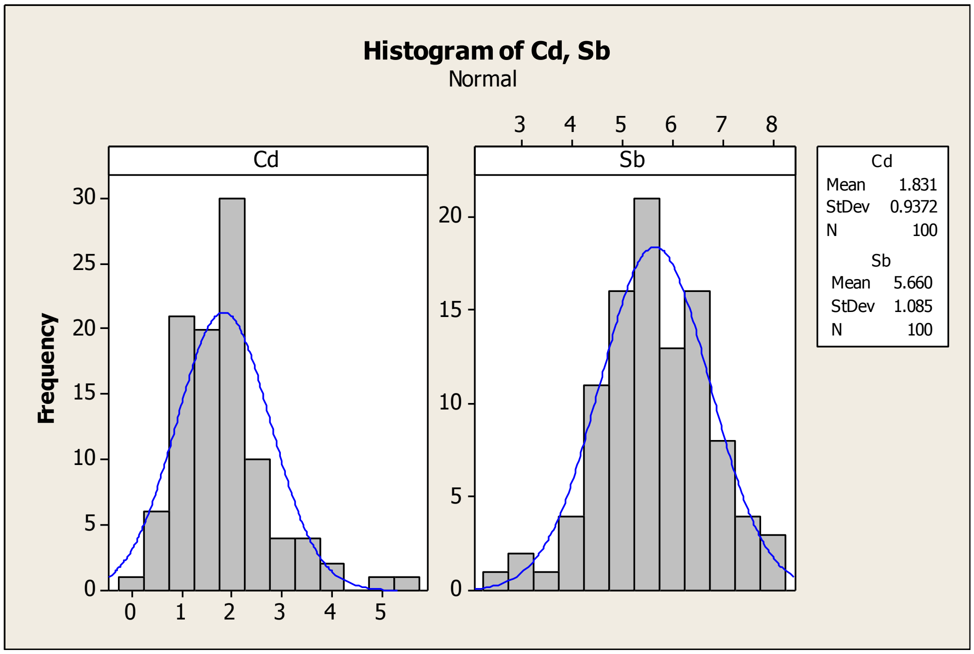


Figure 4.118: Histograms for the variables (metals) – zone 6

Figures 4.117 and 4.118 present the histograms for the variables. From the figures, it can be observed that the variable Cr fits to approximately normal data. Further the variables Sb also shows slightly normal data.

#### 4.1.4.21 Checking for outlying observations – zone 6

It is important to check for the outlying observations. For this purpose, Box plots have been used.

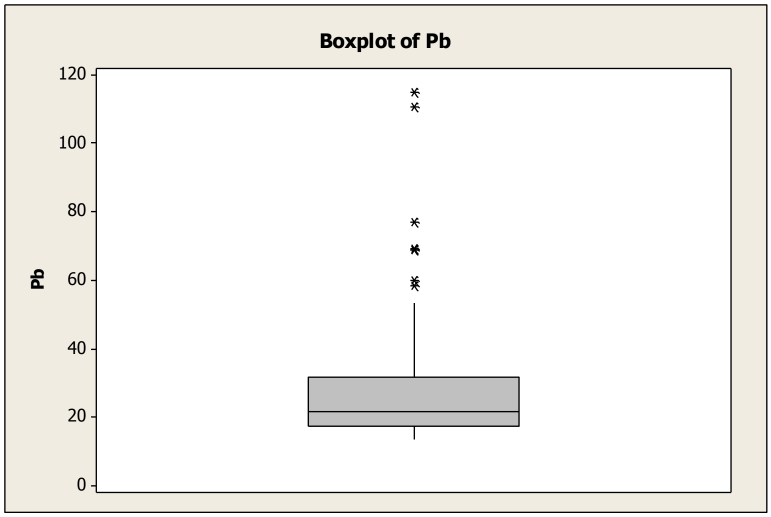


Figure 4.119: Box plot for Pb – zone 6

According the above plot it is noticeable that the data is positively skewed. Further, there are some outliers in the upper end.

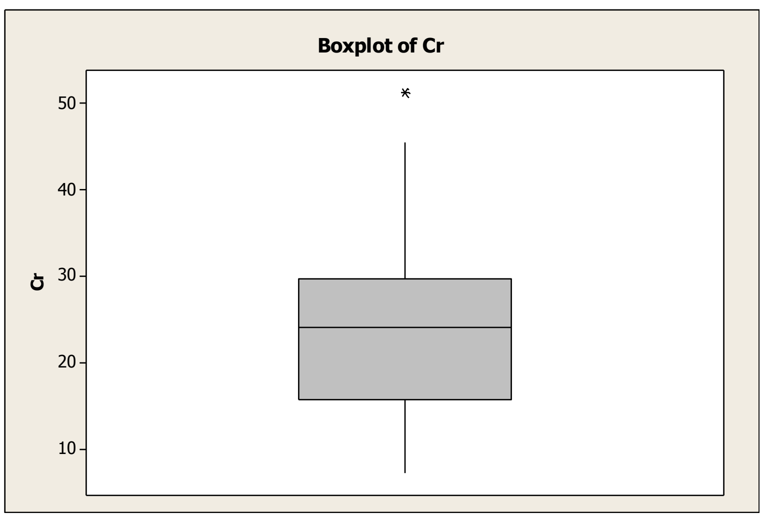


Figure 4.120: Box plot for Cr – zone 6

From the above plot, it is noticeable that the data is negatively skewed. However, there are some outliers.

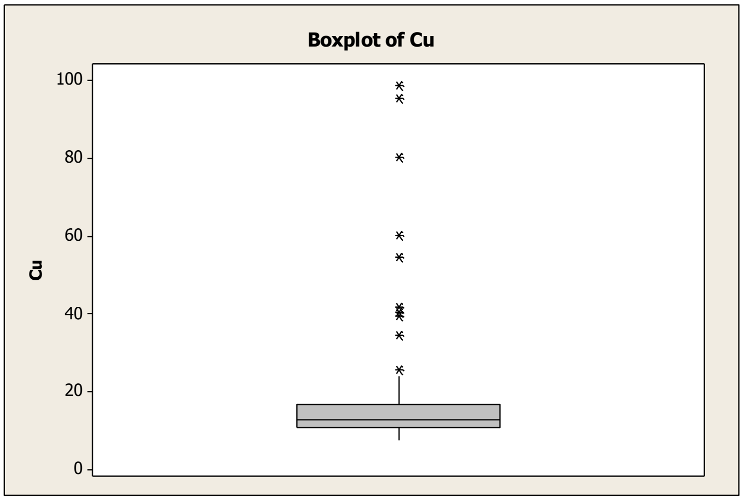


Figure 4.121: Box plot for Cu – zone 6

From the above plot, the data is positively skewed. Further, there are some outliers in the upper end.

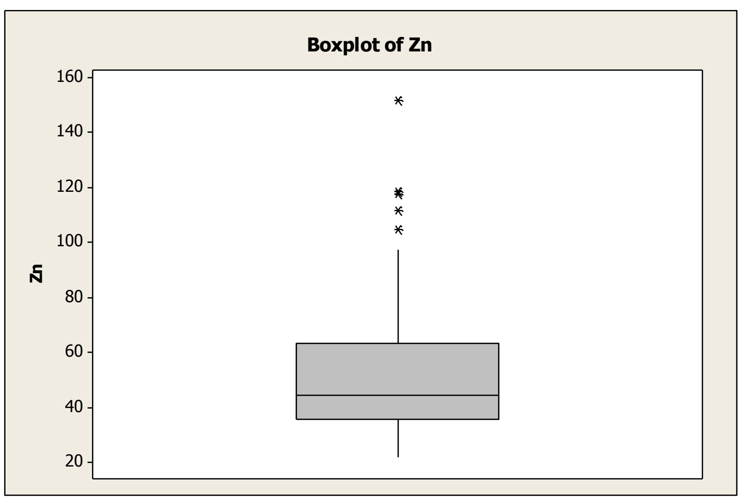


Figure 4.122: Box plot for Zn – zone 6

From the above plot, the data is positively skewed. Further, there are also some outliers.

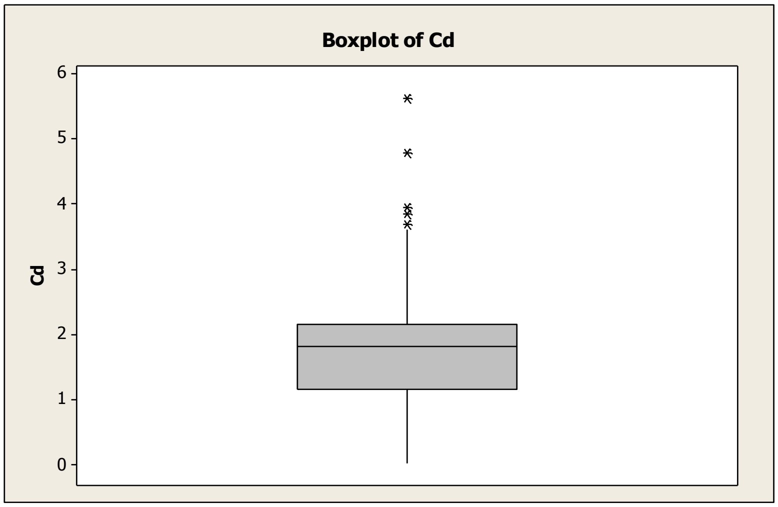


Figure 4.123: Box plot for Cd – zone 6

From the above plot, it is noticeable that some outliers are present in the upper end.

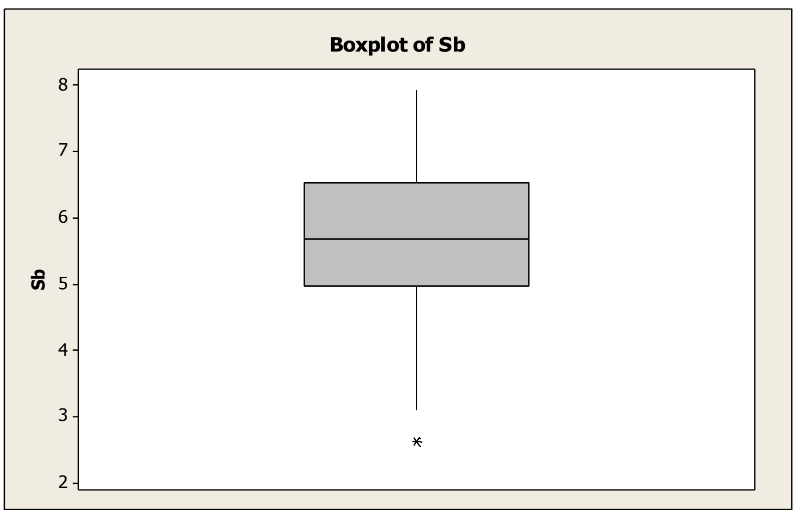


Figure 4.124: Box plot for Sb – zone 6

From the above plot it is noticeable some outliers are in the upper end.

