

**Republic of Iraq
Ministry of Higher Education &
Scientific Research
University of Al-Qadisiyah
College of Sciences
Department of Ecology**



Investigation of some heavy metals concentration in deposited of dust of Al_Samawa streets

Thesis

**Submitted to the council of College of Sciences/University of Al-Qadisiyah -
Department of Ecology as a Partial Fulfilment of the Requirements for
obtaining a Master degree in Ecology .**

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1445 A.H

2024 A.D

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

(وَمَنْ يَتَّقِ اللَّهَ يَجْعَلْ لَهُ مَخْرَجًا * وَيَرْزُقْهُ مِنْ
حَيْثُ لَا يَحْتَسِبُ وَمَنْ يَتَوَكَّلْ عَلَى اللَّهِ فَهُوَ
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شَيْءٍ قَدْرًا*)

صَدَقَ اللَّهُ الْعَظِيمُ

{الطلاق ٢- ٣}

Dedications

I dedicates my message..

My parents.. Mom and Dad, you were the first and last source of affection and support. With every word of gratitude, I thank you both for your unlimited patience and constant encouragement. Every sacrifice and every financial support has been a beacon that lights my way.

Dear husband .. Who has been the blessing of support in my scientific and research journey and has spared no effort in helping me.

My sister .. My dear, my only sister I am truly thankful for having you in my life.

My boys..Abbas and Zain.

Zainab

Acknowledgment

I thank Allah immensely for granting me success and helping me to complete my academic thesis.

I also extend my deepest thanks and gratitude to **Prof Dr. Safaa A. khadum** who kindly agreed to supervise my master's thesis, and who gave me his valuable time and his wealth of information and extensive experience, which constituted a great addition to the research work, as his guidance and advice were the beacon that I used throughout my work Research, so I ask Allah Almighty to reward him with the best reward.

I am especially grateful to **Prof. Dr. Hazim Abed Wali**, the Chief, Environment Section for helping us.

My special thank and sense of gratitude to my family and husband.

ZAINAB MOHAMMED RAOOF
2024

Summary

This study investigates the ranges of metal concentration in dust samples collected from Samawa city streets. In this study, thirty samples (n=30) of roadway dust were collected over the months of June and July in the year 2023, by small brush and plastic bags.

To measure heavy metals lead (Pb), Cadmium(Cd), Chromium(Cr), Copper(Cu), Zinc(Zn) and Mercry(Hg) by Atomic Absorption Spectrophotometer, to compare the levels of heavy metals in Samawa city with global standard values , to measuring particulate matter to detecting the degree of pollution using an air quality measuring device, and measuring Spatial distribution of heavy metals in Samawa city by geographic Information System (GIS). In addition, principal components analysis (PCA) has been drastically utilized to examine the foundation of heavy metals in road dust in order to discover the origins of pollutants in Samawa city via measuring ten streets locations included Al-Jamea, Al-Haidariya, Al-Qishla, Al-Nafut, Al-Mukafaha, Al-Dhubat, Al-Hussien, Al-Sader, Al-Fanadiq and Al-Corniche.

A set of pollution indices were used to evaluate pollution: 1) Geo accumulation index (Igeo), 2) Contamination factor (CF), 3) Pollution load index (PLI), 4) Ecological Risk Factor (Er).

The results of the metal levels within the tested streets decline in the following order: zinc (Z)> lead (Pb)> Copper (Cu)> Chromium (Cr)> Cadmium (Cd)> Mercury (Hg). The concentrations of the metals tested in Samawa street dust are generally lower than their background values (Hong Kong ISQV- low and high), except for Cd which exceeds the Hong Kong ISQV- low. It is important to pay attention to the increasing levels of Cd in the streets.

The Pearson's correlation evaluation changed into utilized to ascertain the affiliation among heavy metals found in dust and the quality of air inside the

streets. Lead (Pb) had a sturdy high-quality correlation with each Copper (Cu) and Zinc (Zn). Additionally, Copper (Cu) suggests a large fine affiliation with Zinc (Zn). Furthermore, Zinc (Zn) had a strong positive correlation with Mercury (Hg), suggesting that both pollutants originate from the same sources of pollution. Copper (Cu) demonstrates a positive correlation with (PM_{2.5}, PM₁₀, and PM_{1.0}). that these particles have the potential to negatively impact respiratory health. Lead (Pb) demonstrates a significant association with PM_{2.5} ($r=0.476$) and a weaker positive correlation ($r=0.429$) with PM₁₀. The concentration of particulate matter (PM_{1.0}, PM_{2.5}, and PM₁₀) in the dust on the streets of Samawa exceeds the limits set by the World Health Organization (WHO).

The Principal components analysis (PCA) results showed The strong positive relationship between (CO₂, PM₁₀ and PM_{2.5}) (0.667), three components, which accounted for 69.28% of the total variation, were identified, suggesting that the sources of heavy metals might be classified into three primary. The initial component consists of PM_{2.5}, PM_{1.0}, PM₁₀, and CO₂. The second component consists of lead (Pb), copper (Cu) and zinc (Zn), indicating that lead (Pb), copper (Cu) and zinc (Zn) found in dust. The third component consists of chromium (Cr) and mercury (Hg).

The levels of street dust pollution with heavy metals were expressed using pollution indices. The findings of the heavy metal geo accumulation index (I_{geo}) in the research region based on Muller's (1979) classification, showed that the areas of Samawah city ranged from uncontaminated to moderately contaminated in the order of Cu > Pb > Hg > Zn > Cr > Cd .The CF values showed that there was a lot of contamination for cd and Pb, and the Al-Fanadiq area had the highest pollution load index (PLI) number. The mean of Ecological risk factor (Er) the index showed that all stations were slightly polluted, except for the element Cadmium (Cd).

The heat map group in the Al-Fanadiq area of cluster 1, it was found that there is an abundance of zinc compared to the other elements. Heat map cluster of high concentration of CO₂ in cluster 1 in Al-Jamea and al-Mukafaha, high concentration of PM_{2.5} in cluster 1, the high concentration of PM_{1.0} in Al-Haidariya in cluster 1 and the high concentration of PM₁₀ in Al-Haidariya area. Geographical distribution of heavy metals in the street dust of Samawa City, high concentrations of Cadmium (Cd) had elevated levels of dust and metal in the streets, particularly in the area (Al-Fanadiq, Al-Hussein, Al-Haidariya, and Al-Sader) and (Al-Jamea) of the city. Zinc (Zn) distribution was most concentrated in Al-Fanadiq, Al-Corniche and Al-Qishla

The spatial distribution of Pb was quite extensive in the (Al-Fanadiq and Al-Corniche). Low levels of mercury (Hg) and copper (Cu) were primarily detected in the area, namely in Al-Mukafaha, Al-Dhubat, and Al-Nafut.

CO₂ levels are generally high in the southern and central parts of the streets of Samawa city. The positive relationship between CO₂ and PM₁₀ and PM_{2.5} (0.667) particles suggests that CO₂ can easily interact with these particles and be inhaled by people, which is bad for health, especially for people with asthma.

This study is crucial for preserving public health and human safety from diseases caused by street dust, and then it is possible to control it, and this study provides valuable insights for city officials to effectively tackle pollutants arising from street dust by implementing road rehabilitation measures that adhere to international standards.

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List of Abbreviation

Symbol	Description
Pb	Lead
Cd	Cadmium
Cr	Chromium
Cu	Copper
Zn	Zinc
Hg	Mercury
IDW	Inverse distance weighted
GIS	Geographic Information System
PM	Particulate matter
HM	Heavy metals
TMs	Toxic metals
CO₂	Carbon dioxide
PCA	Principal Components Analysis
Igeo	Geo accumulation index
CF	Contamination factor
PLI	Pollution load index
Er	Ecological risk factor
ICP-OES	Inductively coupled plasma optical emission spectrometry
WHO	Global Health Organization
APM	Airborne particulate matter
IARC	International Agency for Research on Cancer
BWh	Climate desert hot
KMO	Kaiser–Meyer–Olkin

CHAPTER ONE

INTRODUCTION

1.1 Introduction

One of the obstacles faced by human beings concerns to the introduction of heavy metals into their tissues through several pathways, including as inhalation of air, consumption of contaminated food, and absorption through the skin (Kamani et al. 2017). Heavy metals are well recognized as one of the most prevalent forms of environmental pollutants. The transportation of heavy metals through the atmosphere occurs in the form of gases or as particles that are either adsorbed on or absorbed in suspended particulate matter, as indicated by (Sella et al. 2004 and (Shah and Shaheen .2008). The ingestion of elevated amounts of specific heavy metals can result in substantial adverse health effects, including the development of cancer, in individuals. For example, the presence of increased levels of lead has been found to have detrimental effects on both the kidneys and the brain, potentially leading to miscarriage (Panne et al. 2001). Street dusts are particles that are derived from diverse sources on the surface of streets and subsequently gather in the vicinity of the street (Faiz et al. 2009; Hjortenkrans et al. 2006).

The sources of metals in street dust can be divided into natural sources and anthropogenic emissions. The natural sources of metals are the weathering and corrosion release of parent rock or soil. The anthropogenic emission of metals is more complex, mainly from industrial activities and vehicle-related emissions. The former includes raw metal materials used, the building industry, smelting, mechanical engineering, coal burning, pesticide industry, electroplating, and steel industry, and the latter involves fuel emissions, tires, brake pads, vehicle equipment, and asphalt wear (Duong and Lee, 2011; Lu et al. 2010; Shi et al. 2010). Moreover, waste combustion and construction and demolition operations are among the sources of metal pollution in street dust (Gunawardana et al. 2012; Saeedi et al. 2012).

The three major exposure routes of metals in street dust to humans are ingestion, inhalation, and dermal contact. Some metals are essential elements for humans, such as Lead (Pb), Cadmium (Cd), Chromium(Cr) Copper (Cu), Zinc (Zn), and Mercury (Hg). However, human exposure to high concentrations of metals, even essential metals, in the environment may cause adverse effects on the nervous system, cardiovascular system, kidney function, reproductive system, and endocrine system, including mental retardation, attention deficit, and behavioral abnormalities (Zheng et al. 2010; Ferreira-Baptista and De Miguel, 2005). In addition, the International Agency for Research on Cancer (IARC) also classified many metals , such as arsenic (As), cadmium (Cd), chromium (Cr), Ni, cobalt (Co),and lead (Pb)

The street dust or road dust is composed of minerals, microorganisms, and organic/inorganic substances in soil and atmospheric deposition particles (Shi et al. 2008; Ferreira-Baptista and De Miguel, 2005). Metals are discharged into the atmosphere and can be deposited into the ground through dry and wet deposition. As a result, they can quickly accumulate in street dust, especially in particular weather and road use condition.

Dust accumulation on the streets is a prevalent issue associated with air pollution, which originates from various anthropogenic and natural activity sources (Kadhum et al. 2020; Kamani et al. 2017). The urban center of Samawah has experienced an increase in automobile usage, leading to heightened pollution levels in certain localized regions of the city. This pollution originates from the emission of vehicular exhaust fumes, which intermingle with street dust, thereby contributing to air pollution and an augmented presence of heavy elements. Additionally, the city's geographical positioning, confined by the northwestern desert expanse, further exacerbates these environmental concerns. Hence, there is a compelling need to investigate

the presence of heavy metals inside the streets of Samawah City, given their significance in safeguarding the well-being of the indigenous populace and ensuring the long-term preservation and sustainability of the surrounding ecosystem.

Street dust serves as a reservoir for particle heavy metals, which accumulate on the surfaces of streets, sidewalks, and windows (Jaafar and Kadhum. 2023; Aguilera et al. 2021; Rahman et al. 2019). The transportation of heavy metals through the atmosphere occurs in the form of gases or as particles that are either adsorbed on or absorbed in suspended particulate matter, as indicated by (Sella et al.2004) and (Shah and Shaheen. 2008).

The presence of dust particles carrying heavy metals that are re-suspended in the atmosphere can significantly affect the quality of life and public health of individuals residing in close proximity (Jaafar and Kadhum et al. 2023; Ali et al.2017; Mohmand et al.2015). In addition, (Akoto et al. 2014) and (Saeedi et al. 2012) discovered that being exposed to these metals was linked to a higher likelihood of developing cardiovascular issues, reproductive disorders, and several types of cancer. Hence, it is imperative to investigate the levels of heavy metals and particles in the streets of Samawa due to their potential impact on human health. Fine airborne particles, in particular, may significantly contribute to the decline of public health.

Additionally, the prevailing wind direction played a crucial role in the transportation of these pollutants. However, only a few studies have specifically investigated the origins of particulate matter and heavy metals in the dust found on Iraqi streets. This study holds significance for urban decision-makers as it pertains to the management of toxins and the provision of timely and comprehensive alerts to the community members, both in the immediate and extended periods.

1.2 Aims of the study

1. Evaluate the concentration of particulate matter and heavy metals in the dust found on the streets of Samawa.
2. Determine the sources responsible for the pollution of heavy metals in the street dust.
3. Measure heavy metals in different streets of samawa city.
4. Assess human health risks in that location heavy metals the residants.
5. Spatial distribution of heavy metals in samawa cities by geographic Information System (GIS).
6. Compare the levels of heavy metals in samawa city with pollution indices.

CHAPTER TWO

LITERATURE REVIEW

2.1 Heavy metals:

Naturally occurring elements with high atomic weights and densities at least five times higher than water's are known as heavy metals. Their widespread distribution in the environment as a result of their numerous industrial, household, agricultural, medical, and technical applications has sparked worries about their possible consequences on the environment and public health. Their toxicity is dependent on a number of variables, including as the chemical species, dose, and mode of exposure, in addition to the age, gender, genetics, and nutritional state of those who are exposed. Cadmium, chromium, lead, and mercury are among the priority metals that are significant for public health because of their high levels of toxicity (Tchounwou et al. 2012).

Even at lower exposure levels, these metallic elements are known to cause numerous organ damage and are classified as systemic toxicants. Both the International Agency for Research on Cancer and the U.S. Environmental Protection Agency classify them as human carcinogens (known or probable). (Tchounwou et al. 2012).

While heavy metals are naturally occurring elements present in the earth's crust, most environmental contamination and human exposure are caused by human activities like metal mining and smelting, industrial production, and use of metals and metal-containing compounds in agriculture and domestic settings. (Yang et al. 2005) (Herawati et al. 2000). Because of their existence in trace amounts (ppb range to less than 10ppm) in a variety of environmental matrices, heavy metals are also regarded as trace elements (Kabata- Pendia et al. 2001). Recent rapid industrialization has had a considerable impact on the release of heavy metals into ecosystems (Fu & Wang. 2011). Metal processing, the battery business, paper manufacturing, the fabric and dyeing industry, electrolysis

procedures, and mining operations are a few examples of these manufacturing activities (Qasem et al. 2021).

Such metals are extremely dangerous elements even when present in low quantities due to their significant cancer-causing potential along with their accumulation capability (Nguyen et al. 2013; Zou et al. 2016; Agarwal & Singh. 2017). The reason behind accumulation within various organisms is mainly because of their not degradable feature (El-Sherif et al. 2013; Abbas et al. 2016; He et al. 2020).

These elements are considered priority metals of great public health significance due to their high degree of toxicity. based on experimental and epidemiological studies that demonstrate a link between exposure and cancer incidence in humans and animals. (Wang et al. 2001).

Large amounts of anthropogenic contaminants are introduced into the urban atmosphere by mobile sources (cars and transportation-related activities on the road), stationary sources (power plants, industries, incinerators, and residential heating), and natural surrounding sources (Bradl et al. 2005) (windblown dust, weathering of rocks and minerals, sea salt, volcanic eruptions, etc.). Particulate, liquid, and vapor phases are linked to these contaminants. Subsequently, they are deposited both wet and dry on the Earth's surface. Microbiological, organic, and/or inorganic contaminants can all be found in the air. Because of their toxicity and risk for cancer, inorganic heavy metals such copper, zinc, cadmium, lead, and chromium are among the contaminants that should be of particular concern (Tchounwou PB et al. 2012).

An extensive database containing the absolute concentrations of heavy metals in urban and industrial dust has been presented by earlier studies (Cheng et al. 2018; Men et al. 2018; Zgłobicki et al. 2018; Soltani et al. 2015).

However, the geochemical background—which is dependent on geological conditions—must be used in order to use absolute concentrations to determine the degree of pollution. Comparing environmental quality is more reliable when different geochemical indicators are applied and normalized to background values. (Chen et al.2019; Gope et al. 2018).

Generally speaking, the following indicators offer helpful details regarding the degree of contamination, depending on the calculation method used: (1) The index of geoaccumulation (Igeo) (Liu et al. 2016; Ghazaryan et al. 2015; Inengite et al. 2015; Karim et al. 2015; Chen et al. 2015b; Omotoso and Ojo 2015; Sayadi et al. 2015; Tang et al. 2015; Wang et al. 2015; Guan et al. 2014; Ololade 2014; Dung et al. 2013; Müller .1969) and contamination factor (CF) (Håkanson 1980; Inengite et al. 2015; Loska et al. 2004) as the pollution level each individual heavy metal causes, (2) the pollution load index (PLI), which measures the overall pollution of heavy metals (Tomlinson et al. 1980), (3) the enrichment factor (EF), which identifies the source of heavy metal contamination (natural or man-made) (Inengite et al. 2015; Karim et al. 2015; Mohamed et al. 2014), and (4) the potential ecological risk index (PERI), which indicates the cause of environmental harm (Pejman et al. 2015; Sayadi et al. 2015; Tang et al. 2015; Wang et al. 2015).

Several recent studies have been conducted to ascertain the levels of heavy metals and pollution in street dust in Iraq and outside the country. (Jassim et al. 2021) found that the emissions of exhaust gases from vehicles had a significant impact on the distribution of metal concentrations in Al-Rusafa streets, Baghdad, Iraq, in addition, the dispersion of metal concentrations in the streets of Diwaniyah City was influenced by vehicular emissions and the prevailing wind direction (Al-Dabbas et al. 2018). (Sadeghdoust et al. 2020) conducted a study in Dezful, Iran to examine the potential toxicity of certain metals in street dust. The researchers found that the hazard index (HI) for these metals was

higher in children compared to adults. This confirms that children face a greater risk of exposure to these potentially harmful heavy metals.

According to (Harb et al. 2015), the amounts of specific heavy metals observed in the streets and house dust of Al-Qunfudah governorate in Saudi Arabia do not provide any significant health risks to children and adults. (Zhao et al. 2014) discovered the presence of Co, Cr, Cu, Mn, Ni, Pb, V, and Zn in roadway dust particles smaller than 100 μm in Xining, China. (Jandacka et al. 2017) conducted a study to identify the sources of particulate matter near an urban road in Zilina, Slovakia.

Six heavy elements were studied in the research topic, namely Lead (Pb), Copper (Cu) Cadmium (Cd), Chromium(Cr), Zinc (Zn) and Mercury (Hg) and this is an overview of each element in terms of its presence in the street dust :

1-Lead (Pb)

Small amounts of lead, a naturally occurring bluish-gray metal, are found in the crust of the earth. While lead is a naturally occurring element in the environment, human activities like mining, burning fossil fuels, manufacturing and car emission release large amounts of the metal into the air. Numerous industrial, agricultural, and residential uses exist for lead, Figure (2.1) Various sources of lead pollution in the environment (Sharma & Dubey, 2005). These days, lead-acid batteries, ammo, metal goods (such as pipes and solder), and X-ray shielding devices are all made with it. In the United States, lead was utilized in various industrial applications for an estimated 1.52 million metric tons in 2004.

Of that amount, 83 percent went toward the production of lead-acid batteries, with the remaining amount going toward a variety of goods like sheet lead. (Gabby et al. 2006; Gabby et al .2003). All elements of our environment—air, soil, and water—contain lead and lead compounds as a result of human

activities. Lead in dirt and dust frequently recontaminates houses that have been cleaned (Lee et al. 2019), and it raises blood lead levels in kids who play in bare, contaminated dirt (CDC 2001).

street dust and chips from corroding lead paint on interior surfaces are the main causes of lead poisoning in children (Lanphear et al. 1998). Lead has the potential to impact all bodily systems and organs. Lead exposure can harm the kidneys and brain, which can lead to death (CHSR, 2009). Depending on the region in which he lives, the amount of lead in the air that the human body can absorb can vary from less than 4 mg per day to more than 200 mg per day (Loh et al. 2016).

Ingestion of lead-contaminated food, water, or paints, as well as inhalation of lead-contaminated dust particles or aerosols, are the main ways that lead exposure occurs (ATSDR 1999; ATSDR1992) Age and physiological state are two factors that affect lead absorption. The kidneys absorb the largest percentage of lead in the human body, followed by the liver and other soft tissues like the heart and brain; however, the majority of the lead in the body is found in the skeleton (Flora et al. 2006).

The most susceptible organ system to lead poisoning is the nervous system. A lead exposure's early symptoms on the central nervous system include headache, poor attention span, irritability, memory loss, and dullness (CDC 2001 ; ATSDR 1999.).

