**Ministry of Higher Education and Scientific Research**
**University of Babylon**
**College of Science Department of Geology**

# Study the Environmental Impact of Al- Zubaidiya Power Plant, Wasit Governorate, Eastern Iraq

**A Thesis**

**Submitted to the College of Science University of Babylon, In partial Fulfillment for the Degree of Master of Science in Applied Geology – Geochemistry**

**By**

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## B.Sc.Geology,University of Babylon

## 2018

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**2023A.D** **1444A.H**

﴿ وَلَا تُفْسِدُوا فِي الْأَرْضِ بَعْدَ إِصْلَاحِهَا ذَلِكُمْ خَيْرٌ لَكُمْ إِنْ كُنْتُمْ مُؤْمِنِينَ ﴾

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الأعراف: 85

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I certify that this thesis **(Study The Environmental Impact of Al- Zubaidiya Power Plant, Wasit Governorate, Eastern Iraq**

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# Dedication

I would like to dediate this work to:
My father and my mother with all love
My dear husband Mohammed.
My brothers (Hayder and Moaamel), My sisters (Dhuha and Teeba).
All my loyal friends.

SAFA HUSSAM HUSSAIN

## Summary

The study was conducted in the Al-Zubaidiah district, north of the city of Kut in the Wasit Governorate. The area is characterized by the presence of a large thermal power station that releases various pollutants, including trace elements and polycyclic aromatic hydrocarbons, in the form of gases, solids, and liquids, affecting the air, water, soil, and plants. Ten air sampling stations were selected for winter and summer seasons, along with two water sampling stations on the Tigris River and five wild reed sampling stations for each season. Moreover, 20 soil sampling stations were identified to assess the environmental condition of the study area.

The concentration of suspended particles in the air during both seasons was higher than the Iraqi and international standards. The concentrations of volatile organic compounds (carbon monoxide gas) were within the natural limits of the World Health Organization and the Iraqi standards during both seasons, while the concentrations of carbon dioxide gas exceeded both standards. The lower explosive limit (LEL) concentrations were zero. Additionally, the average concentration of heavy elements (Pb, Cd, Fe, Zn, Ni) was higher than both the Iraqi and WHO standards.

The Tigris River's average values of pH and major and minor ions in both seasons were within the natural limits, except for phosphate, magnesium, calcium, and solids, which were higher than the Iraqi and international standards. The heavy element concentrations in water samples entering and leaving the station (Pb, Fe, Zn) were higher than both Iraqi and global health standards, except for Cd and Ni within the Iraqi and global limits.

The average concentrations of heavy metals (Pb, Cd, Ni) in wild reed plants were within the limits of the WHO polluted site, except for Fe and Zn, which exceeded

the standards. The soil samples' granular size was determined, with clay being dominant, and the soil's origin was from the Mesopotamian plain, which covers the city of Kut and its surrounding areas. X-ray analysis of the soil samples revealed a wide range of minerals, including quartz, calcite, and clay minerals (albite, chlorite, kaolinite, and montmorillonite).

Where the results of X-ray spectroscopy analysis (XRF) soil quality study (SQI) study (based on) different physical, chemical and biological factors varying degrees of contamination

The Pollution Index (PLI) indicated a different pollution index at the site, as it showed site No. 5

Analysis Accumulation Index Accumulation ((I-GEO) Activities Activities associated with heavy cultures in the soil, there are many different elements in the soil, some different texts appeared Uneven pollution across sites, severe pollution was observed in station 10

## List of Contents

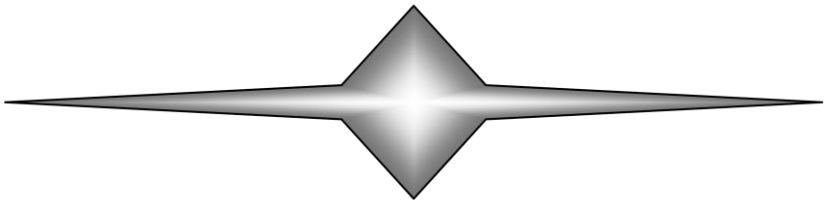
## List of Tables

## List of Figures

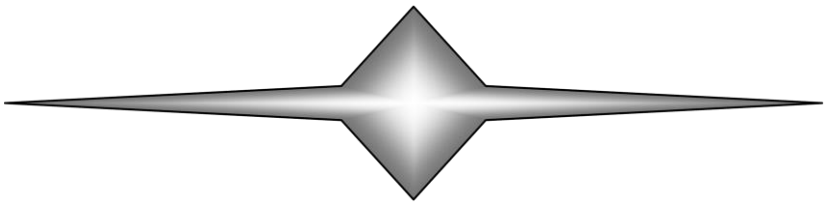
# List of Abbreviations

| Symbols | Total team |
|---|---|
| CF | Contamination factor |
| I-geo | Index of geo-accumulation |
| PLI | Pollution Load Index |
| AQI | Air quality index |
| SQI | Soil quality index |
| WHO | World Health Organization |
| NAAQS | National States Ambient Air Quality Standars |
| TSP | Total Suspended Particls |
| PAHs | Polycyclic aromatic hydrocarbons |
| UV-INDEX | Ultraviolet |
| VOC | Volatile Organic Compounds |
| LEL | Lower Explosive Limits |

# Chapter One



# Introduction



# Introduction

## 1.1 preface

Pollution refers to the presence or introduction into the environment of a substance or thing that has harmful or poisonous effects. Pollution can take many forms, including air, water, and soil pollution, and can be caused by human activities or natural events. It can have a variety of negative effects on the environment and on human health, and can also harm other living organisms ((Environmental Protection Agency, United States). Air pollution is the contamination of the ambient atmosphere as a result of the presence of chemical substances, gases, or particulate matters, they also can damage the vegetation and other living things such as animals and food crops (Padula et al., 2019). The World Health Organization (WHO) reports that air pollution is the number one environmental health risk, in 2012 about 3.7 million deaths were attributable to ambient air pollution and 4.3 million deaths to household air pollution generated by indoor use of solid fuels (wood, charcoal, coal, crop wastes and dung) for cooking and heating (Perera, 2017).

Water pollution is the contamination of water by natural and foreign matter such as microorganisms, chemicals, industrial wastes or other waste or sewage in quantities that are likely to cause damage to living organism. Water pollution not only effects on water quality but also it threatens human health, economic development and social prosperity so that it considered as environmental problem that requires an effective and quick solution (Alaa and Jaeel, 2019).

Soil continually undergoes development by the manner of numerous physical, chemical and biological processes, which include weathering with associated erosion (Ponge, 2015). Contamination by heavy metals has become a widespread serious problem in many parts of the world (Masindi and

Muedi, 2018). Heavy metals enter the environment as a result of both natural and anthropogenic activities. Naturally heavy metals occur in soils, usually at a relatively low concentration, as a result of the weathering and other pedogenic processes acting on the rock fragments on which the rock develops soil parent materials (Mbah and Anikwe, 2010).

Soil pollution is defined as the build-up in soils of determined toxic compounds, chemicals, salts, radioactive materials, or disease producing agents, which have adverse effects on plant growth and animal health (Ashraf et al., 2014). The soil pollution rises due to the fuel combustion and industrial emission from the Wasit Thermal Power Plant which is sited on the Tigris River bank in the Al-Zubaidiya district (Al-Gburi et al., 2017).

## 1.2 The study area

Al-Zubaydiya thermal power plant is located in the north of Al- Zubaidiya city, Wasit province, Iraq, with a longitude (45°04'53.37"E) and latitude (32°46'19.64"N), the station is 120 km southeast of Baghdad (Fig. 1.1). It is one of the projects that have significant environmental impacts on the region began to work the first unit of this station in 2012 and a production capacity of 3301 Mega Watts and the plant Al- Zubaidiya one of the largest electrical stations in Iraq (Fig. 1.1). Zubaidiya thermal power plant, located on the right side of the Tigris River area, was selected as a suitable site for energy production. Established in 2015, this power station consists of six units with a combined output capacity of 2550 MW. The plant operates by utilizing various fuel sources such as natural gas, crude oil, and heavy fuel (Salman in 2018).


Figure (1.1): Location map of the study area (Aldefae et al., 2020)

Figure (1.2): Al-Zubaydiya thermal power plant.

## 1.3 Aims of the study

The purpose of studying the concentrations of pollutants in the air, soil and water surround electric power plant that use fossil fuels is to understand the extent to which the emissions generated by the fossil fuel-powered energy are affecting the environment and human health. By measuring the concentrations of pollutants such as sulfur dioxide, nitrogen oxides, particulate matter, and heavy metals.

The following was done:

1. Determining the types of pollutants resulting from the Al-Zubaydiya thermal power plant.

2. Study the geographical distribution of pollutants in the study area.

3. Determining the effect of these pollutants on water, soil, plants and air (environmental surroundings).

4. Finding solutions that contribute for reducing pollution generated in the study area.

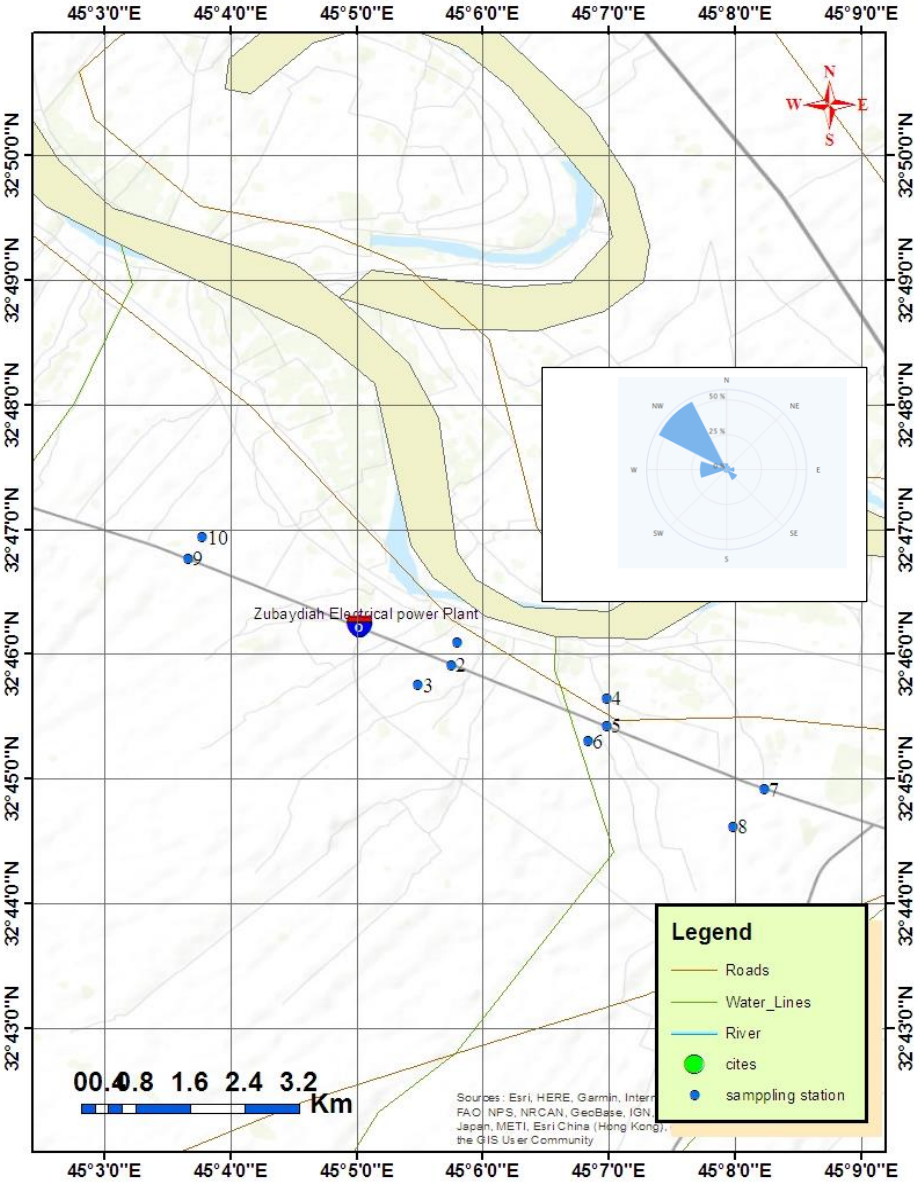



Figure (1-3) location map of study area and samples

## 1.4 Previous studies

Al-Masri and Ali (1985) studied some water parameters such as: sulfate, Alkalinity, chloride, calcium, hardness, and magnesium in Tigris River through Baghdad city, they confirmed that discharging treated and untreated wastewater into river limited the use of water for different uses as it flows downstream.

Habib et al (2012) study the concentration of heavy metals (Fe, Pb, Cd, Ni and Co) in Baghdad soil, they found that Pb, Cd and Co had strongly correlated together and distributed in similar patterns which may be originated from source of diesel and gasoline fuel.

Al-Dabbas et al (2015), determination of total suspended particles concentrations in air of selected locations at Kirkuk, Iraq. They found that the average concentration of TSP in this study is higher than the permissible limits of the Iraqi National determinants and the world limits. Al-Alam and Baiji, Iraq by Al-Hasnawi et al (2016) The polluters of total suspended particles (TSP) and some heavy metals (Cd, Co, and Ni) concentrations were studied in the areas of Al-Fatha, they found that the analyzed values of (TSP) and (Cd) exceeded the limits of Iraqi National and WHO for the two periods. Also, (Ni) values exceeded the limits for July only, while (Co) values were under the limits.

Kazem et al (2018) studied in the Zubaidiya thermal power plant in Wasit province in Iraq by were determined the activity concentrations of radium -226 (236Ra), actinium-228 (238Ac) and potassium -40 (40K) of fly ash the results of uranium were higher than the results of thorium with a limit of 3 to 4 times. These are normal results that confirm that there are no previous or old pollutants in the study areas.

A study by Mahmood and Kamal (2018), focused on gaseous pollution caused by exhaust gas from Al-Zubaydiya thermal power plant included sulfur dioxide ($SO_2$), nitrogen oxide (NO), carbon oxide (CO) and hydrocarbon (HC). they found that $SO_2$ and NOX are much higher than international standards, while (CO and HC) were acceptable and within the Iraqi standard.

Alaa and Jaeel (2019) determine the water quality status at Wasit Thermal Power Plant (WTPP) samples showed higher water pH, total dissolved solids

(TDS), electrical conductivity, and chemical oxygen demand (COD) than that of sampling station upstream to WTPP and lower water dissolved oxygen (DO). Results indicated that discharge from WTPP increased pollution load in river Tigris.

Muslim et al. (2019) assess heavy metals pollution in the surface soils in the Wasit Governorate and they found that that soils samples in the studied area are very polluted by the heavy metals of Titanium, Nickel to considerable with Molybdenum, Chromium, Cadmium, bromine and Strontium, and with moderate pollution of the heavy metals of Copper, Cobalt, Manganese, Vanadium and zinc.

A recent study measured the concentration of the heavy metal lead (Pb) for more than one hundred indoor air samples of different locations in Wasit Governorate, the results showed that the concentration of Pb, in general, is higher than the allowed international values (Jaber et al., 2020).

### 1.5 General overview on area

Kut is center of Wasit governorate, Wasit is located in eastern Iraq, on the border with Iran. Wasit Governorate has an area 17,153 km². The main source of water in Wasit province is the Tigris River with a length of 327 km within the borders of the province (Shadher et al., 2009). Wasit shares internal boundaries with the governorates of Diyala, Baghdad, Babil, Qadissiya, Thi-Qar and Missan: kut is like other provinces which has climate, warm, disert lowlands, inclusive the alluvial plains and the deserts. In Kut has more seasons, summer, winter etc., with little transitional durations between them. Summer, which lasts from May to October, is depict by pure skies, extremely high temperatures, and low comparative humidity; no rain occurs from June through September. In Kut, July and August the daily degrees of temperature are each to (51°C). The daily temperatures ambit in summer is considerable

(Manhi and Al-Kubaisi 2021). Al kut needs to be provided by 1012 MW as maximum, the providing rate is fluctuated and affected by climate in summer and winter, providing of electric energy in winter its better than summer due to losses its little than the days are hot (Sheina et al 2021).

## 1.6 Geology, Geomorphology and Topography of the study area

The geology of Wasit Governorate, in the middle of Iraq, is primarily composed of sedimentary rocks, including sandstone, shale, and limestone. These rocks were formed during different geological periods, ranging from the Jurassic to the Tertiary. The geology of the governorate is affected by the presence of several active tectonic faults, such as the Zagros Fault, which has played a significant role in shaping the landscape and depositing the sediments. The governorate has several oil and gas fields and the geology is important for the exploration and production of oil and gas (Al-Tameemi, 2013). The geomorphology and topography of Wasit are characterized by a mix of flat alluvial plains, rolling hills, and rugged mountains. The flat alluvial plains in the west are formed by the Tigris and Euphrates rivers, which have deposited sediment over time, forming a flat and fertile landscape. The rolling hills in the central part of the governorate are formed by the erosion and weathering of the sedimentary rocks, such as sandstone and limestone (Al-Quraishy & Al-Omari 2013). The rugged mountains in the east, part of the Zagros Mountain range, were formed as a result of tectonic activity. The governorate is also characterized by the presence of several wadies and seasonal lakes, which are formed as a result of flash floods from the nearby mountains (Al-Badry 2002).

## 1.7 Climate of the study area

The climate of the study area in Wasit Governorate in the middle of Iraq is likely to be similar to the general climate of the governorate as a whole,

which is classified as a semi-arid climate, with hot summers and mild winters. The study area is likely to be located in the rain shadow of the Zagros Mountains, which means that it receives very little precipitation. The average annual rainfall is likely to be between 100 mm to 200 mm. The study area's climate is likely to be characterized by high temperatures throughout the year, with average high temperatures reaching around 50°C (122°F) in the summer and dropping to around 20°C (68°F) in the winter Al-Jawadi, (2022). The study area is also likely to have high humidity and high evaporation rates, which can make the heat feel even more intense. The study area is also likely to be affected by dust storms which are common during the spring and summer months. It's important to note that the climate of the study area may vary depending on the specific location within Wasit Governorate (Al-Hassani, et al. (2021).