### 4.1.4.22 Comparing the metals in six regions, Juarez

Table 4.14: Mean, median and standard deviation of the elements for the six regions

| Element | Statistics | Central | East | Green | New town | Old town | Zone 6 |
|---|---|---|---|---|---|---|---|
| Pb | Mean | 30.4 | 49.1 | 24.9 | 50.1 | 62.8 | 28.4 |
| | StDev | 16.6 | 62.7 | 3.3 | 26.2 | 34.5 | 18.3 |
| | Median | 24.4 | 31.7 | 23.1 | 40.8 | 57.7 | 21.8 |
| Cu | Mean | 15.5 | 26.9 | 15.2 | 27.6 | 27.9 | 17.4 |
| | StDev | 7.5 | 53.5 | 2.9 | 9.3 | 16.3 | 15.9 |
| | Median | 13.4 | 16.5 | 14.3 | 25.7 | 23.9 | 12.7 |
| Zn | Mean | 63.1 | 82.9 | 63.1 | 146.7 | 120.1 | 52.6 |
| | StDev | 35.7 | 60.6 | 16.9 | 72.9 | 65.9 | 23.9 |
| | Median | 48.9 | 62.8 | 59.1 | 142.2 | 107.5 | 44.7 |
| Cd | Mean | 1.9 | 1.9 | 1.7 | 1.9 | 1.9 | 1.9 |
| | StDev | 0.9 | 0.9 | 1.2 | 1.1 | 0.9 | 0.9 |
| | Median | 1.8 | 1.8 | 1.6 | 1. 7 | 1.9 | 1.9 |
| Sb | Mean | 5.7 | 5.9 | 6.2 | 5.9 | 5.9 | 5.7 |
| | StDev | 1.3 | 2.5 | 0.9 | 1. 7 | 1.6 | 1.1 |
| | Median | 5.6 | 5.6 | 6.3 | 5.9 | 5.8 | 5.7 |
| Cr | Mean | 23.2 | 39.1 | 23.7 | 40.4 | 40.2 | 23.7 |
| | StDev | 11.2 | 8.5 | 6.2 | 10.2 | 9.8 | 9.2 |
| | Median | 22.1 | 39.6 | 20.9 | 39.3 | 39.6 | 24.3 |

From Table 4.14, it can be observed that the mean values of the elements Pb and Cu for old town is higher than that for other regions. Zn, Cd and Cr s are higher in new town area than other regions. Only for the Sb mean value is higher in green side than that for all other regions.

# Chapter 5: Summary and Conclusion

## 5.1 Summary

This study is an outgrowth from the Encountors bi-national lead community project. The study seeks to address the gap in studies of heavy metals, and establish a database for heavy metal distribution and degree of soil contamination in Juarez. The aim of the study is to quantify and document the geographic distribution of heavy metal concentrations in Ciudad Juarez.

The results of this study could provide valuable information that could help environmental specialists, local authorities, planners, and decision makers develop appropriate polices to protect the environment and increase the awareness of the population as to the negative effects of heavy metal contamination in human health.

The soil samples used in this study are a composite of samples collected from public areas around a selection of 50 municipal blocks in Ciudad Juarez city. The general procedures of EPA method 6200, for field portable XRF, and PAN analytical article (by the analytical x-ray company, with slight modification) were followed for the preparation of samples to achieve a uniform particle grain size of ≤ 40 µm. The procedures for soil samples included grinding, mixing, and pressing in the form of pellets to achieve uniform particle grain size ≤ 40 µm. The soil samples were quantitatively determined using the x-ray fluorescence (XRF) spectrometer. Colored details maps are utilized for the distributions and concentrations of content of soil blocks are produced.

The results of the study are summarized as follows:

In the Juarez soil samples blocks, the soil lead concentration levels were recorded, ranging from 12.6 to 550.3 ppm, while the mean concentration values recorded for lead was 42.8

ppm. Soil chromium concentration levels recorded for chromium ranged from 1.8 to 75.6 ppm; with mean concentration values for chromium at 32.1 ppm. Soil copper concentration levels recorded for Cu ranged from 6.3 to 547.3 ppm; with mean concentration values recorded for Cu at 22.3 ppm. Soil zinc concentration levels recorded for chromium ranged from 20.7 to 415.8 ppm; with mean concentration values recorded for chromium at 83.7 ppm. Soil cadmium concentration levels recorded for cadmium ranged from 0.1 to 6.2 ppm; with mean concentration values for cadmium recorded at 1.9 ppm. Soil antimony concentration levels recorded for antimony ranged from 2.7 to 28.8 ppm; with mean concentration values recorded for Sb at 5.8 ppm.

The results showed that the concentration of the soil samples taken from Juarez differs in the following order: Zn >Pb> Cr > Cu >Sb> Cd.

In term of the correlation between metals, the Pb showed a slight positive correlation with Cr, Cu and Zn. Metal Cr did not show a significant correlation with the other metals, and it showed a minor relationship with Cu and Zn. The metal Cu exhibits a positive correlation with Zn. On the other hand, Zn did not exhibit a significant relationship with Cd and Sb. The metal Cd did not exhibit a significant correlation with the other metals. The correlation between Cr and Zn was recorded as the highest correlation.

In old town soil samples, the resulting concentration levels recorded for lead ranged from 15.2 to 181.9 ppm, with mean concentration values of 62.8 ppm. Chromium ranged from 21.5 to 75.6 ppm, with mean concentration values of 40.2 ppm. Copper ranged from 9.9 to 122.6 ppm, with mean concentration values of 27.9 ppm. Zinc ranged from 36.4 to 341.6 ppm, with mean concentration values of120.1 ppm. Cadmium ranged from 0.5 to 4.7 ppm, with mean

concentration values of1.9, and antimony ranged from 3.1 to 16.9 ppm, with a mean concentration value of 5.9 ppm.

The results indicate that the metal zinc had the highest concentration level 341.6 ppm, and cadmium has the lowest level 0.5 ppm.

The result shows that the concentration of the soil samples taken from old town differs in the following order: Zn>Pb> Cr > Cu>Sb> Cd.

In terms of correlation between metals, the results of this study demonstrated that Pb showed a positive correlation with the Cr, Cu and Zn. The metal Cr showed a correlation with the Cu and Zn. Cu exhibited a positive correlation with Zn and a slight positive relationship with Cd and Sb.  The Metal Zn exhibited no considerably high correlation with other metals. The Metal Cd exhibited no significant correlation with Sb. From the results obtained, it noticeably showed the correlation between Pb and Zn as the highest correlation recorded.

In new town, the resulting concentration levels recorded for lead ranged from 18.2 to 139.8 ppm. Chromium ranged from 23.8 to 74.4 ppm. Copper ranged from 12.1 to 53.4 ppm. Zinc ranged from 42.4 to 414.1 ppm. Cadmium ranged from 0.3 to 5.3 ppm and antimony ranged from 3.32 to 13.41 ppm.

The results indicate that the metal lead has the highest concentration level at 139.8 ppm, and cadmium has the lowest level at 0.3 ppm.

The highest mean concentration value is recorded for the metal Zn, and the minimum concentration is recorded for Cd. The result showed that the concentration of the soil samples taken from Juarez new town differs in the following order: Zn >Pb> Cr > Cu >Sb> Cd.

In terms of correlation between the metals, the metal Pb showed a slight positive correlation with the three variables Cr, Cu and Zn. It is noticeable that the correlation between Cr and Cu is the highest correlation recorded.

In the east side, the resulting concentration levels recorded for lead ranged from 15.9 to 550.3 ppm. Cr ranged from 11.6 to 71.6 ppm. Cu ranged from 8.1 to 547.3 ppm. Zn ranged from 33.6 to 415.8 ppm. Cd ranged from 0.4 to 6.2 ppm, and Sb ranged from 3.3 to 28.8 ppm. The results indicate that the metal lead has the highest concentration level at 550.3 ppm, and Cd has the lowest level at 0.4 ppm.

The highest mean concentration value is recorded for the metal Zn, and the minimum concentration is recorded for Cd. The results show that that the concentration of the soil samples taken from east side differs in the following order: Zn >Pb> Cr > Cu >Sb> Cd.

In terms of correlation between metals, Pb showed a slight positive correlation with Cu and Zn. Cr showed a correlation with Zn. Metal Cu did not exhibit a significant relationship with the Zn, Cd, and Sb. Metal Zn did not exhibit a significant correlation with the Cd, Sb. Metal Cd did not exhibit a significant correlation with Sb. It is noticeable that the correlation between Zn and Cu is the highest correlation recorded.

In central, the resulting concentration levels recorded for lead ranged from 14.1 to 100.4 ppm. Chromium ranged from 3.8 to 57.7 ppm. Copper ranged from 21.7 to 60.7 ppm. Zinc ranged from 21.7 to 222.5 ppm. Cadmium ranged from 0.5 to 4.2 ppm, and antimony ranged from 2.9 to 12.1 ppm.

The results indicated that the metal Zn had the highest concentration level at 222.5 ppm, and Cd had the lowest level at 0.5 ppm.

The highest mean concentration value is recorded for the metal Zn, and the minimum concentration is recorded for Cd. The result showed that the soil samples taken from center differ in the following order: Zn >Pb> Cr > Cu >Sb> Cd.

In terms of correlation between metals, the metal Pb showed a positive correlation with the metals Cr, Cu and Zn. Metal Cr showed a correlation with the Zn and Zn. Cu exhibited a positive correlation with Zn. Metal Zn exhibited no significant correlation with Cd and Sb. Metal Cd exhibits no significant correlation with Sb. It is noticeable that the correlation between Zn and Cr is the highest correlation recorded.

In Green region, the resulting concentration level for lead was ranged from 21.1 to 29.4 ppm. Chromium ranged from 17.9 to 33.9 ppm. Copper ranged from 12.3 to 20.6 ppm. Zinc ranged from 48.4 to 97.3 ppm. Cadmium ranged from 0.7 to 4.1 ppm, and antimony ranged from 4.9 to 7.8 ppm.