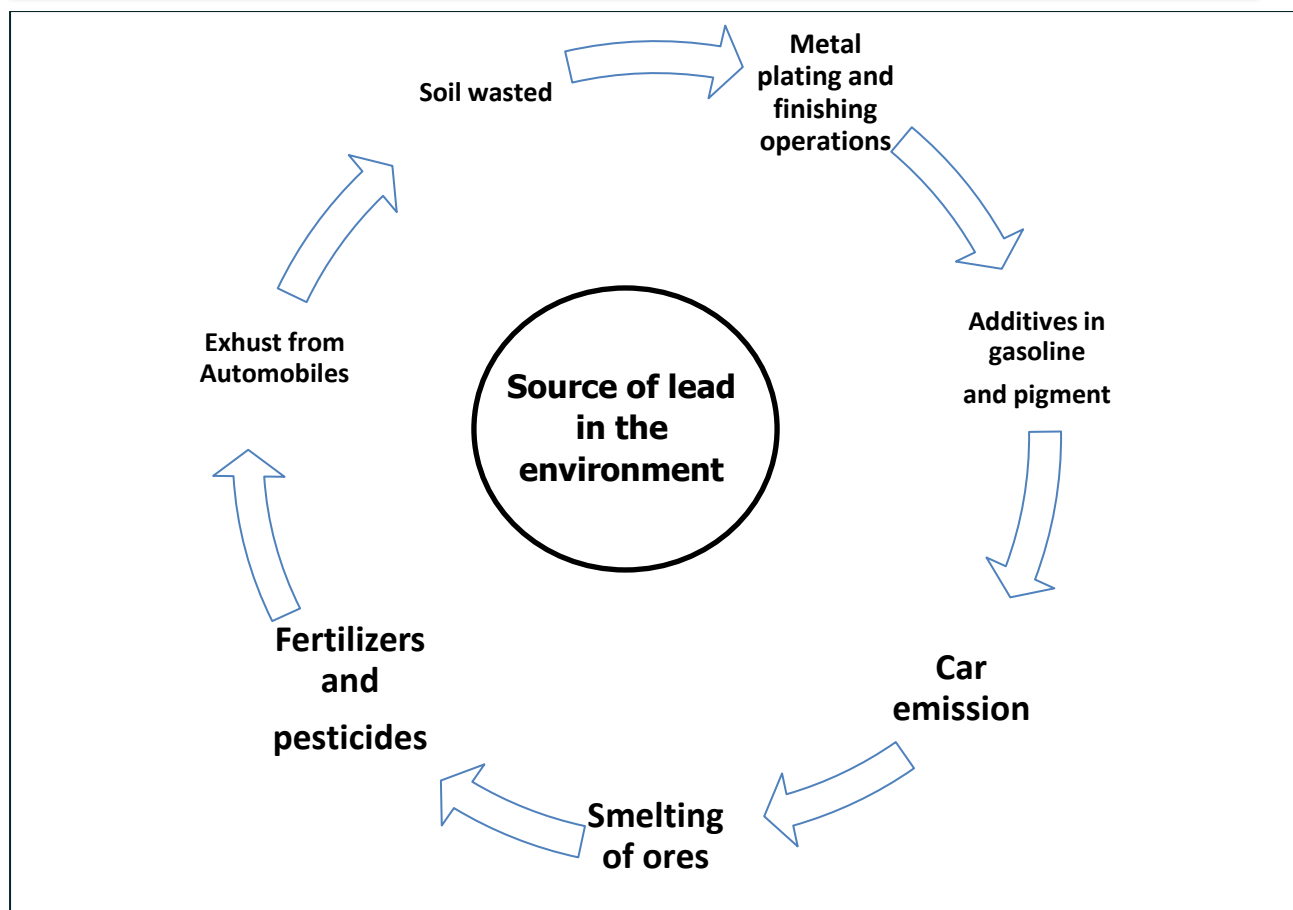


Figure 2.1 Various sources of lead pollution in the environment (Adapted from Sharma & Dubey, 2005).

2- Copper (Cu)

Copper is a light reddish-brown metallic element with the symbol “Cu” High levels of copper (Cu) can have a negative impact on human health as well as the growth of animals and plants (Bost et al. 2016 ; Khazaei et al. 2016) , due These substances, enter the body through the respiratory system, have the potential to bioaccumulate in humans (Kabata-Pendias and Pendias, 1999). As a result, the population may be at risk from this component. According to (Gaetle and Chow.2003), copper induces neuronal disorders and oxidative cell damage.. In recent years, copper pollution has become one of the main causes of concern for environmental health.

The main cause of copper pollution in the environment is copper mining and smelting .Sources of pollution in copper such as vehicle exhaust, coal

combustion, sintering, metal processing, machinery manufacturing, and iron and steel production (Vorobeichik & Kaigorodova, 2017). Health issues like anorexia, depression, anxiety, liver and kidney damage, headaches, and allergies are all exacerbated by copper toxicity (CHSR, 2009).

3- Chromium (Cr)

Chromium is present in rocks, soil, animals and plants. It can be solid, liquid, and in the form of gas. Chromium compounds are very much persistent in water sediments. Many industrial processes involve the extensive use of chromium, which contaminates a variety of environmental systems (Cohen et al .1993).

The primary route of exposure for non occupational human populations occurs via ingestion of chromium containing food and water or dermal contact with products containing chromium (Nickens et al. 2010). Furthermore, metallurgical, refractory, and chemical industries release a large amount of Cr into soil, ground water, and air which causes health issues in humans, animals, and marine life (Fang et al. 2014). 33 tons of total Cr are thought to be released into the environment each year (ATSDR1999) Environmental sources of chromium include Airborne emissions from chemical plants and incineration facilities, cement dust , road dust ,tobacco smoke.

Although in areas near Cr manufacturing, these levels may be exceeded. Significant human exposure to chromium has also been reported to occur through the skin, despite the fact that inhalation is the main method of exposure and the lung is the primary target organ(Costa et al. 1997; Shelnutt 2007). Human respiratory tract cancer, allergies, asthma, and renal damage are just a few of the multiorgan toxicity effects that have been linked to occupational and environmental exposure to compounds containing Cr (Goyer et al. 2001; WHO 1998).

4-Cadmium (Cd)

Cadmium is a heavy metal that poses a significant risk to the environment and human health. It is present in the crust of the earth in large quantities, with

an average concentration of 0.1 mg/kg. Sedimentary rocks have the highest concentration of cadmium compounds in the environment, and marine phosphates have a cadmium content of roughly 15 mg/kg (Gesamp et al.1987).

Naturally occurring in combination with other metals, cadmium is a relatively uncommon heavy metal. According to the US EPA (2000), burning fossil fuels and incinerating municipal waste are the main causes of airborne cadmium contamination. Emissions from vehicles, factories, and incinerators have a significant impact on the amount of cd present in dust samples (Faiz et al. 2009).

The most hazardous substance that can enter the human body through the respiratory system and stay there for a long time is cadmium. Changes in pulmonary function and chest radiographs that are consistent with emphysema are typically linked to chronic inhalation exposure to cadmium particulates. Reduces in olfactory function have been linked to workplace exposure to airborne cadmium particulates (Mascagni et al. 2003) Osteoporosis and decreased bone mineral density have been linked to long-term low-level cadmium exposure, according to a number of epidemiologic studies (Åkesson et al. 2006; Schutte et al. 2008).

Several regulatory bodies have classified cadmium compounds as carcinogens to humans. The U.S. National Toxicology Program and the International Agency for Research on Cancer (IARC 1993) have determined that there is sufficient evidence to support the hypothesis that cadmium causes cancer in humans. The primary grounds for designating cadmium as a human carcinogen are recurrent findings linking occupational exposure to the metal with lung cancer and robust rodent data identifying the pulmonary system as a target site (IARC 1993). Figure 2.2 presents a relative contribution of different sources to human cadmium exposure (Regoli 2005).

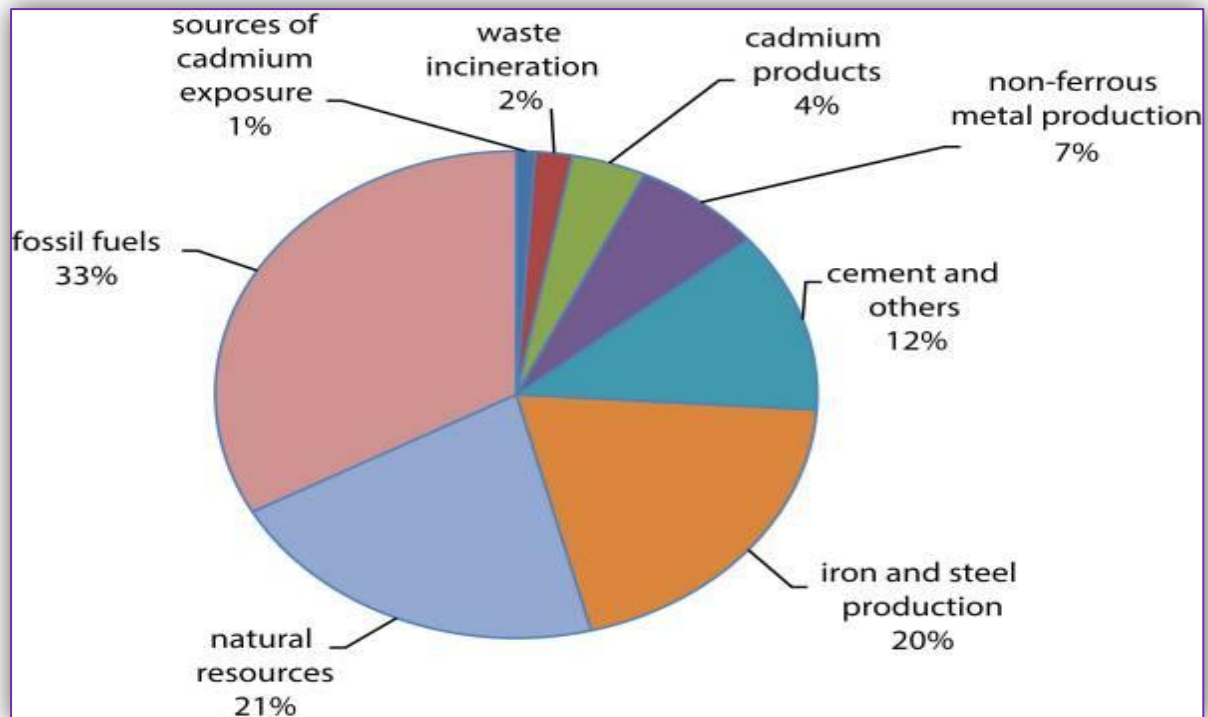


Figure 2.2 A relative contribution of different sources to human cadmium exposure (Regoli 2005).

5-Zinc (Zn)

Many human activities, including the burning of coal and waste, metallurgy, municipal sewage, and tire wear from motor vehicle traffic, mining and metal smelting can contribute to an increase in zinc levels in the various environments (Wan et al. 2020). The excess amount of Zinc can cause system dysfunctions that result in impairment of growth and reproduction (Cluggage,1991; Nolan, 2003).

The clinical signs of zinc toxicities have been reported as vomiting, diarrhea, bloody urine, liver failure, kidney failure and anemia (Kabata-Pendias et al. 2007).The sources of zinc found in street dust include tires, tire wear, brake pads, brake wear, lubricants, diesel exhaust, engine tires, and machine part wear (Valdez Cerda et al. 2011; Bourliva et al. 2017). This shows that vehicle activity may be a significant source of emissions of these heavy metals (Cu, Cd, and Zn) (Zhou et al. 2019).

6-Mercury (Hg)

Mercury is a common environmental toxin and pollutant that causes significant tissue changes in the body and a host of harmful health effects (Sarkar et al.2005). Mercury is present in the environment in a variety of chemical forms that can affect both humans and animals. These comprise organic mercury compounds (Hg^{+2}), inorganic mercury (Hg^{+1}), elemental mercury vapor (Hg^0), and mercuric (Hg^{+2}) (Zahir et al .2005). All living things, including plants and animals, are exposed to mercury because it is a ubiquitous element in the environment (Holmes et al .2009).Is a naturally occurring element found in rocks, soil, vegetation, animals, and volcanic dust and gases.

The industrial oxidation of mined chromium deposits and potentially the burning of fossil fuels, wood, paper, etc. are among its most frequent anthropogenic sources (WHO, 1988). Other common industrial processes include ore refining, chemical and refractory processing, cement and automotive brake linings and catalytic converter production, and tanning (leather) (ATSDR, 2011).

As a chemical element with the atomic number 80 and the symbol Hg, mercury is the only metallic element that can be liquid at room temperature and pressure. Is a silvery-white, (Hammond et al. 2005). As the only heavy metal element that can vaporize at room temperature, mercury is considered one of the most dangerous pollutants in the world and one of the harmful heavy metals, according to the United Nations International Chemical Safety Program (Keeler et al. 2006). Ninety-five percent of the mercury in the atmosphere is elemental mercury, which has the ability to travel to far-off locations in a year (Bergquist and Blum 2009; Yin et al. 2014). During the traffic transport process, a number of reactions involving redox, adsorption to particles, and deposition to the ground would occur simultaneously, resulting in a high concentration in the

street/roadway dust at particular urban districts. As a result, dust particles may serve as atmospheric carriers of mercury.

Street dust and other fine particles can enter human bodies through ingestion, inhalation, or skin contact. This can lead to a variety of harmful health effects, including kidney failure, gingivitis, tremors, and emotional instability (Keshavarzi et al. 2015; Lu et al. 2009; Ordonez et al. 2015; Zheng et al. 2015). This is especially dangerous for children.

2.1.1 Source of heavy metals

Because of its potential toxicity to both humans and the environment, heavy metal contamination is significant (Censi P et al. 2006). Table 2.1 Sources of heavy metals and their harm to human body.

The two main ways that heavy metals are released into ecosystems are through:

- 1) **Natural sources.** Naturally, Heavy metals can result from the subsequent procedures: volcanic eruptions, seismic activities decaying soil (such as surface erosion), and crumbling rocks (Singh et al. 2021; Burakov et al. 2018). There have also been reports that weathering and volcanic eruptions play a major role in the pollution caused by heavy metals (Bradl et al. 2002; He et al. 2002; Fergusson et al. 1990).
- 2) **Anthropogenic sources.** Human-generated minerals have somewhat reactive chemical forms and are therefore dangerous. Much greater than naturally occurring minerals, which are frequently found in forms that are comparatively inactive. The following anthropogenic inputs are linked to industrialization: traffic emissions, urban effluents, fertilizer application, long-term wastewater application in agricultural lands, waste disposal, incineration, and atmospheric deposition (Bilos et al. 2001; Koch. 2001).

Paper processing plants, plastics, textiles, microelectronics, wood preservation, metal processing in refineries, coal burning in power plants, petroleum combustion, nuclear power plants, and high tension lines are examples of industrial sources (Arruti et al. 2010 ; Pacyna et al. 1996).

Pollutants are also released into different parts of the ecosystem by industries, irrigation, drainage, mining and metallurgical processes, and runoff. Anthropogenic heavy metal processes have been observed for some metals that surpass natural fluxes. Metals naturally released into wind-blown dust are mostly from industrial areas.

Some important anthropogenic causes that significantly contribute to heavy metal pollution in the environment are the burning of fossil fuels, which releases mercury, the smelting of copper and zinc, and lead released by car exhaust. It has been discovered that human activity contributes more to environmental pollution than any other factor because of the regular manufacturing of goods to meet the demands of the large population (Ali et al. 2020; Varol et al. 2020 ; Lee et al. 2019; Nour et al. 2019 ; Ding et al. 2018).

Table 2.1 Sources of heavy metals and their harm to human body

Heavy metal	Main sources	Harm to human body	Ref.
Lead (Pb)	Cosmetics, puffed food, water pipes, cast type, radioactive radiation, X-ray protective equipment, <i>etc.</i>	Anemia, neurological disorders, renal injury	Cartro-Sabate M.et al (2019)- Taylor M. P et al (2019).
Cadmium (Cd)	Industrial wastewater, waste batteries, pigments, plastic stabilizers, coating corrosion prevention of steel parts, <i>etc.</i>	Severe bone softening and visceral dysfunction	Liu H. T.et al (2020)- Ma N.et al (2021).
Copper (Cu)	vehicle exhaust, coal combustion, sintering, metal processing, machinery manufacturing, and iron and steel production, <i>etc.</i>	Anorexia, depression, anxiety, liver and kidney damage, headaches.	Kabata-Pendias A.et al (1999)
Mercury (Hg)	Precious metal smelting, cosmetics, lighting lamps, aquatic organisms, dental materials, <i>etc.</i>	Damage brain cells and kidneys, causing systemic poisoning	Zhao Y. L.et al (2019)

Chromium (Cr)	Leather preparation, metal chromium plating, inferior cosmetic raw materials, <i>etc.</i>	Pharyngitis, bronchitis, rhinitis, dermatitis, tuberculosis	Mamais D.et al (2016)- Hamilton E.et al (2018)
Zinc (Zn)	Machinery manufacturing, and emissions from industries such as galvanizing, instrumentation, organic synthesis and papermaking	Metabolic disorder, anemia, zinc fever, <i>etc.</i>	An Y.et al (2019)- Sturikova H.et al (2018)

2.1.2 Effect of Heavy metal on human

Toxic metals (TMs) are environmental pollutants that are ubiquitous. Airborne particulate matter (APM)-bound TMs have the potential to generate adverse effects by inhalation of particulate matter (Lubczyńska et al. 2017; Liu et al. 2019; Fuertes et al. 2014). By dissolving bound soluble metals in lung fluid and macrophage lysosomal fluid, fine particulate matter (PM_{2.5}) enables the metals to pass through the blood-air barrier and enter the bloodstream. However, the immune system may choose to retain the insoluble part or to expel it from the body. It follows that soluble metals are the main source of systemic toxic effects and health concerns to humans (Wiseman, 2015).

Previous studies have shown that urban street dust is polluted to varying degrees by heavy metals (Men et al. 2020; Sun et al. 2020; Ghanavati et al. 2019; Xu et al. 2018 Kim et al. 2016; Lu et al. 2014 ; Zheng et al. 2010 Christoforidis et al. 2009) Moreover, street dust can come into direct contact with the human body and produce hazards to human health (Jayarathne et al .2018; Pan et al .2016), increasing the risk of Alzheimer's disease (Lee 2018 ; Peng et al. 2017) cardiovascular disease (Tellez-Plaza et al. 2012; Navas-Acien et al .2007) and atherosclerosis (Harari et al. 2019; Tinkov et al. 2018).

In addition, the composition and concentrations of heavy metals in urban dust can directly reflect the long-term or short-term human activities in the region. Heavy metals in dust particles, especially fine particles, are re-suspended into the atmosphere, which can cause health risks for local residents via ingestion, inhalation, or dermal exposure (Krupnova et al. 2020). Previous

studies found that among the three exposure pathways, hand-to-mouth ingestion is the most important exposure pathway for human beings to absorb street dust, thus causing certain hazards to the human body, involving both non-carcinogenic risk and carcinogenic risk (Krupnova et al. 2020; Ali et al. 2017).

Cadmium, mercury, arsenic, and lead are examples of heavy metals. Previous study have examined the processes through which heavy metals damage the body. These studies have demonstrated the ability of heavy metals to obstruct essential biological functions, thereby causing abnormal cell functions to be disrupted. From neurological disorders to organ damage, heavy metals have been connected by researchers to a myriad of health problems. Mercury buildup in the brain can impair cognitive function, while lead has been shown to interfere with nervous system growth and function (Flora et al. 2010).

Research has looked into the body's absorption of heavy metals and how they build up in different tissues and organs. It has been discovered that distinct heavy metals target different organs and absorb at different rates. Scholars have investigated the mechanisms through which heavy metals elicit their toxic effects (Menke et al. 2006). This encompasses cellular process disruption, DNA damage, oxidative stress, and interference with vital trace elements.

2.3 Street dust polluted by heavy metals

Depending on traffic and road features (traffic circles, highways, traffic lights, etc.), the heavy metal (HM) content of road dust varies greatly. The brakes are subjected to a lot of heat from friction during high-speed raking; this heat is transferred to the brake discs and results in particle emissions.

Naturally, intersections, curves in the road, traffic lights, and forced braking are the locations with the highest brake wear (Adamiec Ee et al. 2016). About half of the brake residue that wears down is thought to wind up on or near roads. The abrasion of the tire and road surface can also contaminate road dust. (Panko et al. 2013) report that between 0.1 and 10% of tire residue is released into the atmosphere. The remainder is dumped beside or on top of roadways. The majority of people exposed to heavy metals HMs accumulated in road dust and other traffic-related pollutants in urban areas are those who live close to roads or use sidewalks (Chen et al. 2014).

Researchers are very interested in the dust that builds up on the surfaces of roads and streets because it contains pollutants, primarily heavy metals that could be harmful to human health (Bilos et al. 2001) (Manno et al. 2006).A variety of mineral and organic particles, including those from industrial sources and those resulting from vehicle traffic, make up street dust (Wong et al. 2006).

Vehicle operating fluids that leak onto the street surface can also be a source of heavy metals (Lu et al. 2010; Angelone et al. 2002) Current research shows that street dust in urban areas has a higher concentration of trace elements (Shi, X et al. 2013; Al-Khashman et al. 2007; Han, et al. 2006). These elevated concentrations are especially noted for lead, copper, chromium, and cadmium. Studies concentrate on large cities that have a lot of traffic from motor vehicles and are home to industrial emitters (Zhao et al. 2015; Du et al .2013).

The primary causes of street and road dust are anthropogenic and natural (Hjortenkrans et al. 2006; Ferreira-Baptista and DeMiguel. 2005). The city is now the center of human activity due to the quick development of industrialization and urbanization. (Sharma et al. 2021; Yang et al. 2020 ; Wang X et al. 2020). However, a number of factors, including industrial production, transportation, construction, and daily life of residents, have a significant impact on the urban environment. Street dust is a common environmental medium that provides valuable insight into the concentration and spatial distribution of heavy metal pollutants in the surrounding area (Wang et al. 2020 ; Li et al. 2017).