Table (1.1): Mean Monthly Climatic Parameters of Al-Kut for the period (2011-2021) (nasa.gov).

| Months | Air temperature (°C) | Rainfall (mm) | Relative humidity (%) | Wind speed (m/sec) |
|---|---|---|---|---|
| **January** | 10.59 | 0.91 | 57.24 | 2.39 |
| **February** | 12.77 | 0.86 | 52.81 | 2.45 |
| **March** | 17.8 | 0.89 | 44.29 | 2.63 |
| **April** | 24.02 | 0.69 | 36.18 | 2.63 |
| **May** | 30.94 | 0.37 | 26.39 | 2.96 |
| **June** | 36.1 | 0.01 | 16.08 | 4.41 |
| **July** | 38.93 | 0.02 | 14 | 4.43 |
| **August** | 38.39 | 0.01 | 14.79 | 4.02 |
| **September** | 34.64 | 0.01 | 16.02 | 3.3 |
| **October** | 27.57 | 0.49 | 26.18 | 2.59 |
| **November** | 18.08 | 1.33 | 47.81 | 2.36 |
| **December** | 12.13 | 0.82 | 57.28 | 2.41 |

### 1.7.1 Temperature

The temperature rises in Iraq during the summer season, which starts from May and ends during October, and decreases during the winter season, which

starts from November through the end of March (Qutbudin et al., 2019). Table (1.1) shows that mean monthly temperature values range from 10.59 °C in January to 38.93 °C in July. Figure (1.4) represents mean of air temperature of Al-Kut for the period from (2011-2021).

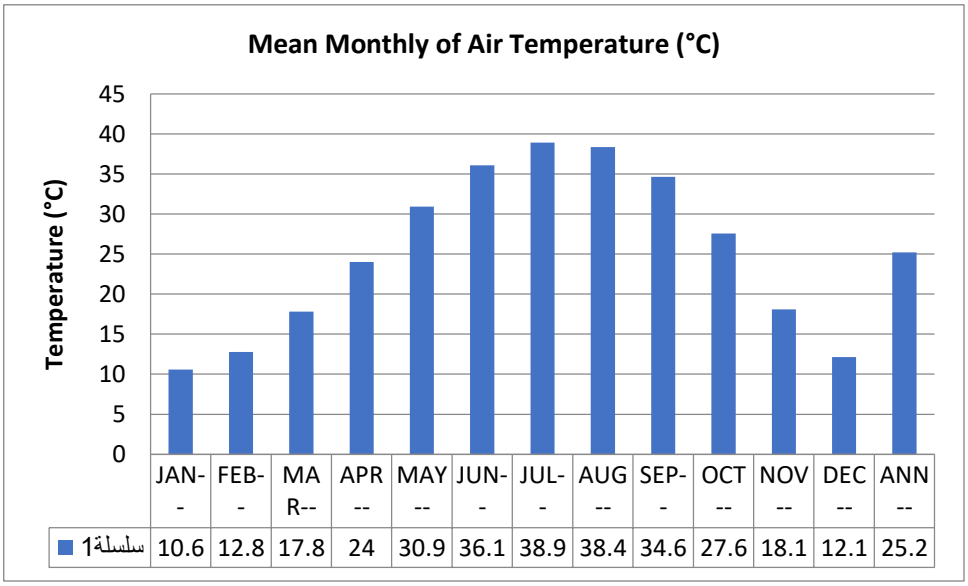



Figure (1.4) Mean Monthly of Air Temperature (°C) of Al-Kut from (2011-2021).

### 1.7.2 Rainfall

Rainfall participates in decreasing air pollution through dissolving of polluting gases of air (e.g. sulfur, nitrogen and carbon dioxides). In addition to reduce a large part of the suspended particulates which fall during the rainfall. Generally, the rainfall in Iraq begins late in October and ends at the end of May (Ewaid et al., 2020). Figure (1.5) shows the annual total of rainfall in millimeter at Al-Kut for the period (2009-2021).

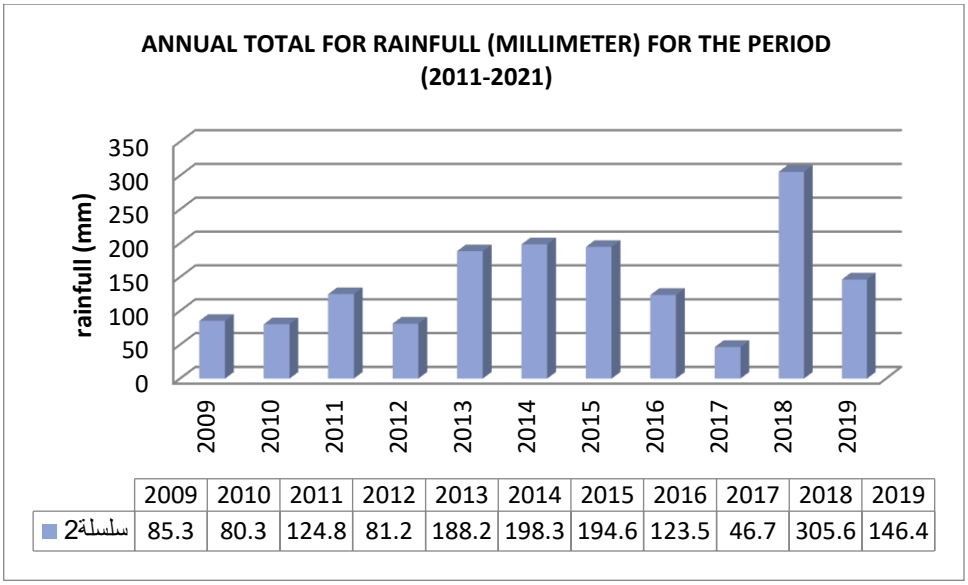



Figure (1.5) Annual total for rainfull (2011-2021).

### 1.7.3 Relative humidity

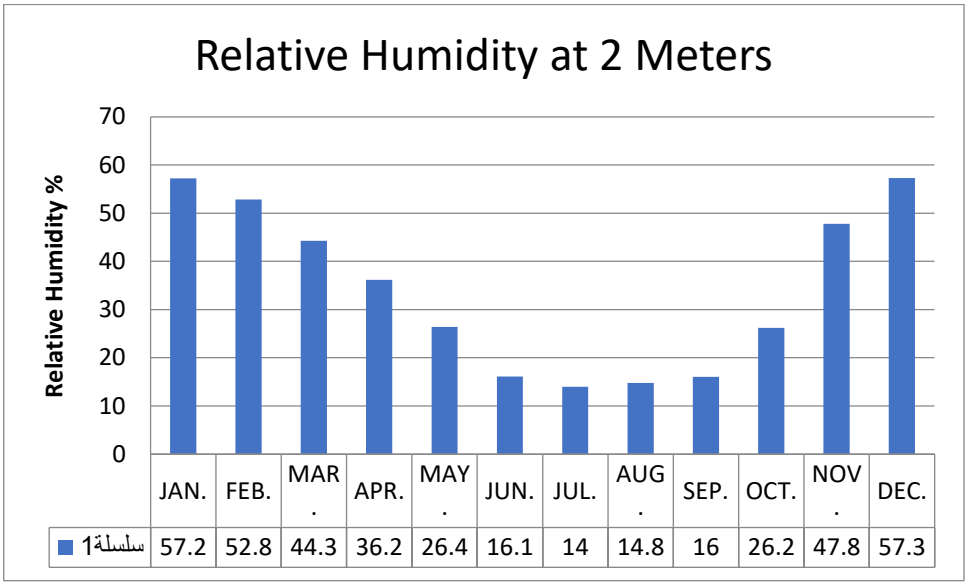



Figure (1.6): Mean Monthly Relative Humidity Al-Kut for the period (2011-2021).

### 1.7.4 Wind Speed and Direction

Al Kut, situated on the Tigris Riverbank, serves as the capital of Wasit province in the eastern region of Iraq (Edan et al., 2021). The prevailing wind direction in the area is southeasterly, as depicted in Figure 1.8 (Edan et al., 2021). The distribution of air pollutants is influenced by wind direction, as it

carries pollutants released from various sources. Consequently, areas facing the prevailing wind direction are more susceptible to contamination compared to areas facing the opposite direction (Wani et al., 2021). Increased wind speed enhances the movement and diffusion of pollutants, leading to a decrease in their concentration in the air (Wani et al., 2021).

Although northwest winds are predominantly observed throughout Iraq, including the study area, the proportion of southeast winds tends to increase during the winter months. The climate in the study area exhibits fluctuations between summer and winter conditions. In certain years, the dominance of southeast winds is evident, resulting in higher rates of rainfall and dust deposition (Attiya and Jones, 2020).

Top of Form

The relationship between wind speed and dusty phenomena is weak or non-existent during the cold season, as a result of the lack of wind and rain speed and high rates of relative humidity (Al Ameri et al., 2019).

These winds can transmit pollutants from sources located in the Southeast of the study area. Therefore, it is important to take into account wind direction at the sampling procedure. The maximum monthly rate of wind speed was 4.43 m/sec in July, while the minimum rate was 2.36 m/sec in November Figure (1.7) shows the mean rates of wind speed of Al-Kut for the period (2011-2021).

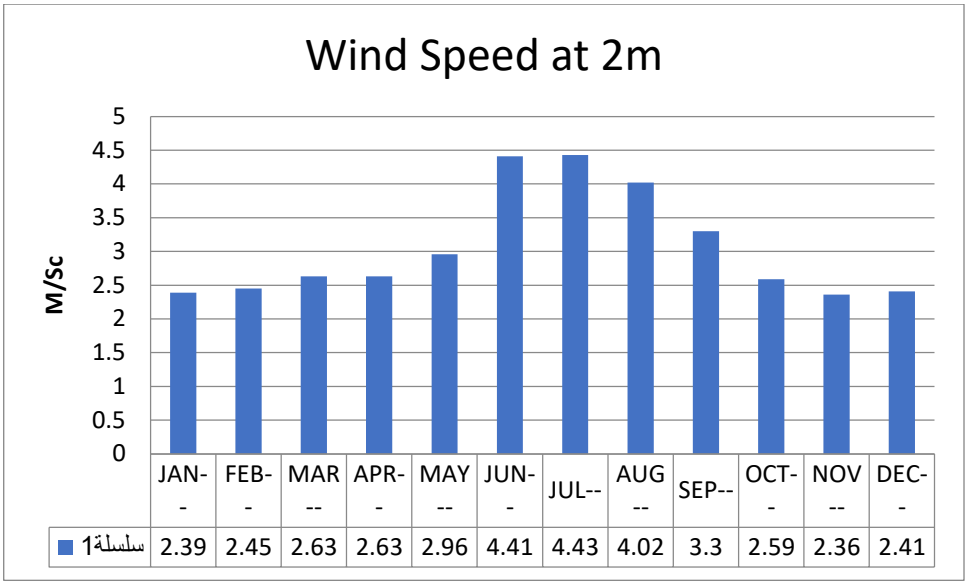
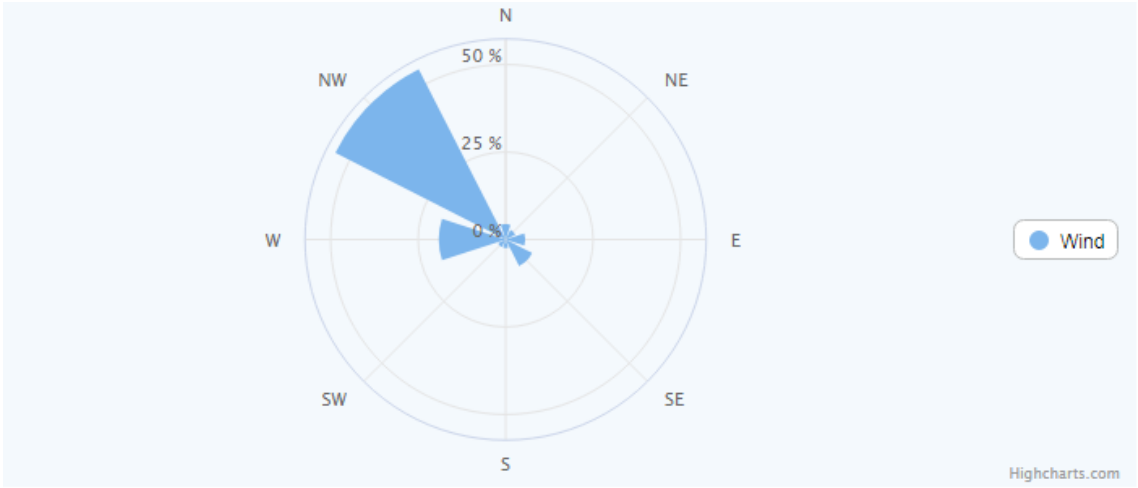



Figure (1.7): The mean rates of wind speed (m/sec) at Al-Kut for the period (2011-2021).

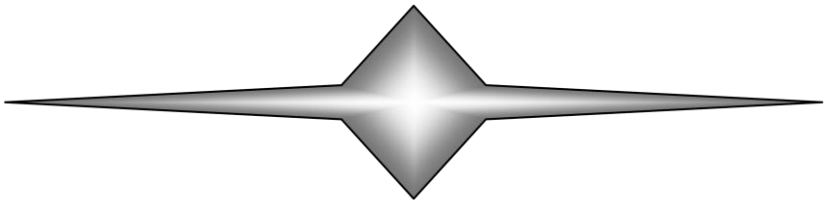



Wind direction graph in Al-Kut using average values according to our data.

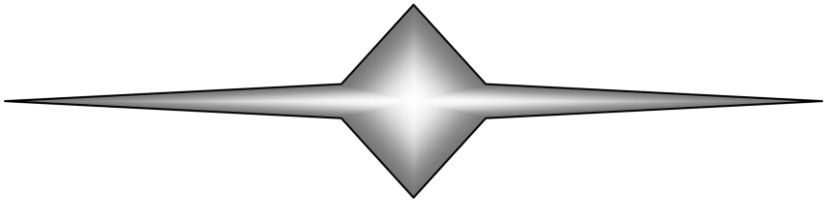
| N ▼ Northern | NE ▲ Northeastern | E ◄ Eeastern | SE ➤ Southeastern | S ▲ Southern | SW ➤ Southwestern | W ► Western | NW ▲ Northwestern |
|---|---|---|---|---|---|---|---|
| **4.4%** | **3.1%** | **5.6%** | **8.5%** | **2.4%** | **2.4%** | **19.1%** | **54.6%** |

Figure (1.8): The annual rates of wind rose at Al-Kut for the period (2011-2021).

# Chapter Two



# Materials and Methods



# Materials and Methods

## 2.1Preface

The following section provides a description of the laboratory and field instruments utilized for measuring and analyzing various environmental factors in soil, plants, and water. The instruments and techniques mentioned encompass the measurement of Total Suspended Particulates (TSP) and gas concentrations (such as CO, $CO_2$, VOC and LEL) in the air. Moreover, methods for analyzing heavy metals (including Pb, Zn, Ni, Fe, Cd) present in environmental components and polycyclic aromatic hydrocarbons (specifically the 15 US Environmental Protection Agency priority ones) in soil and plant samples are discussed. For water samples, both physical and chemical analyses are outlined. It is important to note that the choice of instruments and methodologies employed may vary depending on the specific study and its requirements.

## 2.2 Office work

This paragraph describes the initial office-based tasks carried out as part of a research project focused on a specific region. These tasks involve gathering all relevant literature, theses, and investigations related to geology, hydrology, and meteorology within the study area. Additionally, the passage mentions the creation of topographic and geological maps, as well as the utilization of satellite images specific to the research region. This preliminary office work serves the purpose of acquiring a comprehensive understanding of the existing knowledge about the study area and identifying any gaps in the available literature that the current research project aims to address. Furthermore, it enables the researcher to develop a better comprehension of the physical characteristics of the study region, including its topography and

geology, which subsequently aids in the design of fieldwork and data collection activities.

### 2.3 Field work

This passage describes field excursions that were conducted as part of a research project. The field excursions were conducted between December 1st, 2021 and May 14th, 2022. The purpose of the field excursions was to collect samples of air, water, soil, and plants from the area surrounding a specific plant. The samples were collected in two different seasons, which can help to understand the variability of the air, water, soil and plant parameters, and their possible changes over time. The field excursions are an essential part of the research, as they provide the researcher with the physical samples that are needed to conduct laboratory analysis and measurements to understand the environmental conditions of the study area. The time frame of the field excursions is crucial to study the seasonal variability of the environmental parameters, and to correlate with the meteorological data

#### A. Air sampling

This section describes the process of air sampling that was conducted as part of a research project. The first step in air sampling is to choosing the optimal locations near power plants, taking into account the wind direction, which is an important factor in the distribution of contaminants. Twenty air sampling sites were selected and distributed around the power plant to evaluate the ratio of gases in the air of the study area. The samples were collected in two seasons, first in February 26th 2022, and the second in May 14th 2022. Additionally, twenty sites were chosen to assess Total Suspended Particulates (TSP) in the air. Using a Global Positioning System (GPS), the coordinates of the selected sampling sites were established. This information is used to document the exact location of each sampling site, which can be

helpful in analyzing the data and interpreting the results. The use of GPS coordinates and two seasons sampling can also help to understand the spatial and temporal variability of the air quality in the study area.