The results indicated that the metal lead has the highest concentration of Zn at 79.27 ppm, and Cd has the lowest level at 0.68 ppm.

The highest mean concentration value is recorded for the metal Zn, and the minimum concentration is recorded for Cd. The results showed that the concentration of the soil samples taken from Green differs in the following order: Zn >Pb> Cr > Cu >Sb> Cd.

In Zone 6, the resulting concentration levels for lead ranged from 13.6 to 114.9 ppm. Chromium ranged from 23.7 to 51.3 ppm. Copper ranged from 17.4 to 98.8 ppm. Zinc ranged from 52.6 to 151.8 ppm. Cadmium ranged from 1.9 to 5.7 ppm, and antimony ranged from 5.7 to 7.9 ppm. The results indicated that the metal Zn has the highest concentration level at 151.8 ppm, and Cd has the lowest level at 0.1 ppm.

The highest mean concentration value is recorded for the metal Zn, and the minimum concentration is recorded for Cd. The result showed that the concentration of the soil samples taken from Zone 6 differs in the following order: Zn>Pb> Cr> Cu>Sb> Cd.

In terms of correlation between metals, the Pb showed a positive correlation with the metals Cu and a slightly positive relationship with Zn. Metal Cr did not show a significant correlation with the other metals, it showed a minor positive relationship with the metals Zn and Cu. Metal Cu exhibits a slight positive correlation with Zn. Metal Zn exhibited no considerably high correlation with other metals. Metal Sb exhibited no significant correlation with Cd. It is noticeable that the correlation between Pb and Cu is the highest correlation recorded.

## 5.2 Conclusion

The objective of this study is to quantify and document the geographic distribution of heavy metal concentrations in Ciudad Juarez. The conclusion can be made as follows;

- The study indicated that the soil in Juarez was contaminated with lead, cadmium, zinc, copper, and antimony, and may pose potential hazards to residential population.
- The chromium is recorded at low levels in Juarez soil. The results showed that the concentration of the soil samples taken from Juarez differs in the following order: Zn >Pb> Cr > Cu >Sb> Cd.
- The result shows that the concentration of the soil samples taken from Juarez regions differs in the following order: Zn>Pb> Cr > Cu>Sb> Cd.
- The results indicated that the metals hold no clear pattern of distribution in Juarez soil. High-elevated levels of the metals were recorded in most city areas. This may be due to the dispersion of heavy metals from human activities, especially brick making, tire

burning, and open air fires. These environmental sources of pollution emit their pollutants directly into the air of the city.

## 5.3 Recommendations for Further Research

Heavy metals in soils continue to receive increasing attention due to growing scientific and public awareness of environmental issues. Heavy metals have been detected in many sites of the city of Juarez; it remains challenging to identify the pollution sources of heavy metals and their contribution in contaminated soil in the Juarez. From the data attained, it could be concluded that the risk of metal dispersal obtained from the present research serves as a good starting point for continued research. Further work in this field is highly needed to learn more about the effect of heavy metals in the environment, and their impact on human health.

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# Appendix

## Appendix 1: Concentration of soil samples (ppm)

| Metal | | Cu | Zn | Cd | Sb | Pb | Cr |
|---|---|---|---|---|---|---|---|
| **Count** | ID Block | Conc. (ppm) | Conc. (ppm) | Conc. (ppm) | Conc. (ppm) | Conc. (ppm) | Conc. (ppm) |
| **1** | 37 | 80.228 | 117.567 | 3.852 | 6.738 | 114.947 | 15.747 |
| **2** | 54 | 59.955 | 70.045 | 3.687 | 6.021 | 76.882 | 30.992 |
| **3** | 59 | 95.499 | 111.728 | 5.607 | 7.686 | 110.659 | 29.596 |
| **4** | 71 | 39.337 | 56.344 | 1.167 | 6.258 | 59.952 | 24.355 |
| **5** | 89 | 54.64 | 80.238 | 3.478 | 5.986 | 69.079 | 15.384 |
| **6** | 112 | 25.567 | 59.814 | 4.782 | 5.739 | 69.216 | 26.474 |
| **7** | 116 | 34.445 | 72.563 | 1.703 | 6.561 | 42.498 | 27.345 |
| **8** | 157 | 20.255 | 104.733 | 1.618 | 7.115 | 31.957 | 36.339 |
| **9** | 164 | 16.649 | 80.593 | 0.993 | 6.871 | 33.162 | 8.566 |
| **10** | 166 | 11.751 | 31.3 | 1.543 | 5.555 | 18.614 | 10.555 |
| **11** | 202 | 40.35 | 85.982 | 2.11 | 5.159 | 50.712 | 28.037 |
| **12** | 287 | 22.033 | 47.174 | 0.915 | 6.651 | 31.685 | 27.993 |
| **13** | 389 | 18.149 | 109.86 | 1.566 | 6.675 | 28.745 | 44.917 |
| **14** | 426 | 15.904 | 48.589 | 2.358 | 3.948 | 27.652 | 37.353 |
| **15** | 466 | 19.951 | 67.025 | 1.274 | 4.528 | 34.41 | 43.457 |
| **16** | 489 | 23.839 | 98.968 | 1.672 | 5.022 | 43.349 | 39.092 |
| **17** | 489 | 21.939 | 95.294 | 1.04 | 6.071 | 43.784 | 29.757 |
| **18** | 532 | 34.061 | 92.088 | 1.884 | 6.153 | 62.05 | 36.839 |
| **19** | 551 | 27.082 | 107.459 | 0.789 | 6.162 | 40.869 | 30.625 |
| **20** | 556 | 36.319 | 69.243 | 2.333 | 6.988 | 39.846 | 40.694 |
| **21** | 665 | 10.689 | 39.262 | 1.676 | 4.791 | 17.994 | 23.866 |
| **22** | 762 | 14.369 | 54.777 | 1.102 | 5.247 | 26.963 | 27.953 |
| **23** | 768 | 11.775 | 71.078 | 1.296 | 6.233 | 23.517 | 29.469 |
| **24** | 787 | 22.379 | 73.025 | 1.868 | 5.399 | 21.349 | 29.299 |
| **25** | 860 | 27.547 | 81.007 | 2.846 | 5.311 | 103.062 | 39.307 |
| **26** | 887 | 11.593 | 40.855 | 0.47 | 5.673 | 20.667 | 16.62 |
| **27** | 901 | 13.906 | 39.293 | 1.575 | 3.106 | 17.61 | 32.433 |
| **28** | 978 | 12.921 | 36.305 | 2.344 | 5.851 | 15.111 | 30.475 |
| **29** | 981 | 11.29 | 47.774 | 2.094 | 5.715 | 23.983 | 29.985 |
| **30** | 1000 | 10.247 | 46.443 | 0.609 | 4.956 | 20.698 | 13.993 |
| **31** | 1022 | 17.213 | 63.414 | 1.881 | 5.398 | 33.755 | 34.899 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **32** | 1078 | 18.393 | 54.628 | 1.746 | 5.467 | 30.037 | 38.136 |
| **33** | 1084 | 13.008 | 58.575 | 1.45 | 5.325 | 24.348 | 33.297 |
| **34** | 1120 | 19.748 | 55.462 | 0.859 | 6.669 | 32.881 | 27.026 |
| **35** | 1152 | 21.468 | 87.479 | 0.414 | 5.986 | 60.037 | 39.936 |
| **36** | 1173 | 84.417 | 59.618 | 1.276 | 16.887 | 62.666 | 21.4 |
| **37** | 1216 | 10.987 | 52.596 | 2.434 | 8.261 | 25.114 | 34.444 |
| **38** | 1266 | 14.403 | 49.835 | 1.693 | 9.014 | 40.503 | 28.443 |
| **39** | 1274 | 13.132 | 55.346 | 1.865 | 4.976 | 20.424 | 32.724 |
| **40** | 1298 | 23.438 | 86.989 | 0.912 | 5.278 | 41.621 | 43.24 |
| **41** | 1392 | 17.964 | 85.692 | 1.726 | 3.465 | 52.075 | 38.738 |
| **42** | 1492 | 12.129 | 37.176 | 1.521 | 4.309 | 27.301 | 29.23 |
| **43** | 1515 | 23.14 | 69.309 | 2.159 | 4.583 | 36.319 | 41.775 |
| **44** | 1526 | 17.036 | 52.711 | 0.799 | 3.92 | 19.583 | 40.667 |
| **45** | 1548 | 15.451 | 41.277 | 1.362 | 5.058 | 22.322 | 23.95 |
| **46** | 1577 | 11.438 | 31.379 | 0.338 | 6.154 | 17.79 | 32.354 |
| **47** | 1588 | 11.969 | 39.598 | 1.9 | 5.3 | 21.387 | 21.789 |
| **48** | 1591 | 16.795 | 66.565 | 2.82 | 6.473 | 34.562 | 36.166 |
| **49** | 1592 | 15.274 | 62.741 | 3.444 | 5.227 | 26.981 | 33.787 |
| **50** | 1593 | 15.043 | 51.468 | 0.974 | 6.213 | 21.939 | 34.137 |
| **51** | 1655 | 13.528 | 40.105 | 1.407 | 6.517 | 18.579 | 28.963 |
| **52** | 1691 | 13.396 | 55.26 | 2.294 | 4.605 | 27.599 | 23.4 |
| **53** | 1694 | 19.632 | 79.169 | 2.847 | 6.324 | 35.149 | 34.93 |
| **54** | 1720 | 13.536 | 56.753 | 1.24 | 4.994 | 31.493 | 23.55 |
| **55** | 1733 | 18.339 | 70.732 | 2.668 | 6.453 | 28.525 | 27.314 |
| **56** | 1739 | 14.856 | 61.349 | 0.59 | 6.536 | 36.913 | 31.133 |
| **57** | 1773 | 20.554 | 126.095 | 3.169 | 4.886 | 53.396 | 43.596 |
| **58** | 1777 | 36.096 | 103.229 | 3.024 | 5.116 | 69.049 | 44.955 |
| **59** | 1816 | 21.314 | 105.017 | 1.562 | 6.154 | 67.134 | 43.182 |
| **60** | 1854 | 48.285 | 94.897 | 2.363 | 5.617 | 35.094 | 44.544 |
| **61** | 1931 | 18.297 | 59.134 | 3.616 | 4.522 | 23.193 | 28.146 |
| **62** | 2072 | 8.065 | 53.082 | 1.306 | 5.074 | 19.271 | 41.297 |
| **63** | 2121 | 18.074 | 205.482 | 2.076 | 5.44 | 51.568 | 50.718 |
| **64** | 2128 | 11.943 | 47.831 | 2.282 | 4.27 | 20.141 | 24.334 |
| **65** | 2129 | 15.135 | 41.169 | 2.068 | 6.178 | 16.778 | 32.414 |
| **66** | 2134 | 12.694 | 59.323 | 0.534 | 5.905 | 22.263 | 24.493 |
| **67** | 2144 | 13.815 | 35.844 | 2.051 | 3.563 | 16.324 | 23.293 |
| **68** | 2177 | 10.797 | 102.379 | 1.057 | 5.197 | 19.783 | 31.373 |
| **69** | 2188 | 11.911 | 36.02 | 0.686 | 6.969 | 15.806 | 46.755 |
| **70** | 2215 | 10.578 | 55.468 | 1.861 | 3.78 | 16.106 | 41.182 |
| **71** | 2224 | 12.426 | 42.318 | 1.339 | 4.514 | 16.271 | 35.545 |