In the meantime, street dust plays a significant role as a carrier of both organic and inorganic pollutants, particularly heavy metals, due to its large surface area (Zhao et al. 2009). Heavy metals are both sucked up and deposited by street dust, which also absorbs them from atmospheric deposition. Owing to heavy metals' toxicity, cumulative trends, and potential for non-degradation in street dust (Gbadamosi et al. 2018) it has garnered a lot of interest.

Unchecked urbanization efforts lead to a rise in pollutants and different particle size fractions in roadway dust burdens (Victoria et al. 2014). (Amato et al. 2009; EEA, 2004), the streets get covered in dust and atmospheric aerosols (Pant and Harrison, 2013; Yu et al. 2006). Due to human activity and wind movement, street dust does not remain on the ground for very long before resuspending into the atmosphere (Amato et al. 2009). Street dust is less common when there is rain, water vapor, sweeping, and shoveling (Amato et al. 2010; Yu et al. 2006).

Street dust resuspension degrades air quality and raises particulate matter (PM) exposure (Schauer et al. 2006). Negative health effects have been linked to roadway dust exposure (HEI et al. 2012; Lin et al. 2002). These effects are linked to the toxicity of dust-containing materials, including mineral compounds

(Fanning et al. 2007; Schlesinger, 2006), microbes (Alghamdi et al. 2014; Lighthart, 1997), and heavy metals (Lippmann and Chen, 2009).

A significant concentration of heavy metals from both natural and anthropogenic sources may be present in the road dust that accumulates on the surfaces of urbanized and industrialized areas, among other environmental components (Liu et al. 2014,2019; Shi and Lu, 2018; Soltani et al. 2015). As a result, road dust serves as a sink for heavy metals that come from human activity and may be a useful indicator of the degree of environmental pollution in places that are heavily contaminated. More importantly, breathing in, consuming, and coming into touch with road dust can expose humans to elevated levels of heavy metals, which can have a negative impact on their health (Men et al. 2018).

Furthermore, a significant portion of the heavy metals in road dust may be dissolved by runoff from the road, which might carry the metals into receiving bodies of water and pose a variety of ecological problems (Liu et al. 2016). Consequently, identifying this pollution and assigning its origins is crucial in light of the significance of road dust as a sink and transport of heavy metals (Trujillo-González et al. 2016; Men et al. 2018).

Road dust is made up of different particles that have been deposited on paved surfaces, such as sidewalks. Heavy metals (HMs) and other pollutants can enter this dust from both anthropogenic and natural sources. The mining industry (Tapia et al. 2018), homes, the deterioration of urban infrastructure (Lee et al. 2018), the smelting industry (Aguilera et al. 2019), electronic-waste recycling activities (Lin et al. 2017; Leung et al. 2008), and traffic-related emissions (Budai and Clement, 2018) are examples of anthropogenic sources. These pollutants associated with traffic can specifically be either exhaust or non-exhaust emissions.

Previous studies of this object study in Mexico city conducted by (Bautista-Hernández et al. 2022) ,study in Tehran , Iran conducted by (Kamani et al. 2017) , study in Lublin ,Poland conducted by (Zgłobicki et al. 2019) , another study in Beijing, China conducted by (Xinhao Chen et al. 2022).

2.4 Air pollutants particles matter

2.4.1 Particulate matter

Particulate matter is one of the most dangerous types of air pollutants. Tiny solids found in fine particles can cause major health issues and decrease vision. Particulate matter (PM) comes from a variety of sources, including factories, cars, fires, and construction sites. There are two categories for particulate matter: PM_{2.5} and PM₁₀. Particulate matter with a diameter of 10 micrometers or less is referred to as PM₁₀. PM_{2.5}, on the other hand, refers to particulate matter that typically has a diameter of 2.5 micrometers or less. Figure (2.3) compares the size of particulate matter with the width of an average human hair.

It is observable that PM_{2.5} particles are much smaller than PM₁₀ and drastically smaller than the width of a human hair - allowing it to enter and accumulate in the lungs, where most damage is caused. The figure also states the possible substances that could make up the different types of particulate matter - with PM₁₀ consisting mostly of natural substances such as dust, whereas PM_{2.5} is mostly made from results of heavy industry and human interference, such as combustion particles (Han et al. 2014).The EPA produced this diagram (Particulate Matter (PM) Basics, 2018) as a scale reference.

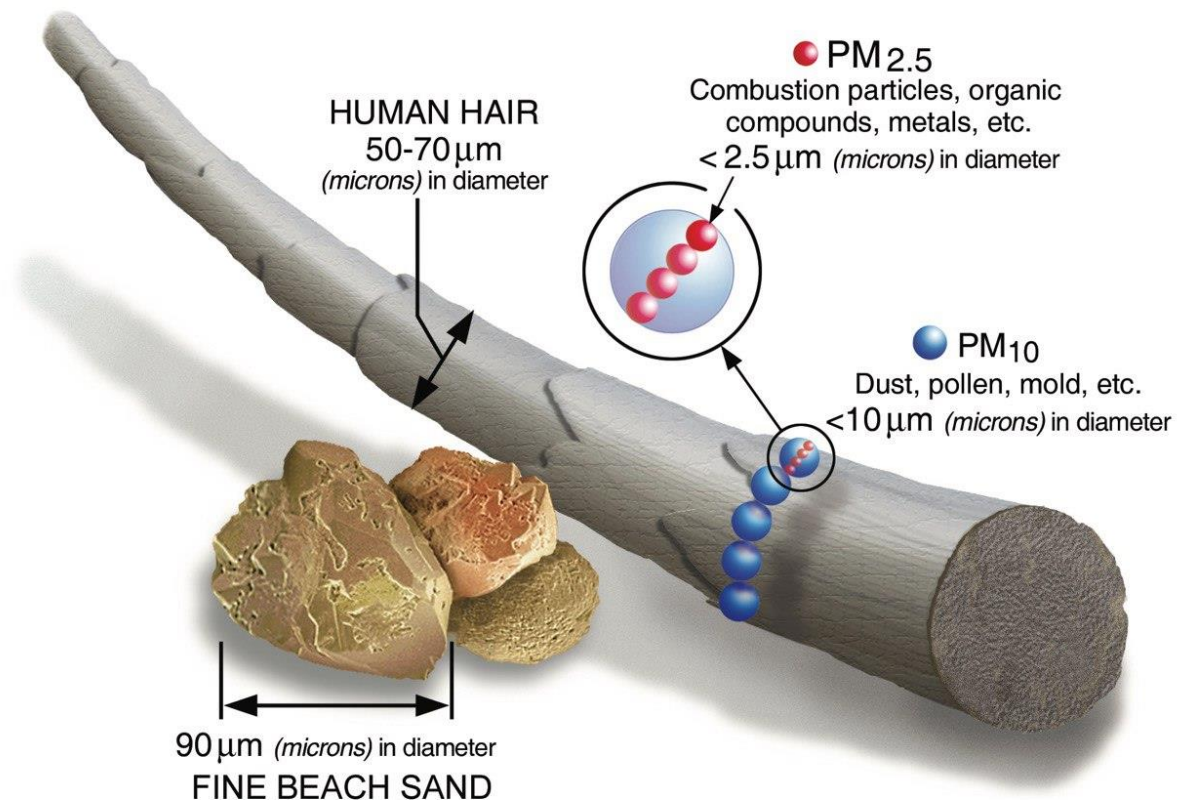


Figure (2.3) Size of the particulate matter compared to the size of a human hair. (Hubbard et al.2021).

PM particles are estimated to indirectly cause up to 52,000 deaths per year just in the united states, according to a study (Mokdad et al. 2004). A study in 2002 indicated that PM 2.5 not only accumulated in the lungs - it leads to high plaque deposits in the arteries themselves, due to the accumulation of particles deep in the lungs. This effect increases the chance of cardiovascular disease, most notably heart-attack. Thus, prolonged PM 2.5 exposure have expanded to affect other body systems, and not limited respiratory system as first predicted (Luo et al .2014).

Particulate Matter is most commonly expressed in micrograms per cubic meter of air ($\mu\text{g}/\text{m}^3$).Table 2.2 show concentration levels of PM 2.5 against respective air quality levels According to San Joaquin Valley air control center this metric refers to the concentration of particulates in air. Currently, the EPA mandates that the health standard of PM 2.5 to be no greater than 35 $\mu\text{g}/\text{m}^3$ and

PM 10 to be no greater than 150 $\mu\text{g}/\text{m}^3$ (Particulate Matter (PM) Standards, 2016). Regardless of the level of particulate matter, there is no “safe” level of particulate matter. According to San Joaquin Valley air control center, the concentration levels of PM_{2.5} against respective air quality levels can be explained as followed (Real-Time Air Advisory Network, 2020).

Table (2.2) The concentration levels of PM 2.5 against respective air quality levels According to San Joaquin Valley air control center

Air Quality	PM 2.5 Concentration ($\mu\text{g}/\text{m}^3$)
Good	1-12
Moderate	13-35
Unhealthy for Sensitive Groups	36-55
Unhealthy	56-75
Very Unhealthy	>75

Each of the many gaseous and particulate components that make up air pollution is harmful to the respiratory and cardiovascular systems. The rate of emissions, the amount of sunlight and wind, and other factors all affect the composition of air pollution. Nitrogen dioxide (NO_2), nitric oxide (NO), sulfur dioxide (SO_2), ozone (O_3), and carbon monoxide (CO) are examples of gaseous components of air pollution (Chin et al. 2015; Newby et al. 2015, Brook et al. 2010).

The components of air pollution known as particulate matter (PM) are carbonaceous particles along with reactive metals and organic compounds that have been adsorbed onto them. Nitrates, sulfates, endotoxin, polycyclic aromatic hydrocarbons, and metals like iron, copper, nickel, zinc, and vanadium

are frequently found in Particle matter (PM) (Newby DE et al. 2015; Brook RD et al. 2010).

Particle size determines the classification of PM into three categories: coarse (PM₁₀, diameter $<10\mu\text{m}$), fine (PM_{2.5}, diameter $< 2.5\mu\text{m}$), and ultrafine (PM_{0.1}, diameter $<0.1\mu\text{m}$). Coarse particles are found in many natural and man-made sources, and they usually don't go much deeper than the upper bronchus. Fossil fuel combustion produces fine and ultrafine particles, which are more harmful to health than coarse particles because they can enter small airways and alveoli (Chin et al. 2015; Miller et al. 2012). Location-specific variations in the organic and metal components of particles notwithstanding, there is a consistent correlation between elevated levels of PM_{2.5} and adverse cardiovascular outcomes (Brook et al, 2004; M. Abu-Allaban et al. 2003).

Particulate matter (PM) pollution is primarily caused by progressive urbanization, which is demonstrated by the growth of residential areas and road transportation (Chattopadhyay et al. 2010). The granular aerosol that is created when PM is suspended in the atmosphere threatens locals' health and deteriorates the quality of the air. The diameter of dust particles determines their classification. PM₁₀, the largest PM, has a diameter ranging from 10 to 100 μm . Because of their size, these particles are expelled from the body through coughing and are blocked by the upper respiratory tract. Their entry into the respiratory system irritates the larynx and nose.

They may also be a factor in ocular irritation. Because they are respirable, particles with a diameter between 2.5 and 10 μm are more hazardous to human health. This indicates that they enter the trachea, bronchi, and bronchioles, among other respiratory system organs PM_{2.5}. PM 0.2 particles, which are the most easily absorbed by the respiratory system, range in diameter from 0.2 to

2.5 μm . According to (Mazurzyk et al. 2020), these particles enter the alveoli of the lungs and travel deep within them before entering the bloodstream. Consequently, particulate matter pollution can harm the heart as well as the circulatory system in addition to endangering the respiratory system, this is especially risky for elderly people and children (Heinzerling et al. 2016; Terzano et al. 2010).

A study carried out at a clinic in Vladivostok, (Russia) between 2008 and 2012 confirmed that respiratory fractions, even at low doses, contribute to the increase in asthma mortality (Veremchuk et al. 2016). PM poses a risk to human health due to its composition as well as its size and capacity to enter the body and harm the respiratory and circulatory systems. Fires, fuel combustion, tire abrasion, and industrial operations all produce dust particles. This means that they are frequently made up of different hazardous chemical compounds. According to (Veremchuk et al. 2016, air pollutants, particularly nano- and microparticles, have the ability to adsorb extremely toxic, frequently mutagenic, and carcinogenic elements and compounds on their surface, including heavy metals (Noh et al. 2019). According to (Świetlik and Trojanowska, 2015), eight metals are known to be released into the air in Poland: As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn. On the smallest fraction of particulate matter, heavy metals accumulate.

2.4.2 Carbon dioxide

Air pollution can be defined as the existence of one or more pollutants in the air at a level and during a time sufficient to damage human life, plant life, animal life, commercial or personal properties and the quality of the environment (Cetin 2016). The level of CO₂ was measured as 411 ppm in Krakow, Poland (Chmura, 2008), 477 ppm in Rome (Liolios et al. 2010) , 384 ppm in the Spanish Plateau (Garcia et al. 2012). One known air pollutant is carbon dioxide. The effects of CO₂ on health are revealed by contemporary research.

High air pollution will be susceptible to respiratory and other dangerous diseases. Air pollution-related diseases include ARI (Acute Respiratory Infection), Wet Lungs, Asthma, and Heart Attack. These diseases are severe, so there are not a few costs that each individual must incur to get good health; these conditions will affect spending on health matters, according to (Apergis et al. 2020).

A 2017 study found that travel by car is the main source of CO₂ pollution (Sources of CO₂, 2018).

The generation of electricity, emissions from industry, and domestic activities are some additional significant sources of CO₂. While carbon dioxide has always been a vital component of the respiratory cycle, prolonged exposure to high concentrations can cause disease and slow down brain activity. Parts per million, or ppm, is the standard unit of measurement for carbon dioxide. Table (2.3) A 1994 study summarizes the following effects of higher CO₂ concentrations (Rice, 2003):

Table (2.3) Effects of higher CO₂ concentrations (Rice, 2003)

Health Effect	CO₂ Concentration (PPM)
Acceptable	1,000
Increase in Respiratory rate	10,000
Dizziness and Confusion	50,000
Visual Disturbances, vomiting, disorientation	100,000
Death	250,000

2.5 Multivariate Analysis

According to (Shan et al. 2013), multivariate statistical analysis is a great tool for finding common patterns in the distribution of data, which eventually leads to reducing the initial dimensions of data sets and simplifying their interpretation. This study employed multivariate statistical techniques, including as:

2.5.1 Principal components analysis (PCA)

PCA is the most common multivariate statistical method used in environmental studies to reduce the data while retaining important information and to extract a smaller number of independent factors that can be easily interpreted for analyzing relationships among the observed variables (Loska and Wiechuya, 2003; Tokalioglu and Kartal, 2006). PCA starts with the correlation matrix describing the dispersion of the original variables and extracting the eigenvalues and eigenvectors (Lu et al., 2010). .in this study, for the purpose of this exercise, a data matrix consisting of ten sites and six metals was considered (Rajaram et al., 2014).

The SPSS 25.0 software (International Business Machines Corporation, USA).was used to perform PCA of the heavy metal data obtained during the

laboratory testing, to identify the source of heavy metal into in road dust and to evaluate the correlation coefficient between them (Kalin et al. 2000, Kumaret al. 2017). The Kaiser–Meyer–Olkin (KMO) and Bartlett’s test were performed to examine the suitability of the data for PCA. KMO is a measure of sampling adequacy that point to the proportion of variance which is common variance, i.e., which might be caused by underlying factors. The high values (close to 1) typically indicates that PCA may be useful.

PCA is awidely applied multivariable statistical method to identify the potential sources of street-dustmetals. (Ghanavati et al. (2019) , Shabanda et al .(2019). has been drastically utilized to examine the foundation of heavy metals in road dirt Roy,S et al.(2019) .The sources of heavy metals in street dust fall are complex and extensive and are mainly divided into natural and human sources. Principal component analysis, often known as PCA was utilized in order to track out the source of heavy metals that were found in street dust. PCA uses dimensionality reduction to convert multiple original environmental variables into a few comprehensive ones .It calculates the variance in these parameters and the characteristic quantities of the covariance matrix. In this manner, the predominant constituents of numerous environmental pollutants may be identified. As PCA concentrates and extracts environmental pollutant data, it is widely used to evaluate and analyzes street dust pollution (Xiong et al ; 2015) .Before doing a PCA analysis to determine the amounts of heavy metal pollution in the dust, it is necessary to first identify the primary components of the data set, The contamination levels of heavy metals in dust can be accurately presented by the principal components, which comprise the majority of the information that is contained in the assessed indexes. During the process of principal component analysis (PCA), it is important to maximize the variance of a linear combination of the data set's variables (Zhiyuan et al; 2011).

2.5.2 Pearson correlation coefficients

The Pearson's correlation evaluation changed into utilized to ascertain the affiliation among heavy metals found in dust and the quality of air inside the streets. Additionally, (Yang et al. 2011) used the Pearson correlation coefficient to analyze the relationships that heavy metals have with one another as well as with the main elements of their environment.

This study included an investigation of the relationships that exist between heavy metals with particle matter and each other, as well as with each other, because relationships between heavy metals and particulate matter can provide information about their sources (Oliva & Espinosa, 2007).

2.5.3 Cluster analysis

The cluster analysis is a statistical technique used to identify groups or clusters of similar sites based on similarities within a class and dissimilarities between different classes (Kannel et al. 2007). The cluster analysis is aimed at investigating existing similarities for different zones of the study area based on the concentration of the heavy metals and particle matter in the zones in Samawa city. The method also helps to identify the most dominant element in the study area. In this study we determined the concentration of six heavy metals Lead (Pb), Chromium (Cr), Copper (Cu), Cadmium (Cd), Zinc (Zn), Mercury (Hg), utilizes heat map cluster. The easiest way to understand a heat map is to think of a cross table or spreadsheet which contains colors instead of numbers. The default color gradient sets the lowest value in the heat map to dark blue, the highest value to a bright red, and mid-range values to light gray, with a corresponding transition (or gradient) between these extremes. Heat maps are well-suited for visualizing large amounts of multi-dimensional data and can be used to identify clusters of rows with similar values, as these are displayed as areas of similar color. (Fernandez NF et al. 2017). Heat map is particularly useful for discovering clusters based on the spatial distance between data points.

As (Weinstein, 2008) mentions :For visualization, by far the most popular graphical representation has been the clustered heat map, which compacts large amounts of information into a small space to bring out coherent patterns in the data.

2.5.4 Geographical information system (GIS)

A geographic information system (GIS) is a computer program that collects, stores, verifies, and presents information about locations on the surface of the Earth. Streets, buildings, and plants can all be displayed on a single map using GIS. People are better able to recognize, evaluate, and comprehend patterns and relationships as a result. Any information that contains a location can be used by GIS. There are numerous ways to describe the location, including address, latitude and longitude.

The impact of human activity on the concentration of heavy metals can therefore be geographically highlighted as a result (Shan et al. 2013). In this study, the ArcGIS tool (IDW) was used to forecast the levels of heavy metals and display the area that was polluted.

2.5.5 Inverse distance weighted (IDW):

One of the most popular interpolation techniques is conserved as inverse distance weighted (IDW). By measuring the surrounding values anticipated location, it is utilized to forecast the values for any unmeasured site (Childs, 2004). It is essentially predicated on two hypotheses: first, that the influence of a point's unknown value is greater on the close control point than on the far points. Second, the inverse of the distance between points is directly proportional to the impact degree point. The following equation can be obtained from it (Bartier and Keller, 1996; Huang et al. 2011).

$$Z = \frac{\sum_{i=1}^N w_i \cdot z_i}{w_i} = \frac{\sum_{i=1}^N z_i / D^p_i}{w_i}$$

Where :

Z : refers to the interpolated value of unknown point .

W_i : is the weighting function that control the significance of control point.

Z_i and Z_i : is the observed value at the control point i which represent the nearest neighborhood of produced interpolated point and it is ranging between 20 to 30.

N : is the nearest neighborhood of control points that is usually required time consummation.

D^p_i : refer to the distance between I and interpolated point.

p : is a weighting exponent which is an arbitrary positive real number, p is equal to 1 in inverse distance weighting (Guan , 2008).

2.6 Previous local and global studies on heavy metals in street dust

To determine the extent of heavy metal contamination in street dust, researchers frequently look at the total concentration of these metals in the dust.

There are different studies were conducted to search for pollution of heavy metals content in street dust over the world, like the study by Skorbilowicz et al. (2023), in Suwałki (Poland). Presents an analysis of the content and spatial distribution of heavy metals (HM) in street dust in Suwałki, a city located in northeastern Poland. The HM content of street dust was also evaluated using the geochemical index (Igeo), enrichment factor (EF), and contamination factor (CF), and local HM sources were identified using chemometric methods. The arithmetic averages of HM contents in dust arranged in the following order: $Fe > Zn > Mn > Cu > Cr > Ni > Pb$, were 11,692.80, 215.97, 194.78, 142.84, 63.59, 17.50, 17.04 mg/kg , respectively. Higher values than the local background occurred for Cr, Cu, Ni, Zn and Pb. The values of Igeo, CF, and EF indicate that the highest pollution in dust is due to Zn and Cu. The spatial

distribution of metals was evaluated using maps of HM content in road dust samples from Suwałki. The spatial distribution of HM showed areas with high contents of Cr, Cu, Ni, Zn and Pb located mainly in the central and eastern parts of the city. Statistical models of multivariate analysis (FA) and cluster analysis (CA) identified two sources of HM. The first source of pollution was associated with local industrial activity and motor vehicle travel, and the second with natural sources.