Table 2.1 shows the locations of the gas sampling sites for winter and summer

| Site No. | Longitude (E) | Latitude (N) |
|---|---|---|
| A1 | 45° 05' 44.77" | 32° 45' 54.83" |
| A2 | 45° 05' 47.37" | 32° 46' 05.72" |
| A3 | 45° 05' 35.45" | 32° 45' 46. 66" |
| A4 | 45° 06' 58.55" | 32° 45' 38. 91" |
| A5 | 45° 06' 58.53" | 32° 45' 25. 02" |
| A6 | 45° 06' 49.8" | 32° 45' 18. 03" |
| A7 | 45° 08' 13.71" | 32° 44' 54" |
| A8 | 45° 07' 58.71" | 32° 44' 37. 18" |
| A9 | 45° 03' 39.64" | 32° 46' 46.06" |
| A10 | 45° 03' 46. 5" | 32° 46' 56.27" |

**B. the field devices**

As part of the research project, the field devices employed for measuring gas concentrations in the air include a Gasmet device. Specifically, the Gasmet device, model DX4040, manufactured by Gasmet Technologies Oy, is utilized for measuring concentrations of CO, $CO_2$, VOC, and LEL. This portable and digital equipment, powered by a 15V-20V power supply from Finland, is commonly used in air monitoring (Figure 2.1) (Gasmet Technologies Oy, n.d.).

The Gasmet device offers the advantage of simultaneously measuring the concentration of multiple gases. Its portability and user-friendly nature make it highly suitable for field measurements. By utilizing this device, researchers can gain insights into the spatial and temporal variability of air quality in the study area. Additionally, the Gasmet device enables the evaluation of the impact of the power plant on the surrounding air (Gasmet Technologies Oy, n.d.).

Figure (2.1): gas meter device

**C. portable dust sampler**

The use of a portable dust sampler as a field device in a research project. The device is used to determine the total suspended particles (TSP) and trace elements in the air in the study region. The device is portable and has a unique working method, it needs to be placed above a high point for about an hour in front of the source at specific distances. The device is manufactured by Rotheroe & Mithell Limited Company in the United Kingdom. The device uses a Glass Fiber Filter with a diameter of 50 mm to hold the suspended solids in the air flow. The passage also mentions that there is a Figure (2.2) that shows the appearance of the portable dust sampler. This device is commonly used for air quality monitoring, it's able to measure TSP (Total Suspended Particles) and trace elements, it's portable and easy to use, which makes it ideal for field measurements. The device can help to understand the spatial and temporal variability of the air quality in the study area and to evaluate the impact of the power plant on the surrounding air.

Figure (2.2): portable dust sampler device

**D. Water sampling**

The process of collecting water samples as part of a research project. The water samples were collected along the Tigris River between December 2021 and May 2022, four water samples were collected before and after the power plant. The samples were collected in 1.5-liter plastic bottles and were used for Physiochemical analysis. The bottles were filled to the neck and rinsed three times with the water sample. Temperature, pH, and Electrical Conductivity (EC) were measured in the field using a waterproof portable meter. The passage also mentions that there is a figure (2.5) that shows the appearance of the portable meter. Additionally, the passage mentions that the coordinates of the water sampling sites along the Tigris River are provided in Table 2.2. This information is used to document the exact location of each sampling site, which can be helpful in analyzing the data and interpreting the results. The use of GPS coordinates and two seasons sampling can also help to understand the spatial and temporal variability of the water quality in the study area.

Table 2.2: Coordinates of Euphrates River water sampling sites for winter and summer

| Water symbols | Coordinates | |
|---|---|---|
| | Latitude (N) | Longitude (E) |
| W1 | 32° 46' 23. 58" | 45° 05' 54. 65" |
| W2 | 32° 46' 25. 84" | 45° 05' 41. 58" |

**E. Soil sampling**

As part of the research project, the process of collecting soil samples is crucial, emphasizing the significance of obtaining representative samples that accurately represent the entire study area. It is essential to recognize that the quality of soil analysis is dependent on the quality of the samples delivered to the laboratory.

The initial step in collecting soil samples involves clearing the area surrounding the power plant of leaves, grass, and other large external materials. Subsequently, twenty soil samples are obtained from depths ranging from 0 to 20 cm. Each sample consists of approximately two kilograms of surface soil, which is carefully stored in a designated storage bag for subsequent elemental composition analysis, assessment of chemical characteristics, and grain size analysis.

Furthermore, a subset of the collected soil samples, weighing 100 grams, is sieved and placed in a brown glass bottle. These samples are stored in a refrigerator until the analysis of Polycyclic Aromatic Hydrocarbons (PAHs) can be conducted.

To document the precise location of each sampling site, the coordinates are recorded and presented in Table 2.3. This information plays a crucial role in analyzing the data and interpreting the results accurately. By utilizing GPS coordinates, researchers can better understand the spatial variability of soil quality within the study area.

Bottom of Form

Table (2.3) Coordinates of the Soil Sampling Sites at Study Area

| Soil samples N. | Coordinates | |
|---|---|---|
| | Latitude(N) | Longitude(E) |
| S1 | 32° 75' 87.91" | 45° 09' 84.43" |
| S2 | 32° 75' 64.87" | 45° 09' 59.45" |
| S3 | 32° 75' 75.48" | 45° 09' 51.27" |
| S4 | 32° 75' 86.89" | 45° 11' 70. 51" |
| S5 | 32° 75' 05. 6" | 45° 11' 36. 65" |
| S6 | 32° 75' 44. 5" | 45° 11' 55.82" |
| S7 | 32° 75' 30. 38" | 45° 11' 48. 51" |
| S8 | 32° 75' 61.82" | 45° 11' 74. 8" |
| S9 | 32° 76' 15. 131" | 45° 09' 99. 26" |
| S10 | 32° 76' 40. 54" | 45° 10' 02. 77" |
| S11 | 32° 79' 00. 55" | 45° 37' 44. 5" |
| S12 | 32° 79' 03. 5" | 45° 76' 95. 1" |
| S13 | 32° 79' 06. 25" | 45° 77' 70. 7" |
| S14 | 32° 79' 08. 85" | 45° 78' 14. 2" |
| S15 | 32° 79' 08. 98" | 45° 78' 68. 2" |
| S16 | 32° 81' 06. 76" | 45° 61' 21. 2" |
| S17 | 32° 81' 0. 87" | 45° 62' 73. 2" |
| S18 | 32° 81' 09. 13" | 45° 61' 21. 2" |
| S19 | 32° 81' 11. 0" | 45° 62' 02. 9" |
| S20 | 32° 81' 35. 9" | 45° 60' 28. 4" |

**F. Plant sampling**

The process of collecting plant samples as part of a research project. The study collected one species of plants around the power plant, reed plant samples were collected in plastic bags in two seasons, the first collection was in December 2021 and the second was in May 2022. Ten sampling were taken from the plant. After sampling, then dried in an oven under 50 °C before being analyzed in the laboratory. The passage also mentions that the coordinates of the plant samples are provided in Table (2.4), which can be helpful in analyzing the data and interpreting the results. The use of GPS coordinates and two seasons sampling can also help to understand the spatial and temporal variability of the plant quality in the study area and to evaluate the impact of the power plant on the surrounding plant life.

Figure (2.3). plant sample

Table (2.4): Coordinates of the plant Sampling Sites at Study Area for winter and summer.

| Plant samples N. | Coordinates | |
|---|---|---|
| | Latitude (N) | Longitude (E) |
| P1 | 32° 78' 42. 59" | 45° 07' 53. 6" |
| P2 | 32° 75' 05. 6" | 45° 11' 36. 65" |
| P3 | 32° 75' 86. 89" | 45° 11' 70. 51" |
| P4 | 32° 75' 73. 79" | 45° 09' 56. 56" |
| P5 | 32° 76' 33. 02" | 45° 10' 04. 6" |
| P6 | 32° 45' 51. 14" | 45° 05' 53. 89" |
| P7 | 32° 45' 31. 28" | 45° 07' 01. 38" |
| P8 | 32° 45' 38. 81" | 45° 06' 58. 97" |
| P9 | 32° 44' 54. 48" | 45° 08' 14. 51" |
| P10 | 32° 46' 25. 84" | 45° 05' 41. 58" |

## 2.4 Laboratory work

This crocess is describing the next step in the research process, which is the laboratory work for the samples that were collected in the field. The section will include details about the procedures, techniques, and analysis used to study the samples collected from the research region. It is not specified what are the details of the laboratory work, but it will be discussed in the next sections of the research.

### 2.4.1 Laboratory Work for Air Samples

The laboratory work that is being conducted on the air samples collected from the research region. It states that before the sampling process begins, a specific procedure is used to prepare the instrument for the air samples. However, it is not specified what is the procedure is, but it is important to prepare the instrument properly to ensure accurate and reliable results.

## A. Preparation of air samples for measuring Total suspended particulates (TSP)

There are several methods for preparing air samples for measuring Total Suspended Particulates (TSPs), but a common method is using a high-volume air sampler.

1-First, the high-volume air sampler is calibrated to ensure accurate flow rates.

2-The sampler is then placed in the desired location for a specified amount of time, typically 24 hours.

3-After sampling, the filter in the sampler is removed and weighed to determine the amount of TSPs collected.

4-The filter is then analyzed using microscopy or other analytical techniques to determine the size and composition of the particulates.

It's important to note that depending on the application, different samplers, filters and methods may be used, such as low-volume samplers, cascade impactors, etc (EPA). (2020).

## B. Preparation of air samples for measuring heavy metals

The preparation of air samples for measuring heavy metals involves several important steps, including sampling, preservation, and subsequent analysis. The specific method employed depends on the type of heavy metal being measured and the matrix of the sample, whether it is in particulate or gaseous form (Gharaibeh et al., 2009).

For particulate phase sampling, high-volume air samplers are commonly used to collect particles onto filters. The collected filters are then weighed, and a portion of the filter is extracted using a suitable solvent, such as acid or aqua regia. The extracted solution is then analyzed using techniques such as Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) or Atomic

Absorption Spectrophotometry (AAS) to determine the concentrations of heavy metals (Gharaibeh et al. 2009).

Once the air samples are collected, they are sent to a laboratory for analysis of trace element concentrations, specifically using Atomic Absorption Spectrometry (AAS). In this process, a Shimadzu AA-7000 model, manufactured in Japan Figure 2.4, is utilized (Perry and Young 1977).

The digestion method for the samples follows these steps:

1-The filters containing contaminants are dissolved using a mixture of acidic perchlorate and nitric acid (1:4) sizes ($HNO_3$, $HClO_4$).

2-The resulting mixture is placed in a closed bottle and subjected to agitation in a vibrator water bath at 45 °C for an hour or until the solution achieves homogeneity. Then, the solution is poured into a beaker that has been cleaned with nitric acid and filled with distilled water.

3-The solution is further diluted with non-ionic water until it reaches a final volume of 25 ml.

4-To calculate the metal concentration in the air samples, the following equation is used:

$$\text{Metal Conc. } (\mu g/m) = C * Vi / VT \quad \text{(Equation 2-3).}$$

Here, C represents the concentration of the element in the sample in parts per million (ppm) unit, Vi is the sample size in milliliters (ml) unit, and VT is the total volume of air drawn in cubic meters.

5-The volume of air drawn (VT) can be determined using the equation

$$VT = (V1 + V2 / 2) \times t / 1000$$

where t is the sampling time in minutes, V1 and V2 are the volume of air recorded by the iron ball at the beginning and end of the sampling.

This procedure is based on the method described by Aldabbas et al. in 2015 and is commonly used to measure the concentration of suspended particles in air samples (Aldabbas et al. 2015).

Figure (2.4) Atomic Absorption Spectrometry

### 2.4.2 Laboratory Work for Water Samples

#### A. Major and minor ions

The laboratory work being done on the water samples collected from the research region. The analysis includes the measurement of major ions such as $K^+$, $Na^+$, $Ca^{+2}$, $Mg^{+2}$, $Cl^-$, $SO_4^{-2}$ and minor ions such as $NO_3$, $PO_4$. These ions are important indicators of water quality and can provide information on the sources and processes that affect the water. The physiochemical features of the water samples are being evaluated in the laboratories of Babylon University's College of Science. The results of these analyses presented in Table (2.5) and can provide valuable information on the current water quality of the study area.

#### B. Heavy metals

The laboratory work being done on the soil samples collected from the research region to determine the concentrations of trace elements such as Ni, Fe, Cd, Zn, and Pb. The analysis is being done using an atomic absorption spectrophotometer (AAS) instrument. AAS is an analytical technique that

measures the absorption of light by atoms in a sample. This method is widely used for the determination of trace elements in soils, water, and other materials. The laboratory where this analysis is being conducted is the Laboratory of Geochemistry/Department of Earth Science at the University of Babylon, as shown in Figure (2.4). This analysis will provide valuable information about the levels of these elements in the soil and their potential impact on the environment and human health.

**1. Preparation - Digestion of water samples for determined heavy metals**

The laboratory work being done on the water samples collected from the research region to determine the concentrations of heavy metals. The method used for this analysis is called digestion, which involves the use of nitric and hydrochloric acids to break down the samples. This process is known as sample preparation. Digestion allows for the measurement of total metals, which include all metals, both dissolved and particulate, that are inorganically and biologically bonded. The method used for total metals analysis is called APHA 3030A. The term "Total recoverable metals" is also used which refers to the concentration of the analytic determined in an unfiltered aqueous sample after treatment with a hot dilute mineral acid. This analysis will provide valuable information about the levels of these elements in the water and their potential impact on the environment and human health. (Hedin et al. 2019).

The steps taken to prepare the water samples for digestion in order to determine the concentrations of heavy metals. The process begins with shaking the sample to homogenize it, then 50ml of the sample is taken and placed in a digestion vessel. Nitric and hydrochloric acids are added to the sample, and it is then heated for 2-2.5 hours at 95±5°C. Once the sample has cooled for at least 30 minutes, it is reconstituted back to 50ml with de-ionized

water. The sample is stored in a cool place until it is sent to the lab for analysis using an Atomic-absorption spectrometer. The concentration of heavy metals in the water is calculated using the formula provided where M.C represents the metal concentration in mg/L, A represents the element concentration on the sample, B represents the final volume of the sample in mL, and C represents the primary sample volume in ml.

$$M.con = \frac{A * B}{C} \dots\dots\dots\dots\dots 2.4$$


Figure (2.5) Flame photometer

Table (2.5). Methods of analysis and name of laboratories achieved.

| Parameters | Methods of analysis | Name of laboratory |
|---|---|---|
| Temperature C° | waterproof portable meter device | in the field |
| Ph | waterproof portable meter devic\e | |
| EC µs/c | waterproof portable meter device | |
| TDS (mg/l) | Vaporization, in 105 C (hot plate) (Abawi, 1990) | Laboratory of geochemistry / Department at College of Science, University of Babylon |
| $Na^+$, $K^+$ | Flame photometer Fig (2.7) | Laboratory of chemical department at |

| | | |
|---|---|---|
| | | collage of science / Babylon University |
| Th,$Ca^{+2}$, $Mg^{+2}$ | Titration with EDTA )Ethylene Diamine Tetra Acidic Acid( (Vogel,1961), Fig (2.8) | Laboratory of geochemistry / Department at College of Science, University of Babylon |
| $Cl^{-}$ | Titration with $AgNO_3$ (Vogel, 1961) | |
| $PO_4^{-}$, $NO_3^{-}$ | UV-visble spectrophotometer (Abawi, 1990) | Laboratory of geochemistry / Department at College of Science, University of Babylon |
| $SO_4$= | Gravimetric method with ignition of residue (Vogel, 1961) | |

### 2.4.3 Laboratory Work of Soil Samples

The soil samples are collected and taken to a laboratory for examination and testing. The following analyses were performed:

### A. Physical parameter is included

Wet sieving and hydrometer methods were used to measure grain size in soil. The grain size analysis is divided into two stages: first, the Sieve Analysis; and second, the Hydrometer Analysis. Second, 200 g of soil was used and washed on a sieve 200 (0.075 m) to separate the sand from the mud and silt, while the mud was separated from the slit by using the Hydrometer method, where 50 g of transit soil from the sieve 200 (0.075 m) was placed in a cylinder and 140 ml of the substance purchased (Na-Hexametaphosphate) was placed above it, and then the size was (ASTM D- 422.2007). Figure (2.6) shows the results of the study conducted at Babylon University's Department of Applied Geology's Laboratory of Geochemistry.

Figure (2.6) grain size soil analysis

**B. Chemical parameters are included**

**1. Electrical conductivity (EC), Hydrogen (PH)**

pH and EC (electrical conductivity) are two commonly used parameters to measure the chemical properties of sediment. pH is a measure of the acidity or basicity (alkalinity) of a solution and is commonly measured in sediment samples using a pH meter or pH paper. The pH scale ranges from 0 to 14, with 7 being neutral. Sediments that are more acidic have a lower pH, while sediments that are more basic have a higher pH. The pH of sediment is an important indicator of the chemical and biological processes occurring within the sediment and can also be used to infer the presence of certain types of minerals or pollutants.EC is a measure of the ability of a solution to conduct electricity and is commonly measured in sediment samples using an EC meter. The conductivity of a solution is affected by the concentration of ions present in the solution. Sediments that are more saline or contain more dissolved minerals will have a higher EC. EC can be used as an indicator of

the mineral content of the sediment, and can also be used to infer the presence of certain types of pollutants (USGS.2019). That is a common method for measuring the pH of soil. The 1:1 (soil: water) suspension is prepared by mixing an air-dried soil sample (100g) with 100 mL of distilled water and swirling it for 1 hour on a stirrer. This ensures that the soil is well mixed with the water and that any particles that may be present are suspended in the solution.

Then, a Whatman No. 42 filter paper is used to filter the suspension, this is to remove any solid particles from the solution and ensure that the pH measurement only reflects the pH of the liquid portion of the soil sample.

A pH meter is then used to measure the pH of the filtrate, and an electrical conductivity (EC) meter is used to measure the conductivity of the extract. The EC is often reported in units of mS/cm (millisiemens per centimeter).

It's worth mentioning that the measurements should be taken under controlled conditions to ensure accuracy, such as correct calibration of the instruments before use, and making sure that the measurements are taken at room temperature. All those parameters are conducted at laboratories of the college of science Babylon University. Department of applied geology laboratory of geochemistry.

**2. X-ray Diffraction (XRD)**

To prepare samples for X-Ray Diffraction, the following steps were taken:

1-Air dried and finely ground to a 200–mesh powder using a ceramic mortar and pestle.