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|---|---|---|---|---|---|---|---|
| **72** | 2333 | 22.086 | 108.107 | 0.896 | 6.096 | 52.373 | 49.484 |
| **73** | 2348 | 31.729 | 158.553 | 2.557 | 6.558 | 43.093 | 48.213 |
| **74** | 2388 | 26.367 | 140.36 | 1.878 | 7.566 | 71.038 | 51.057 |
| **75** | 2460 | 28.132 | 179.584 | 1.06 | 6.169 | 104.11 | 44.613 |
| **76** | 2536 | 17.861 | 95.971 | 1.418 | 4.897 | 46.177 | 31.353 |
| **77** | 2597 | 24.153 | 123.22 | 0.85 | 4.498 | 70.645 | 41.247 |
| **78** | 2610 | 52.355 | 243.629 | 1.663 | 6.426 | 170.957 | 59.912 |
| **79** | 2637 | 21.437 | 151.474 | 1.314 | 5.698 | 74.244 | 63.958 |
| **80** | 2641 | 24.349 | 106.367 | 1.257 | 5.529 | 56.859 | 37.71 |
| **81** | 2648 | 23.423 | 152.491 | 3.066 | 5.717 | 77.673 | 47.414 |
| **82** | 2690 | 13.052 | 74.894 | 2.181 | 6.807 | 24.141 | 29.075 |
| **83** | 2691 | 22.14 | 50.59 | 2.596 | 6.667 | 24.232 | 36.719 |
| **84** | 2706 | 11.967 | 67.071 | 1.15 | 4.876 | 26.442 | 46.418 |
| **85** | 2776 | 12.023 | 68.388 | 1.649 | 4.184 | 23.048 | 35.585 |
| **86** | 2780 | 16.231 | 44.898 | 1.724 | 5.474 | 29.562 | 46.482 |
| **87** | 2794 | 15.07 | 51.723 | 0.971 | 5.051 | 23.128 | 37.292 |
| **88** | 2798 | 16.511 | 56.558 | 1.829 | 6.306 | 22.719 | 42.927 |
| **89** | 2816 | 10.967 | 39.994 | 0.937 | 4.787 | 19.664 | 42.686 |
| **90** | 2865 | 13.719 | 42.704 | 1.173 | 4.068 | 18.338 | 41.777 |
| **91** | 2882 | 160.137 | 157.91 | 2.236 | 7.899 | 50.302 | 52.789 |
| **92** | 2981 | 15.255 | 60.463 | 2.003 | 5.051 | 34.138 | 36.503 |
| **93** | 3005 | 11.766 | 51.061 | 0.825 | 5.133 | 68.818 | 30.009 |
| **94** | 3027 | 9.959 | 47.92 | 2.325 | 3.031 | 22.724 | 33.45 |
| **95** | 3041 | 18.186 | 82.665 | 1.271 | 6.15 | 53.236 | 31.461 |
| **96** | 3045 | 15.495 | 48.743 | 1.063 | 5.411 | 25.658 | 32.032 |
| **97** | 3075 | 17.795 | 92.483 | 2.016 | 6.058 | 40.524 | 37.677 |
| **98** | 3084 | 12.064 | 75.643 | 1.909 | 4.983 | 33.873 | 30.136 |
| **99** | 3112 | 16.454 | 108.39 | 0.524 | 6.533 | 40.61 | 36.871 |
| **100** | 3132 | 15.427 | 60.109 | 2.63 | 4.685 | 40.385 | 39.56 |
| **101** | 3207 | 19.762 | 86.045 | 4.668 | 4.75 | 58.928 | 46.933 |
| **102** | 3338 | 25.138 | 134.961 | 2.859 | 5.377 | 62.902 | 44.606 |
| **103** | 3403 | 22.869 | 142.025 | 0.849 | 5.223 | 64.037 | 45.16 |
| **104** | 3407 | 21.217 | 107.331 | 2.867 | 4.687 | 48.749 | 52.216 |
| **105** | 3484 | 14.984 | 85.582 | 2.14 | 4.403 | 52.496 | 37.529 |
| **106** | 3489 | 19.332 | 119.828 | 1.322 | 6.419 | 65.418 | 40.609 |
| **107** | 3550 | 24.248 | 84.954 | 1.759 | 4.97 | 62.852 | 47.191 |
| **108** | 3640 | 23.556 | 133.181 | 1.473 | 5.39 | 86.686 | 47.72 |
| **109** | 3660 | 30.297 | 109.96 | 2.854 | 8.571 | 77.703 | 40.539 |
| **110** | 3668 | 18.509 | 67.586 | 1.014 | 5.183 | 25.421 | 34.977 |
| **111** | 3685 | 19.041 | 113.357 | 2.436 | 6.004 | 49.35 | 43.563 |

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| **112** | 3758 | 13.994 | 54.39 | 1.517 | 5.016 | 27.112 | 41.298 |
| **113** | 3772 | 18.205 | 94.471 | 1.599 | 5.874 | 45.242 | 50.67 |
| **114** | 3784 | 30.278 | 131.885 | 3.397 | 6.996 | 61.945 | 45.592 |
| **115** | 3797 | 27.726 | 149.415 | 0.964 | 5.634 | 35.307 | 41.215 |
| **116** | 3823 | 15.744 | 77.414 | 1.857 | 4.794 | 34.908 | 41.776 |
| **117** | 3827 | 21.822 | 119.694 | 2.584 | 6.535 | 68.201 | 45.94 |
| **118** | 3841 | 19.669 | 79.149 | 2.441 | 6.236 | 40.272 | 37.409 |
| **119** | 3922 | 14.187 | 52.073 | 2.273 | 4.559 | 23.543 | 39.5 |
| **120** | 3926 | 18.814 | 100.845 | 1.164 | 6.308 | 53.548 | 45.125 |
| **121** | 3943 | 13.711 | 62.752 | 1.843 | 4.2 | 33.905 | 38.735 |
| **122** | 3954 | 18.464 | 100.334 | 2.055 | 7.936 | 74.454 | 41.532 |
| **123** | 3976 | 28.81 | 122.925 | 1.122 | 7.595 | 148.463 | 75.587 |
| **124** | 4036 | 27.779 | 126.542 | 2.575 | 6.335 | 83.074 | 47.406 |
| **125** | 4079 | 38.058 | 129.153 | 1.979 | 5.591 | 100.591 | 31.241 |
| **126** | 4128 | 39.394 | 174.237 | 2.98 | 6.784 | 73.924 | 38.4 |
| **127** | 4230 | 28.057 | 197.255 | 1.211 | 6.903 | 142.23 | 34.378 |
| **128** | 4286 | 40.612 | 332.662 | 3.712 | 6.516 | 157.341 | 64.44 |
| **129** | 4300 | 41.295 | 163.174 | 1.398 | 6.357 | 181.962 | 45.03 |
| **130** | 4350 | 37.75 | 183.955 | 2.115 | 8.592 | 114.375 | 52.252 |
| **131** | 4361 | 50.396 | 168.511 | 2.254 | 5.339 | 83.939 | 46.835 |
| **132** | 4372 | 29.152 | 96.661 | 1.653 | 4.991 | 74.721 | 37.438 |
| **133** | 4403 | 44.013 | 228.171 | 1.587 | 6.633 | 94.062 | 39.278 |
| **134** | 4407 | 25.445 | 130 | 1.477 | 4.529 | 48.902 | 34.094 |
| **135** | 4418 | 26.29 | 75.045 | 2.154 | 6.803 | 45.41 | 25.631 |
| **136** | 4446 | 23.498 | 97.547 | 0.471 | 6.302 | 70.398 | 28.173 |
| **137** | 4475 | 28.211 | 84.373 | 2.265 | 6.24 | 61.787 | 40.823 |
| **138** | 4541 | 33.286 | 180.948 | 2.509 | 7.068 | 87.163 | 34.339 |
| **139** | 4642 | 23.651 | 95.087 | 2.726 | 5.871 | 81.309 | 53.017 |
| **140** | 4685 | 43.343 | 197.636 | 3.946 | 6.624 | 94.754 | 44.591 |
| **141** | 4718 | 37.766 | 129.718 | 1.8 | 8.442 | 82.328 | 31.376 |
| **142** | 4753 | 45.77 | 136.875 | 2.624 | 5.105 | 63.81 | 53.968 |
| **143** | 4768 | 35.316 | 196.556 | 2.849 | 5.856 | 78.194 | 59.354 |
| **144** | 4780 | 24.678 | 143.321 | 1.741 | 6.02 | 48.977 | 53.703 |
| **145** | 4782 | 37.856 | 203.593 | 1.793 | 6.001 | 66.146 | 43.432 |
| **146** | 4846 | 34.378 | 154.394 | 2.537 | 5.702 | 68.398 | 44.729 |
| **147** | 4880 | 36.73 | 203.36 | 1.957 | 5.76 | 75.798 | 41.093 |
| **148** | 4912 | 54.031 | 313.411 | 3.869 | 6.424 | 90.617 | 48.483 |
| **149** | 4934 | 25.523 | 122.741 | 2.83 | 4.918 | 61.252 | 47.036 |
| **150** | 4993 | 122.593 | 326.802 | 4.646 | 8.127 | 114.222 | 46.576 |
| **151** | 5043 | 49.447 | 188.311 | 2.924 | 5.801 | 79.38 | 48.173 |