Also , a study was conducted in the heavy metal in street of the Madrid city (Spain) by Delgado-Iniesta et al .(2022), In this work, sampling was carried out in the urban area of Madrid to analyze the content of total heavy metals (Zn, Pb, Cu, Cr, Ni, and Cd) in the street dust. Contamination was evaluated using various indices, such as the (CF), (EF), (Igeo), (RI), (PLI), the Human Health Index Hazard Index (HI), and Cancer Risk (CR). Pollution indices were related to traffic density and color. Traffic density was the factor that most influenced the values of the pollution indexes, but no significant differences were found with the color of street dust. The pollution levels were high or very high in Pb, Zn, and Cd regarding the environmental pollution indexes. Ingestion was the main route of exposure to heavy metals contained in street dust.

Another study conducted by Wojciech et al. (2021) in lublin poland. The objective of this study was to assess the spatial and temporal variation in health risk posed by heavy metals contained in street dust in the area of Lublin. The content of Cd, Cr, Cu, Ni, Pb and Zn, commonly regarded as the most serious sources of pollution in urban areas, was analysed (Charlesworth et al. 2011; Kabata-Pendias, A et al. 1999). The heavy metal content in street dust in Lublin had already been studied (Zgłobicki et al. 2019; Zgłobicki et al. 2018). So far research on this problem has been conducted mainly in cities with a high impact of industrial emissions, which currently do not seem to be a very important

source of pollution in Lublin this paper assesses the levels of hazard index and cancer risk for Cd, Cr, Cu, Ni, Pb and Zn contained in street dust collected in 2013 and 2018 at 62 points located in different parts of a small/medium-sized city (Lublin, Poland). Heavy metals contents were analysed by means of XRF spectrometry (in the fraction $<63\ \mu\text{m}$). Despite the fact that the concentrations of some elements (Zn, Cd and Cu) in street dust are 6–7 times higher than the geochemical background, this does not pose a risk of non-carcinogenic effects. The average hazard index (HI) for the individual elements reaches very low levels (<0.01).

In another study conducted by (Aguilera et al. 2021) in Morelia, Michoacan (Mexico). Among the complex components of street dust, heavy metals (As), (Ba), (Cd), (Co), (Cr), (Cu), (Fe), (Hg), (Mn), (Ni), (Pb), (V) and (Zn) contamination have drawn public attention because of the high toxicity, concealment, persistence and biological accumulation in the ecosystem and humans (Lin et al. 2017). They can enter the human body via inhalation, ingestion and dermal exposure, and can have both a non-carcinogenic and carcinogenic risk (Xu et al. 2019) They may accumulate in the fatty tissues in the body and affect the central nervous and circulatory systems, disrupt the normal functioning of our internal organs, act as cofactors in other diseases and may cause DNA damage (Safiur Rahman et al . 2019) At present, As, Cd, Cr (VI) and Ni have been identified as carcinogenic metals to humans, while Pb is classified as probably carcinogenic to humans (Aminiyan et al. 2018) ; Tchounwou et al 2012) .

Kuy cai et al. (2019) conducted a study in Shijiazhuang, China investigation was conducted to determine levels and sources of Cd, Cr, Cu, Pb, Zn, Ni, and Hg contamination in street dust from Shijiazhuang, China. The concentrations of the heavy metals were mapped for the three Shijiazhuang ring

roads, with the results showing significant differences between each ring. Application of enrichment factors and geo accumulation indexes showed that there was significant enrichment and accumulation of Cd, Pb, Zn, and Hg. Multivariate statistical analyses showed that Cd, Pb, Zn, and Hg levels were mainly controlled by human activities, while Cr, Ni, and Cu levels were associated with natural sources. The results showed that the mixed (traffic and industry) group contributed 53.55%, 59.7%, and 62.25% of the Cd, Pb, and Zn concentration, respectively, while the natural sources group contributed 58.01%, 65.09%, and 66.91% of the Cu, Ni, and Cr concentration, respectively. The burning coal group was found to be responsible for 63.38% of the Hg present in the samples.

In another study was conducted by Kamani,et al. (2017) in Tehran ,Iran. This investigation was conducted to determine the content and contamination level of the heavy metals Cd, Cr, Cu, Ni, Pb and Zn, which occur frequently in the street dusts of central Tehran. In the present study, sixty street dust samples were collected from the central area of Tehran and were digested in the laboratory to determine the content of Zn, Ni, Cd, Cr,Cu and Pb, using inductively coupled plasma optical emission spectrometry (ICP-OES). The level of contamination with the analyzed metals was determined according to the following indices: (Igeo), (EF), (PI), (IPI) and (RI). Average EF values and were placed into the “very severe enrichment” class. (Er) also indicated that Cd had the highest risk, and it was classified as of considerable potential ecological risk. Therefore, it is necessary to pay more attention to the appearance of Cd in the human environment. The calculated IPI values showed that the pollution levels of the street dust samples ranged from high to extremely high. Numerous recent studies have been conducted to determine heavy metal content and contamination in street dusts around the world (Faiz et al. 2009; Shi and Wang 2013; Zhang et al. 2014). The air pollution of Tehran has also been the subject

of several evaluations of the spatial and temporal distributions of pollutant concentrations (Kamani et al. 2014a, 2014b; Leili et al. 2008).

Also , a study was conducted in the heavy metal in street of the Sarajevo Area, Bosnia and Herzegovina by Razanica et al .(2014), Street dust samples from urban and suburban areas were collected from the Sarajevo area, during the spring season of 2013. Samples were collected from low and high-density traffic roads, industrial zones, parks, parking places, hospitals and local health centers, school gardens. The highest metal concentrations were found in samples from industrial zone and in the streets with heavy traffic. The lowest levels of the metal concentrations were found in the samples from health centers and school gardens. The concentrations of the metals were, in most of cases, similar to the mean world-wide contents of the street dust samples. Correlations between heavy trace metal levels of the dust samples were also evaluated. The correlation coefficient statistical analysis was conducted on heavy metal concentrations. A significant positive correlation relationship was found between Pb and Cu ($r = 0.88$), and between Pb and Zn ($r = 0.57$). This might be explained by the presence of these metals in similar source (i.e. the bodies and tires of automobiles).

Another study was conducted by (Sudip et al. 2010) in Edinburgh, Scotland. This study aims to analyse RDS heavy metal concentrations on road deposited sediment (RDS) using Riccarton Campus of HeriotWatt University, Edinburgh, Scotland as a study site. RDS samples were collected at two transverse positions from different sites over a 4 month period in order to describe the influence of traffic on heavy metal emissions. The heavy metal concentrations of the RDS were determined by strong nitric acid digestion and atomic absorption spectrometry. Furthermore for both positions the highest concentrations for all metals were associated with the finer fraction ($<63 \mu\text{m}$)

and stronger correlations between the metals were found further from the curb than near the curb, indicating that metals accumulating on the road surface further from the curb may likely be from the same source (traffic), while the sources of metals near the curb are more diverse. (Charlesworth et al. 2003; Robertson et al. 2007). Most of the previous RDS studies have been based on samples collected within 1 m from the curb along roads (Charlesworth et al. 2003).

In another study conducted by (Mostafa et al. 2024) in Cairo, Egypt. Thirty road dust samples from six major roads were collected. ICP-OES was used to analyze the samples in order to determine the contamination grade using the pollution indices, decipher metal sources and geochemical associations using multivariate analysis, and evaluate the ecological and human health risks. The spatial pattern showed that new urban communities exhibited lower contamination levels compared to unplanned old districts, especially for traffic elements (Pb, Zn, and Cu). CF values indicated very high contamination levels for Pb and Zn, whereas the highest PLI value was observed at Ramses Street. All EF values were higher than 1.5, indicating the anthropogenic enrichment of metals. RI values classified Cairo as a region with considerable ecological risk, observing that Hg was the main contributor. Correlation analysis and PCA showed that Pb and Zn originated from vehicle exhaust, Hg, Cu, and As from domestic and industrial activities, and Fe and Co from natural origin. Cr and Ni exhibited potential carcinogenic risks for children through ingestion; conversely, the non-carcinogenic risks were within safe levels.

Other study conducted by Khwedim et al. (2022) in Kirkuk, Iraq. Three dust samples were collected from three locations (residential, commercial and industrial areas). The collected samples were analyzed for Cd, Cr, Cu, Ni, Pb, Zn, and radioactivity (Gamma rays). The concentrations of the proposed heavy

metals (Cr, Cu, Fe, Ni, Pb, and Zn) were analyzed to be measured in the atmospheric dust. They were divided into two groups; the first (Cr and Cu) is within limits in the atmosphere. The second one (Fe, Ni, Pb, and Zn) exceeded the limits. The results of Pi reveal that the studied area was unpolluted with (Cr and Cu), with moderate pollution with (Pb), and high polluted with (Fe, Ni, and Zn).

In another study conducted by (Abed, S et al. 2020) in Baghdad, Iraq. This study sought to define the metals bioaccumulation from street dust . The samples were collected that research the levels, sources, and health hazard model Cd, Cr, Zn and Cu. The geo accumulation Index (Igeo) found that the contamination level for Cd was moderately to strongly polluted in Karada, Jihad and Kinidi streets. Hence, it is important to measure the level of cadmium in the local environment. The relative bioaccumulation of chromium was high in Jadriyah Street (87.2%). The PCA showed two major sources of these minerals in Baghdad road dust that Cd, Zn are likely to originate from tire wear, brake wear and vehicular emissions as well as the fact that Cr and Cu originate from metal processing industries. Assessing hazard to human health utilized measure population show suggested both non-carcinogenic and carcinogenic hazards minerals Baghdad road dust harmless to human environment.

Study conducted by Al-Dabbas et al. (2018) in Diwaniyah, Iraq. Roadside dust samples were collected from selected areas of Diwaniyah city Qadisiyah Governorate - Southern Iraq. The heavy metals (Fe, Co, Ni ,Cu, Zn and Pb) in these streets dust samples were studied and used as indicator for pollution by using three of main indices (I- geo, CF, and PLI). Determination of heavy metal in the roadside dust is with XRD and XRF methods. I-geo for Co, Zn, Pb, and Ni in the studied sites shows relative values of class 1, which indicated the slightly polluted, while I-geo for Fe and Cu shows relative values

of class 0, which indicated no pollution. The contamination factor for Co, Zn, Pb, and Ni classified as class 2, which indicate moderately contamination, while the contamination factor for Fe and Cu classified as class 1, which indicate low contamination. PLI values in the all of studied sites classified as class 2 (Deterioration on site quality) indicating local pollution, as well as denote perfection with (class 0) of no pollution. The distribution pattern of metals percentages was affected by gases emitted from transportation vehicles as well as the prevailing wind direction.

Finally, study conducted by Al-Dulaimi et al. (2021) in Al-Fallujah, Iraq. The study aims are to determine heavy metals concentrations (Cd, Cr, Cu, Ni, Pb, Zn). The areal distribution of the reported heavy metals showed specific and non-specific patterns indicating point and non-point pollution sources. The heavy metals potential sources in house dust in the study area were characterized using correlation, Principle components and cluster analyses. The correlation matrix analysis results show a significant positive correlation at $P < 0.05$ was found between Cd-Cu ($R = 0.32$), Cd-Ni ($R = 0.73$), and Cd-Pb ($R = 0.92$). The correlation analysis showed significant positive correlation relations between CrNi ($R = 0.45$), Cr-Pb ($R = 0.29$), Cu-Pb ($R = 0.37$), and Ni-Pb ($R = 0.65$). The results of PCA are Two large factors were extracted with an eigenvalue greater than 1 and constituted 69.93 % of total variance. Factor 1 elucidated 48.23% of variation in metal data with largest positive loadings on Ni (0.89), Cr (0.72), Cd (0.65), and Pb (0.63).

Table (2.4) display Heavy metals concentration (mg/kg) in street dust from previous local and international studies.

Table 2.4 Heavy metals concentration (mg/kg) in street dust from previous local and international studies.

City/Country	Pb	Cd	Cr	Cu	Zn	Hg	Reference
Samawa (Iraq)	18.01	1.38	9.89	13.25	27.95	0.009	-
Suwalki (Poland)	17..04	-	63.95	142.84	215.97	-	Skorbiłowicz, et al (2023)
Madrid City (Spain)	290	1.25	100	411	895	-	Delgado-Iniesta et al .(2022)
Lublin (Poland)	62.0	6.3	108.5	114.9	364.4	-	Wojciech et al .(2021)
Morelia, Michoacan (Mexico)	502.9	3.7	104.3	696.7	634.6	56.5	Anahi Aguilera et al.(2021)
Shijiazhuang (China)	154.78	1.86	131.70	91.06	469.17	0.29	Kui Cai et al .(2019)
Tehran (Iran)	81.28	0.43	38.16	286.14	694.79	-	Kamani et al .(2017)
Sarajevo, Bosnia and Herzegovina	202	1.42	21.82	86.99	192	-	Razanica et al (2014)
Edinburgh (Scotland)	118	57	16	1	213	-	Sudip et al. (2010)
Cairo megacity (Egypt)	66	-	26	26	201	0.90	Mostafa et al .(2024)
Kirkuk (Iraq)	24	-	10	6	169	-	Khwedim et al.(2022)
Al-Fallujah, Iraq	75.57	14.77	289.45	65.03	292.85	-	Al-Dulaimi et al. (2021)
Baghdad (Iraq)	-	0.55	6.47	9.80	13.12	-	Abed, S et al.(2020)
Diwaniyah (Iraq)	-	-	43	45	115	-	Al-Dabbas et al. (2018)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental design

The experiment was conducted to measure the concentrations of heavy elements as shown in the (Figure 3.1).

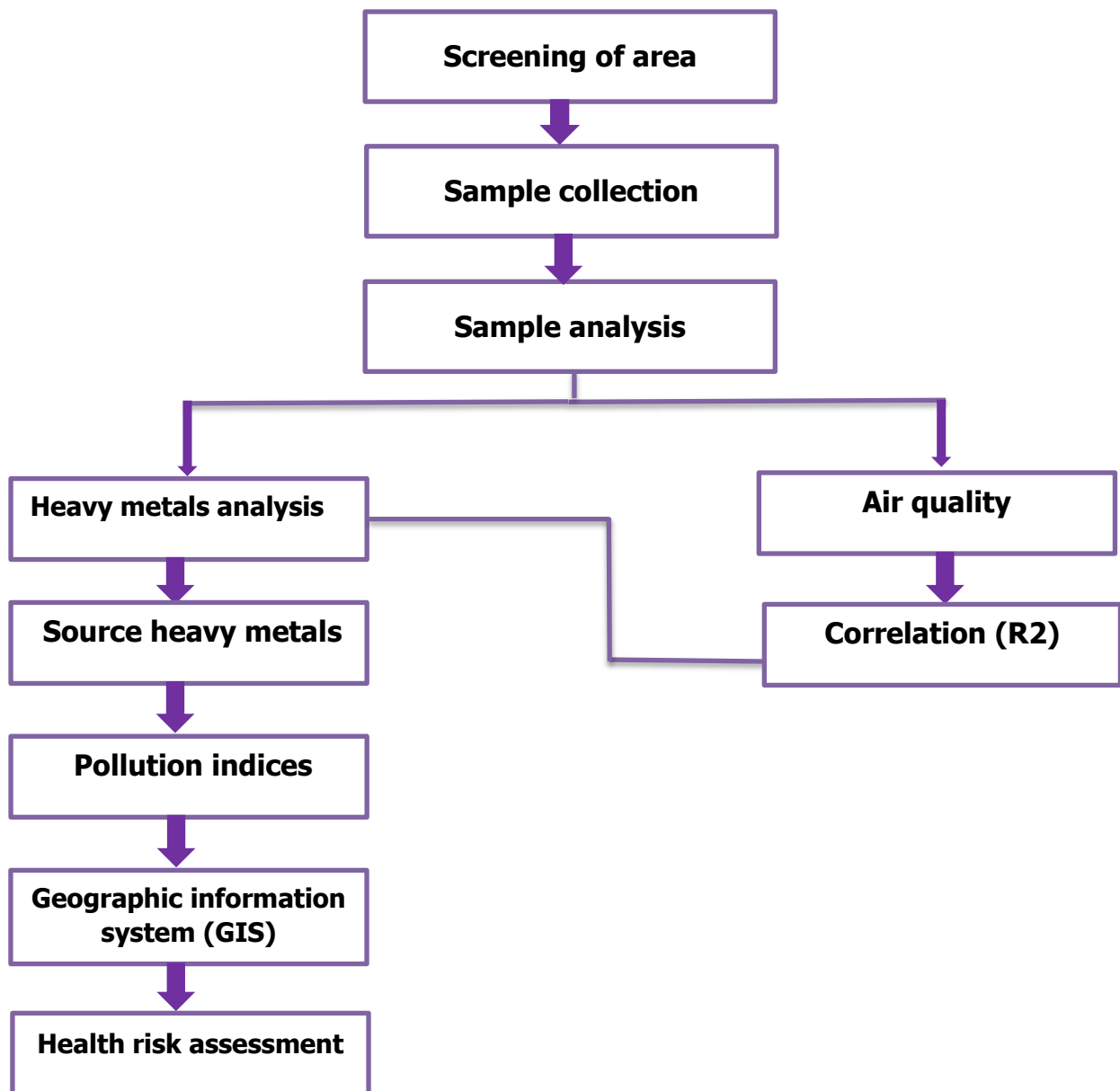
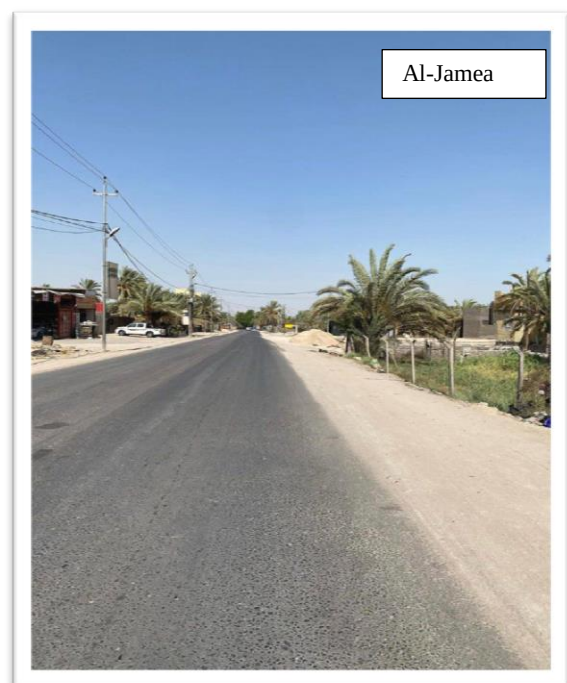
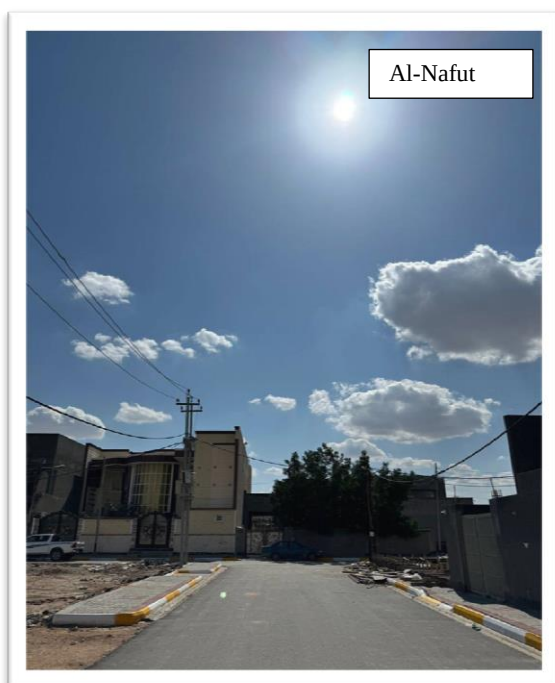


Figure 3:1 Design for a comprehensive research that was conducted in a number of heavy metals in Al-Samawa City.

3.2 Study area

Samawa is situated 280 kilometers southeast of Baghdad at coordinates $31^{\circ} 19' 0''$ N, $45^{\circ} 17' 0''$ E. Samawah is an urban center located in Iraq, as stated by (Karima et al. 2018). The present capital of the Al Muthanna Governorate is Samawah. The city is located in the northern edge of the governorate, almost equidistant between Baghdad and Basra. Figure (3.3) show the Iraq map and sample collection in Al-Samawa street. Samawah is classified as having a hot desert climate (BWh) according to the Köppen–Geiger climate classification system. The majority of precipitation occurs during the winter season. The mean yearly temperature in Samawah is 23.8°C (74.8°F). The yearly precipitation is approximately 106 mm (4.17 in). The study was conducted in 10 distinct sites within the city of Samawa, including the Al-Jamea, Al-Haydariyah, Al-Qishla, Al-Nafut, Al-Mukafaha, Al-Dhubat, Al-Hussein, Al-Sader, Al-Fanadiq, and the Corniche. Figure 3.2 show street of samawa.