2-Placed into a circular container, with the top surface of the sample smoothed with a flat spatula and a glass slide.

3-Scanned from 5° to 60° at x° 2 theta per minute on the sample holder of the XRD apparatus at the ministry of science and technology.

## 3. X-ray fluorescence (XRF)

X-ray fluorescence (XRF) is a technique that uses X-rays to identify and quantify the elemental composition of several solid materials, allowing for chemical characterization of the analyzed material and correlation with other properties. The work is done in this way for the purpose of identifying and knowing the minerals of the main elements in the soil (Weindorf, et al 2014).

The XRF examination requires the preparation of samples before starting the examination.

1- Unwanted impurities must be removed from the sample, then we dry them in an oven at a temperature of 105 degrees Celsius to get rid of excess moisture to obtain accurate results.

2- Then the soil is well ground to get rid of soil clusters and it is preferable to sift it

3- Press soil samples well, remove the air voids from them and place them in the sample cup for XRF so that the sample will be accurate and orderly to be ready for examination.

These steps may require effort and time, but will provide accurate results (Shefsky, 1997).

It can be asserted that the X-ray fluorescence examination is the ideal way to find out the chemical composition of antiques or artifacts of great value because it does not cause damage to the model and gives accurate results, (Janssens et al., 2000).


Figure (2.7): The device of XRF

**4. Polycyclic aromatic hydrocarbons (PAHs) analysis**

Polycyclic aromatic hydrocarbons (PAHs) are a group of chemicals that are composed of multiple aromatic rings and are found in a variety of sources such as fossil fuels, wood combustion, wildfires, volcanic eruptions and tobacco smoke (Zhang et al., 2011). They can also be formed during the incomplete burning of organic matter. PAHs can be harmful to human health and the environment when they are present in high concentrations.

Analysis of PAHs involves the detection and quantification of these compounds in various environmental matrices such as air, water, soil, sediment and biota. Different analytical methods can be used to detect and quantify PAHs such as:

Gas Chromatography (GC) combined with Mass Spectrometry (MS).

High-Performance Liquid Chromatography (HPLC) combined with Mass Spectrometry (MS).

Inductively Coupled Plasma-Mass Spectrometry (ICP-MS).

Fluorescence Spectrophotometry.

UV-Vis Spectrophotometry.

The choice of analytical method will depend on the sample matrix, the required sensitivity and the specific PAHs of interest. The analysis of PAHs is typically performed in laboratories that are certified for environmental analysis (Lago et al., 2003).

It is important to note that the presence of PAHs does not always indicate an environmental problem. The levels of PAHs and their potential impact on human health and the environment need to be evaluated in context of the specific location and the background levels.

Sample for PAHs analysis should be stored in glass containers, protected from light and refrigerated until extracted. In this study, extraction was conducted by sonication method using ultrasonic instrument (Model 405, Industrial BLT type, Ambient to 50 C, 40kHz, Korea), because of fast and easy extraction process compared with other methods. Soil samples (l gm) were dried at air temperature and after sieving (through 50 meshes sieve), were suspended in 10 ml of acetonitrile and extracted in ultrasonic bath at 40-45oC for 45- 60 minutes. Extracts were settled for 10 min, and centrifuged at 5000-6000 rpm for 15 min (Arbabi et al., 2004). Elutes were filtered by 25mm, 2μm pore size, and submitted to Gas Chromatography (GC) Figure (2.8).

PAHs concentration was measured by GC, with chromatographic conditions as follows:

- Column Oven (SE-30) =100 (HOLD 1 MIN) -300C (HOLD 2 MIN)

(10C/MIN)

- Tem Injector=280C
- Injection Volume= 1 μl

- Tem Detecter (FID)= 310C

- Pressure = 100Kpa

$$Cs = \frac{Cst * Asamp}{Ast} . \frac{D.F}{wt} \dots\dots\dots\dots (2.6)$$

Where Cs: hydrocarbon concentration

Cst: stander concentration

Asamp. area of the sample

Ast: area of the standard

D.F: dilution factor

Wt : weight of the sample


Figure (2.8) Gas chromatography.

### 2.4.4 for Plant Samples

**1. Heavy metals**

An atomic absorption spectrophotometer was used to identify heavy metals in plant samples (Atomic Absorption Spectroscopy). Each plant item was thoroughly washed with tape water and then distilled water to eliminate

dust and soil particles for this reason. The plant components were cleaned and dried in a 105 ºC oven for 24 hours. Then the samples were digested according to (Zovko and Romic, 2011).

1- In a 100 mL beaker, a 0.5g sample of plant leaf was obtained.

2- 5 milliliters concentrated (65%) $HNO_3$.

3- 2 mL $HClO_4$ was added to the mixture.

4- The digest was heated on a hot plate until it became clear. After cooling, the digest was filtered using a Whatman filter paper. In a 50 mL volumetric (measuring) flask, the filtrate was collected and diluted to the desired concentration with distilled water Figure (2. 9.A and B).

Heavy metal concentration has been calculated from the equation.

$$M.con = \frac{A * B}{W} \dots\dots\dots\dots\dots\dots (2.14)$$

Where: M.C = Metal Concentration in mg/kg

A: Element concentration on sample (reading devise) in mg/L

B: The final velum of the sample in mL = 50ml

W: wight of sample in gram = 0.5 gm

**2. Poly cyclic aromatic hydrocarbons (PAHs) analysis**

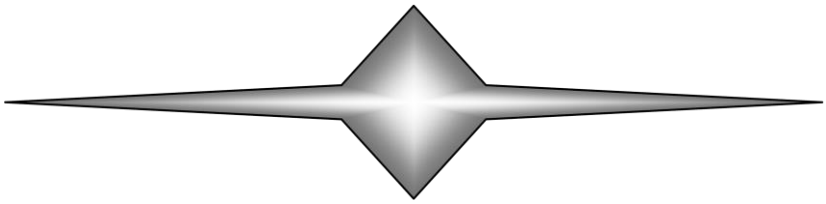
The following procedures were used to extract polycyclic aromatic hydrocarbons from plants:

1. The plant leaves were collected and dried by combining 15g of anhydrous sodium sulphate with them until they were fully dry and pulverized.

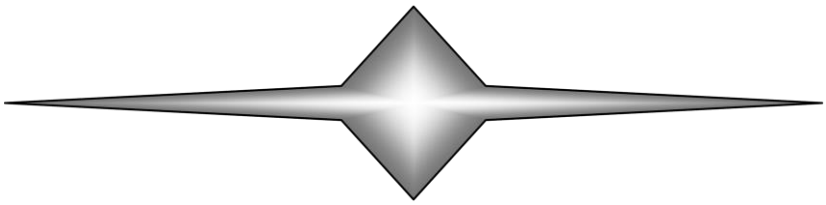
2. 30 g of paper samples were combined with 100 ml of dichloromethane (DCM), acetone, and hexane (1: 1: 1), and Sonication was performed for 25 minutes at 45-40 ° C for one hour. The method is then completed as in soil extraction (US EPA, 2007). (Figure 2.9. C).


Figure (2.9) : (A) Digestion method for measuring heavy metals for plants , (B and C) Digestion method for measuring heavy metals for air's filters.

# Chapter Three



# Assessment of Air pollution



# Assessment of Air pollution

## 3.1 preface

In this chapter, the pollution levels in a specific area were assessed by measuring and evaluating Total Suspended Particles (TSP), gases, and heavy metals. The analysis was conducted using the ArcGIS 10.6 program, allowing for a comprehensive examination and comparison of the results with international standards. Additionally, maps were generated using the ArcGIS software to visualize the spatial distribution of pollutant percentages within the study area. The focus of the measurements was primarily on air pollutants, and specific types of pollutants were investigated for each environmental component.

The purpose of this chapter was to evaluate and understand the pollution levels within a particular area. The measurements included the assessment of Total Suspended Particles (TSP), gases, and heavy metals. By utilizing the ArcGIS 10.6 program, a detailed analysis was performed, enabling a comprehensive comparison of the obtained results against international standards. To enhance the understanding of the data, maps were created using the ArcGIS software, which effectively displayed the spatial distribution of pollutant percentages throughout the study area. The measurements specifically targeted air pollutants, with specific types of pollutants being investigated for each environmental component.

## 3.2 Air pollution

Air pollution is caused by a variety of substances, including gases, particles, and biological molecules. Some of the most common pollutants found in the air include:

Carbon monoxide (CO): A colorless, odorless gas that is toxic to humans and animals when inhaled in high concentrations. It is produced by the incomplete burning of fossil fuels CO (EPA).

Carbon dioxide ($CO_2$): A colorless, odorless gas that is a byproduct of human activities such as the burning of fossil fuels and deforestation. It is a greenhouse gas that contributes to climate change $CO_2$ (EPA).

Volatile Organic Compounds (VOCs): A group of chemicals that evaporate easily at room temperature and can be found in a variety of sources, including industrial emissions, solvents, and certain consumer products. They can contribute to the formation of ground-level ozone and smog Volatile Organic Compounds (EPA).

Lower Explosive Limit (LEL): The concentration of a substance in air that can catch fire. Lower Explosive Limit of Methane is 5% which is a dangerous gas if not ventilated properly Lower Explosive Limit (LEL) of Methane" (HSE UK).

Air pollution encompasses various pollutants, including particulate matter like dust, pollen, and soot, as well as biological molecules such as pollen and mold spores. The impact of these pollutants on human health and the environment depends on their concentration, duration of exposure, and specific nature. Atmospheric pollution is defined as the presence of contaminant substances or energy in the air, which can negatively affect human health, welfare, and the environment (Almetwally et al. 2020). Additionally, atmospheric pollution is characterized by the existence of substances or energy in the atmosphere in quantities and durations that can cause harm to human, plant, or animal life, damage human-made materials and structures, induce changes in weather and climate, or interfere with human activities and property enjoyment (Sultan et al. 2013).

In the study area, air pollutants are released into the atmosphere by sources such as petroleum refineries, thermal power plants, and gaseous power plants. These pollutants are emitted as gases and particulates through flares and chimneys. To assess environmental pollution at the Zubaidiya power plant, ten air sampling sites were selected.

The analysis conducted in the selected area focuses on measuring Total Suspended Particle (TSP) concentrations, gases such as CO, $CO_2$, volatile organic compounds (VOC), and lower explosive limit (LEL). Additionally, the study involves the assessment of trace elements, including cobalt (Co), cadmium (Cd), copper (Cu), lead (Pb), and nickel (Ni), present in the local environment.

### 3.3 Particulate Matter

Particulate matter refers to airborne particles that exist in various sizes, typically ranging from less than 0.1 micrometers (μm) to 10 micrometers (μm) in diameter. These particles can be in solid or liquid form and consist of a wide range of substances, such as dust, pollen, soot, smoke, and other fine particles (Harrison, 1992; cited in Al-Saadi, 2012). When present in the air, these particles can undergo chemical reactions, giving rise to secondary pollutants that pose significant environmental risks. For instance, suspended particles have the capacity to block sunlight, resulting in an increase in atmospheric darkness (Al-Maliky, 2006). These particles can remain airborne for varying durations, ranging from a few seconds to several months, and can eventually settle on surfaces such as air, water, and solid objects (Al-Saadi, 2012; Hashim, 2009).

In the study area, the concentration of total suspended particles (TSP) ranged from 234.74 to 938 $\mu g/m^3$, with a mean TSP concentration of 511.36 μg/m3 during the winter season and ranging from 283.08 to 3043.17 $\mu g/m^3$

with an average of 1027 μg/$m^3$ during the summer season. These concentrations exceeded the allowable limits established by the Iraqi Standards (2008) and WHO (1996) (Table 3.1). The highest TSP value of 1955.56 μg/m3 was observed at station A1 during the winter season, while station A8 recorded the highest TSP value during the summer season. These stations are located in close proximity to the chimneys of the thermal power plant, aligned with the prevailing wind direction. Conversely, the lowest TSP value of 168.78 μg/$m^3$ was recorded at station A5 during the winter season, and station A9 had the lowest TSP value during the summer season. Figure 3.1 provides an overview of the spatial distribution of TSP in the study area.

The concentration of particulate matter is influenced by weather conditions, particularly wind direction and speed. In the summer, wind patterns can disperse particulate matter away from its source, resulting in lower concentrations near the emission point and higher concentrations at greater distances. In contrast, stagnant wind patterns during the winter season can lead to the accumulation of particulate matter in proximity to the source, causing higher concentrations in the vicinity of the power station and lower concentrations further away. Temperature inversions, which are more common in winter, can also contribute to the trapping of pollutants near the ground, leading to higher concentrations of particulate matter in close proximity to the emission source (Flores-Chapa & Delgado 2011).

**Table (3.1)** TSP in winter season Comparison with Iraqi Standards (2008) and WHO (1996) for 24 hours.

| Stations | TSP (μg/$m^3$) |
|---|---|
| A1 | 938.9671 |
| A2 | 511.6959 |
| A3 | 300.3003 |
| A4 | 391.2363 |
| A5 | 234.7418 |
| A6 | 782.4726 |
| A7 | 555.5556 |

| | |
|---|---|
| A8 | 694.4444 |
| A9 | 391.2363 |
| A10 | 312.989 |
| Ave | 511.3639 |
| Max | 938.9671 |
| Min | 234.7418 |
| Iraqi standards (μg/m$^3$) 24 h | 150 |
| WHO, 1996 (μg/m$^3$) 24 h | 75 |

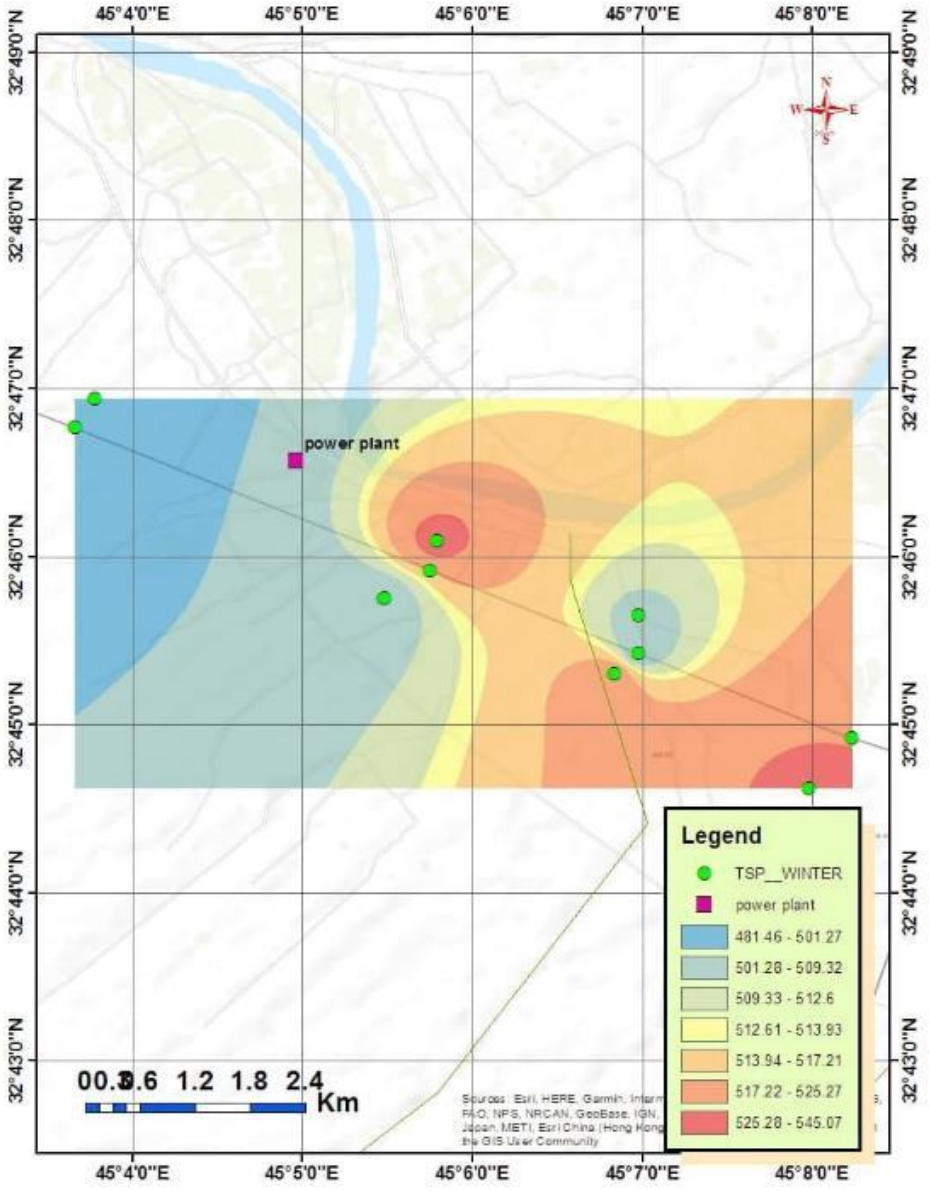



Figure (3.1) GIS Map showing total Suspended Particles Distribution in winter season in the Air of Study Area.