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|---|---|---|---|---|---|---|---|
| **152** | 5076 | 27.086 | 153.522 | 1.8 | 5.124 | 74.04 | 49.122 |
| **153** | 5125 | 10.004 | 41.509 | 1.124 | 4.354 | 31.473 | 37.947 |
| **154** | 5130 | 14.69 | 53.36 | 2.427 | 6.167 | 25.255 | 37.973 |
| **155** | 5135 | 15.526 | 50.017 | 0.704 | 5.331 | 24.659 | 43.362 |
| **156** | 5141 | 170.471 | 353.03 | 5.536 | 9.488 | 182.166 | 65.175 |
| **157** | 5142 | 121.987 | 362.748 | 6.067 | 10.707 | 232.566 | 71.51 |
| **158** | 5145 | 19.02 | 61.469 | 0.989 | 5.274 | 32.326 | 46.403 |
| **159** | 5170 | 14.901 | 47.018 | 1.321 | 5.896 | 18.839 | 39.595 |
| **160** | 5215 | 12.767 | 49.091 | 0.561 | 6.242 | 20.025 | 36.464 |
| **161** | 5289 | 16.029 | 52.913 | 2.451 | 4.676 | 22.959 | 49.769 |
| **162** | 5302 | 9.834 | 54.183 | 2.031 | 4.028 | 30.77 | 41.368 |
| **163** | 5308 | 13.22 | 56.373 | 1.796 | 4.565 | 30.668 | 52.589 |
| **164** | 5351 | 22.427 | 75.363 | 2.223 | 3.857 | 36.109 | 42.291 |
| **165** | 5359 | 14.483 | 50.596 | 2.782 | 3.674 | 24.301 | 42.838 |
| **166** | 5377 | 19.759 | 52.775 | 1.387 | 5.106 | 28.885 | 39.381 |
| **167** | 5404 | 21.558 | 42.622 | 1.591 | 4.806 | 30.475 | 41.653 |
| **168** | 5412 | 19.13 | 88.066 | 0.866 | 6.555 | 23.824 | 36.714 |
| **169** | 5451 | 66.807 | 111.491 | 1.886 | 4.631 | 50.982 | 49.669 |
| **170** | 5464 | 17.511 | 220.929 | 1.127 | 7.659 | 39.738 | 39.7 |
| **171** | 5483 | 15.431 | 53.589 | 1.938 | 5.646 | 31.603 | 39.861 |
| **172** | 5501 | 57.357 | 150.961 | 1.977 | 11.451 | 83.736 | 44.928 |
| **173** | 5512 | 17.508 | 84.415 | 3.161 | 6.64 | 32.938 | 45.401 |
| **174** | 5530 | 24.73 | 88.325 | 1.305 | 7.372 | 39.408 | 36.076 |
| **175** | 5556 | 18.459 | 122.197 | 1.159 | 6.228 | 50.924 | 33.024 |
| **176** | 5562 | 21.663 | 54.297 | 2.324 | 5.625 | 26.239 | 33.742 |
| **177** | 5568 | 16.326 | 94.376 | 1.534 | 5.764 | 59.25 | 48.016 |
| **178** | 5636 | 29.654 | 97.439 | 1.233 | 10.468 | 63.067 | 43.991 |
| **179** | 5676 | 18.162 | 81.899 | 2.056 | 5.961 | 46.746 | 34.405 |
| **180** | 5706 | 15.622 | 80.686 | 1.783 | 4.343 | 32.072 | 43.266 |
| **181** | 5715 | 14.121 | 68.955 | 2.03 | 8.498 | 137.855 | 45.124 |
| **182** | 5724 | 20.138 | 121.829 | 2.153 | 6.142 | 95.284 | 38.704 |
| **183** | 5797 | 30.29 | 170.964 | 2.49 | 5.046 | 74.965 | 49.847 |
| **184** | 5856 | 40.795 | 307.509 | 2.597 | 9.522 | 63.328 | 47.024 |
| **185** | 5896 | 18.993 | 87.252 | 1.438 | 5.827 | 39.076 | 36.292 |
| **186** | 5903 | 24.322 | 113.371 | 2.207 | 7.346 | 62.815 | 47.503 |
| **187** | 5904 | 21.427 | 123.098 | 2.054 | 7.274 | 70.569 | 44.205 |
| **188** | 5910 | 18.493 | 103.345 | 3.518 | 4.965 | 41.481 | 45.075 |
| **189** | 5968 | 17.383 | 97.327 | 0.932 | 5.862 | 48.447 | 40.553 |
| **190** | 5991 | 17.034 | 73.785 | 1.493 | 5.553 | 41.16 | 29.896 |
| **191** | 6033 | 18.927 | 95.238 | 2.872 | 6.542 | 54.166 | 42.899 |

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| **192** | 6054 | 15.042 | 54.829 | 2.172 | 4.633 | 28.929 | 38.065 |
| **193** | 6164 | 23.177 | 117.555 | 1.363 | 5.141 | 36.463 | 30.057 |
| **194** | 6190 | 27.206 | 118.834 | 1.486 | 5.351 | 49.806 | 46.81 |
| **195** | 6225 | 76.375 | 281.612 | 2.41 | 7.66 | 142.452 | 50.886 |
| **196** | 6269 | 44.001 | 161.382 | 2.481 | 5.48 | 88.78 | 48.11 |
| **197** | 6280 | 39.352 | 136.697 | 2.951 | 5.297 | 73.63 | 37.278 |
| **198** | 6281 | 49.408 | 341.551 | 2.092 | 5.603 | 82.916 | 56.081 |
| **199** | 6313 | 27.653 | 115.046 | 1.369 | 6.248 | 57.628 | 36.793 |
| **200** | 6317 | 41.331 | 157.407 | 2.454 | 7.228 | 126.336 | 38.407 |
| **201** | 6334 | 41.017 | 179.574 | 2.718 | 8.439 | 84.486 | 44.93 |
| **202** | 6370 | 34.032 | 175.341 | 0.995 | 6.226 | 54.836 | 40.264 |
| **203** | 6435 | 26.421 | 163.644 | 1.316 | 7.462 | 51.04 | 42.924 |
| **204** | 6499 | 23.656 | 178.414 | 3.651 | 4.495 | 47.474 | 39.787 |
| **205** | 6522 | 22.917 | 140.349 | 3.845 | 5.862 | 36.895 | 36.048 |
| **206** | 6556 | 25.396 | 109.165 | 1.275 | 4.733 | 34.946 | 43.501 |
| **207** | 6558 | 35.777 | 201.037 | 1.553 | 4.434 | 29.229 | 31.377 |
| **208** | 6581 | 39.053 | 213.987 | 0.678 | 6.821 | 139.709 | 42.586 |
| **209** | 6596 | 38.238 | 159.778 | 2.812 | 5.909 | 60.215 | 74.343 |
| **210** | 6698 | 53.375 | 306.687 | 1.704 | 7.845 | 79.345 | 46.445 |
| **211** | 6706 | 25.605 | 143.525 | 1.081 | 13.416 | 69.228 | 40.974 |
| **212** | 6716 | 13.566 | 69.416 | 1.431 | 5.825 | 39.186 | 38.817 |
| **213** | 6759 | 27.915 | 156.482 | 2.354 | 4.692 | 47.355 | 39.257 |
| **214** | 6773 | 30.086 | 105.565 | 1.53 | 5.464 | 34.466 | 35.922 |
| **215** | 6813 | 29.735 | 152.717 | 0.648 | 7.619 | 58.844 | 37.219 |
| **216** | 6849 | 22.148 | 128.856 | 2.302 | 5.139 | 35.536 | 38.422 |
| **217** | 6856 | 29.395 | 129.946 | 2.062 | 5.665 | 43.056 | 36.875 |
| **218** | 6877 | 21.128 | 63.296 | 2.443 | 6.263 | 28.885 | 41.123 |
| **219** | 6882 | 34.71 | 115.067 | 1.689 | 5.974 | 26.793 | 37.497 |
| **220** | 6920 | 36.173 | 85.578 | 1.45 | 3.405 | 40.249 | 36.172 |
| **221** | 6923 | 20.647 | 79.176 | 2.507 | 7.088 | 28.396 | 30.019 |
| **222** | 6949 | 17.81 | 74.389 | 1.41 | 7.069 | 78.213 | 31.464 |
| **223** | 7001 | 25.202 | 144.082 | 2.197 | 5.391 | 27.847 | 40.835 |
| **224** | 7150 | 34.891 | 218.529 | 0.25 | 5.876 | 77.613 | 51.912 |
| **225** | 7158 | 23.747 | 142.185 | 1.31 | 6.288 | 95.432 | 51.774 |
| **226** | 7174 | 17.373 | 291.762 | 1.949 | 4.815 | 40.156 | 26.019 |
| **227** | 7235 | 28.716 | 174.705 | 1.546 | 5.149 | 40.584 | 36.469 |
| **228** | 7242 | 39.807 | 150.437 | 5.273 | 6.101 | 41.028 | 51.528 |
| **229** | 7244 | 28.262 | 125.095 | 0.855 | 5.87 | 43.851 | 30.759 |
| **230** | 7258 | 15.191 | 52.467 | 0.936 | 5.383 | 82.886 | 44.911 |
| **231** | 7271 | 31.156 | 155.884 | 0.471 | 5.883 | 96.303 | 59.938 |