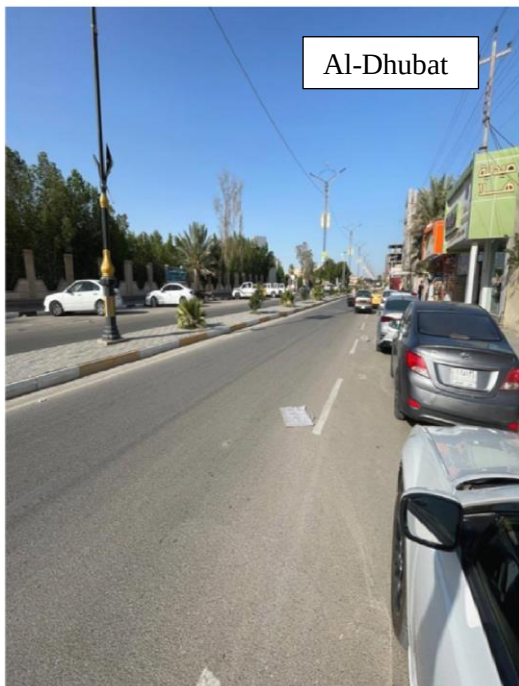




Al-Qishla



Al-Mukafaha



Al-Dhubat



Al-Corniche

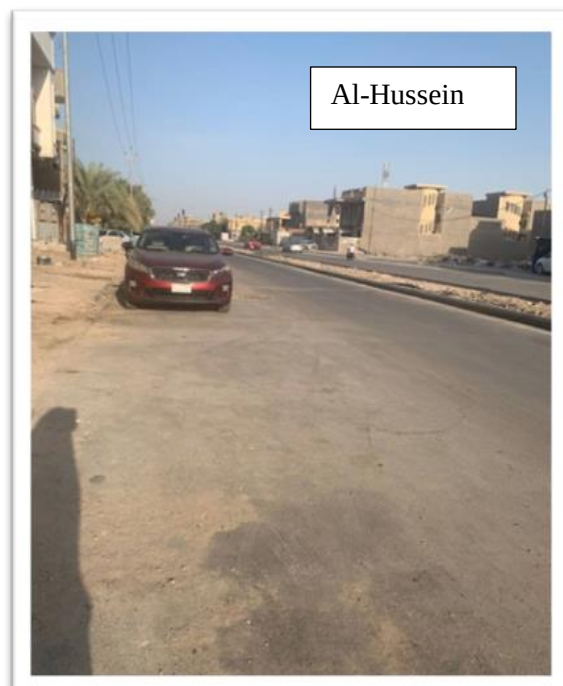
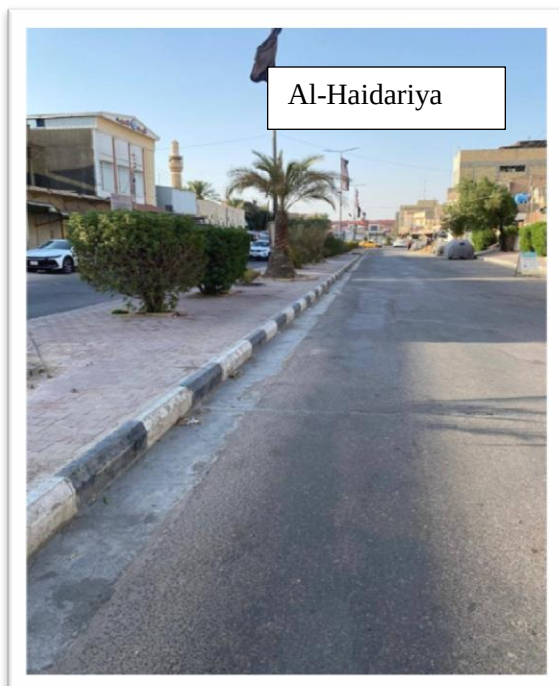
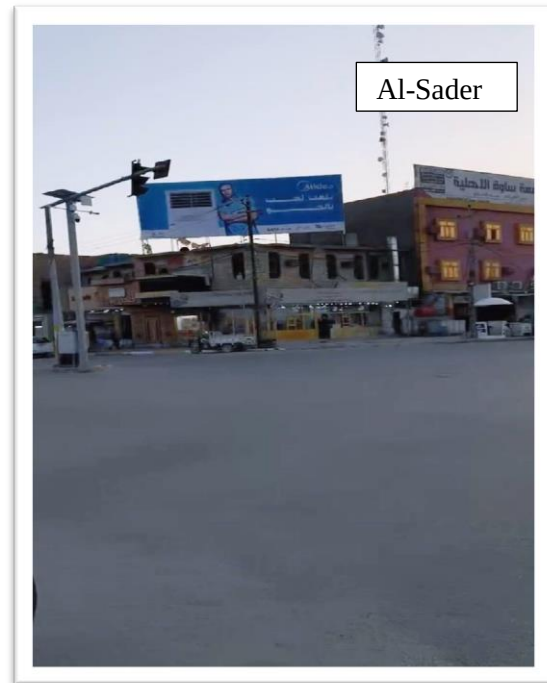
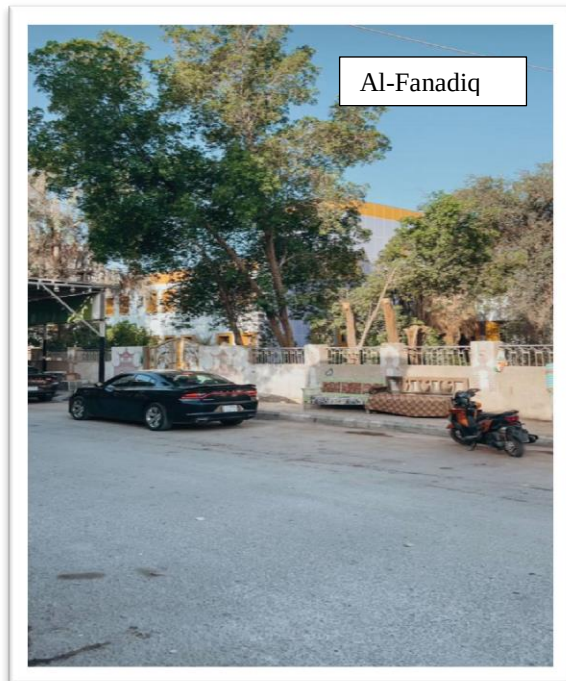


Figure 3.2 images of Street of samawa city

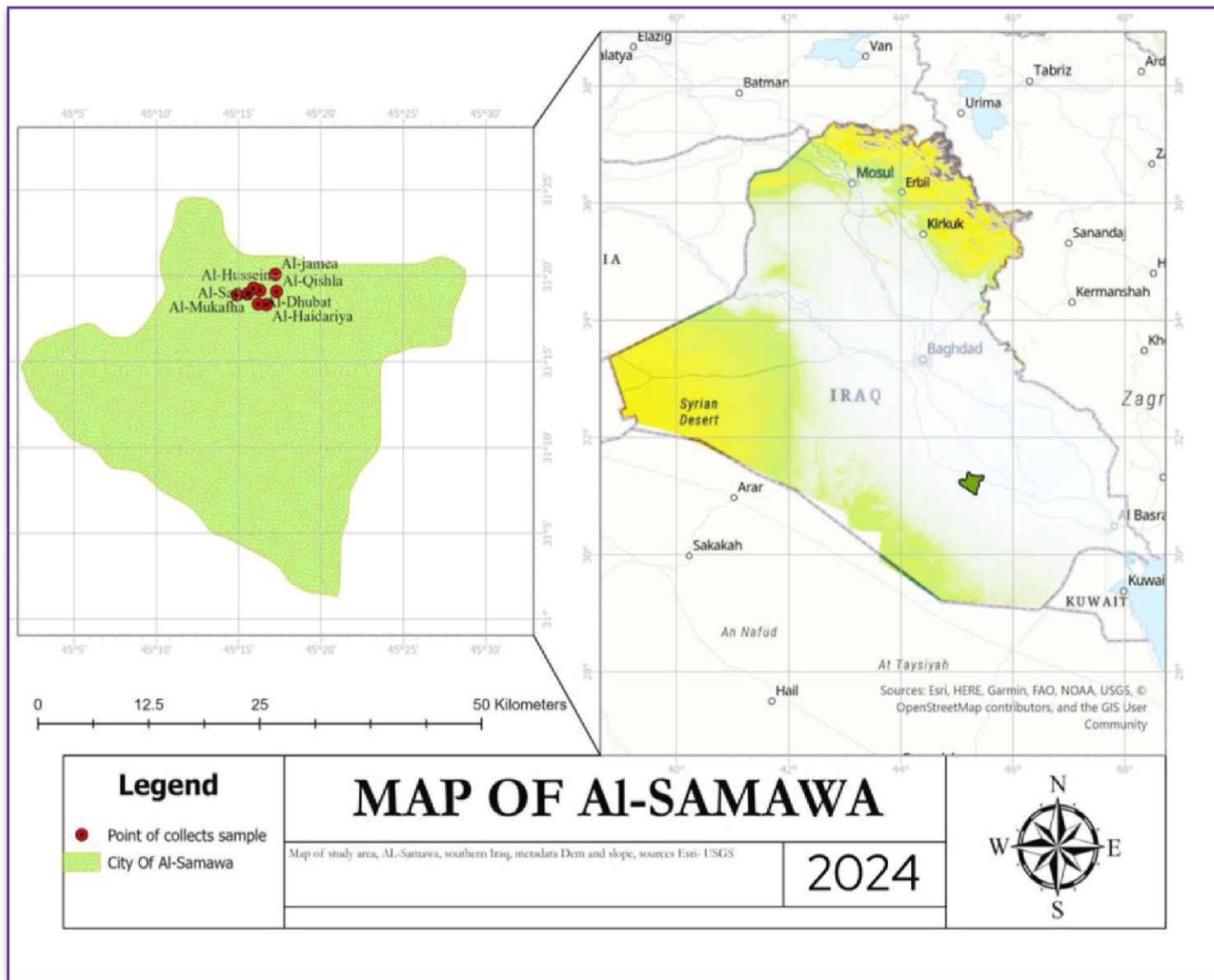


Image 3:3 Iraq map and sample collection in Al-Samawa streets.

3.3 Sample collection

Roadway dust was obtained, as stated by (Trujillo-González et al. 2016), according to the information. thirty samples (n=30) of roadway dust were collected over the months of June and July in the year 2023. An inventory of the locations, descriptions, and coordinates of the samples that were collected is presented in Table 3.2. Figure 3.4 Using a brush and a frame measuring 0.25 square meters, the dust components from the streets of Samawa were collected. Polyethylene bags were used to store the dust samples that were collected to be investigated. The samples were labelled (name of each street), placed in an ice box, and then placed in the refrigerator, and the temperature was set to -4 degrees Celsius. the items were transferred to the laboratory in a meticulous manner. The analysis of heavy metals in street dust was conducted based on (Ismail; et al 1993). The trace metal concentration of the samples was determined using the SHIMADZU AA-7000 Atomic Absorption Spectrophotometer. Equipment and chemicals were used to analyze the samples and get the results (Table 3.1).

Table (3.1): Devices and chemicals used for the current study.

Device name	Supplying company
Atomic Absorption Spectrophotometer	SHIMADZU AA-7000
Air quality measuring	Gallen Kamp
Brush	China
Frame measuring	China
Polyethylene bags	China
Camera	Apple U.S.A
Flask	TWT Germany
Standard Spectrum Germany	Spectrum Germany

Refrigerator	Samsung , Korea
Chemicals used	
Hydrochloric acid	HClO ₄
Nitric acid	HNO ₃
Double-distilled water	(DDW)

Table 3.2 The longitude, latitude and description for all areas.

Region	Longitude	Latitude	Description
Al-Jamea	31.334749	45.287142	Commercial area
Al-Haidariya	31.305211	45.278102	Residential area
Al-Qishla	31.318118	45.288343	Residential area
Al-Nafut	31.314703	45.248409	Industrial area
Al-Mukafaha	31.315741	45.259133	Close to gas station
Al-Dhubat	31.319044	45.271592	Residential area
Al-Hussein	31.321324	45.264996	Residential area
Al-Sader	31.305842	45.269730	Close to Battery changing
Al-Fanadiq	31.310449	45.284852	Commercial area
Al-Corniche	31.315488	45.289002	Commercial area



Figure 3.4 Brush and Polyethylene bags to collect sample dust.

3.4 Samples Analysis

The dust street samples (1 g) were dissolved in a 10-ml solution of a mixture of HNO_3 (AnalaR grade, R&M 65%) and HClO_4 (AnalaR grade, R&M 70%) in a ratio of 4:1 (v/v). The dissolution process took place in a pre-heated block digester at a low temperature of 40 °C for 1 hour, followed by an increase in temperature to 140 °C for 3 hours (Ismail 1993). After digestion, the samples were diluted to a level of 40 ml with double-distilled water (DDW) and passed through a Whatman No. 1 filter paper into 40-ml volumetric flasks that had been cleaned. The materials were analyzed for trace metal levels using an Atomic Absorption Spectrophotometer (SHIMADZU AA-7000). Figure 3.5 show image of Atomic Absorption Spectrophotometer device.



Figure 3:5 Atomic Absorption Spectrometer (AAS) for analysis heavy metals.

3.5 Air quality measurement

The air quality was measured in the streets of the city of Samawa and in ten different locations in order to determine the air quality and its impact on public health. Three readings were taken every five minutes, with an interval of 15 minutes ($n=30$), for an hour for each location, using an air quality measuring device. Easy of use is one of the most crucial considerations when selecting an air monitoring equipment. Air quality measurements ought to be quick, easy, and convenient. This device (Figure 3.6) is characterized by being small and portable, with which particle matter (PM2.5 , PM1.0 , PM10) , carbon dioxide (CO₂) ,Temperature and Humidity are measured .



Figure 3.6 Air quality measuring device.

3.6 Indices of Pollution

3.6.1 Geoaccumulation index (*I_{geo}*)

The geo-accumulation index (*I_{geo}*), proposed by Muller (Muller 1969), was employed to assess the level of heavy metal contamination in the street dust samples. Numerous research (Lu et al. 2009; Shi and Wang, 2013; Smuc et al. 2009; Yaylalı-Abanuz, 2011) have generally used this indicator to assess heavy metal pollution. The measure assesses the level of pollution in street dust in relation to pre-industrial levels (Weissmannova' et al. 2015).

I_{geo} is calculated by Eq. 1:

$$I_{geo} = \log_2(C_n/1.5B_n) \quad (\text{Eq.1})$$

where :

C_n : is the content of the heavy metal in the street dust sample.

B_n : is the geochemical background value.

factor 1.5 is the background matrix correlate factor due to natural fluctuation in the content of a given chemical elements in the environment with minimum anthropogenic influence (lu et al. 2009 , muller et al.1999 , shi et al. 2010 , wei et al. 2009). Table 3.3 shows the geo-accumulation index for the metal under investigation. The final class, which is available to anyone, may be 100 times more concentrated than the background concentration.

Table 3.3 Geo-accumulation index classification (Muller,1969)

Description	<i>I_{geo}</i> value	Class
Uncontaminated	$I_{geo} \leq 0$	0
Uncontaminated to moderately contaminated	$0 < I_{geo} \leq 1$	1
Moderately contaminated	$1 < I_{geo} \leq 2$	2
Moderately to heavily contaminated	$2 < I_{geo} \leq 3$	3

Heavily contaminated	$3 < I_{geo} \leq 4$	4
Heavily to extremely contaminated	$4 < I_{geo} \leq 5$	5
Extremely contaminated	$I_{geo} > 5$	6

3.6.2 Contamination factor (CF)

The CF, which Hakanson (1980) first proposed to measure the amount of heavy metal contamination in sediment, were used to measure the amount of heavy metal contamination in street dust (Roy et al. 2019; Trojanowska and Świetlik 2019; Aguilera et al. 2021). Based on the determined values of Cf, four levels of heavy metal contamination were proposed, which are detailed in (Table 3.4) Eq. 2 was used to calculate the (Cf).

$$CF = C_s / C_B \quad (\text{Eq.2})$$

Where:

Cs: (mg/kg) are the concentration of heavy metal in a street dust sample.

CB: Background sample where Cd(0.30), Cr(90), Zn(95), Cu(45), Pb(20), Hg(0.08). (Taylor 1964)

Table 3.4 Classification of contamination factor by (Hakanson ,1980).

The factor of contamination	Description
$CF < 1$	Slightly polluted
$1 \leq CF < 3$	Moderately polluted
$3 \leq CF < 6$	Highly polluted
$CF \geq 6$	Extremely polluted

3.6.3 Pollution load index (PLI)

One of the intricate indicators that aids in determining the overall level of heavy metal contamination is the pollution load index. It is computed as the geometric mean of the individual values of CF_n (Tomlinson et al. 1980). It can be expressed by the equation:

$$PLI = \sqrt[n]{(CF_1 \cdot CF_2 \cdot CF_3 \dots CF_n)}$$

(Eq.3)

PLI: pollution load index .

CF: is the contamination factor.

n: number of metals are there.

There is pollution if the PLI is greater than 1, and there is none if it is less than 1.

3.6.4 Ecological Risk Factor (Er)

Er is a dimensionless metal toxicity response factor that represents the potential ecological risk associated with a single metal. The ecological risk that heavy metals pose to humans and ecosystems is reflected in the toxic response factor Tr. The toxic response factors for Cu, Cr, Pb, Cd, and Zn were derived from published research (Hakanson 1980). Calculated by the following Eq.4 (Hakanson 1980; Ghanavati et al. 2019; Roy et al. 2019).

$$E_r = T_r \times C_f \quad (\text{Eq.4})$$

where :

Er: is the Ecological risk factor.

Cf: is the contamination factor

Tr: is the toxic factor for each heavy metal, according to Hakanson, 1980 the corresponding toxicity system of each metal (Cu=Pb=5, Cd=30, Cr=2, Hg=40, Zn=1), Detailed levels of the Er were shown in Table (3.5).

Table 3.5 Classification Ecological risk factor (Er) by (Hakanson, 1980)

Category	Description
$Er < 40$	Low
$40 \leq Er < 80$	Moderate
$80 \leq Er < 160$	Considerable
$160 \leq Er < 320$	High
$Er \geq 320$	Very high potential ecological risk

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Heavy metals and particle matter in street dust

Concentrations of heavy metals in dust samples collected from the streets of Samawa are presented in Table 4.1. The average concentrations of Pb, Cd, Cr, Cu, Hg, Zn in all examined streets are 18.01 mg/kg, 1.83 mg/kg, 9.89 mg/kg, 13.25 mg/kg, 27.95 mg/kg, respectively. The heavy metals levels in the examined streets decline in the following order: zinc (Zn) > lead (Pb) > copper (Cu) > chromium (Cr) > cadmium (Cd) > mercury (Hg). In Al-Corniche Street, the concentration of Pb was measured at a high level of 32.77 mg/kg, but in Al-Hussein Street, the concentration was found to be the lowest at 4.91 mg/kg. The Pb levels in Samwah were lower than those found in street dust samples from the largest city in Mexico (128.2 mg/kg) (Aguilera et al. 2021) and Dezful, Iran (54 mg/kg) (Sadeghdoust et al. 2020). Nevertheless, the concentration of Pb in Smawah exceeded that of Shiraz, Iran, which was measured at 11 mg/kg (Keshavarzi B et al. 2015).

The dust sample collected from Al-Haidariya Street had the greatest Cd concentration, measuring 2.22 mg/kg. Conversely, the lowest Cd concentration of 0.61 mg/kg was found in the dust sample from Al-Dhubat Street. The concentration of Cd in the samples exceeded that of Dust Street Ottawa (Canada) (0.4 mg/kg) (Rasmussen et al. 2001) and Dust Street Amman (Jordan) 1 mg/kg, (Jiries et al. 2003). The highest content of Cr in the dust 13.09 mg/kg was in the Al-Sader area and the lowest level was 6.52 mg/kg in the Al-Mukafaha area. Compared to previous studies Cr levels in Lanzhou dust ranged from 18.8 to 135 mg/kg, with the maximum concentration 7.18 times higher than the minimum value. The lowest concentration of Cr (18.8–101 mg/ kg, average 82.7 mg/ kg) was found in Qilihe.

The highest concentration of Cu was Al-Fanadiq street, where it reached 52.63 mg/kg because it is a commercial area with high car traffic, which is

considered highly polluted. The lowest value was in the Al-Dhubat street, 3.53 mg/kg. This means that it is less polluted with Cu because it is a residential area. Numerous studies (Duong et al. 2011; Liu et al. 2016), and (Thorpe et al. 2016) have suggested that brake abrasion may be the cause of a high concentration of Cu in an urban setting. Consequently, the region with the highest concentration of Cu in this study may be the result of exhaust fumes from fuel combustion in high-rate traffic as well as brake abrasion from frequent braking.

Zinc (Zn) is found in significant concentrations in dust samples as a result of traffic emissions, which include engine emissions, mechanical vehicle abrasion, and tire and brake wear. Zinc is an essential trace element that is widely disseminated in the environment (Duong et al. 2011). Zinc concentrations reached their highest levels in Al-Fanadiq street at 74.97 mg/kg, while their lowest levels were in the Al-Jamea area at 6.48 mg/kg. In the absence of soil and dust background data in Iraq, we are comparing our results with the low and high levels of Hong Kong's ISQV (Chapman PM et al. 1999).

In the current investigation, all the metals exhibited decreased Hong Kong ISQV, except for Cd (1.83 mg/kg), which exceeded the low Hong Kong ISQV threshold of 1.5 mg/kg (Table 4:1). A comparison of heavy metals concentrations in street dusts of Lanzhou Concentrations of Zn in street dust ranged from 41.5 to 109 mg/kg with a geometric mean of 56.6 mg/kg. for mercury, The low value was recorded in all study areas except for Al-Fanadiq street, which reached (0.06 mg/kg).

Table 4:1 Total concentration of heavy metals (mg/kg) in study area.