Table (3.2) TSP in summer season Comparison with Iraqi Standards (2008) and WHO (1996) for 24 hours.

| Stations | TSP (μg/m$^3$) |
|---|---|
| A1 | 841.2198 |
| A2 | 1195.499 |
| A3 | 843.8819 |
| A4 | 1125.176 |
| A5 | 562.5879 |
| A6 | 925.9259 |
| A7 | 849.2569 |
| A8 | 3043.171 |
| A9 | 283.0856 |
| A10 | 601.557 |
| Ave | 1027.135 |
| Max | 3043.171 |
| Min | 283.0856 |
| Iraqi standards (μg/m$^3$) 24 h | 150 |
| WHO, 1996 (μg/m$^3$) 24 h | 70 |

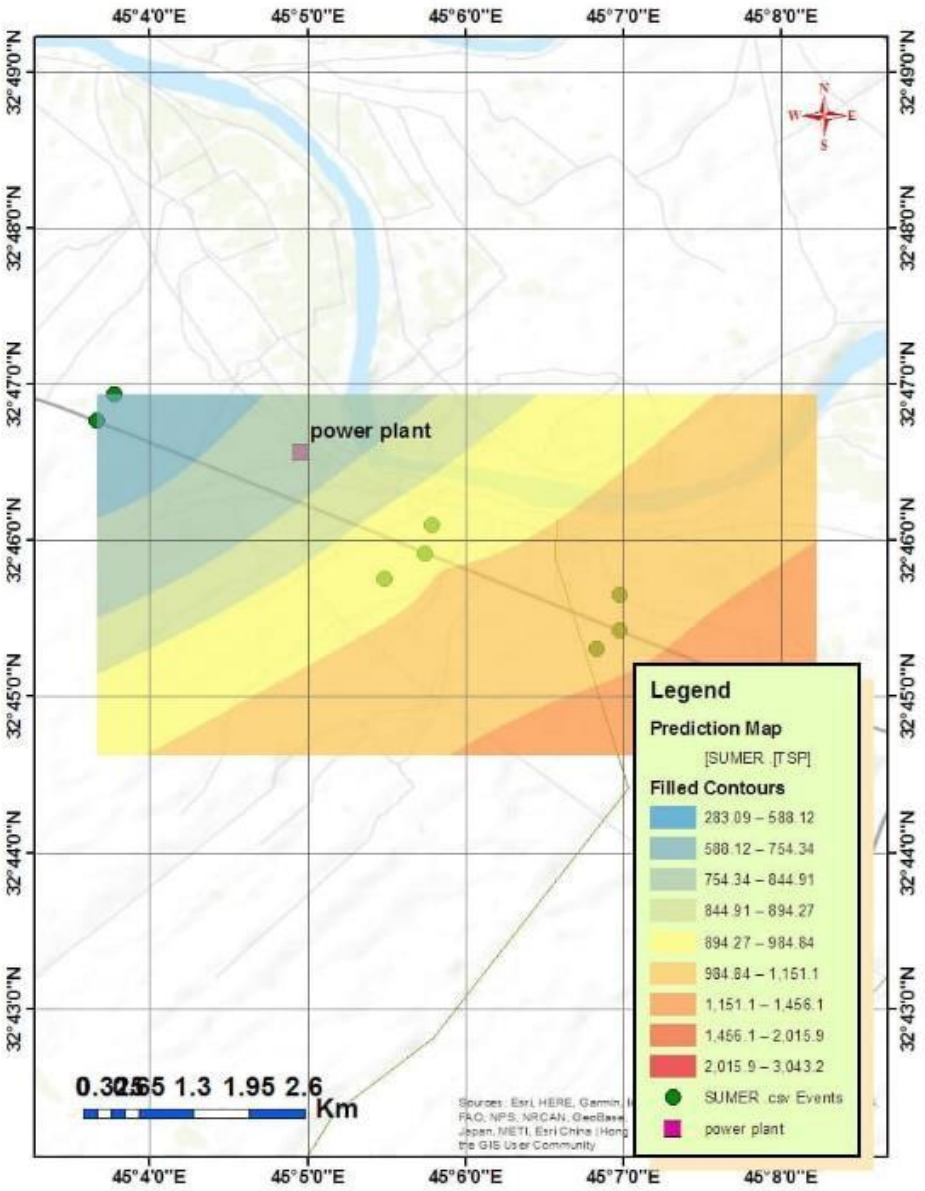



**Figure (3.2)** GIS Map showing total Suspended Particles Distribution in summer season in the Air of Study Area.

### 3.4 Gases in air

The study included the tabulation of the range and mean values of gases (CO, $CO_2$, VOC, LEL) in relation to the National Ambient Air Quality Standards (NAAQS) (2016) and WHO (1996). The corresponding values were presented in Tables 3.3 and 3.4, while Appendix A contained the detailed concentration measurements of these gases.

Table (3.3) Range and mean concentrations of gasses in winter season in comparison with NAAQS and World Standards.

| Gases | Range | Mean | NAAQS 2016 | WHO (1996) |
|---|---|---|---|---|
| | | | | |
| CO | 0-6 | 1.83 | 10 | 9 |
| $CO_2$ | 790-1030 | 901 | ----- | 250 |
| VOC | 0.1-0.5 | 0.26 | | 0.50 |
| LEL | 0 | 0 | | 15.5 |

Table (3.4) Range and mean of gasses concentrations in summer season comparison with NAAQS and WHO.

| Gases | Range | Mean | NAAQS 2016 | WHO (1996( |
|---|---|---|---|---|
| | ppm | | | |
| CO | 1-2 | 1.3 | 10 | 9 |
| $CO_2$ | 950-1810 | 1431 | ----- | 250 |
| VOC | 0.2-0.5 | 0.36 | | 0.50 |
| LEL | 0 | 0 | | 15.5 |

### 3.4.1 Carbon Monoxide (CO)

According to Pepper et al. (2006), CO is generated when carbon-based materials undergo incomplete combustion. Prolonged exposure to low levels of CO can affect cardiovascular health, while high levels of exposure can be toxic.

During the winter season, CO values were not detectable in stations A3, A8, A9, and A10, and ranged from 0-6 ppm with a mean value of 1.6 ppm in the other stations (Table 3.3). Station A1 had the highest concentration of CO, while stations A2, A4, and A7 had the lowest concentrations.

In the summer season, the mean concentration of CO was 1.3 ppm with a range of 1-2 ppm. Station A3, A6, and A9 had the highest concentrations, while stations A1, A2, A4, A5, A7, A8, and A10 had the lowest concentrations. The results were compared with the NAAQS and WHO limits, and were found to be within the limit (Tables 3.3, and 3.4). Figures 3.2 and 3.3 depict the distribution of CO in the air of the study area during the winter and summer seasons, respectively.

### 3.4.2 Carbon Dioxide ($CO_2$)

According to Miller and Spoolman (2010), about 93% of atmospheric $CO_2$ is generated by the natural carbon cycle, with the remaining 7% originating from human activities. However, since the utilization of fossil fuels such as coal, oil, and natural gas to generate energy for electricity and transportation fuel, $CO_2$ levels have risen considerably (Williams, 2005).

In this study, the concentration of $CO_2$ varied from site to site and was compared to the limits set by WHO. During the winter season, the range of $CO_2$ concentration was from 790 to 1030 parts per million (ppm), with the highest concentration observed in station A7 and the lowest in A5 (see Appendix A). The mean concentration of $CO_2$ during winter was 901 ppm (Table 3.3).

During the summer season, the mean concentration of $CO_2$ was 1431 ppm, with a range of 950-1810 ppm. Station A4 recorded the highest concentration, while A2 had the lowest (Table 3.4). The results were compared to the NAAQS and WHO limits, and were found to exceed the standard limits. Figures 3.4 and 3.5 depict the distribution of $CO_2$ in the study area during winter and summer, respectively.

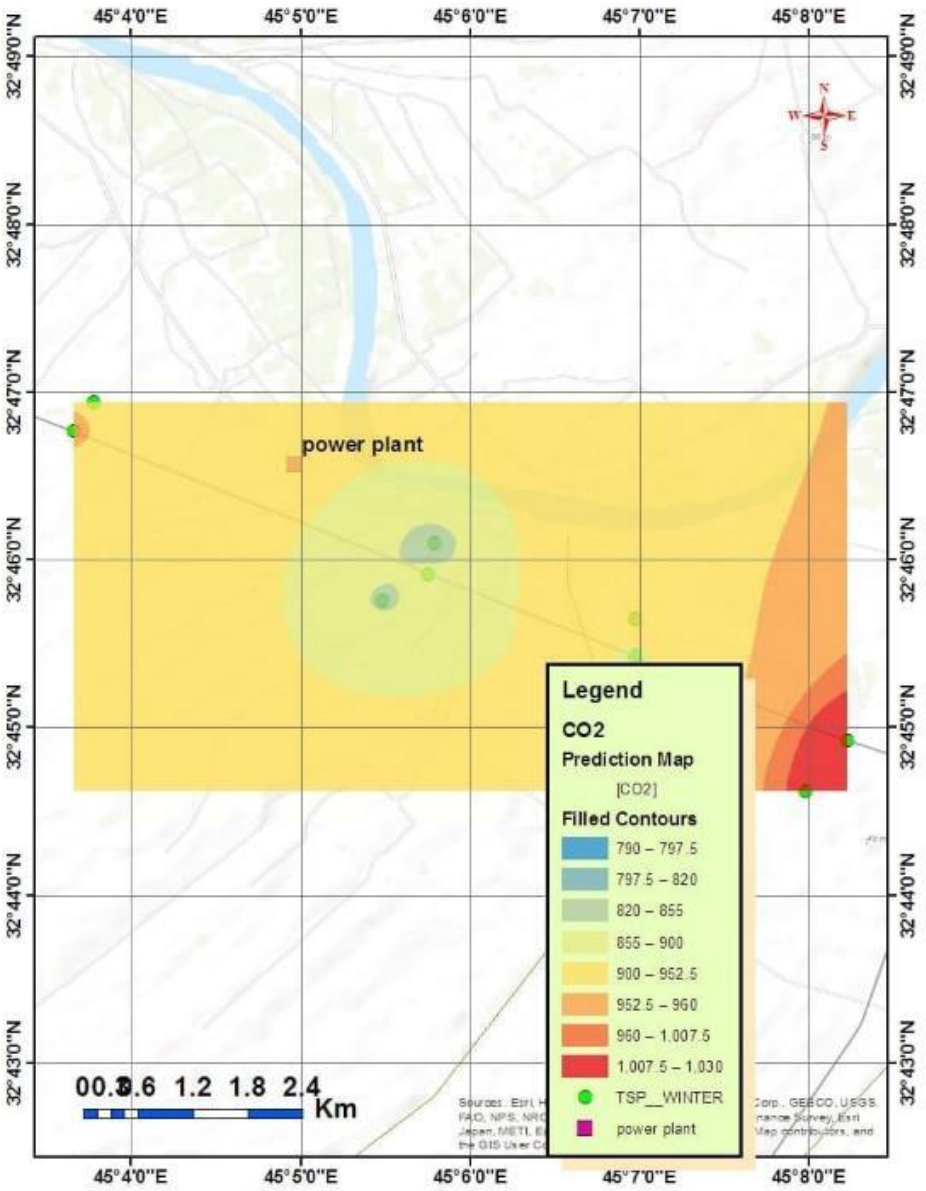



Figure (3.3) GIS Map showing distribution of (CO2) in the air of the study area in winter season.

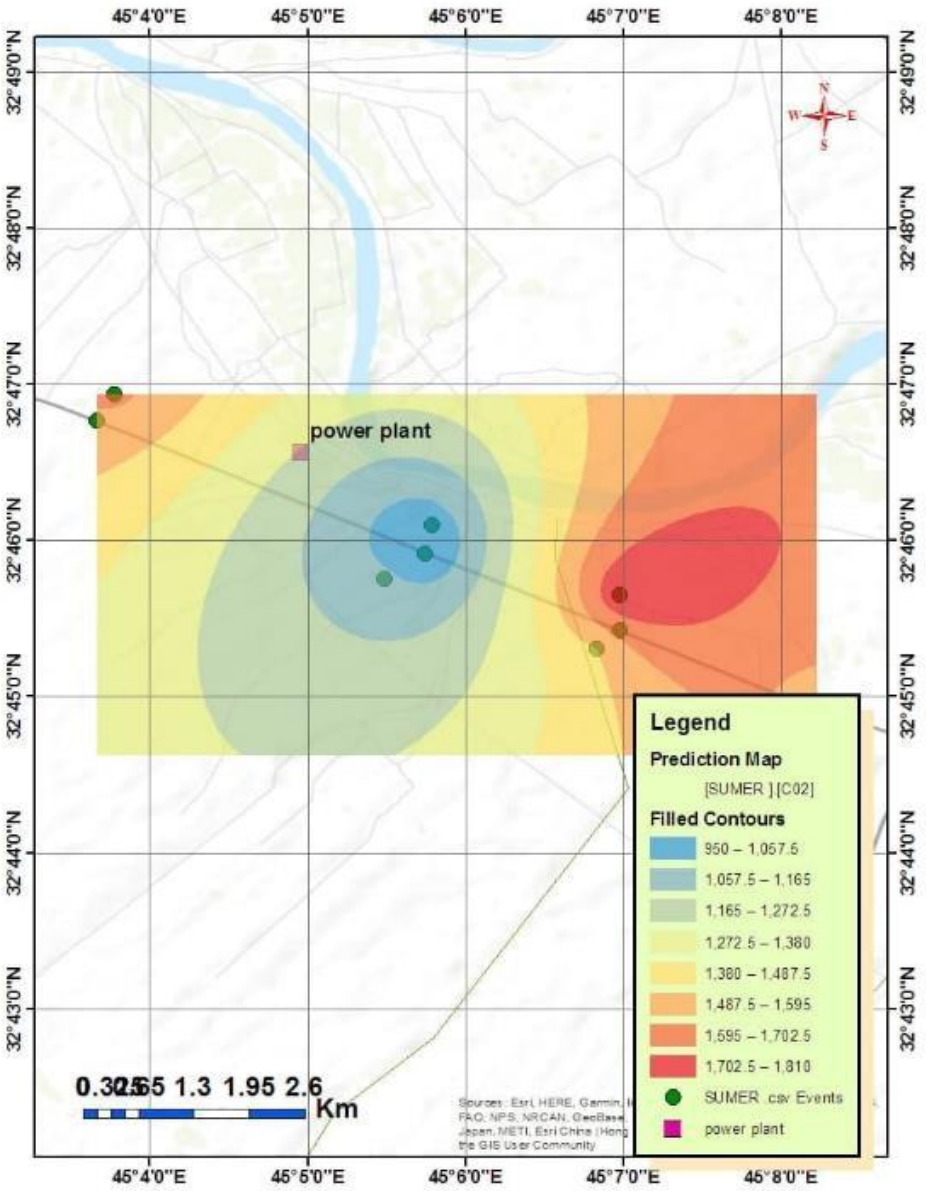



Figure (3.4) GIS Map showing distribution of ($CO_2$) in the air of the study area in summer season.

### 3.4.3 Volatile organic compounds VOC

Volatile organic compounds (VOCs) are gaseous hydrocarbons that are partially burnt or unburned at ambient temperatures. VOCs are emitted from various sources, including the petrol tanks and crankcase of vehicles, as well as other stationary sources (Wang et al., 2013). VOCs are a complex group of organic chemicals that are primarily generated during the burning process of fossil fuels and consist mainly of alkenes, alkanes, cycloalkanes, aromatics,

and oxygenates (Sun et al., 2016). These compounds are highly toxic environmental pollutants, many of which are carcinogenic, mutagenic, and teratogenic (Wu et al., 2016). High concentrations of VOCs are found in major cities and the atmosphere of urban areas due to the increasing traffic (Liaud et al. 2015). VOCs in the ambient air can affect air quality over long distances (Derstroff et al., 2016).

In the winter, the study area's VOC concentrations ranged from 0.1-0.5 parts per million (ppm), with the highest concentration found in station A2 and the lowest in station A5 (Appendix A). The mean concentration of VOCs was 0.26 ppm. In the summer, the mean concentration was 0.36 ppm, with a range of 0.2-0.5 ppm. The highest concentration was found in stations A4, A5, and A6, while the lowest was found in stations A1, A2, and A10 (Appendix A). The results were compared to WHO limits, and the mean concentration was higher than these limits (Figure 3.5, 3.6)

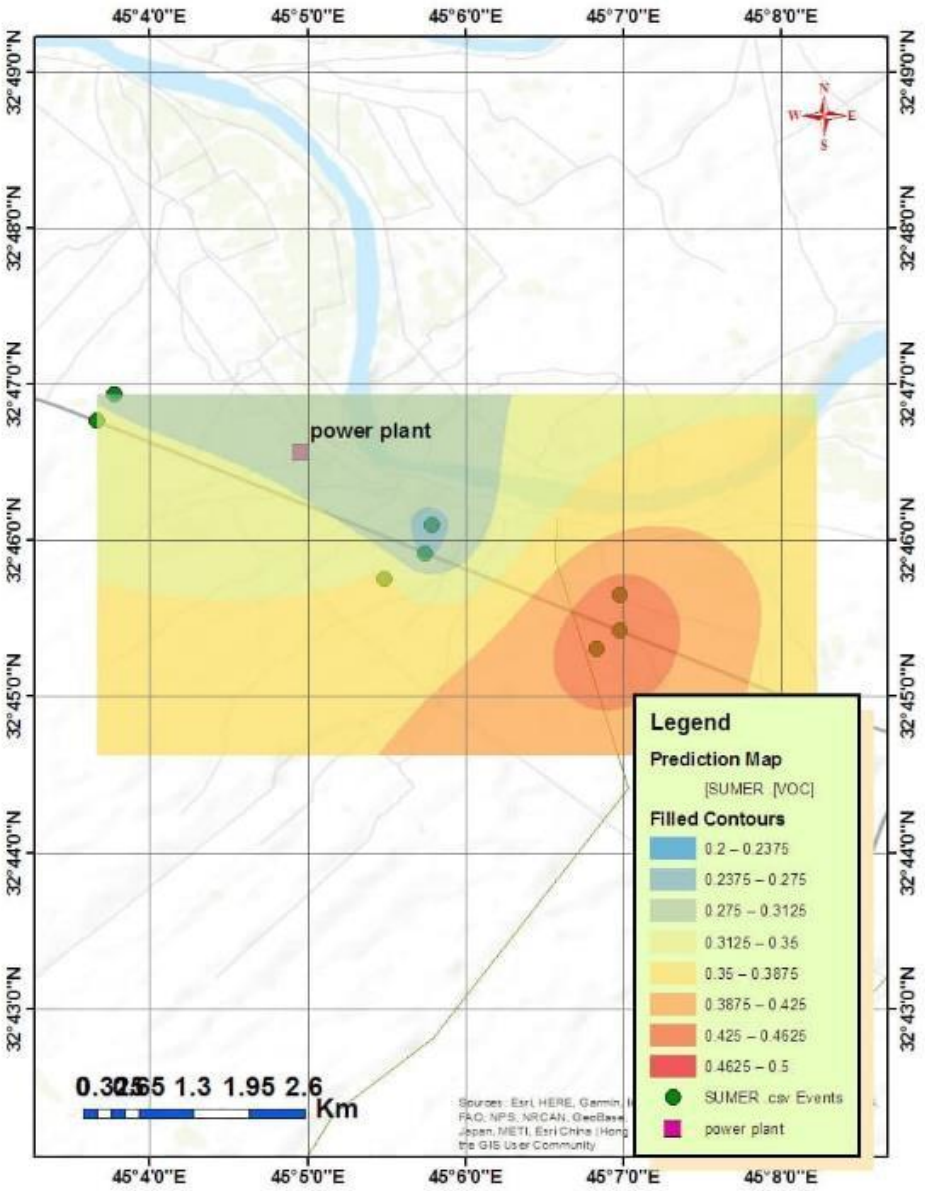



Figure (3.5) GIS Map showing distribution of (VOC) in the air of the study area in summer season.