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| **232** | 7336 | 20.294 | 102.811 | 1.488 | 5.821 | 36.547 | 35.416 |
| **233** | 7480 | 13.057 | 57.07 | 0.949 | 3.328 | 22.268 | 32.567 |
| **234** | 7503 | 24.279 | 173.487 | 3.509 | 5.445 | 40.728 | 28.411 |
| **235** | 7508 | 30.503 | 414.05 | 3.056 | 5.17 | 40.743 | 40.039 |
| **236** | 7514 | 12.809 | 53.555 | 1.259 | 6.188 | 18.103 | 30.598 |
| **237** | 7519 | 17.975 | 68.94 | 2.966 | 5.256 | 38.142 | 42.242 |
| **238** | 7542 | 20.776 | 107.046 | 1.672 | 4.393 | 27.403 | 49.209 |
| **239** | 7568 | 20.583 | 161.845 | 1.677 | 6.394 | 34.963 | 23.752 |
| **240** | 7581 | 12.089 | 42.448 | 1.374 | 6.83 | 20.036 | 26.881 |
| **241** | 7665 | 30.853 | 158.586 | 1.244 | 4.983 | 44.363 | 42.266 |
| **242** | 7717 | 18.976 | 96.805 | 1.533 | 2.968 | 31.308 | 27.442 |
| **243** | 7764 | 16.65 | 66.906 | 4.032 | 5.67 | 28.22 | 30.018 |
| **244** | 7820 | 12.246 | 97.273 | 1.98 | 4.931 | 22.601 | 19.827 |
| **245** | 7830 | 13.6 | 53.3 | 1.536 | 6.311 | 21.091 | 20.924 |
| **246** | 7842 | 20.504 | 66.766 | 0.81 | 6.529 | 29.369 | 33.84 |
| **247** | 7915 | 16.286 | 49.693 | 0.686 | 5.422 | 22.499 | 24.341 |
| **248** | 7939 | 12.528 | 48.37 | 1.608 | 6.249 | 23.036 | 18.765 |
| **249** | 8005 | 14.231 | 59.04 | 0.973 | 7.718 | 26.921 | 17.882 |
| **250** | 8078 | 17.42 | 86.32 | 2.01 | 5.79 | 31.216 | 32.104 |
| **251** | 8089 | 13.313 | 58.409 | 0.52 | 5.574 | 73.509 | 25.938 |
| **252** | 8102 | 12.825 | 47.014 | 2.511 | 5.629 | 23.561 | 32.603 |
| **253** | 8123 | 7.986 | 26.784 | 1.011 | 3.247 | 17.084 | 45.538 |
| **254** | 8127 | 11.312 | 37.613 | 1.853 | 5.74 | 15.589 | 22.597 |
| **255** | 8166 | 13.672 | 43.628 | 2.658 | 5.107 | 17.474 | 31.572 |
| **256** | 8168 | 13.687 | 43.56 | 2.227 | 4.635 | 17.417 | 26.161 |
| **257** | 8170 | 10.399 | 32.641 | 0.832 | 4.6 | 14.614 | 36.368 |
| **258** | 8179 | 8.311 | 26.203 | 0.033 | 5.747 | 14.561 | 15.964 |
| **259** | 8180 | 17.837 | 65.743 | 1.692 | 5.371 | 43.718 | 27.374 |
| **260** | 8190 | 14.127 | 43.354 | 2.798 | 4.978 | 21.134 | 29.304 |
| **261** | 8191 | 8.092 | 25.083 | 3.093 | 6.763 | 15.386 | 19.798 |
| **262** | 8217 | 22.201 | 41.051 | 1.947 | 5.606 | 17.137 | 19.489 |
| **263** | 8247 | 13.976 | 61.1 | 1.936 | 5.094 | 32.787 | 49.392 |
| **264** | 8253 | 12.815 | 57.714 | 1.901 | 3.543 | 22.829 | 48.48 |
| **265** | 8260 | 18.254 | 62.64 | 1.596 | 5.759 | 32.154 | 40.132 |
| **266** | 8272 | 20.931 | 119.529 | 1.478 | 5.524 | 81.635 | 37.923 |
| **267** | 8296 | 16.776 | 54.848 | 1.069 | 5.101 | 23.39 | 38.359 |
| **268** | 8310 | 22.707 | 136.979 | 0.734 | 5.6 | 47.819 | 37.088 |
| **269** | 8318 | 16.898 | 62.407 | 1.06 | 5.282 | 29.534 | 46.666 |
| **270** | 8343 | 9.782 | 34.322 | 1.128 | 5.06 | 18.308 | 31.13 |
| **271** | 8355 | 17.435 | 81.478 | 2.365 | 4.956 | 22.535 | 34.031 |

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| **272** | 8388 | 13.96 | 50.559 | 1.079 | 4.842 | 23.41 | 24.647 |
| **273** | 8434 | 13.201 | 55.065 | 1.575 | 7.055 | 31.324 | 21.351 |
| **274** | 8438 | 9.635 | 37.1 | 1.583 | 6.054 | 17.369 | 15.9 |
| **275** | 8448 | 15.312 | 36.507 | 1.972 | 6.547 | 17.181 | 12.779 |
| **276** | 8462 | 11.549 | 39.129 | 1.905 | 5.435 | 17.945 | 17.808 |
| **277** | 8465 | 10.725 | 34.208 | 1.841 | 5.301 | 29.19 | 13.565 |
| **278** | 8476 | 16.853 | 43.84 | 0.609 | 7.76 | 30.757 | 13.039 |
| **279** | 8526 | 12.138 | 32.32 | 0.867 | 6.918 | 45.735 | 33.66 |
| **280** | 8530 | 10.546 | 31.818 | 1.917 | 6.062 | 69.033 | 38.889 |
| **281** | 8546 | 14.636 | 57.265 | 1.221 | 5.275 | 17.599 | 35.439 |
| **282** | 8549 | 19.222 | 64.859 | 1.947 | 4.354 | 29.49 | 30.819 |
| **283** | 8628 | 24.671 | 96.643 | 1.783 | 5.835 | 30.159 | 45.404 |
| **284** | 8632 | 12.006 | 47.582 | 1.488 | 4.96 | 29.016 | 34.452 |
| **285** | 8702 | 16.19 | 49.922 | 1.127 | 4.201 | 28.277 | 36.817 |
| **286** | 8705 | 14.422 | 77.062 | 1.51 | 3.457 | 23.072 | 51.349 |
| **287** | 8708 | 16.047 | 66.97 | 2.371 | 6.358 | 38.068 | 33.012 |
| **288** | 8798 | 17.919 | 49.234 | 1.002 | 6.182 | 20.791 | 52.556 |
| **289** | 8801 | 16.393 | 54.393 | 1.342 | 6.085 | 33.603 | 30.394 |
| **290** | 8826 | 10.785 | 65.343 | 3.199 | 7.224 | 20.141 | 27.055 |
| **291** | 8835 | 14.763 | 59.961 | 1.645 | 5.181 | 39.552 | 40.109 |
| **292** | 8851 | 24.008 | 66.418 | 1.145 | 5.775 | 35.863 | 40.308 |
| **293** | 8862 | 16.17 | 75.836 | 2.353 | 5.032 | 55.076 | 40.371 |
| **294** | 8870 | 14.303 | 50.062 | 0.94 | 5.165 | 37.039 | 40.873 |
| **295** | 8880 | 19.961 | 65.89 | 1.546 | 5.501 | 39.935 | 43.555 |
| **296** | 8896 | 13.935 | 42.822 | 0.682 | 4.728 | 21.17 | 35.432 |
| **297** | 8954 | 20.875 | 94.647 | 2.055 | 5.189 | 259.404 | 37.739 |
| **298** | 8972 | 15.831 | 68.261 | 1.187 | 4.495 | 33.71 | 38.448 |
| **299** | 8997 | 12.773 | 33.532 | 1.943 | 6.641 | 19.186 | 28.484 |
| **300** | 9012 | 29.129 | 62.067 | 1.154 | 6.882 | 45.976 | 38.006 |
| **301** | 9052 | 13.726 | 48.633 | 1.188 | 5.206 | 20.481 | 40.603 |
| **302** | 9062 | 547.209 | 415.767 | 2.894 | 9.184 | 96.332 | 46.742 |
| **303** | 9081 | 13.654 | 50.287 | 1.364 | 3.451 | 184.752 | 32.995 |
| **304** | 9086 | 15.953 | 57.849 | 3.089 | 3.729 | 38.712 | 26.883 |
| **305** | 9109 | 13.602 | 65.045 | 2.187 | 5.319 | 35.369 | 29.143 |
| **306** | 9117 | 21.447 | 110.184 | 2.003 | 3.782 | 40.498 | 35.829 |
| **307** | 9162 | 11.5 | 34.2 | 2.566 | 5.422 | 19.585 | 20.701 |
| **308** | 9163 | 26.112 | 174.684 | 0.931 | 4.005 | 37.251 | 40.612 |
| **309** | 9188 | 17.596 | 54.252 | 2.018 | 6.975 | 25.163 | 37.132 |
| **310** | 9215 | 26.949 | 100.924 | 1.911 | 5.793 | 44.359 | 40.027 |
| **311** | 9222 | 16.185 | 69.442 | 2.297 | 5.596 | 34.225 | 27.004 |