Regions	Pb	Cd	Cr	Cu	Zn	Hg
Al-Jamea	20.13	2.01	7.50	8.23	6.84	0.00
Al-Haidariya	22.00	2.22	9.38	14.51	33.51	0.00
Al-Qishla	21.06	1.86	11.66	10.90	48.96	0.00
Al-Nafut	7.02	1.66	12.80	7.14	13.46	0.00
Al-Mukafaha	17.79	1.77	6.52	5.36	8.83	0.00
Al-Dhubat	10.01	0.61	7.61	3.53	15.54	0.01
Al-Hussein	4.91	2.12	9.95	7.19	15.74	0.00
Al-Sader	14.51	2.18	13.09	8.33	16.33	0.00
Al-Fanadiq	29.96	2.20	12.23	52.63	74.97	0.06
Al-Corniche	32.77	1.74	8.17	14.71	45.40	0.02
Total mean	18.01	1.83	9.89	13.25	27.95	0.009
Hong Kong ^a ISQV-low	75	1.5	80	65	200	0.28
^a Hong Kong ISQV-high	218	9.6	370	270	410	1

4.2 Air quality measuring

The study also performed measurements of air quality to assess the levels of particulate matter of 1.0, 2.5 and 10 microns in ten different locations in the streets of Samawa. The PM_{2.5} concentrations in Al-Haidariya Street were recorded at 104 µg/m³, indicating high levels. Contrastingly, Al-Hussein Street had a lesser concentration of PM_{2.5}, quantified at 31 µg/m³. The implied concentration of PM_{2.5} has reached 67.3 µg/m³.

The Al-Haidariya street had the best concentration of PM_{1.0}, measuring 68 µg/m³, while the Al-Hussein road had the lowest value, measuring 17 µg/m³. The total mean of PM_{1.0} has reached 43.9 µg/m³.

The PM₁₀ measurements found that Al-Haidariya Avenue had the highest value at 139 µg/m³, while Al-Qishla Street and Al-Hussein Street had the lowest

values ($39 \mu\text{g}/\text{m}^3$ respectively). The average concentration of PM_{10} has reached $86.3 \mu\text{g}/\text{m}^3$.

The World Health Organization (WHO), revealed that the levels of particulate matter (PM_{10} and $\text{PM}_{2.5}$) on the streets of Samawa exceeded the allowable limit. In the absence of soil and dust background data in Iraq.

Zn is primarily released through tire and brake wear, as well as diesel exhaust emissions. Additionally, certain Zn compounds are employed as additives in motor oil (Budai et al. 2018; Swietlik et al. 2015). Chromium (Cr) can be emitted via vehicle exhaust (Gunawardena et al. 2014). Therefore, Cr comes from different anthropogenic activities.

Table (4.2) shows that the average levels of carbon dioxide are very similar, with the highest levels appearing in the Al-Haidariyah, Al-Qishla, Al-Sader, Al-Fanadiq and Al-Jamea areas (600 ppm, 663 ppm, 663 ppm, 663 ppm, 622 ppm). These areas can be considered the areas where human activities are at the highest level. The rest of the regions showed lower levels, with the lowest level in Al-Dhubat, Al-Hussein regions was 400 ppm, and Al-Nafut was 451 ppm with an average of 551.

As in a previous study that took place in Kastamonu city center (January 2017), This study aims to determine the changes in air quality throughout the day depending on the weather conditions and traffic density in various areas of Kastamonu city centre. The highest CO_2 level was found to be 867 ppm due fossil fuels, while it was 873, 1005 and 1050 ppm due Car smoke emission and transportation, Since the middle of the 20th century, annual emissions from burning fossil fuels have increased every decade, from close to 11 billion tons of carbon dioxide per year in the 1960s to an estimated 36.6 billion tons in 2023 according to the Global Carbon Budget 2023.

Table (4.2) Changes in air quality in different area in Samawa city.

Regions	PM _{2.5}	Particulate matter (µm)	PM ₁₀	Co ₂ (ppm)
		PM _{1.0}		
Al-Jamea	64	41	85	600
Al-Haidariya	104	68	139	663
Al-Qishla	37	34	39	663
Al-Nafut	38	40	50	451
Al-Mukafaha	80	46	100	598
Al-Dhubat	80	46	100	400
Al-Hussein	31	17	39	400
Al-Sader	86	56	115	622
Al-Fanadiq	76	45	97	663
Al-Corniche	77	46	99	450
Total mean	67.3	43.9	86.3	551
WHO, (2000)		25	25	

4.3 Multivariate statistics

4.3.1 Pearson correlation coefficients

The Pearson correlation coefficients for heavy metals in street dust in Samawa are presented in Table 4.3 and Figure (4.1), Lead (Pb) has a robust positive correlation with Copper (Cu) and Zinc (Zn) ($r=0.509$; $r=0.570$) respectively, suggesting a potential common source.

They suggested that the source of these elements could be attributed to industrial and traffic-related activities. Furthermore, Lead (Pb) demonstrates a weaker positive association with PM_{2.5} ($r=0.476$) and a weaker positive correlation ($r=0.429$) with PM₁₀, indicating that these particles may have an adverse impact on human health in the streets of Samawa. Pb can be derived from the depletion of lead wheel weights (Shabanda et al. 2019) Copper (Cu) has a significant positive connection with Zinc (Zn) ($r=0.712$), Zn had a strong

positive correlation with Mercury (Hg) ($r=0.459$) in Samawa streets, suggesting a potential common source. Additionally, Cu demonstrates a strong positive correlation with $PM_{2.5}$ and PM_{10} ($r=0.530$; $r=0.484$) respectively, and a weak positive correlation with $PM_{1.0}$ ($r=0.437$).

This indicates that these particles may have an adverse impact on respiratory health in the streets of Samawa. The presence of Chromium (Cr) in Samawa streets showed no correlation with heavy metals and particulate pollution.

The strong positive correlation indicates that these toxic metals originate from common human activity sources. When comparing the current study with previous studies, it was found that the current study was higher than the previous study dezful, Iran (Sadeghdoust et al. 2020), the PCA results ,factor loading >0.7 and 64.3% total variance, contains Cr, Ni, Cd, Pb and Cu, this indicates that Cr, Ni, Cd, Pb and Cu, Less than the current study. (Saeedi et al.2012) observed a strong association between the presence of Cu and Zn in the street dust of Tehran

The correlation coefficient between pollutants showed that the Lead (Pb) element had a positive and significant correlation at $p < 0.01$ with Copper (Cu) (0.75) and Zinc (Zn) (0.51). The strong positive correlation indicates that these toxic metals originate from common human activity sources.

The strong positive relationship between CO_2 and PM_{10} and $PM_{2.5}$ (0.667) particles suggests that CO_2 can easily react with these particles and be breathed in by people, which is bad for health, especially for people with asthma. In addition, a weak positive correlation between CO_2 , Cadmium (Cd) (0.443) and $PM_{1.0}$ (0.437) indicated that automobile emissions and commercial activities were the sources of Cd, CO_2 , and $PM_{1.0}$, respectively. And, in this case, cadmium exposure over an extended period of time is linked to renal dysfunction. Prolonged exposure to a particular substance can result in the

development of obstructive lung diseases, such as proteinuria, as well as injury to the kidneys and bones (Koji et al. 2004).

As a result of the ability of air mass movement to discharge heavy metals, the respiratory system can directly assimilate them. Consequently, even trace amounts of heavy metals can be harmful (Zgłobicki et al. 2018). It should also be remembered that the individual indices show slightly different pollution levels, even though the general trends for the specific elements are maintained in Samawa street dust. The problem of improving the method of calculating the indices requires further study. Figure 4.1 show Pearson correlation of heavy metals and particles matter in study area.

Table (4.3) The correlation coefficient between metals concentrations and particles matter

Pb		Cd	Cr	Cu	Zn	Hg	PM _{2.5}	PM _{1.0}	PM ₁₀	CO ₂
Pb	1									
Cd	0.059	1								
Cr	0.204	0.160	1							
Cu	0.509**	0.126	-0.002	1						
Zn	0.570**	0.073	0.102	0.712**	1					
Hg	0.127	0.095	0.200	0.225	0.459**	1				
PM _{2.5}	0.476**	0.301	0.107	0.530**	0.390*	0.186	1			
PM _{1.0}	0.306	0.277	0.045	0.437*	0.320	0.040	0.667**	1		
PM ₁₀	0.429*	0.229	0.085	0.484**	0.334	0.225	0.958**	0.616**	1	
CO ₂	0.207	0.443*	0.167	0.345	0.219	0.334	0.667**	0.437*	0.667**	1

****P ≤ 0.01 ; *P ≤ 0.05**

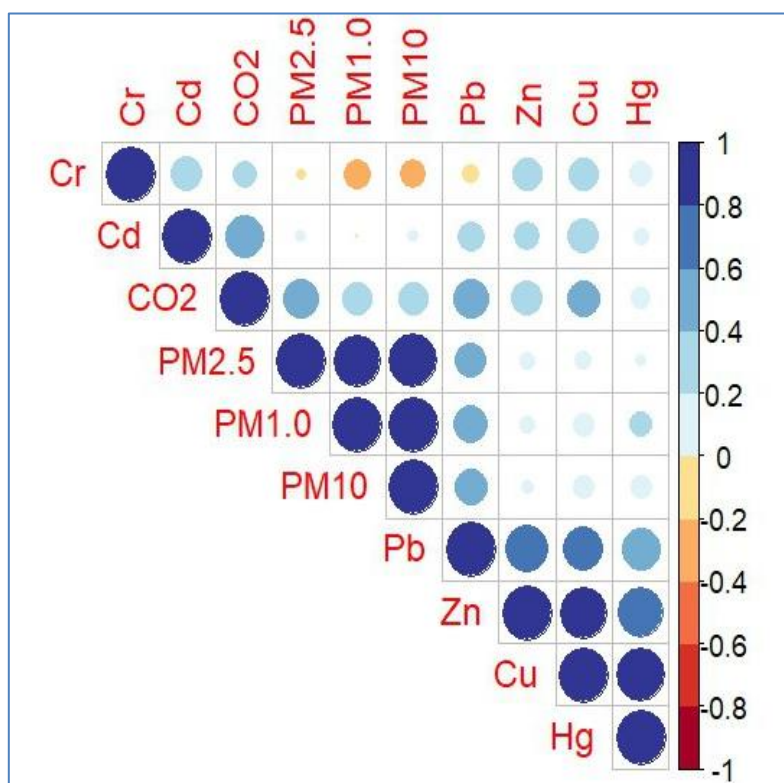


Figure 4.1 Pearson correlation of heavy metals and particles matter in study area.

4.3.3 Principal Components Analysis (PCA)

It is a widely applied multivariate statistical method to identify potential sources of street dust metals (Phi et al. 2017; Shabanda et al. 2017).

The analysis of PCA is used to identify the sources of anthropogenic pollution of heavy metals in the streets of Samawah (Chen et al. 2014). Table 4.5 displays the factor loading values and eigenvalues obtained using varimax rotation.

The Kaiser–Meyer–Olkin (KMO) test showed a value of 0.737, while Bartlett's test of sphericity showed statistical significance ($p < 0.000$), suggesting that the data is likely to be factorizable. Table 4.4 show the Kaiser–Meyer–Olkin (KMO) test and Bartlett's test.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.737
Bartlett's Test of Sphericity	Approx. Chi-Square	157.591
	df	45
	Sig.	.000

Table 4.4 Kaiser–Meyer–Olkin (KMO) test and Bartlett's test.

Principal Component Analysis (PCA) conducted on metals and air quality of street dust in Samawa city that identified three components with eigenvalues exceeding one. Three components, which accounted for 69.28% of the total variation, were identified, suggesting that the sources of heavy metals might be classified into three primary Table (4.6) and Fig (4.2).

The initial component consists of PM_{2.5}, PM_{1.0}, PM₁₀, and CO₂. The second component consists of lead (Pb), copper (Cu) and zinc (Zn), indicating that lead (Pb), copper (Cu) and zinc (Zn) found in dust often come from the settling of particles emitted by vehicles, such as exhaust particles produced during fuel combustion and particles from brake linings (Ali et al. 2017). The third component consists of chromium (Cr) and mercury (Hg). Zinc (Zn) is primarily released through tire and brake wear, as well as diesel exhaust emissions. Additionally, certain Zn compounds are employed as additives in motor oil (Budai et al. 2018, Swietlik et al. 2105). Chromium (Cr) can be emitted via vehicle exhaust (Gunawardena et al. 2014).

Therefore, Chromium (Cr) comes from different anthropogenic activities. Moreover, according to the findings of (Lee et al. 2018), lead (Pb) chromate in dust particles is derived from yellow street paint. Moreover, they contend that lead chromate-containing paint is among the most significant sources of Pb contamination in street dust; thus, lead chromate paint may serve as a likely source of Cr and Pb in the street dust of Mexico City (Aguilera et al. 2021).

As a result of abrasion, humidity, temperature, and light exposure (it is a photosensitive pigment), lead chromate begins to degrade; paint and pigments crack, peel, and transform into chalk, releasing metal particles into the urban environment (Legalley & Krekeler, 2013). As a result, lead (Pb) and chromium (Cr) concentrations in the dirt of Samawa streets may rise.

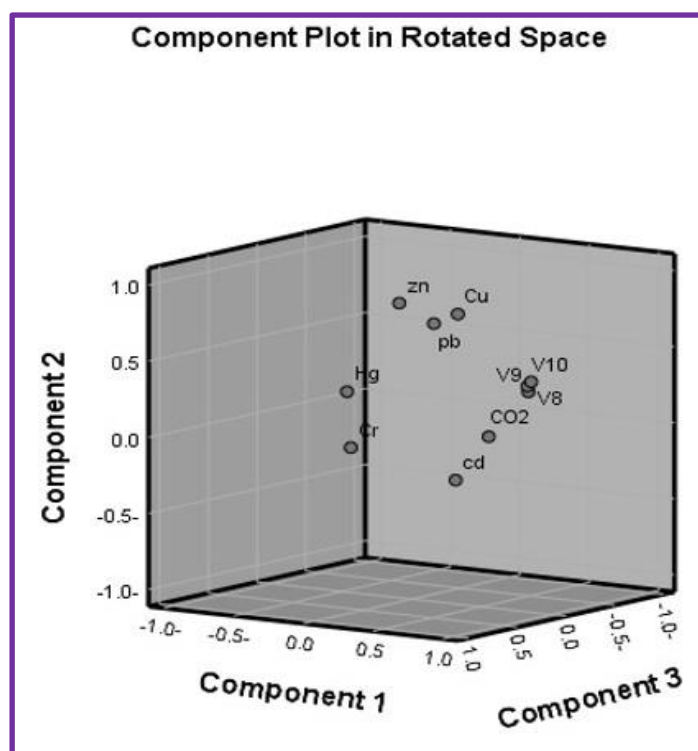
Mercury, an element that occurs naturally in gas and oil, can attain concentrations as high as 10 mg/ kg in crude oil (Wilhelm and Bloom, 2000), Despite the low concentrations of mercury, this percentage may increase in street dust in Samawah due to the presence of many influencing factors in the city of Samawah, which poses a real danger to the city's local residents.

When comparing the PCA results of this study with previous PCA studies such as a study that occurred in Tehran, Iran (Kamani et al. 2017) .The PCA results ,factor loading >0.7 and 64.3% total variance, contains Cr, Ni, Cd, Pb and Cu. This indicates that Cr, Ni, Cd, Pb and Cu ,Less than the current study.

High concentration of PCA can be defined as anthropogenic constituents and may originate from similar sources, especially high-tem perature processes such as residential and commercial boilers, automobiles, waste incineration and industrial metallurgical process. PCA (69.28%) of the total variation, in this study less than PCA (82.377%) of Baghdad Iraq (Abed et al. 2020).

Table (4.6) Rotated Component Matrix^a

	Component		
	1	2	3
Pb	0.208	0.730	0.068
Cd	0.574	-0.218-	0.368
Cr	0.071	-0.004-	0.725
Cu	0.321	0.792	-0.016-
Zn	0.082	0.877	0.244
Hg	0.027	0.356	0.702
V8	0.858	0.404	0.000
V9	0.729	0.302	-0.156-
V10	0.833	0.373	0.001
CO2	0.787	0.084	0.333
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.			
a. Rotation converged in 7 iterations.			

**Figure 4.2: Component plot in rotated space of heavy metals in study area.**

4.4.4 Heat map cluster

The cluster heat map is an ingenious display that simultaneously reveals row and column hierarchical cluster structure in a data matrix. It consists of a rectangular tiling with each tile shaded on a color scale to represent the value of the corresponding element of the data matrix. The rows (columns) of the tiling are ordered such that similar rows (columns) are near each other. On the vertical and horizontal margins of the tiling there are hierarchical cluster trees. Weinstein (2008). Non-statisticians can benefit from using heat maps to understand and analyze data because they are readable and intuitive when displaying data through color depth and It is not subject to standards, but rather to dynamic statistical analysis (Carroll LN et al. 2014 ; Ohannessian et al. 2017). We attempted to use heat map data visualization technology in our study to show and examine data on heavy metals and particulate matter. Red color indicates the highest percentage of pollution, and blue color indicates the lowest percentage of pollution , It will be in the form of a cluster .

Cluster 1 It includes a Al-Fanadiq area , cluster 2 includes Al-Haidariya, Al-Qishla and Al-Corniche area As for cluster 3 include Al-Jamea, Al-Mukafaha, Al-Sader, Al-Dhubat , Al-Nafut and Al-Hussein area . Al-Fanadiq are the most polluted areas with respect to Zinc(Zn)>Copper(Cu)>Lead(Pb)>Chromium (Cr)>Cadmium(Cd)> Mercury(Hg) , As for the Al-Haidariya area, the highest polluted element was Zn>Pb>Cu>Cr>Cd>Hg.

The concentration of elements in the Corniche area , Al-Jamea area and Al-Mukafaha area are ranges from highest to lowest according to the order Pb>Zn>Cu>Cr>Cd>Hg, As for the Al-Sader area and Al-Dhubat area the concentration of elements from the most contaminated to the least contaminated is as follows Zn>Pb>Cr>Cu>Cd>Hg, As for the Al-Nafut area the concentration of elements from the most contaminated to the least contaminated is as follows Zn>Cr>Pb>Cu>Cd>Hg, As for the Al-Hussein area, the concentration of elements ranges as follows Zn > Cr >Cu >Pb >Cd >Hg. The CA results for the

metals studied are shown in Fig. 4.3 as a clusters. Previous study occurred in Detroit of michigan (Denny M et al. 2022) in this study of Detroit observed Two main clusters are observed, with Cluster 1 containing Cd, Ag, Cr, Zn Ni, and Cu and Cluster 2 containing Pb, As, Hg, and Ba.

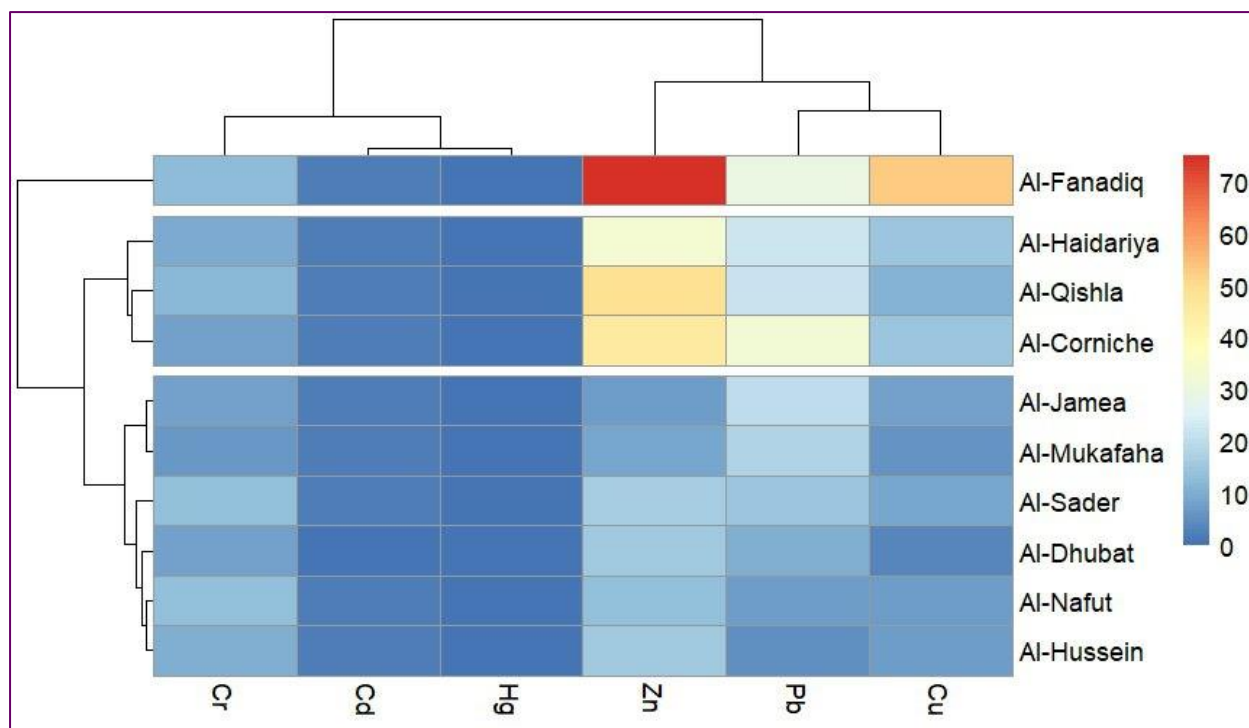


Figure 4.3 Heat map cluster of heavy metals in study area.