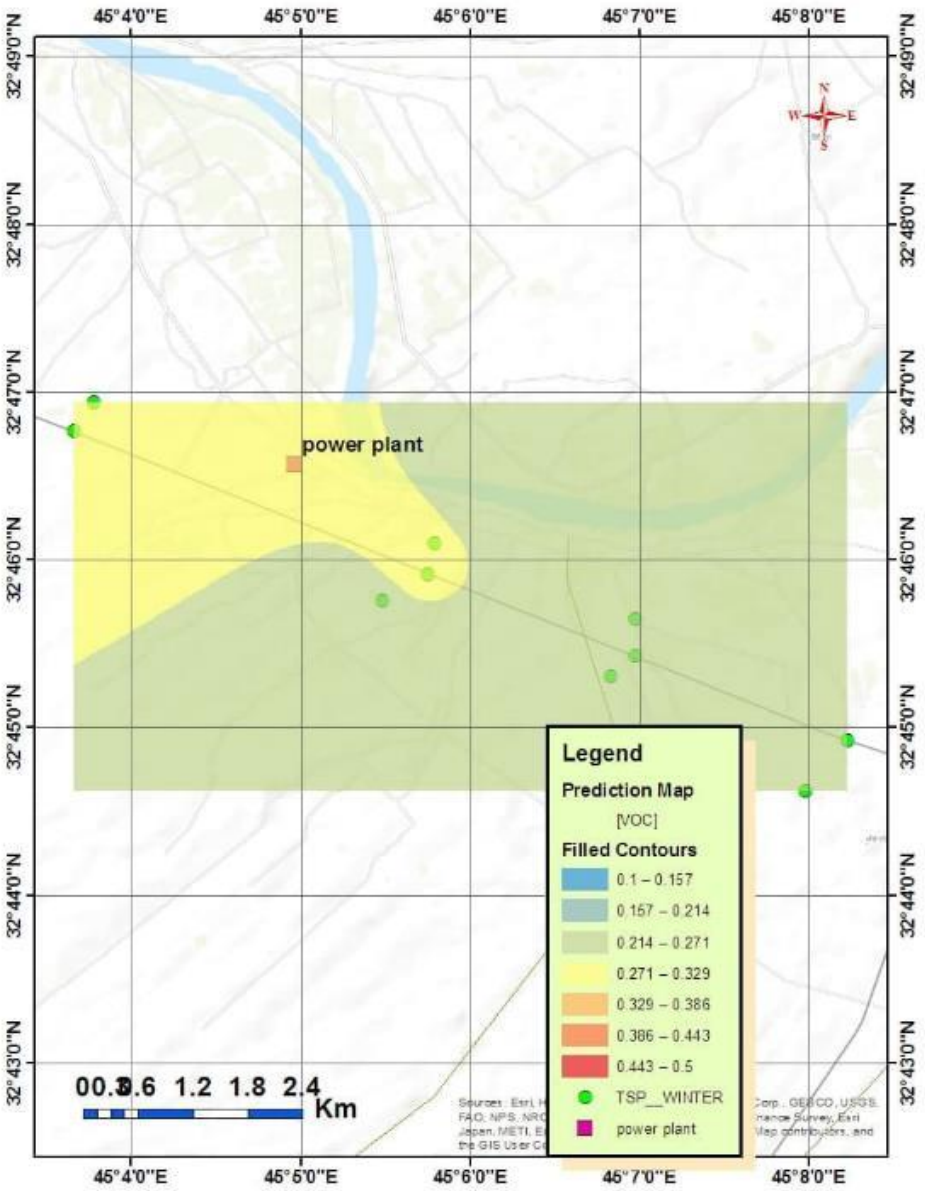



Figure (3.6) GIS Map showing distribution of (VOC) in the air of the study area in winter season.

### 3.4.4 LEL

The term L.E.L. represents the lower explosive limit of a combustible compound, usually a gas or solvent, and means the minimum per cent by volume of the gas, or vapor, in air which will just allow a flame to propagate completely through the mixture when ignited. Concentrations just below the lower explosive limit will usually propagate a flame only partially through the mixture (Bhaduri et al., 2021).

Tables (3.3 and 3.4) shows that Low Explosive Limit (LEL) gases were zero (0), which indicated that LEL were not emitted at all locations during the recorded time.

### 3.5 Heavy metals in air

The atmosphere contains various pollutants, including heavy metals, which can exist in different forms such as gases, aerosols, and particles. These metals are emitted into the air from various sources, such as industrial activities, transportation, and natural processes. Due to atmospheric circulation, they can be transported over long distances. Fine particles, including heavy metals, can remain suspended in the air for extended periods, ranging from hours to weeks, and can travel long distances. These particles pose a greater risk to human health compared to larger particles because they can penetrate deep into the lungs and enter the bloodstream, leading to respiratory and cardiovascular issues. Additionally, heavy metals can accumulate in the environment, including soil and water bodies, and enter the food chain, resulting in contamination of crops and aquatic organisms, ultimately affecting human health. Therefore, it is crucial to monitor and control the levels of heavy metals in the air to safeguard human health and the environment (Zhou et al., 2022).

Table 3.5 provides the range and mean concentrations of trace elements, along with a comparison to the Iraqi standards (2008) and WHO guidelines (1996) for air quality. The results demonstrate that the concentration of trace elements in the study area generally exceeds the international and Iraqi standards. In the winter season, the average concentrations of Pb, Fe, Zn, Cd, and Ni are 1.24 $\mu g/m^3$, 0.82 $\mu g/m^3$, 17.21 $\mu g/m^3$, 0.85 $\mu g/m^3$, and 0.325 $\mu g/m^3$, respectively. The WHO standard for Pb, Cd, and Ni is exceeded. Similarly, in the summer season, the average concentrations of Pb, Fe, Zn,

Cd, and Ni are 1.14 µg/m3, 0.336 µg/$m^3$, 21.34 µg/$m^3$, 0.191 µg/$m^3$, and 0.258 µg/$m^3$, respectively. Again, the WHO standard for Pb is exceeded, and the Iraqi standard for Pb is also surpassed. Therefore, measures should be taken to improve the air quality in the study area and meet both international and Iraqi standards (Zhou et al., 2022).

Table (3.5) Mean of Trace Elements Concentration in the Air of Study Area in winter season (µg/$m^3$).

| Station /trace element | Pb | Fe | Zn | Cd | Ni |
|---|---|---|---|---|---|
| A1 | - | - | - | - | - |
| A2 | 1.01 | 1.27 | 4.46 | 0.16 | 0.18 |
| A3 | 1.04 | 0.88 | 15.77 | 0.19 | 0.22 |
| A4 | 1.10 | 0.18 | 12.75 | 0.19 | 0.27 |
| A5 | 1.13 | 0.15 | 18.24 | 0.20 | 0.23 |
| A6 | - | - | - | - | - |
| A7 | 1.36 | 1.20 | 20.87 | 0.19 | 0.24 |
| A8 | 1.46 | 1.10 | 23.53 | 0.18 | 0.88 |
| A9 | 1.46 | 0.92 | 24.06 | 0.18 | 0.19 |
| A10 | 1.43 | 1.09 | 23.96 | 0.20 | 0.08 |
| Average | 1.246 | 0.821 | 17.216 | 0.185 | 0.325 |
| WHO, 1996 (µg/$m^3$) | 0.5 | ----- | | 0.05 | 0.2 |
| Iraqi standards, 2008 (µg/$m^3$) | 1.5 | ----- | | ----- | ----- |

Table (3.6) Mean of Trace Elements Concentration in the Air of Study Area in summer season(µg/$m^3$).

| Station /trace element | Pb | Fe | Zn | Cd | Ni |
|---|---|---|---|---|---|
| A1 | 0.90 | 0.30 | 19.44 | 0.16 | 0.03 |
| A2 | 1.07 | 0.33 | 21.21 | 0.26 | 0.03 |
| A3 | 1.33 | 0.27 | 21.50 | 0.19 | 0.87 |
| A4 | 0.79 | 0.38 | 21.57 | 0.16 | 0.24 |
| A5 | 1.17 | 0.41 | 21.63 | 0.20 | 0.17 |
| A6 | 1.11 | 0.25 | 21.99 | 0.18 | 0.25 |
| A7 | 1.62 | 0.27 | 21.77 | 0.18 | 0.23 |
| A8 | - | - | - | - | - |
| A9 | 1.13 | 0.48 | 21.66 | 0.20 | 0.24 |
| A10 | - | - | - | - | - |
| Average | 1.140 | 0.336 | 21.346 | 0.191 | 0.258 |
| WHO, 1996 (µg/$m^3$) | 0.5 | ---- | | 0.05 | 0.2 |
| Iraqi standards, 2008 (µg/$m^3$) | 1.5 | ----- | | ----- | ----- |

### 3.5.1 Lead (Pb)

Lead is a highly toxic heavy metal that can have severe impacts on both human health and the environment. Emissions of inorganic particles like PbBrCl (lead bromochloride) from various sources such as gasoline, industrial processes, and mining activities are among the primary contributors to lead exposure. Prolonged exposure to lead can result in a range of health issues, including nervous system damage, reproductive and developmental disorders, and an increased risk of certain cancers (Jaya et al., 2010). These particles tend to settle within distances spanning from a few hundred meters to 1-2 kilometers from their emission sources. The concentration of lead in the air can vary depending on location, with human exposure levels ranging from less than 4 μg/day to over 200 μg/day (Al-Sultani, 2006). Depending on the extent of exposure, lead can adversely affect various bodily systems, including the nervous system, kidney function, immune system, reproductive and developmental systems, and cardiovascular system (Mohamed 2016).

In the winter season, Table 3.5 presents the concentrations of lead, ranging from 1.0145 $\mu g/m^3$ to 1.46 $\mu g/m^3$, with an average of 1.246 $\mu g/m^3$. These results were compared to the Iraqi and WHO standards, within the limits set by the WHO. Similarly, in the summer season, Table 3.6 demonstrates lead concentrations ranging from 0.7898 $\mu g/m^3$ to 1.6191 $\mu g/m^3$, with an average of 1.14 $\mu g/m^3$. Again, these results were compared to the Iraqi and WHO standards, meeting the limits defined by the WHO. Figure 3.7 visually displays the distribution of lead in the air (Jaya et al., 2010; Al-Sultani. 2006; Mohamed, 2016).

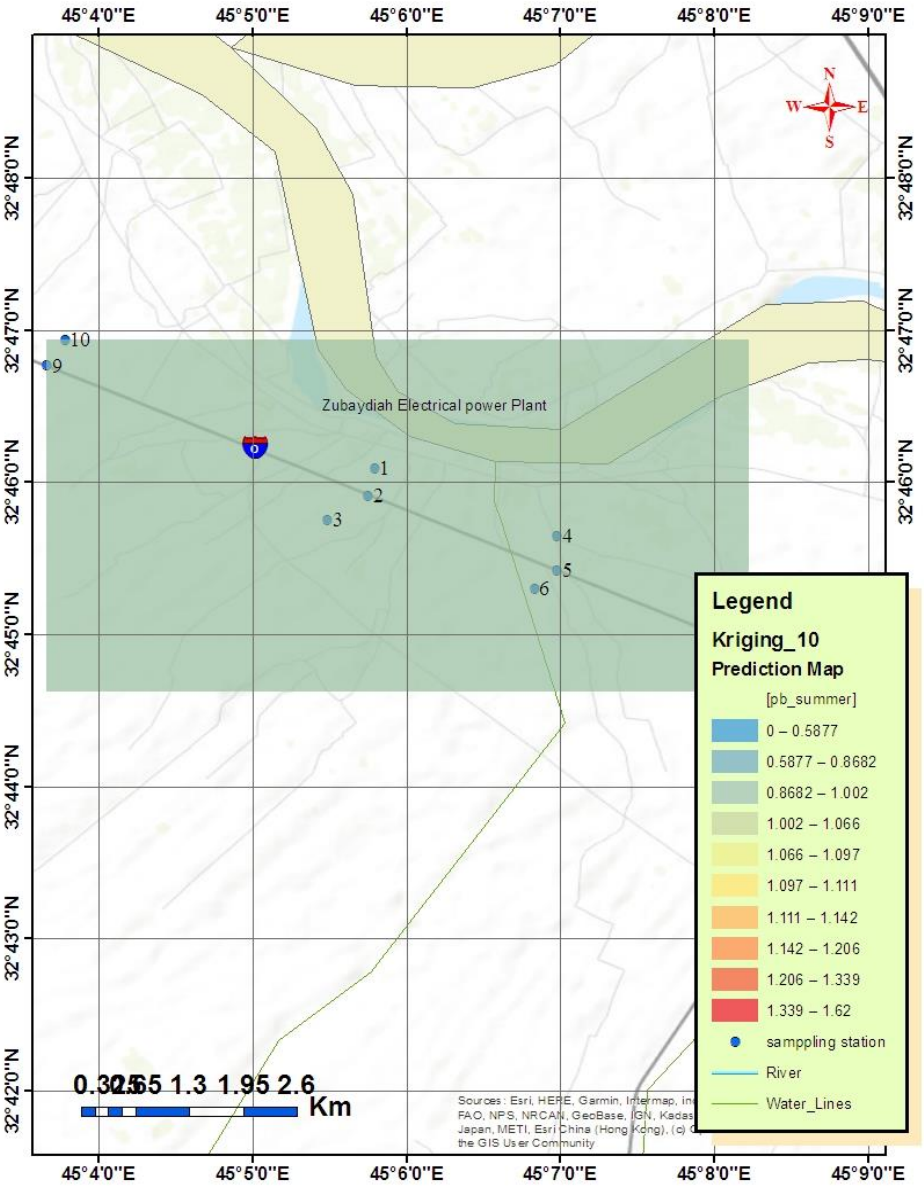



**Figure (3.7)** GIS Map showing distribution of lead in the atmosphere of the study area during the summer season

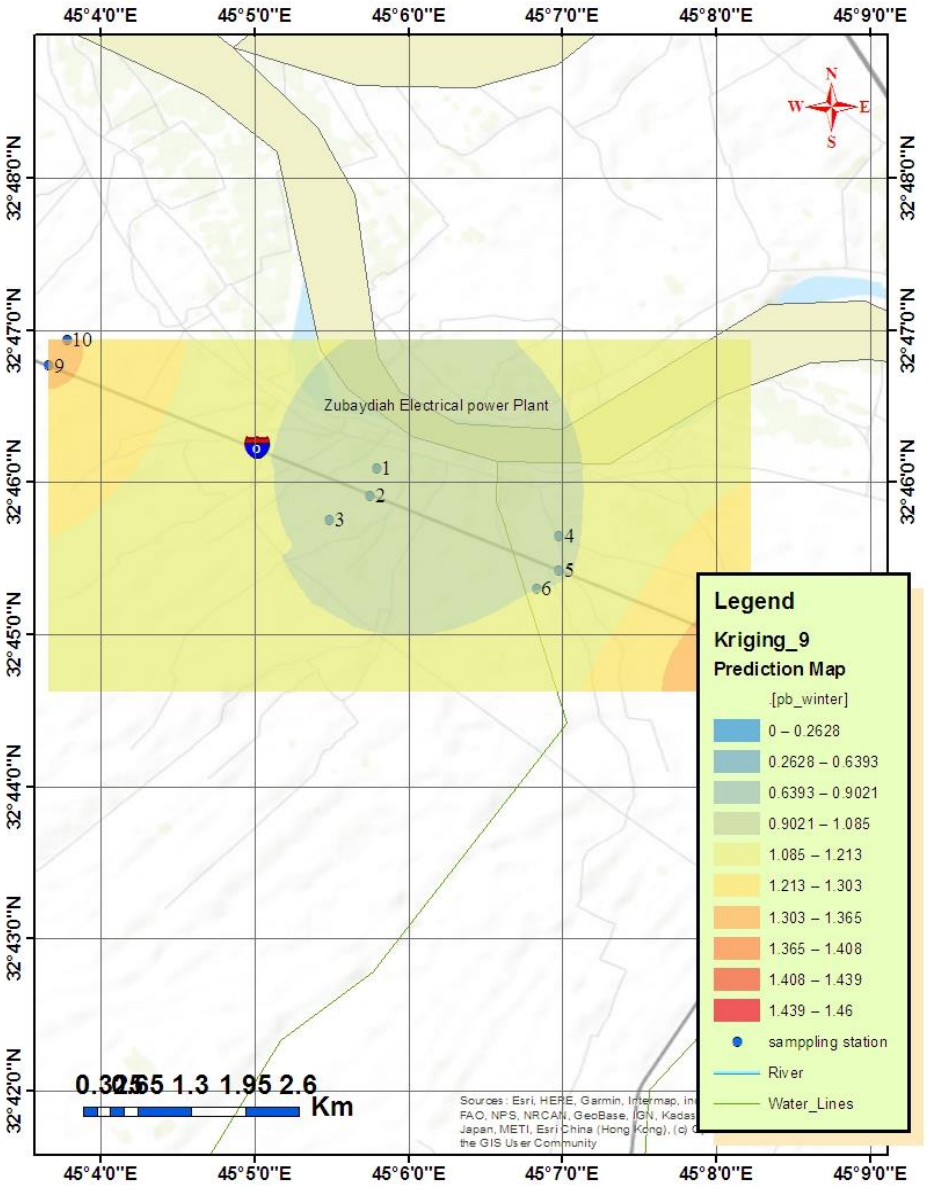



Figure (3.8) GIS Map showing distribution of lead in the atmosphere of the study area during the winter season

### 3.5.2 Cadmium (Cd)

Cadmium (Cd) in the atmosphere primarily originates from human activities, with significant emissions attributed to coal and oil-fired power plants, as well as metal industries (Kabata-Pendias and Mukherjee, 2007). This toxic metal has detrimental effects on the kidneys, skeletal system, and respiratory system, and it is classified as a human carcinogen. While cadmium is naturally present in the environment at low levels, human activities have

substantially increased its levels in environmental media, thereby impacting population exposure (WHO, 2019).