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|---|---|---|---|---|---|---|---|
| **312** | 9243 | 24.496 | 68.197 | 2.986 | 5.782 | 31.951 | 33.018 |
| **313** | 9299 | 23.519 | 140.531 | 3.037 | 5.993 | 68.685 | 43.662 |
| **314** | 9307 | 29.405 | 222.481 | 4.101 | 5.993 | 52.869 | 43.562 |
| **315** | 9315 | 21.674 | 156.146 | 0.566 | 6.362 | 107.867 | 53.995 |
| **316** | 9334 | 15.06 | 88.949 | 0.765 | 5.26 | 43.95 | 36.691 |
| **317** | 9397 | 14.122 | 66.892 | 1.06 | 6.892 | 32.927 | 32.925 |
| **318** | 9415 | 60.678 | 133.93 | 2.394 | 6.025 | 62.508 | 57.6 |
| **319** | 9417 | 23.99 | 96.737 | 0.655 | 7.668 | 77.647 | 34.224 |
| **320** | 9423 | 24.281 | 126.193 | 1.067 | 7.605 | 48.662 | 34.567 |
| **321** | 9497 | 21.238 | 96.58 | 1.901 | 5.113 | 25.334 | 39.395 |
| **322** | 9504 | 16.275 | 131.094 | 1.757 | 7.464 | 29.194 | 39.436 |
| **323** | 9535 | 13.008 | 50.176 | 2.092 | 6.225 | 26.426 | 21.57 |
| **324** | 9564 | 21.706 | 127.55 | 2.287 | 5.042 | 43.452 | 39.523 |
| **325** | 9591 | 21.79 | 118.428 | 1.194 | 5.275 | 38.503 | 33.363 |
| **326** | 9603 | 18.858 | 68.113 | 2.39 | 5.741 | 29.449 | 33 |
| **327** | 9628 | 13.153 | 50.415 | 2.456 | 4.679 | 28.856 | 38.016 |
| **328** | 9631 | 29.1 | 145.38 | 2.474 | 3.59 | 28.972 | 43.834 |
| **329** | 9655 | 20.016 | 80.583 | 1.824 | 6.408 | 78.304 | 32.893 |
| **330** | 9659 | 16.658 | 78.2 | 1.515 | 4.002 | 20.946 | 30.389 |
| **331** | 9696 | 28.932 | 126.315 | 2.396 | 4.42 | 550.25 | 38.917 |
| **332** | 9705 | 34.14 | 73.592 | 1.078 | 6.192 | 44.701 | 30.84 |
| **333** | 9726 | 13.171 | 42.84 | 1.798 | 5.117 | 52.631 | 35.456 |
| **334** | 9780 | 13.325 | 41.992 | 1.53 | 4.218 | 23.9 | 44.276 |
| **335** | 9781 | 17.882 | 72.732 | 2.084 | 8.954 | 33.107 | 44.18 |
| **336** | 9798 | 256.743 | 175.945 | 6.197 | 28.71 | 277.987 | 31.071 |
| **337** | 9805 | 12.115 | 39.511 | 1.766 | 4.398 | 23.065 | 33.595 |
| **338** | 9827 | 23.565 | 48.113 | 1.24 | 4.674 | 26.126 | 24.628 |
| **339** | 9837 | 15.666 | 53.11 | 2.791 | 4.313 | 30.201 | 34.394 |
| **340** | 9854 | 18.105 | 55.001 | 1.261 | 5.206 | 30.549 | 25.281 |
| **341** | 9862 | 12.38 | 41.223 | 0.322 | 6.774 | 20.325 | 27.567 |
| **342** | 9898 | 15.592 | 66.408 | 1.709 | 6.242 | 34.054 | 23.923 |
| **343** | 9912 | 31.87 | 36.709 | 1.42 | 6.648 | 24.772 | 11.568 |
| **344** | 9941 | 29.334 | 55.577 | 1.479 | 5.738 | 20.193 | 40.126 |
| **345** | 9982 | 35.775 | 95.661 | 1.575 | 5.685 | 25.526 | 34.143 |
| **346** | 10008 | 17.424 | 57.177 | 2.016 | 5.712 | 29.31 | 31.051 |
| **347** | 10062 | 27.629 | 74.254 | 0.903 | 8.396 | 255.466 | 39.908 |
| **348** | 10063 | 16.095 | 40.201 | 1.775 | 3.227 | 18.534 | 37.238 |
| **349** | 10074 | 25.716 | 51.282 | 1.29 | 5.528 | 20.878 | 42.712 |
| **350** | 10086 | 16.132 | 69.201 | 1.311 | 7.225 | 58.911 | 45.704 |
| **351** | 10089 | 16.452 | 48.898 | 2.086 | 4.064 | 22.706 | 37.261 |

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|---|---|---|---|---|---|---|---|
| **352** | 10108 | 15.59 | 70.111 | 1.13 | 5.372 | 27.885 | 25.147 |
| **353** | 10122 | 29.708 | 53.743 | 0.575 | 3.856 | 27.64 | 26.437 |
| **354** | 10169 | 12.711 | 43.808 | 2.201 | 5.038 | 22.066 | 20.644 |
| **355** | 10180 | 10.541 | 54.433 | 3.32 | 4.394 | 68.225 | 18.901 |
| **356** | 10186 | 10.671 | 50.134 | 2.567 | 6.111 | 54.327 | 20.912 |
| **357** | 10188 | 9.4 | 46.338 | 1.424 | 9.021 | 21.37 | 24.256 |
| **358** | 10220 | 12.509 | 46.431 | 1.119 | 6.465 | 26.061 | 15.106 |
| **359** | 10225 | 20.642 | 45.544 | 2.856 | 6.352 | 27.235 | 15.132 |
| **360** | 10299 | 11.173 | 41.515 | 1.001 | 6.085 | 29.727 | 20.97 |
| **361** | 10345 | 15.794 | 67.981 | 1.178 | 5.213 | 52.065 | 29.811 |
| **362** | 10419 | 15.582 | 65.752 | 1.212 | 6.542 | 63.822 | 28.179 |
| **363** | 10429 | 8.561 | 33.895 | 1.956 | 4.853 | 15.906 | 12.18 |
| **364** | 10448 | 11.174 | 49.884 | 1.877 | 4.321 | 22.863 | 25.313 |
| **365** | 10457 | 8.728 | 29.081 | 1.097 | 5.288 | 16.204 | 13.406 |
| **366** | 10476 | 12.112 | 45.612 | 1.408 | 5.014 | 32.404 | 24.518 |
| **367** | 10477 | 10.108 | 32.294 | 2.25 | 6.134 | 18.506 | 14.384 |
| **368** | 10509 | 14.541 | 65.099 | 1.323 | 6.558 | 18.788 | 18.179 |
| **369** | 10584 | 14.989 | 83.804 | 2.175 | 5.501 | 42.181 | 27.417 |
| **370** | 10592 | 12.481 | 37.72 | 2.454 | 5.267 | 20.464 | 13.347 |
| **371** | 10595 | 19.024 | 114.786 | 2.624 | 5.948 | 29.898 | 32.677 |
| **372** | 10647 | 12.167 | 37.281 | 0.735 | 5.381 | 21.011 | 16.421 |
| **373** | 10693 | 26.634 | 112.147 | 1.062 | 5.758 | 36.275 | 32.188 |
| **374** | 10701 | 14.57 | 40.182 | 1.946 | 8.6 | 22.621 | 16.603 |
| **375** | 10723 | 18.017 | 76.677 | 1.816 | 5.183 | 82.991 | 38.995 |
| **376** | 10744 | 22.514 | 103.286 | 3.329 | 4.891 | 28.786 | 34.199 |
| **377** | 10760 | 12.523 | 58.119 | 0.95 | 5.121 | 25.373 | 22.368 |
| **378** | 10768 | 13.353 | 47.361 | 1.523 | 5.598 | 27.406 | 17.193 |
| **379** | 10781 | 18.966 | 74.559 | 0.87 | 5.417 | 100.386 | 24.347 |
| **380** | 10788 | 98.782 | 151.782 | 3.228 | 7.834 | 38.476 | 25.843 |
| **381** | 10805 | 23.857 | 97.412 | 1.133 | 6.398 | 34.787 | 29.292 |
| **382** | 10821 | 15.08 | 41.89 | 2.428 | 5.758 | 20.198 | 15.753 |
| **383** | 10832 | 11.632 | 29.508 | 1.248 | 6.361 | 17.87 | 9.92 |
| **384** | 10840 | 10.971 | 33.35 | 2.548 | 7.08 | 16.919 | 14.36 |
| **385** | 10864 | 12.285 | 31.988 | 2.107 | 4.224 | 46.564 | 15.921 |
| **386** | 10869 | 10.045 | 49.813 | 1.017 | 5.394 | 22.834 | 19.059 |
| **387** | 10882 | 11.96 | 38.53 | 1.353 | 4.408 | 16.204 | 15.745 |
| **388** | 10884 | 19.35 | 34.399 | 1.219 | 5.568 | 17.394 | 17.998 |
| **389** | 10899 | 10.996 | 48.505 | 1.401 | 5.04 | 17.647 | 13.697 |
| **390** | 10905 | 12.975 | 36.417 | 1.185 | 6.856 | 16.778 | 11.254 |
| **391** | 10974 | 11.206 | 33.98 | 2.303 | 6.023 | 16.629 | 23.269 |

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| **392** | 10999 | 12.998 | 49.897 | 2.395 | 4.747 | 33.941 | 23.847 |
| **393** | 11050 | 9.77 | 39.89 | 2.594 | 5.872 | 21.515 | 7.889 |
| **394** | 11063 | 18.659 | 41.258 | 1.475 | 5.644 | 28.823 | 15.563 |
| **395** | 11081 | 9.46 | 31.172 | 1.701 | 5.452 | 19.205 | 8.227 |
| **396** | 11088 | 8.88 | 32.42 | 3.113 | 5.759 | 19.93 | 16.351 |
| **397** | 11100 | 10.283 | 43.14 | 1.925 | 5.589 | 35.606 | 22.049 |
| **398** | 11122 | 9.111 | 35.408 | 1.356 | 5.388 | 18.398 | 10.758 |
| **399** | 11127 | 9.692 | 57.896 | 2.204 | 5.67 | 19.725 | 12.849 |
| **400** | 11161 | 10.504 | 35.337 | 1.489 | 5.268 | 19.189 | 13.236 |
| **401** | 11178 | 12.09 | 47.711 | 3.261 | 9.424 | 21.884 | 22.031 |
| **402** | 11226 | 22.565 | 95.323 | 2.641 | 4.596 | 36.233 | 32.578 |
| **403** | 11247 | 10.401 | 32.65 | 1.67 | 5.302 | 15.32 | 10.997 |
| **404** | 11326 | 9.8 | 28.832 | 3.079 | 6.065 | 19.97 | 8.663 |
| **405** | 11330 | 8.804 | 21.681 | 2.699 | 5.802 | 15.313 | 9.698 |
| **406** | 11349 | 9.896 | 41.734 | 1.296 | 4.945 | 19.882 | 16.522 |
| **407** | 11374 | 16.401 | 38.471 | 1.375 | 6.484 | 18.585 | 22.176 |
| **408** | 11400 | 8.643 | 101.018 | 0.738 | 6.25 | 25.082 | 16.531 |
| **409** | 11419 | 15.454 | 37.84 | 1.207 | 6.677 | 23.743 | 18.098 |
| **410** | 11447 | 10.017 | 35.095 | 2.376 | 4.242 | 20.758 | 20.169 |
| **411** | 11452 | 10.689 | 28.82 | 1.534 | 6.283 | 18.599 | 3.712 |
| **412** | 11489 | 17.719 | 130.609 | 1.718 | 5.839 | 29.221 | 34.305 |
| **413** | 11492 | 9.075 | 41.817 | 0.423 | 4.913 | 19.503 | 25.302 |
| **414** | 11507 | 16.712 | 89.097 | 1.046 | 5.711 | 23.796 | 31.887 |
| **415** | 11511 | 13.976 | 110.462 | 1.317 | 3.178 | 22.458 | 34.437 |
| **416** | 11531 | 10.428 | 30.803 | 1.41 | 5.092 | 16.665 | 14.979 |
| **417** | 11599 | 12.153 | 30.686 | 2.133 | 4.864 | 20.985 | 12.227 |
| **418** | 11605 | 14.551 | 102.56 | 2.94 | 5.099 | 31.642 | 39.056 |
| **419** | 11620 | 9.896 | 39.749 | 2.006 | 5.97 | 21.301 | 6.676 |
| **420** | 11639 | 35.572 | 83.072 | 2.059 | 4.207 | 26.02 | 39.156 |
| **421** | 11662 | 19.564 | 108.495 | 1.782 | 4.89 | 34.15 | 36.159 |
| **422** | 11710 | 13.309 | 57.864 | 2.291 | 5.5 | 39.569 | 41.588 |
| **423** | 11736 | 17.821 | 71.604 | 1.619 | 5.143 | 61.262 | 45.553 |
| **424** | 11754 | 14.564 | 70.926 | 1.545 | 5.264 | 58.308 | 51.218 |
| **425** | 11768 | 15.653 | 64.458 | 2.025 | 4.408 | 32.653 | 39.467 |
| **426** | 11816 | 11.102 | 42.14 | 1.797 | 6.708 | 18.673 | 18.359 |
| **427** | 11866 | 7.331 | 27.506 | 3.946 | 7.925 | 14.42 | 10.385 |
| **428** | 11874 | 10.815 | 36.32 | 2.314 | 4.801 | 21.345 | 9.994 |
| **429** | 11882 | 16.595 | 45.731 | 0.769 | 5.899 | 23.533 | 14.271 |
| **430** | 11885 | 9.396 | 27.2 | 2.013 | 5.065 | 16.69 | 12.153 |
| **431** | 11916 | 10.085 | 35.44 | 2.603 | 6.534 | 20.565 | 25.706 |