Figure 4.4 Showed three clustrings, cluster 1 contained Al-Sader, Al-Jamea, Al-Mukafaha ,Al-Haidariya and Al-Fanadiq area cluster 2 contained only Al-Qishla area cluster 3 contained Al-Dhubat ,Al-Corniche , Al-Nafut and Al-Hussein area. Areas in Cluster 1 and 2 had a high concentration of carbon dioxide, as the highest concentration was in dark red in the Al-Qishla, Al-Fanadiq, and Al-Haidariyah areas, followed by Al-Sader and control areas, which were in light red.

Areas in cluster1 and 2 had a high concentration of carbon dioxide. The highest concentration was in dark red in the Al-Qishla, Al-Fanadiq, and Al-Haidariyah areas, followed by Al-Sader and Al-Mukafaha areas. It was in light red, reaching 600 ppm, and the lowest concentration of carbon dioxide was in the

third complex, in the Al-Dhubat and Al-Hussein areas, followed by it the Corniche and Al-Nafut areas, where it reaches about 400 ppm. These high concentrations of CO₂ were due to human activities , gain the pollution from anthropogenic sources and traffic.

PM_{2.5} showed high concentration reache to 100 μm in cluster 1 in Al-Haidariya and Al-Sader area followed by Al-Mukafaha , Al-Jamea and Al-Dhubat .Cluster 3 showed high concentration of PM_{2.5} in the Al-Dhubat ,Al-Cornich and Al-Nafut areas. The lowest concentration of PM was in the Al-Hussein areas and in cluster 2 in Al-Qishla area.It ranges from light blue to dark blue.

PM_{1.0} showed high concentration in cluster 1 in Al-Haidariya area after that Al-Fanadiq ,Al-Mukafaha and Al-Sader area then Al-Jamea areas. Also, the highest concentrations of PM_{1.0} were reached in Cluster 3 in the Al-Dhubat and Corniche areas, and the lowest concentration was in the Al-Hussein and Al-Nafut areas, while Cluster 3 had the lowest concentration in the Al-Qishla area. PM₁₀ The highest concentration showed in the Al-Haidariya area in Cluster 1, followed by the Al-Sader area, Al-Mukafaha, and then the Al-Jamea area as well, with a gradient from light blue to dark blue.

Cluster 3 The highest concentration of the PM₁₀ was in the Al-Dhubat and Al-Corniche area, followed by the Al-Nafut and Al-Hussein areas, while Cluster 2 showed the lowest concentration in the Al-Qishla area.

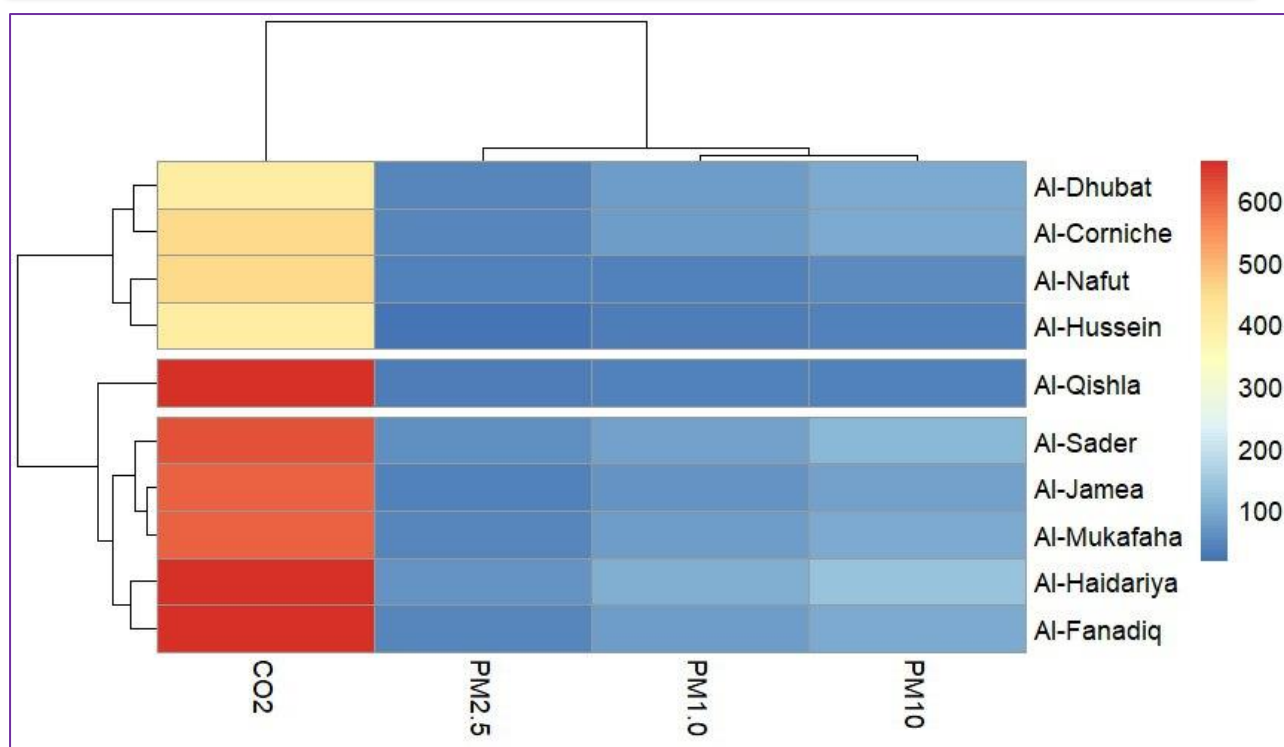


Figure 4.4 Heat map cluster of particle matter (PM2.5 ,PM1.0 , PM10) and CO2 in study area.

4.3 Geographical information system (GIS)

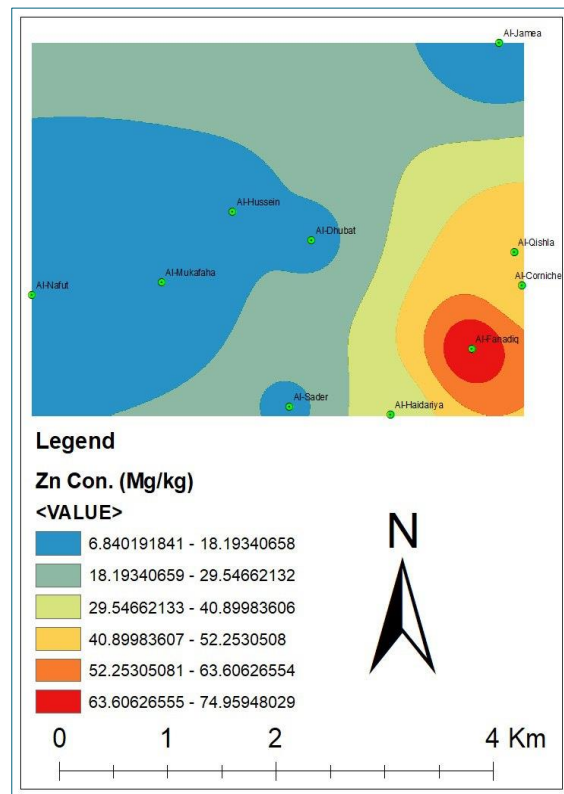
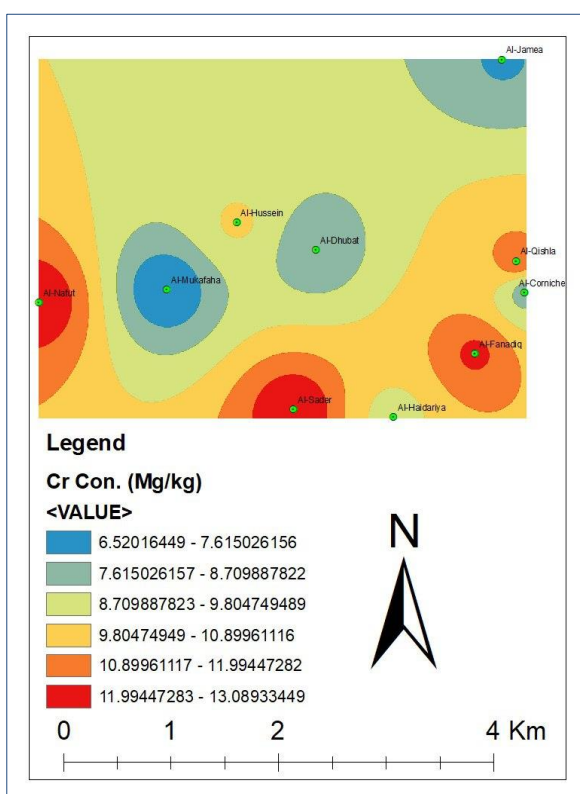
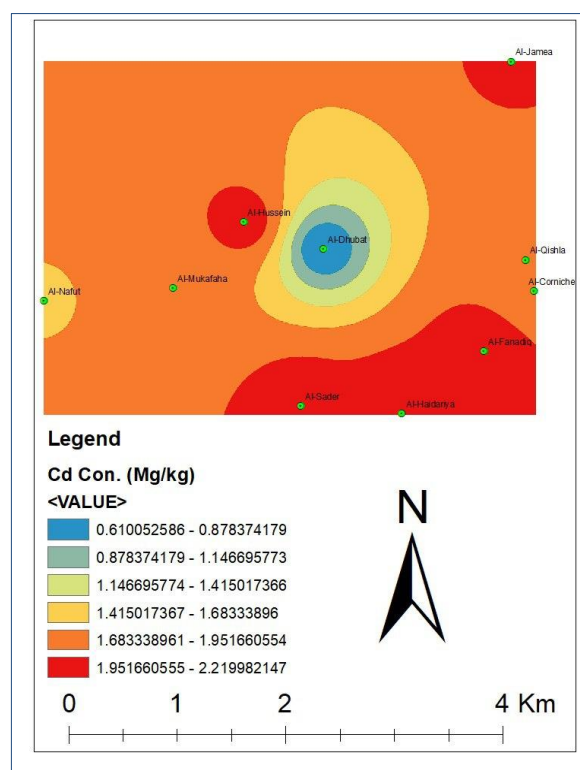
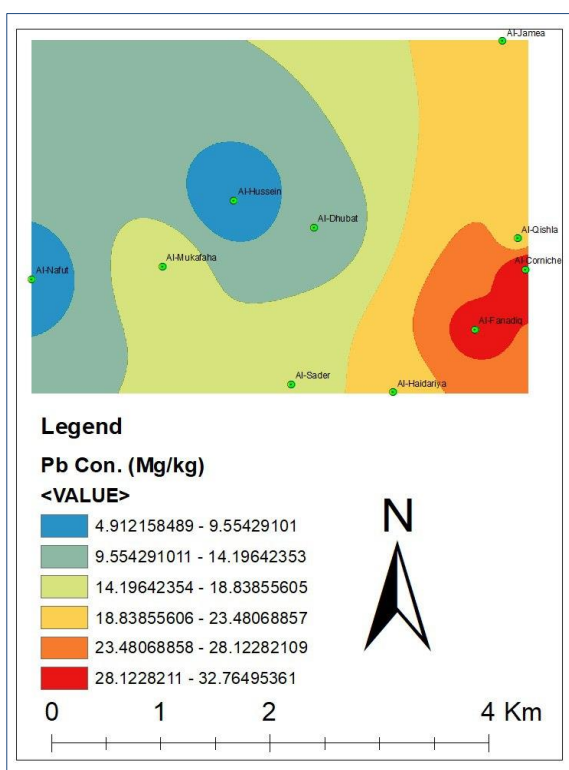
4.3.1 Spatial mapping of the heavy metal in street dust

Figure 4.5 displays the geographical distribution of heavy metals in the street dust of Samawah City, generated using the Inverse Distance Weighted approach in ArcGIS 10.8. The maps indicate that areas with high concentrations of Cd had elevated levels of dust and metal in the streets, particularly in the southeastern (Al-Fanadiq, Al-Hussein, Al-Haidariya, and Al-Sader) and northeastern (Al-Jamea) of the city. Human activities like burning petroleum, discarding commercial waste, and using specific building materials all contributed significantly to cadmium contamination, and also Cadmium levels are elevated in the Al-Fanadiq, Al-Hussein, Al-Haidariya, and Al-Sader areas due to high population density and the expansion of industrial zones. Previous

research studies have shown that heavy metals tend to accumulate in locations with high human activity and increased waste emissions (Wang et al. 2019; Chai et al. 2021). Zinc (Zn) distribution was most concentrated in Al-Fanadiq and Al-Corniche in the southeast of the city, and northeast in Al-Qishla. Low levels of mercury (Hg) and copper (Cu) were primarily detected in the northwest region of the area, namely in Al-Mukafaha, Al-Dhubat, and Al-Nafut. Conversely, elevated concentrations were sporadically spread across the eastern and central sections of Samawah City, particularly in urban zones.

The spatial distribution of Pb was quite extensive in the southwest (Al-Fanadiq and Al-Corniche), While the northeastern side has almost no lead contamination, lead contamination in street dust is caused by car smoke contaminated with lead petroleum, as well as commercial and household waste in containers that may be left out in the streets for long periods.

Figure 4.6 analyzed the regional distribution characteristics of air quality parameters such as PM1.0, PM2.5, PM10, and CO₂. Each air quality in Samawah City exhibits a unique distribution pattern. CO₂ levels are generally high in the southern and central parts of the streets of Samawah city. The reason for the rise in carbon dioxide in the streets of the city of Samawah may be due to the burning of car fuel, as well as the smoke of factories near the city, in addition to the population increase that the city is witnessing. As for the suspended particles in the air of the streets of the city of Samawah, they were highly concentrated in the south and center of the City, especially in Al-Haidariya and Al-Sader. The rise in suspended particles could be attributed to the arid environment of the city, as well as emissions from oil combustion and coal burning at power plants. Industrial emissions from various sectors (Belis et al. 2013). Suggesting that transportation, industry, and biomass burning in Samawah City are significant sources of fine particles in urban areas.



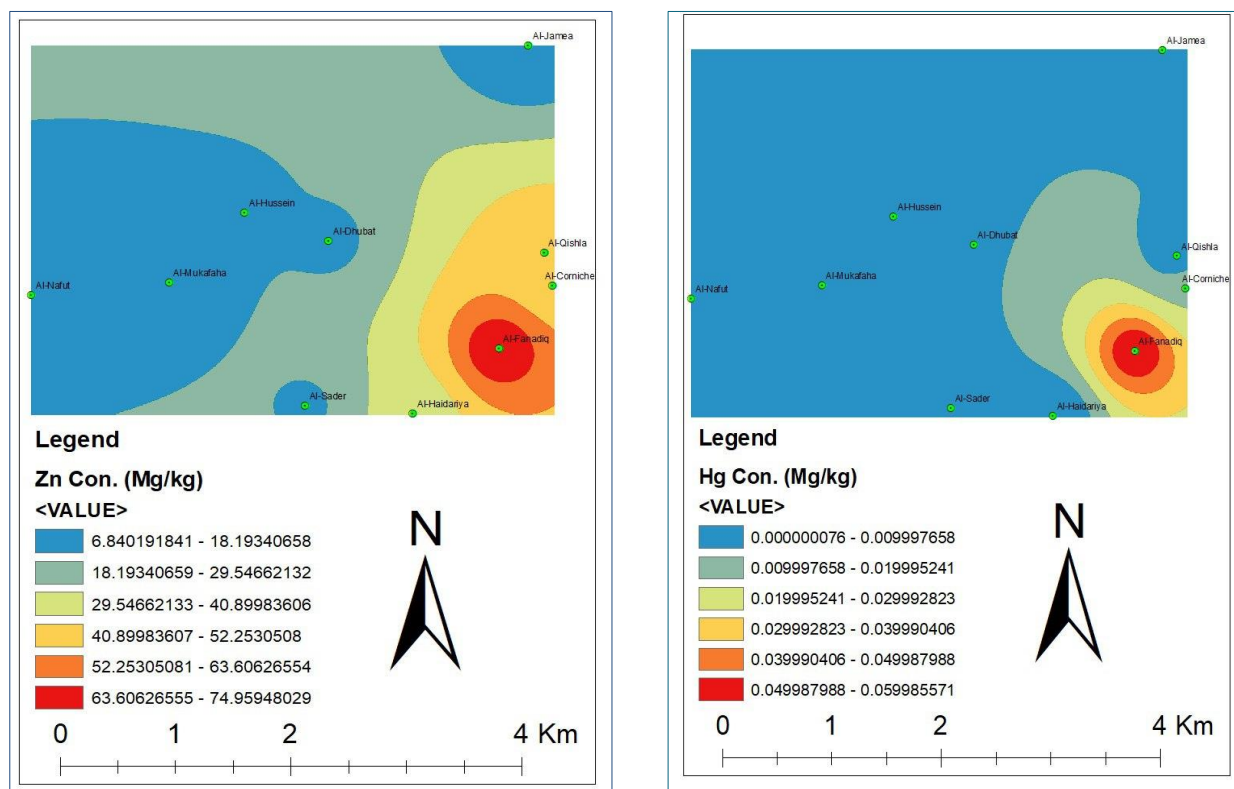


Figure 4.5 displays the geographical distribution of heavy metals in the street dust of Samawa City.

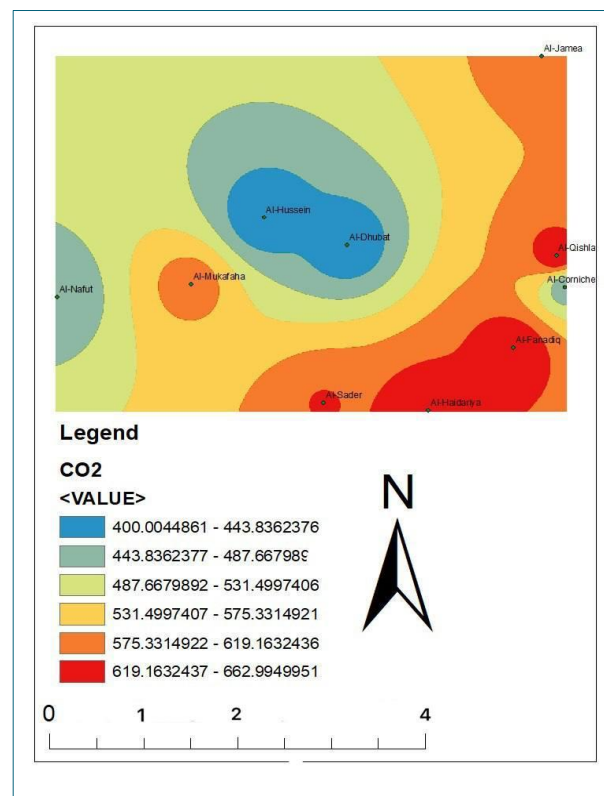
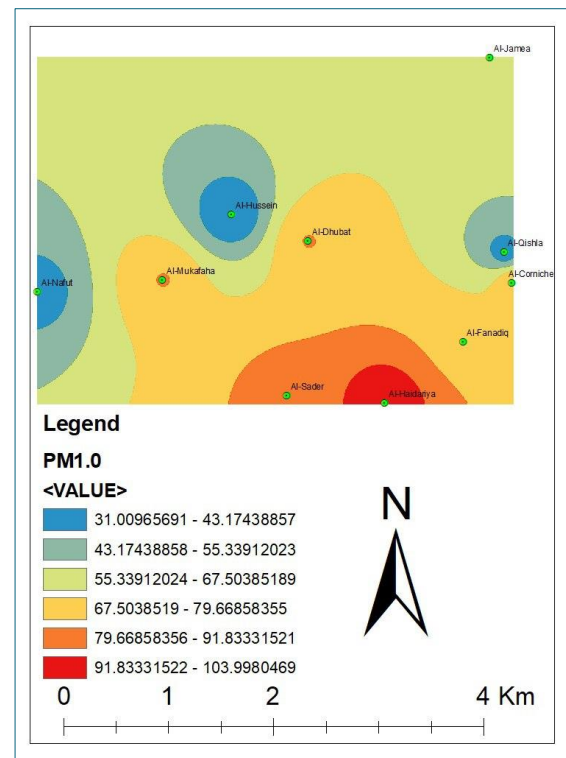
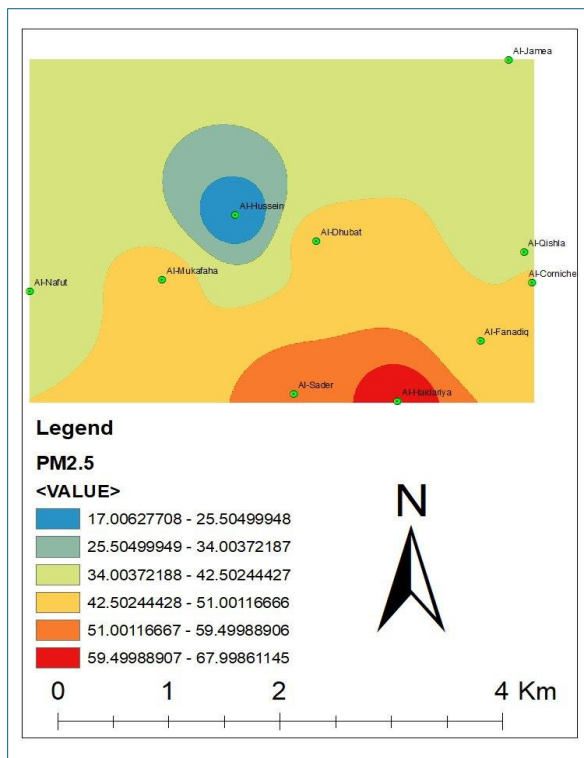


Figure 4.6 displays analyzed the regional distribution characteristics of air quality parameters such as PM1.0, PM2.5, PM10, and CO2 in the street dust of Samawa

4.5 Pollution Indices

Pollution indicators were utilized to evaluate the amount of dust pollution in the streets in several districts of the Al-Samawa Governorate.