In the winter season, Table 3.5 displays the concentrations of cadmium, ranging from 0.16 μg/$m^3$ to 0.2 μg/$m^3$, with an average concentration of 0.185 μg/$m^3$. These results were compared to WHO standards, which have a limit of 0.2 μg/$m^3$ for cadmium. Likewise, in the summer season, Table 3.6 illustrates cadmium concentrations ranging from 0.2 μg/$m^3$ to 0.16 μg/$m^3$, with an average of 0.26 μg/$m^3$. Once again, these findings were evaluated against the WHO standards, demonstrating compliance with the limits established by the WHO. Figure 3.9 visually represents the distribution of cadmium in the air (Kabata-Pendias and Mukherjee, 2007; WHO, 2019).

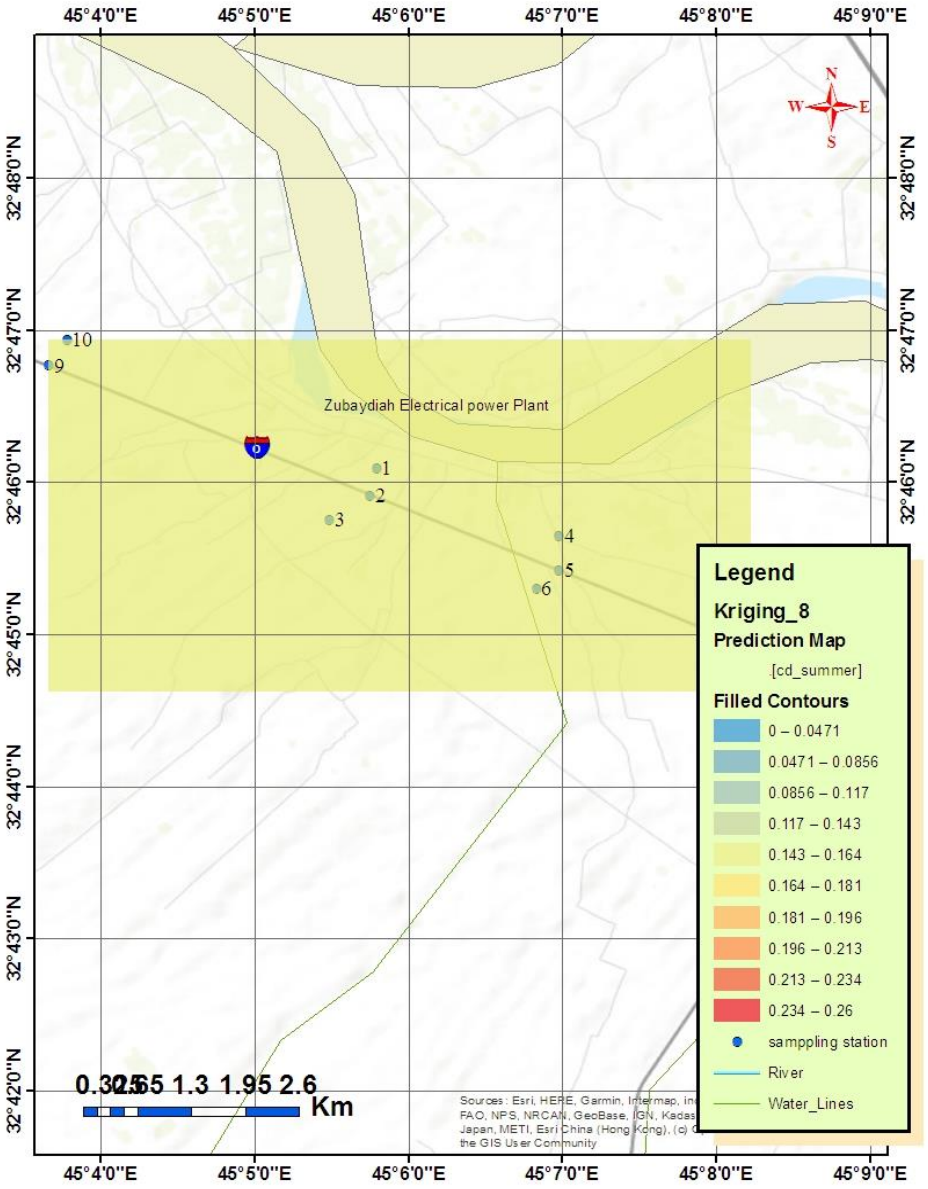



**Figure (3.9)** GIS Map showing distribution of Cadmium in the atmosphere of the study area during the summer season

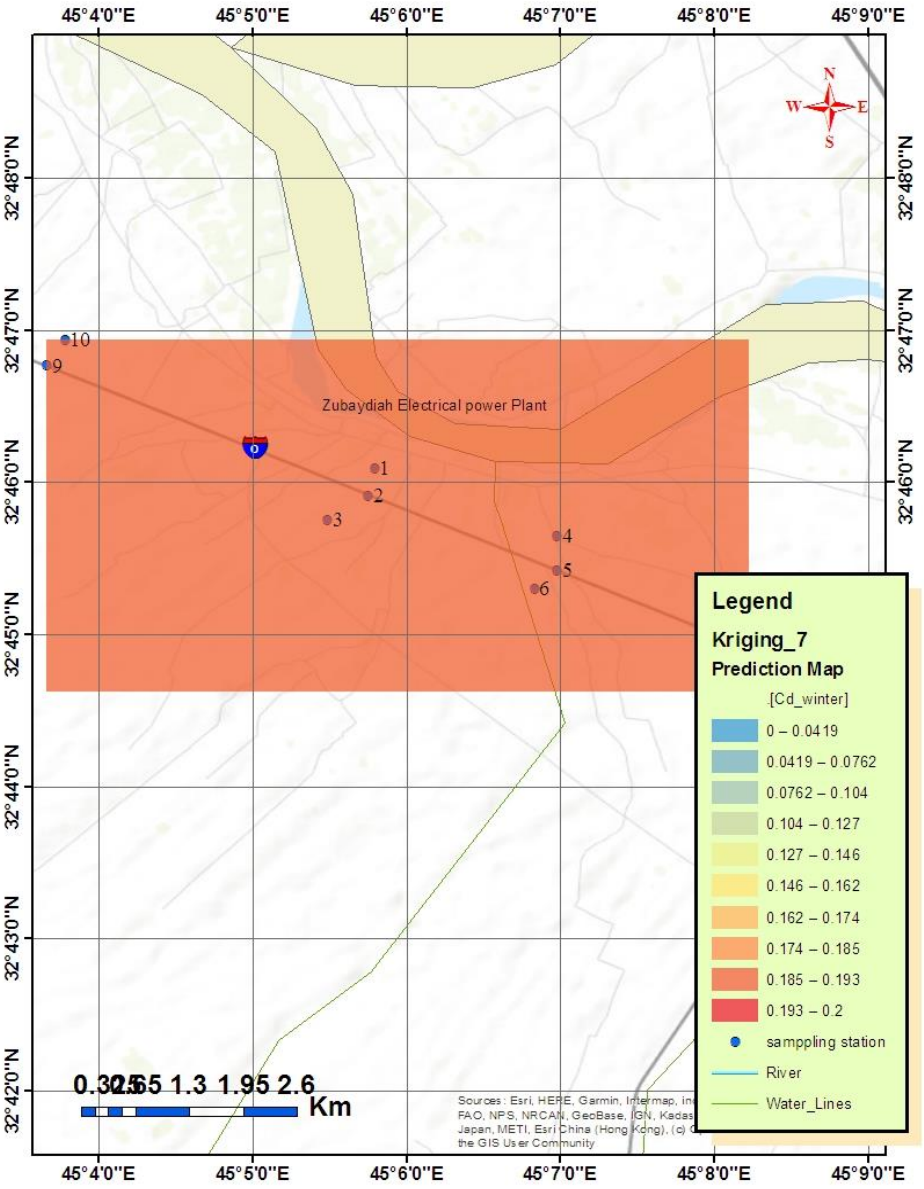



**Figure (3.10)** GIS Map showing Distribution of Cadmium in the atmosphere of the study area during the winter season

### 3. 5. 3 Iron (Fe)

Iron is an essential element for the human body and plays a vital role in various metabolic processes. It is necessary for the prevention of anemia and is generally considered non-harmful within certain limits. However, excessive levels of iron in the body, beyond the allowed threshold of 0.3 milligrams per liter (mg/L), can be detrimental to health. Studies have suggested that iron in the environment may primarily originate from natural sources, while other

elements, such as heavy metals, may predominantly result from human activities. While iron is necessary for maintaining health, it is crucial to ensure that its concentration does not exceed the permissible level to avoid potential adverse effects on human health. The conducted study in the study area documented the concentrations of iron (Fe) as shown in Table 3.5. The recorded concentrations ranged from 0.15 μg/$m^3$ to 1.27 μg/$m^3$, with an average concentration of 0.821 μg/$m^3$ during the winter season. Similarly, during the summer season, Table 3.6 presented iron concentrations ranging from 0.25 μg/$m^3$ to 0.48 μg/$m^3$, with an average concentration of 0.36 μg/$m^3$. The increase in iron concentration during the winter season could possibly be attributed to certain factors, which require further investigation and analysis Figure 3.11.

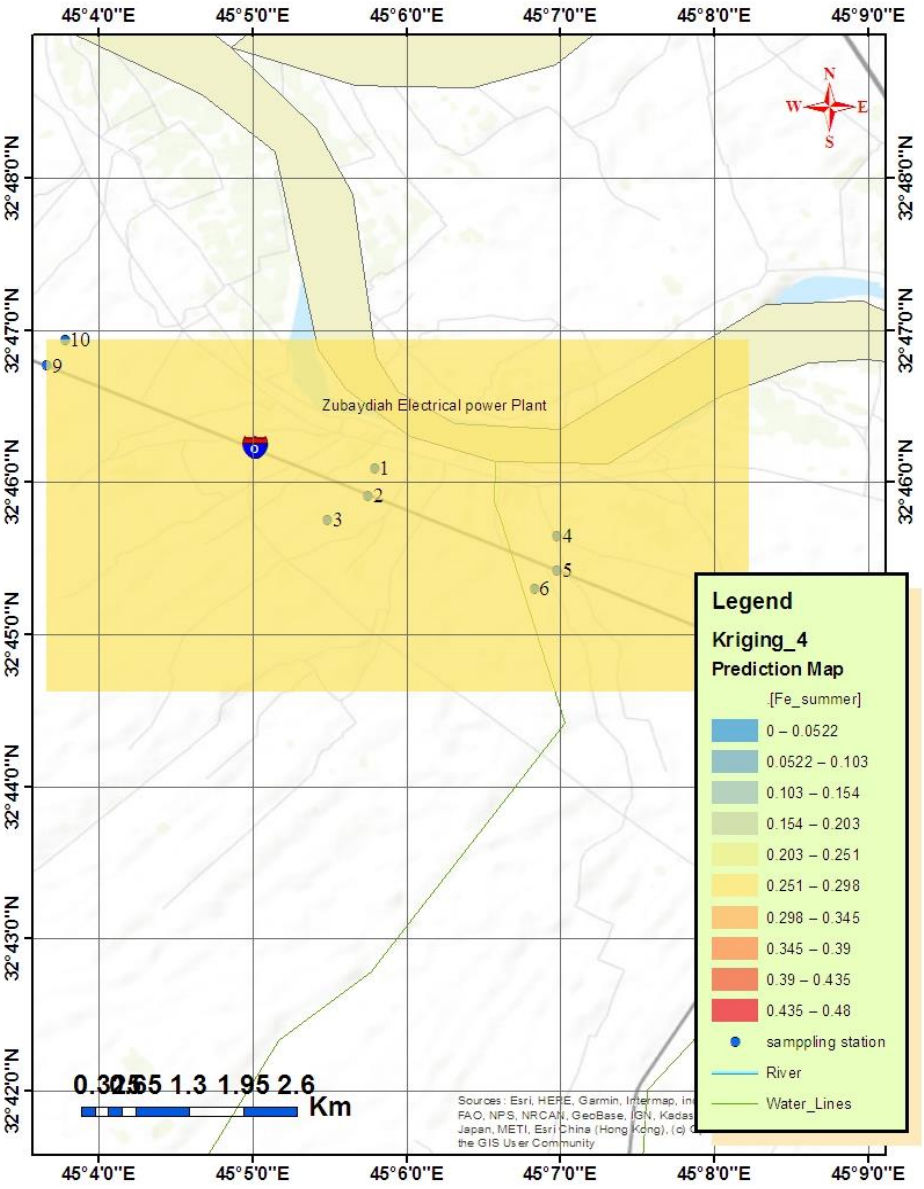



**Figure (3.9: A) Distribution of Iron in the atmosphere of the study area during**

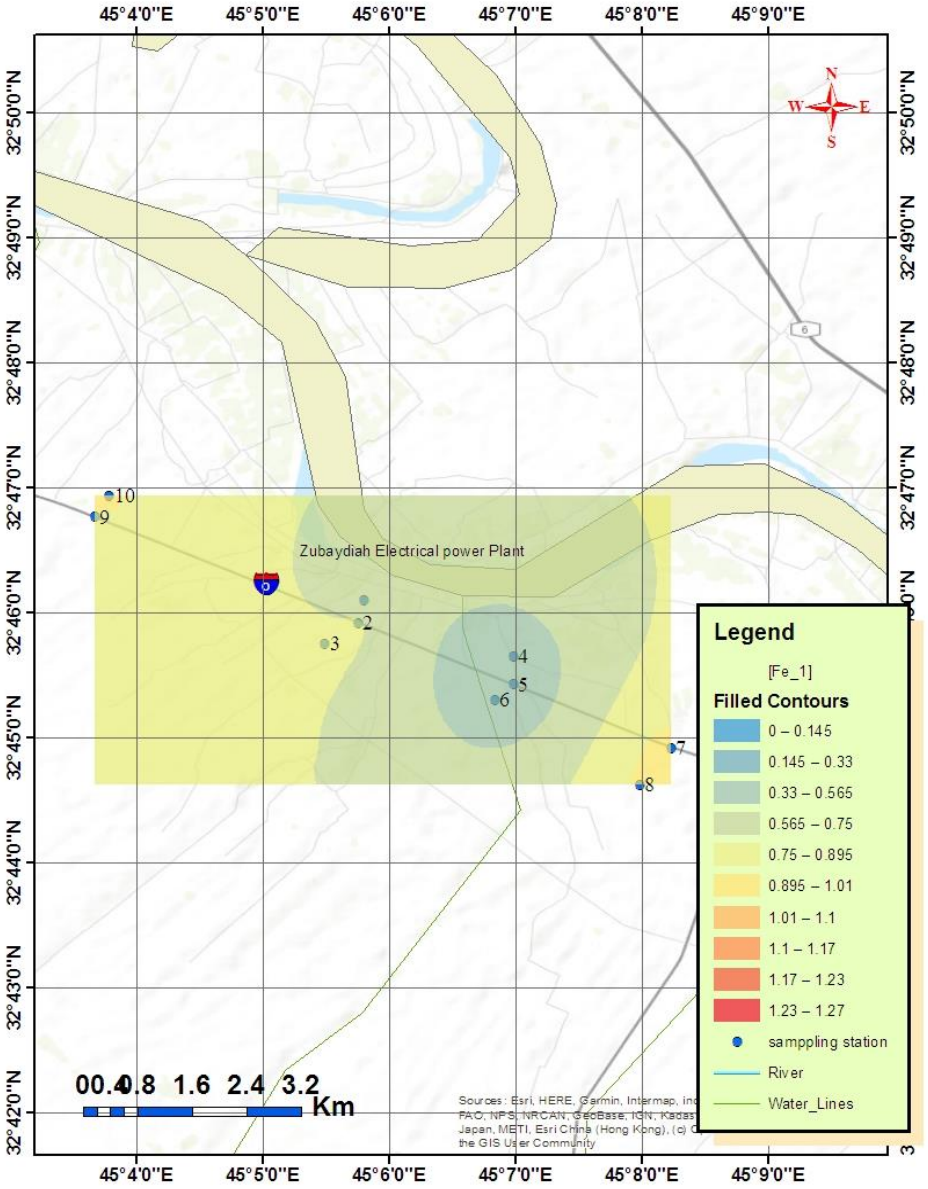



Figure (3.11) GIS Map showing distribution of Iron in the atmosphere of the study area during the winter season

### 3. 5.4 Zinc (Zn)

Zinc is classified as belonging to the second toxicity class, and its presence serves as a reliable indicator of potential air pollution. Prolonged accumulation of zinc in the topsoil can have adverse effects on both human health and the environment, particularly in urban areas (Baltrėnaitė et al., 2014). The elevated levels of zinc in soil are primarily attributed to human

activities, such as industries associated with fertilizers, pesticides, liquid manure, and composted materials (Al-Sareji et al., 2021).