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|---|---|---|---|---|---|---|---|
| **432** | 11935 | 13.713 | 62.389 | 1.507 | 5.141 | 22.908 | 28.415 |
| **433** | 11943 | 11.03 | 47.756 | 1.801 | 7.447 | 18.582 | 26.695 |
| **434** | 11965 | 14.974 | 58.377 | 2.027 | 6.598 | 28.756 | 29.464 |
| **435** | 11998 | 13.204 | 77.224 | 1.923 | 6.851 | 22.075 | 23.261 |
| **436** | 12022 | 9.78 | 52.789 | 2.125 | 6.097 | 24.536 | 27.881 |
| **437** | 12085 | 11.761 | 50.147 | 1.988 | 5.969 | 28.956 | 32.453 |
| **438** | 12097 | 12.864 | 54.408 | 1.357 | 5.245 | 24.224 | 32.136 |
| **439** | 12112 | 11.982 | 41.286 | 1.862 | 4.431 | 18.426 | 24.072 |
| **440** | 12144 | 14.726 | 57.436 | 1.366 | 5.141 | 53.384 | 35.89 |
| **441** | 12149 | 11.671 | 47.794 | 1.41 | 6.112 | 29.197 | 29.509 |
| **442** | 12241 | 10.489 | 41.85 | 1.633 | 5.361 | 34.678 | 25.699 |
| **443** | 12243 | 9.823 | 34.063 | 1.94 | 5.691 | 18.112 | 15.002 |
| **444** | 12245 | 13.58 | 79.701 | 1.394 | 3.399 | 35.157 | 30.504 |
| **445** | 12250 | 12.742 | 45.244 | 1.26 | 6.685 | 18.702 | 19.333 |
| **46** | 12256 | 41.554 | 87.262 | 3.097 | 7.606 | 51.628 | 29.902 |
| **447** | 12322 | 11.166 | 41.507 | 1.15 | 6.738 | 20.465 | 18.73 |
| **448** | 12326 | 10.906 | 44.004 | 0.883 | 4.938 | 23.221 | 23.233 |
| **449** | 12370 | 10.696 | 44.1 | 2.074 | 5.514 | 14.643 | 20.501 |
| **450** | 12381 | 9.231 | 35.706 | 0.434 | 5.681 | 16.308 | 18.792 |
| **451** | 12382 | 9.78 | 40.22 | 1.891 | 2.619 | 15.172 | 17.502 |
| **452** | 12392 | 14.154 | 38.904 | 0.905 | 4.615 | 24.172 | 25.002 |
| **453** | 12441 | 13.797 | 43.447 | 3.794 | 4.957 | 22.295 | 22.244 |
| **454** | 12447 | 17.781 | 81.17 | 1.415 | 4.818 | 25.862 | 27.352 |
| **455** | 12451 | 11.331 | 36.368 | 1.67 | 5.586 | 20.342 | 13.829 |
| **456** | 12481 | 11.034 | 51.312 | 2.059 | 5.366 | 23.428 | 16.459 |
| **457** | 12523 | 18.311 | 118.714 | 2.015 | 4.916 | 23.881 | 24.883 |
| **458** | 12531 | 19.13 | 85.181 | 1.626 | 5.664 | 24.447 | 16.122 |
| **459** | 12556 | 11.721 | 63.347 | 1.359 | 7.759 | 23.561 | 14.556 |
| **460** | 12587 | 8.649 | 40.486 | 2.189 | 7.721 | 20.931 | 11.592 |
| **461** | 12671 | 8.394 | 28.298 | 0.92 | 6.807 | 15.105 | 5.412 |
| **462** | 12711 | 13.731 | 63.401 | 2.727 | 6.32 | 23.983 | 27.699 |
| **463** | 12753 | 12.471 | 40.489 | 2.305 | 5.81 | 18.512 | 20.532 |
| **464** | 12779 | 12.73 | 92.06 | 0.936 | 6.517 | 32.815 | 34.154 |
| **465** | 12787 | 11.126 | 52.229 | 0.816 | 5.126 | 23.65 | 19.434 |
| **466** | 12810 | 10.456 | 34.403 | 2.132 | 5.269 | 16.732 | 12.053 |
| **467** | 12818 | 13.807 | 88.562 | 1.488 | 5.728 | 30.554 | 27.798 |
| **468** | 12821 | 11.918 | 52.837 | 1.583 | 4.165 | 19.069 | 21.9 |
| **469** | 12849 | 13.144 | 42.23 | 0.795 | 6.486 | 18.641 | 18.779 |
| **470** | 12856 | 14.469 | 76.468 | 2.734 | 5.967 | 21.883 | 27.268 |
| **471** | 12862 | 16.425 | 92.522 | 2.192 | 4.363 | 21.712 | 30.818 |

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| **472** | 12870 | 14.618 | 28.354 | 1.511 | 6.271 | 21.125 | 9.026 |
| **473** | 12881 | 11.272 | 35.341 | 0.977 | 6.126 | 18.911 | 7.209 |
| **474** | 12896 | 10.026 | 27.452 | 1.071 | 4.573 | 16.926 | 16.391 |
| **475** | 12922 | 7.562 | 28.239 | 2.202 | 5.892 | 16.423 | 4.937 |
| **476** | 12945 | 13.731 | 46.909 | 1.605 | 5.149 | 21.537 | 19.402 |
| **477** | 12967 | 8.76 | 27.481 | 1.454 | 6.649 | 14.015 | 16.065 |
| **478** | 12981 | 9.946 | 40.899 | 3.285 | 4.253 | 20.613 | 10.072 |
| **479** | 13019 | 10.321 | 29.125 | 1.568 | 5.293 | 15.047 | 9.822 |
| **480** | 13054 | 8.151 | 22.347 | 2.129 | 6.398 | 15.225 | 7.644 |
| **481** | 13070 | 9.977 | 33.928 | 2.406 | 7.327 | 13.576 | 15.396 |
| **482** | 13078 | 11.342 | 40.075 | 1.286 | 6.902 | 27.335 | 18.962 |
| **483** | 13081 | 12.003 | 34.418 | 1.566 | 4.797 | 21.617 | 16.629 |
| **484** | 13085 | 11.573 | 47.802 | 2.379 | 4.927 | 24.749 | 25.453 |
| **485** | 13086 | 11.512 | 54.116 | 1.801 | 6.397 | 18.778 | 14.142 |
| **486** | 13094 | 21.18 | 40.506 | 4.021 | 3.635 | 17.287 | 22.49 |
| **487** | 13124 | 18.293 | 30.981 | 3.672 | 12.075 | 17.699 | 6.031 |
| **488** | 13145 | 9.003 | 24.851 | 3.798 | 5.363 | 15.823 | 9.747 |
| **489** | 13179 | 8.629 | 22.851 | 1.9 | 6.524 | 15.111 | 8.139 |
| **490** | 13183 | 8.262 | 22.134 | 0.297 | 4.026 | 14.373 | 7.407 |
| **491** | 13252 | 10.16 | 36.002 | 3.603 | 6.081 | 18.186 | 14.971 |
| **492** | 13294 | 7.407 | 31.857 | 2.818 | 5.76 | 12.57 | 6.01 |
| **493** | 13301 | 9.748 | 24.633 | 2.647 | 6.421 | 19.847 | 1.729 |
| **494** | 13307 | 9.509 | 23.907 | 0.789 | 5.318 | 14.327 | 3.805 |
| **495** | 13323 | 6.269 | 23.636 | 2.156 | 4.463 | 13.446 | 6.202 |
| **496** | 13336 | 7.574 | 24.394 | 3.041 | 6.342 | 15.468 | 4.291 |
| **497** | 13371 | 8.428 | 26.821 | 2.33 | 5.313 | 21.129 | 6.523 |
| **498** | 13379 | 9.365 | 28.576 | 0.563 | 6.395 | 17.596 | 12.066 |
| **499** | 13489 | 9.159 | 24.49 | 2.612 | 4.489 | 16.742 | 9.413 |
| **500** | 13499 | 7.752 | 21.455 | 2.166 | 6.543 | 14.474 | 7.055 |
| **501** | 13653 | 7.344 | 20.64 | 2.099 | 5.811 | 14.711 | 4.226 |
| | | | | | | | |

# Vita

Samia Grimida was born in Tripoli, Libya. She obtained a Bachelors degree of Metrology from University of Tripoli (formally Alfateh University) in 1996. She worked in Libyan Environment General Authority from 1996 to 2008. During this period of her career, she has served several positions and tasks of supervisory and leaderships: head of Technical corporation

In, 2008, she gained her master's degree in Geography from university of Tripoli, her thesis was entitled- Sustainable Environmental indicators in western coastal part of Libya.

Grimida moved to the United States in October, 2008, and in 2010, she admitted to the doctoral program in the Environmental Science and Engineering at The University of Texas at El Paso. Grimida received The UTEP 21$^{th}$ Century Scholar 2013

While at UTEP Grimida worked as a research associate for UTEP Facility department and teaching assistant for the department of ESE.

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