4.4.1 Geo accumulation index (Igeo)

The findings of the heavy metal geoaccumulation index in the research region based on Muller's (1979) classification, showed that the areas of Samawa city ranged from uncontaminated to moderately contaminated where, as shown in the Table (4:7) that all study areas appeared to be unpolluted with Zinc(Zn) , Mercury(Hg) , Chromium(Cr), and Cadmium(Cd) which fell within category (0) while Pb and Cu fell between two categories (0,1) as some areas such as al-gamea , Al-Haidariya, Al-Qishla, Al-Nafut, Al-Mukafha, Al-Dhubat, Al-Hussein, Al-Sader and Al-Corniche were unpolluted (class 0) with Copper (Cu), while Al-Fanadiq were unpolluted to moderately polluted (class1) value (0.226) for Copper(Cu) , for Pb was areas such as Al-Jamea, Al-Haidariya, Al-Qishla, Al-Nafut, Al-Mukafaha, Al-Dhubat, Al-Hussein, Al-Sader, Al-Fanadiq not contaminated (class 0), and other areas such as Al-Corniche belong to class (1) value (0.127) for pb which indicates that they are not polluted to moderately polluted.

The mean values of Igeo decrease in the order of $Cu > Pb > Hg > Zn > Cr > Cd$ Lead is a toxic heavy metal and can accumulate in living organisms, as well as in the food chain, as there is no safe level of exposure to lead (Salminen et al. 2005).

The source of lead in soil and atmospheric dust in urban cities is from automobile exhaust emissions and electric power plants that run on fossil fuels, (Zannoni et al. 2016). When comparing the current study with the results of other studies, it was found that the concentration of heavy metals in the current study was higher from study of Tehran (Kamani et al. 2017).

The main reason for the increase in the concentrations of heavy metals in street dust is due to the increase in traffic density. This conclusion has been confirmed by many studies conducted in different countries of the world (Divrikli et al. 2011; U, Victor et al. 2013), . Al-Khashman et al. 2007), which showed that the concentration of heavy metals in street dust increases with the increase in vehicle traffic density.

Previous studies, a study in Warsaw, Poland, (Dytłow et al. 2020) also showed results I_{geo} were below 0, which corresponds to an unpolluted level (Müller, 1979). However, the median values of Cadmium (Cd), Zinc (Zn), and Copper (Cu) obtained in the following order: $0 \leq I_{geo} \leq 1$ indicated unpolluted to moderately polluted level. Other studies study of Lanzhou city of China (Jiang et al. 2017) The Cd results showed higher results than the current study. The I_{geo} value for Cadmium (Cd) was greater than 0 for all dust samples and ranged from 0.108 to 2.02, suggesting a moderate contamination of street dust by Cd, significantly impacted by anthropogenic activities.

Table (4:7) Geo accumulation index (Igeo) with its classes to samples of study area.

Regions	Igeo						Igeo Class					
	Pb	Cd	Cr	Cu	Zn	Hg	Pb	Cd	Cr	Cu	Zn	Hg
Al-Jamea	-0.575	-4.481	-4.137	-3.035	-4.380	0	0	0	0	0	0	0
Al-Haidariya	-0.447	-4.335	-3.846	-2.217	-2.088	0	0	0	0	0	0	0
Al-Qishla	-0.509	-4.591	-4.117	-3.215	-1.541	-7.565	0	0	0	0	0	0
Al-Nafut	-2.094	-4.654	-3.982	-3.239	-3.403	-3.830	0	0	0	0	0	0
Al-Mukafaha	-0.753	-4.665	-4.370	-3.652	-4.011	-5.955	0	0	0	0	0	0
Al-Dhubat	-1.582	-7.770	-3.148	-3.668	-3.196	-3.443	0	0	0	0	0	0
Al-Hussein	-2.609	-5.991	-2.761	-2.644	-3.178	-4.726	0	0	0	0	0	0
Al-Sader	-1.047	-5.946	-2.365	-2.294	-3.124	-4.072	0	0	0	0	0	0
Al-Fanadiq	-0.001	-5.937	-2.463	0.226	-0.926	-0.962	0	0	0	1	0	0
Al-Corniche	0.127	-6.272	-3.044	-1.613	-1.650	-2.072	1	0	0	0	0	0

4.4.2 Contamination Factor (CF)

The contamination factor results for street dust in Al-Samawa Governorate Table (4:7) and the (Hakanson,1980) classification ranged from slightly polluted to extremely polluted, with Chromium (Cr) (0.11) and Mercury (Hg) (0.15) showing slightly polluted in all study areas. The results of the study also showed that all studied areas were slightly polluted for pb (0.90), Copper (Cu) and Zinc (Zn) were showed (0.29). As for Cd (6.18) it showed extremely polluted du $Cf \geq 6$.

The results of study of street dust in some city (Al-Jamea, Al-Haidariya, Al-Qishla, Al-Nafut, Al-Mukafaha, Al-Dhubat, Al-Hussein, Al-Sader) showed that ranged from moderately polluted . As for the Al-Fanadiq and Al-Dhubat area, it

showed a highly degree of polluted for Cadmium (Cd). According to CF, Al-Haidariya city had the highest value of Cadmium (Cd) (7.431) pollution $Cf \geq 6$, indicating that it is a extremely contaminated area.

Due to the wide industrial uses of cadmium, including its use in engine lubricants, rechargeable batteries, lubricating oils, and poor fuels, as well as its release from fuel combustion and tire friction,, as a result of these uses, it accumulates in the street dust of these sites that contain high concentrations of the element. (Al-Jubouri, 2017). Cadmium is widely used in paints, plastics, and the manufacturing of cadmium-nickel batteries (Kabadayi and Cesur 2010). High levels of Cd have been discovered in dust samples from Pakistani expressways (Faiz et al. 2009) and industrial areas in Korea (Duong and Lee 2011). Cadmium (Cd) contamination in dust samples is strongly influenced by traffic emissions as well as industrial and incinerator emissions.

Therefore, it would seem reasonable to assume that traffic and industrial emissions in this densely populated mixed-use commercial and industrial area are the cause of the high concentration observed at this sampling location. Al-Dhubat had the lowest concentrations 2.06 (Table 4.8), Due to its distance from the city center, low traffic volume, and focus mostly on cultural and educational pursuits, this area is likely less contaminated by heavy metals from industry and vehicle emissions. A higher CF of heavy metals means a higher risk for the local environment (Nemati et al. 2013).

When comparing the current study with previous studies, it was found that the study in Delhi, India (Suryawanshi et al. 2016) was lower than the current study ,the contamination factors (CF) indicated high very contamination factor ($6 \leq CF$) of Pb ,Zn and Cu and considerable contamination levels $Cf < 6$) of Cadmium (Cd) and Chromium (Cr) in the road dust from the industrial areas.

Table (4.8) The contamination factor and the pollution load index of heavy metals.

Regions	Pb	Cd	Cr	Cu	Zn	Hg	PLI
Al-Jamea	1.006	6.715	0.182	0.322	0.072	0	0
Al-Haidariya	1.100	7.431	0.322	0.322	0.352	0	0
Al-Qishla	1.053	6.223	0.242	0.242	0.515	0.007	0.23
Al-Nafut	0.351	5.954	0.158	0.158	0.141	0.105	0.30
Al-Mukafaha	0.889	5.91	0.119	0.119	0.092	0.024	0.23
Al-Dhubat	0.500	2.060	0.078	0.078	0.163	0.137	0.22
Al-Hussein	0.245	7.073	0.159	0.159	0.165	0.056	0.27
Al-Sader	0.725	7.297	0.203	0.203	0.171	0.089	0.39
Al-Fanadiq	1.498	7.342	1.169	1.169	0.789	0.769	1.44
Al-Corniche	1.638	5.820	0.326	0.326	0.477	0.356	0.74
Mean	0.90	6.18	0.11	0.29	0.29	0.15	0.38

4.4.3 Pollution load index (PLI)

The PLI of six metals was computed (Table 4.8) and used as an index to assess the level of contamination at the sampling location .The values of PLI were less than 1 of the sampling locations, which indicates (as described in Materials and methods) an no pollution in study area .However, one of the sampling locations had values greater than 1in Al-Fanadiq area where was its value 1.44 greater than 1, indicating deterioration of site quality.

When compared with previous studies, it was found that the study in the city of Al-Qadisiyah, Iraq (Al-Dabbas et al. 2018) was higher than the current study whereas five sites were classified as class 2 (Deterioration on site quality) indicating local pollution, ranging from 1.05 to 1.55. Another study was higher than the current study in Detroit ,Michigan (Denny M et al. 2022).Showed the average PLI of sample types decreases in the order: industrial > residential >

commercial > and soil. In total, 92% of all samples had a PLI >2 including 100% of commercial and industrial samples. Another study was higher than the current study in Madrid City of Spain (Delgado-Iniesta et al. 2022), whereas PLI in previous study of Madrid reaches a value greater than 15 therefore.

4.4.4 Ecological risk factor (Er)

The mean Er value is of the order Cadmium (Cd)> Mercury (Hg)> Lead (Pb)> Copper (Cu)> Zinc (Zn)> Chromium (Cr) (Table 4.4). The study's findings demonstrated that the heavy metals index of potential environmental risks (Er) for street dust, as presented in Table (4.9), varied from low to moderate risks based on classification (Zhao et al. 2014). As for the elements, it was discovered that all but Cd fall into the category $Er < 40$, meaning that these metals have low risk across the whole study area.

In contrast, the potential ecological risk of cadmium is found to be moderate in the Al-Dhubat regions, falling into the category (40–80). In comparison, the Er for Cd in the remaining regions (Al-Jamea, Al-Haidariya Al-Qishla, Al-Nafut, Al-Mukafha, Al-Hussein, Al-Sader, Al-Fanadiq, and Al-Corniche) ranged into the 160–320 range, indicating a high ecological risk. Therefore, the use of sources of cadmium, which is considered to be one of the elements harmful to human health and which causes a number of health issues, culminating in cancerous diseases, and which enters humans through the food chain, needs to be reduced. When compared with previous studies such as a study in Xianyang City, NW China (Shi et al. 2012), the results were similar to the current study.

The mean Er value is of the order: $Cd > Cu > Pb > Ni > Zn > Cr > Mn$. The mean Er of each metal is lower than 40, which means they have low potential ecological risk. When comparing this study with a previous study, the mean of (Cadmium) Cd in Er values were 185.4. When comparing this study with a

previous study in Tehran ,Iran (Kamani et al. 2017), the mean Er values were 143.03 less than the current study, as the mean of Cd in Er values was 185.4.

Table (4:9) Ecological risk factor (Er) of heavy metals of samples collected from the study area.

Regions	Pb	Cd	Cr	Cu	Zn	Hg
Al-Jamea	5.03	201.4	0.170	0.914	0.072	0
Al-Haidariya	5.50	222.9	0.208	1.612	0.352	0
Al-Qishla	5.26	186.7	0.259	1.211	0.515	0.316
Al-nafut	1.75	178.6	0.284	0.794	0.141	4.216
Al-Mukafha	4.44	177.3	0.145	0.596	0.092	0.966
Al-Dhubat	2.50	61.82	0.169	0.393	0.163	5.516
Al-Hussein	1.22	212.2	0.221	0.799	0.165	2.266
Al-Sader	3.62	218.9	0.290	1.019	0.171	3.566
Al-fanadiq	7.49	220.2	0.271	5.848	0.789	30.78
Al-Corniche	8.19	174.6	0.181	1.634	0.477	14.26
Mean	4.5	185.4	0.22	1.48	0.29	6.16

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

1. The concentrations of the metals tested in Samawa street dust are generally lower than their background values (Hong Kong ISQV- low and high), except for Cd which exceeds the Hong Kong ISQV- low.
2. It is important to pay attention to the increasing levels of Cadmium (Cd) in the streets. The concentration of particulate matter (PM1.0, PM2.5, and PM10) in the dust on the streets of Samawa exceeds the limits set by the World Health Organization (WHO).
3. The maps indicate that areas with high concentrations of Cd had elevated levels of dust and metal in the streets, particularly in the southeastern (Al-Fanadiq, Al-Hussein, Al-Haidariya, and Al-Sader) and northeastern (Al-Jamea) of the city.
4. Analyzes the regional distribution characteristics of air quality parameters such as PM1.0, PM2.5, PM10, and CO₂. Each air quality in Samawa City exhibits a unique distribution pattern. As for the suspended particles in the air of the streets of the city of Samawah, they were highly concentrated in the city, especially in Al-Haidariya and Al-Sader.
5. Principal Component Analysis (PCA) result showed the source of heavy metals in samawa street was from automobile smoke and traffic.
6. All the study stations were unpolluted except for the hotels and corniche stations, which were in category 1, indicating moderate pollution according to Igeo, and all of them were slightly polluted according to the CF index, except for Cd, which was extremely polluted. The PLI index agreed with the two previous indices, indicating that there was no pollution, while the Er index showed that all stations were slightly polluted, except for the element Cadmium (Cd).

Recommendations

1. This study provides valuable insights for city officials to effectively tackle pollutants arising from street dust by implementing road rehabilitation measures that adhere to international standards.
2. Researching more about other heavy metals to be a comprehensive risk assessment in the street dust.
3. Controlling the exhaust gases of industries and cars in order to have clean air and without heavy metals. preventive actions by health and environmental decision-makers and politicians can lead to useful actions. Useful measures can include industrial exhaust gas control, car exhaust gas control, road traffic control, and environment-friendly,laws.
4. research is needed on the seasonal variation of the content of the heavy metals in Samawa street dust, multi-year trends and their content in different sizes of dust particles.

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الخلاصة

تتناول هذه الدراسة تحديد مدى تركيز المعادن في عينات الغبار التي تم جمعها من شوارع مدينة السماوة. وفي هذه الدراسة تم جمع ثلاثين عينة (ن=30) من غبار الطرق خلال شهري حزيران وتموز من عام 2023 بواسطة الفرشة الصغيرة والأكياس البلاستيكية.

لقياس المعادن الثقيلة الرصاص (Pb) والكاديوم (Cd) والكروم (Cr) والنحاس (Cu) والزنك (Zn) والزرنيق (Hg) بواسطة جهاز مطياف الامتصاص الذري، ومقارنة مستويات المعادن الثقيلة في مدينة السماوة بالقيم القياسية العالمية، وقياس الجسيمات العالقة إلى الكشف عن درجة التلوث باستخدام جهاز قياس جودة الهواء، وقياس التوزيع المكاني للمعادن الثقيلة في مدينة السماوة بواسطة نظام المعلومات الجغرافية (GIS). بالإضافة إلى ذلك، تم استخدام تحليل المكونات الرئيسية (PCA) بشكل جذري لفحص أساس المعادن الثقيلة في غبار الطريق من أجل اكتشاف مصادر الملوثات في مدينة السماوة من خلال قياس عشرة مواقع في شوارع شملت الجامعة والحيدرية والقشلة والنفط والمقاومة والضباط والحسين والصدر والفنادق والكورنيش.

تم استخدام مجموعة من مؤشرات التلوث لتقييم التلوث: (1) مؤشر التراكم الجغرافي (Igeo)، (2) عامل التلوث (CF)، (3) مؤشر حمل التلوث (PLI)، (4) عامل الخطر البيئي (Er)

اظهرت نتائج الدراسة بأن نمط تركيز المعادن تتأزليا هو: الزنك > (Zn) الرصاص > (Pb) النحاس (Cu) الكروم > (Cr) الكاديوم > (Cd) الزرنيق (Hg). تكون تركيزات المعادن المختبرة في غبار شوارع السماوة أقل عموماً من قيم الخلفية (ISQV) في هونغ كونغ- منخفض وعالي، باستثناء الكاديوم الذي يتجاوز ISQV في هونغ كونغ- منخفض. من المهم الانتباه إلى المستويات المتزايدة من الكاديوم في الشوارع.

تم استخدام تقييم ارتباط بيرسون لتحديد الارتباط بين المعادن الثقيلة الموجودة في الغبار ونوعية الهواء داخل الشوارع. أظهر الرصاص (Pb) ارتباطاً قوياً وعالي الجودة بكل من النحاس (Cu) والزنك (Zn). بالإضافة إلى ذلك، يشير النحاس (Cu) إلى ارتباط جيد كبير بالزنك (Zn). علاوة على ذلك، كان للزنك (Zn) ارتباط إيجابي قوي بالزرنيق (Hg)، مما يشير إلى أن كلا الملوثين ينشأ من نفس مصادر التلوث. يُظهر النحاس (Cu) ارتباطاً إيجابياً مع PM2.5 و PM10 و PM1.0. أن هذه الجسيمات لديها القدرة على التأثير سلباً على صحة الجهاز التنفسي. يُظهر الرصاص (Pb) ارتباطاً مهماً مع PM2.5 (r = 0.476) وارتباطاً إيجابياً أضعف (r = 429) مع PM10 يتجاوز تركيز الجسيمات PM1.0 و PM2.5 و PM10 في الغبار في شوارع السماوة الحدود التي حددتها منظمة الصحة العالمية (WHO)

وأظهرت نتائج تحليل المكونات الرئيسية (PCA) أن العلاقة الإيجابية القوية بين CO2 و PM10 و PM2.5 (0.667)، تم تحديد ثلاثة مكونات، والتي شكلت 69.28% من التباين الإجمالي، مما يشير إلى أنه يمكن تصنيف مصادر المعادن الثقيلة إلى ثلاثة مكونات أساسية. يتكون المكون الأولي من PM2.5 و PM1.0 و PM10 و CO2. يتكون المكون الثاني من الرصاص (Pb) والنحاس (Cu)

والزنك (Zn)، مما يشير إلى أن الرصاص (Pb) والنحاس (Cu) والزنك (Zn) موجودة في الغبار. يتكون المكون الثالث من الكروم (Cr) والزنابق (Hg).

تم التعبير عن مستويات تلوث الغبار في الشوارع بالمعادن الثقيلة باستخدام مؤشرات التلوث، فقد أظهرت نتائج مؤشر تراكم المعادن الثقيلة (Igeo) في منطقة البحث استناداً إلى تصنيف مولر (1979)، أن مناطق مدينة السماوة تتراوح من غير ملوثة إلى ملوثة بشكل معتدل بترتيب: $Cr > Zn > Hg > Pb > Cu$ ، وأظهرت قيم CF وجود قدر كبير من التلوث بالكاديوم والرصاص، وكانت منطقة الفنادق ذات أعلى رقم من مؤشر حمل التلوث PLI، وأظهر متوسط مؤشر عامل الخطر البيئي (Er) أن جميع المحطات كانت ملوثة بشكل طفيف، باستثناء عنصر الكاديوم (Cd).

وقد وجد في مجموعة خريطة الحرارة في منطقة الفنادق من المجموعة 1 وجود وفرة في الزنك مقارنة بالعناصر الأخرى. كما أظهرت خريطة الحرارة في مجموعة تركيز عالي لثاني أكسيد الكربون في المجموعة 1 في الجامعة والمكافحة، وتركيز عالي للجسيمات العالقة 2.5 في المجموعة 1، وتركيز عالي للجسيمات العالقة 1.0 في الحيدرية في المجموعة 1 وتركيز عالي للجسيمات العالقة 10 في منطقة الحيدرية. أما التوزيع الجغرافي للمعادن الثقيلة في غبار شوارع مدينة السماوة، فقد أظهرت تركيزات عالية من الكاديوم (Cd) ارتفاع مستويات الغبار والمعادن في الشوارع، وخاصة في مناطق (الفنادق، والحسين، والحيدرية، والصدر) ومنطقة (الجامعة). وكان توزيع الزنك (Zn) أكثر تركيزاً في الفنادق والكورنيش وفي القشلة.

كان التوزيع المكاني للرصاص واسع النطاق في (الفنادق والكورنيش). تم الكشف عن مستويات منخفضة من الزنابق (Hg) والنحاس (Cu) في منطقة المكافحة والضباط والنفط.

تكون مستويات ثاني أكسيد الكربون مرتفعة بشكل عام في الأجزاء الجنوبية والوسطى من شوارع مدينة السماوة. تشير العلاقة الإيجابية بين ثاني أكسيد الكربون والجسيمات PM10 و PM2.5 (0.667) إلى أن ثاني أكسيد الكربون يمكن أن يتفاعل بسهولة مع هذه الجسيمات ويستنشقها الناس، وهو أمر سيئ للصحة، وخاصة للأشخاص المصابين بالربو.

هذه الدراسة حاسمة للحفاظ على الصحة العامة وسلامة الإنسان من الأمراض الناجمة عن غبار الشوارع، ومن ثم يمكن السيطرة عليها، وتوفر هذه الدراسة رؤية قيمة لمسؤولي المدينة لمعالجة الملوثات الناجمة عن غبار الشوارع بشكل فعال من خلال تنفيذ تدابير إعادة تأهيل الطرق التي تلتزم بالمعايير الدولية.



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أستخدام الاحصاءات المتعددة المتغيرات وبعض مؤشرات التلوث لتقييم المعادن الثقيلة
في غبار الشوارع المترسب في مدينة السماوة

رسالة مقدمة إلى مجلس كلية العلوم / جامعة القادسية - قسم البيئة كجزء من متطلبات
نيل شهادة الماجستير
من قبل

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بكالوريوس علوم البيئة- جامعة المثنى 2016_2017

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