Zinc plays a crucial role as a co-factor in more than a hundred enzyme reactions. It is involved in food metabolism for both plants and animals and is essential for growth, particularly in the early stages of development. Despite the small required amount, reducing zinc levels can lead to bone and skin damage, as well as fertility issues. In males, a deficiency in zinc has been linked to chronic cardiac diseases, especially arterial conditions (Al-Dabbas et al., 2012; Habib et al., 2012). The average concentration of zinc in the study area's atmosphere during the winter season was recorded as 7.21 $\mu g/m^3$ (Table 3.4). Similarly, during the summer season, the mean concentration of zinc in the atmosphere was measured at 21.346 $\mu g/m^3$ (Table 3.4).

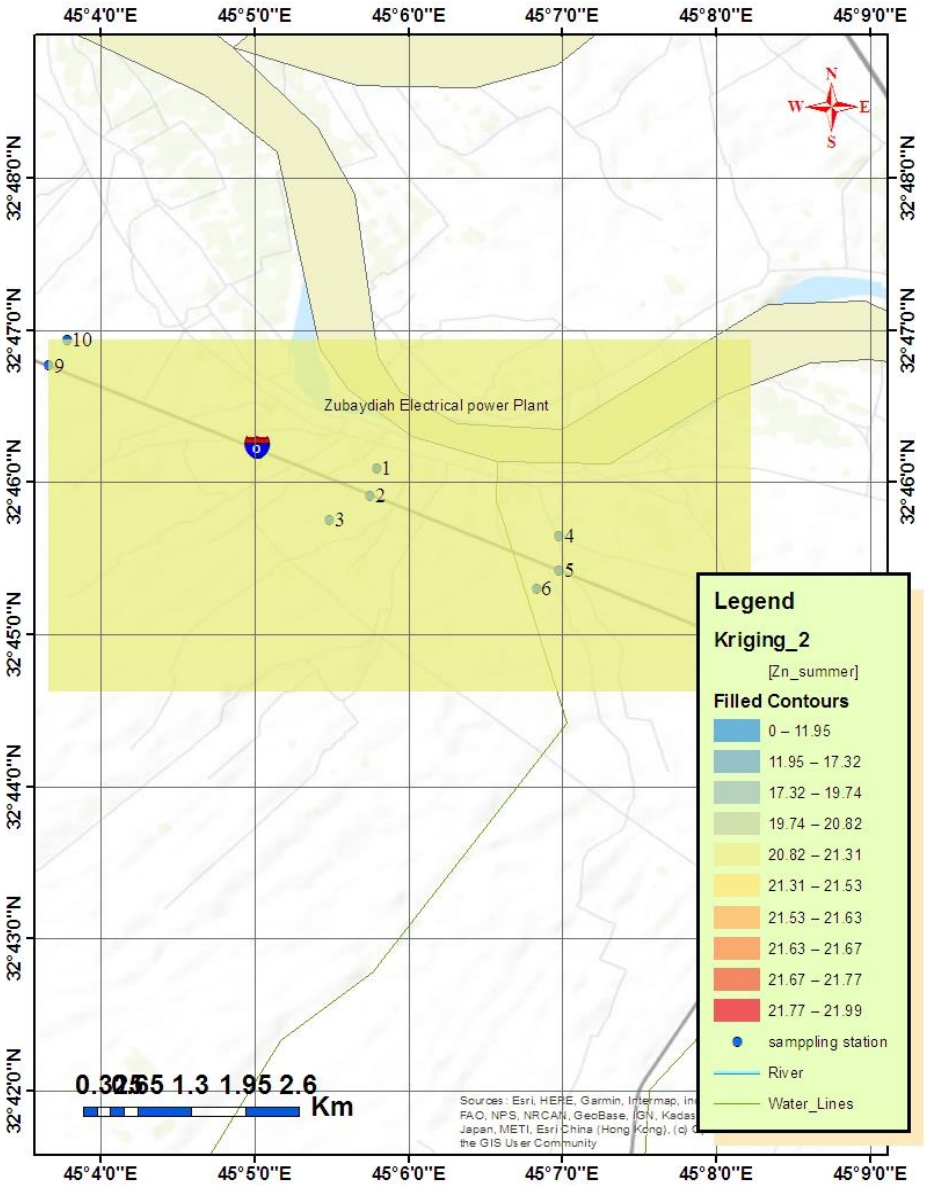



**Figure (3.12)** GIS Map showing Distribution of Zinc in the atmosphere of the study area during the summer season

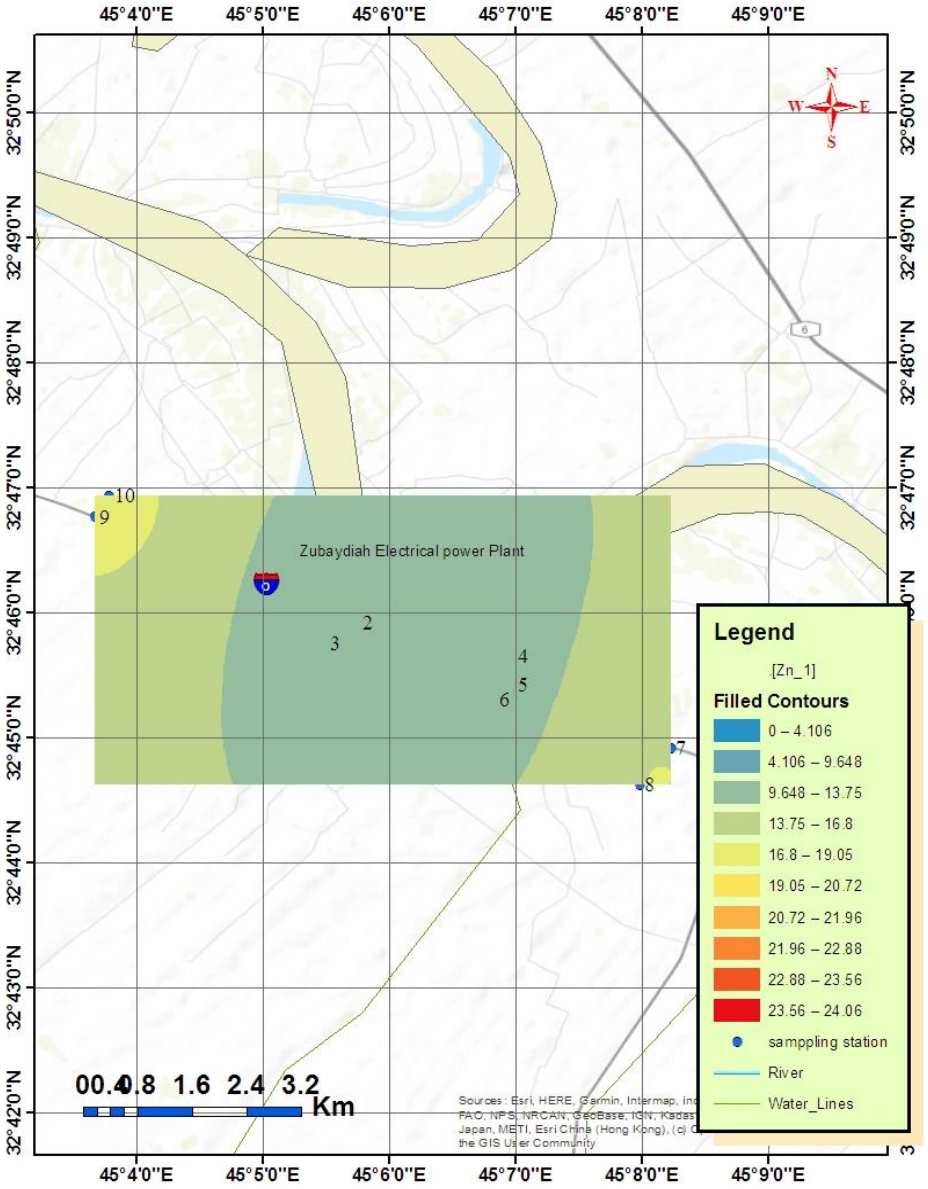



**Figure (3.13)** GIS Map showing Distribution of Zinc in the atmosphere of the study area during the winter season

### 3.5.5 Nickel (Ni)

Nickel (Ni) concentrations in the air exhibit significant variability depending on the location and season, as revealed in the research conducted by Kabata-Pendias and Mukherjee (2007). The presence of nickel in the air can originate from both natural and anthropogenic sources. Natural sources, such as windblown dust and volcanic activity, contribute approximately 56% and 29% of the nickel emissions, respectively. Anthropogenic sources, on the

other hand, include the burning of residual and fuel oil (62%) and nickel metal refining (17%) (Kabata-Pendias & Mukherjee 2007). In the study area, the average concentration of nickel during the winter season exceeded the limit set by WHO (1996), as indicated in Table 3.5. The recorded value was 0.325 μg/m$^3$. Conversely, during the summer season, the mean concentration of nickel matched the WHO limit, as presented in Table 3.6, with a value of 0.258 μg/m$^3$. Distribution of Nickel in the atmosphere of study in Figure 3.14.

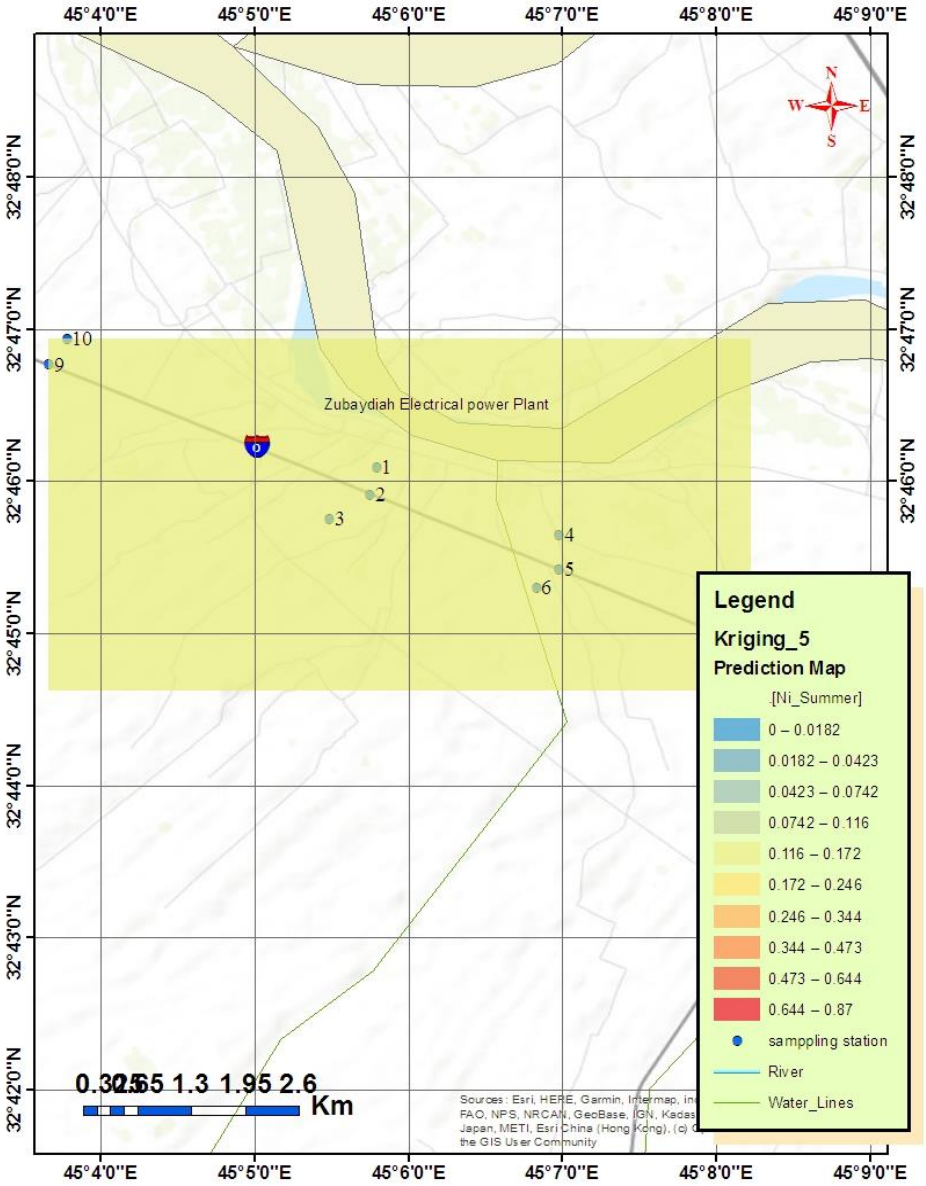



**Figure (3.14)** GIS Map showing Distribution of Nickel in the atmosphere of the study area during the summer season

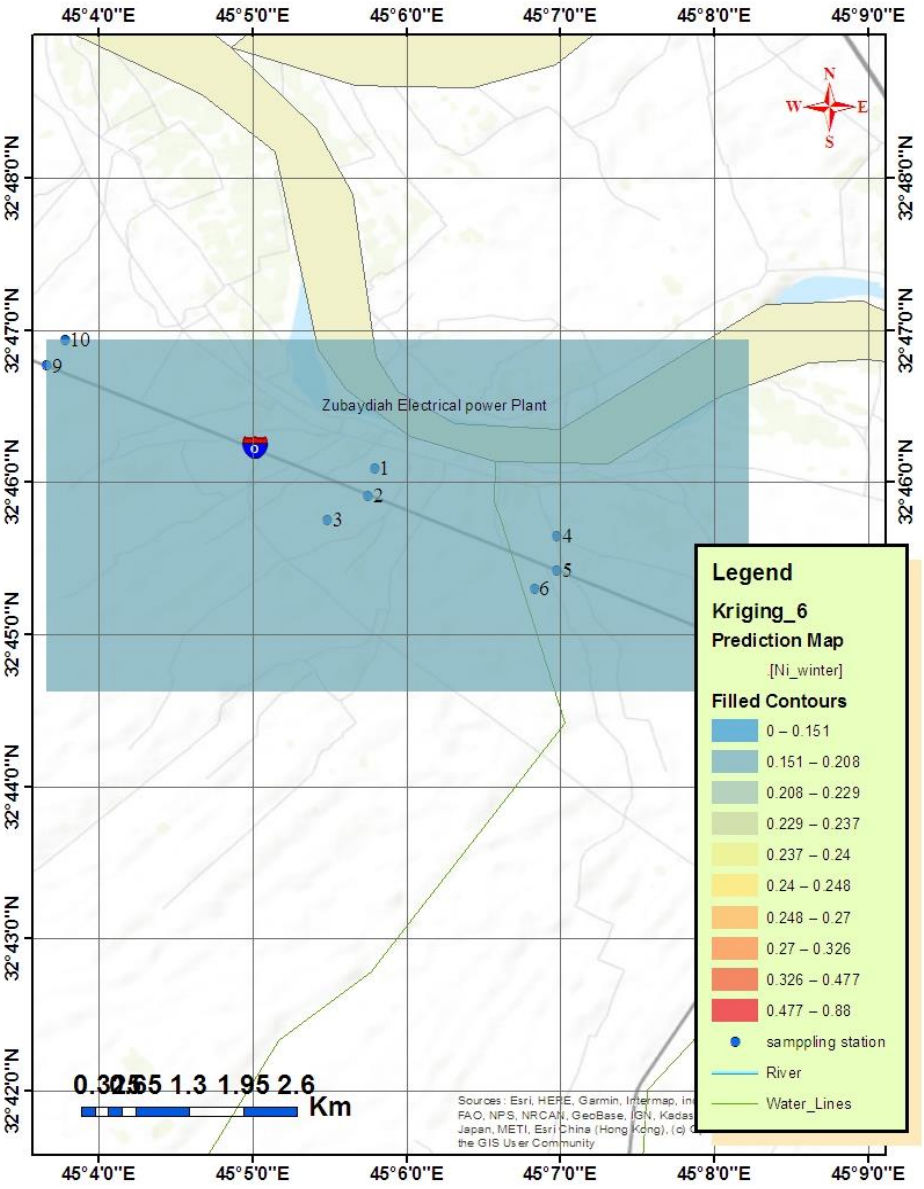



**Figure (3.15)** GIS Map showing Distribution of Nickel in the atmosphere of the study area during the winter season

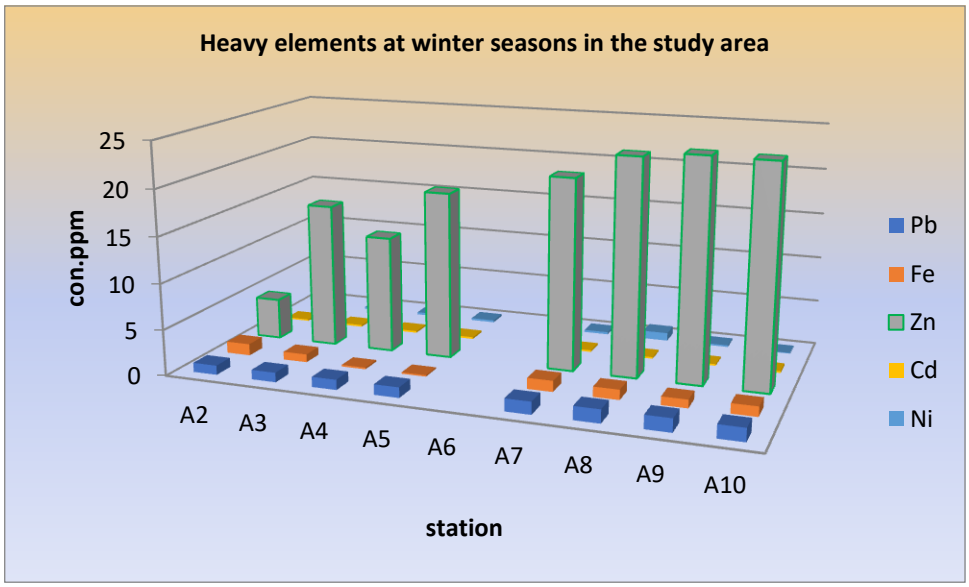



Figure (3.16) Heavy elements in winter seasons of the study area

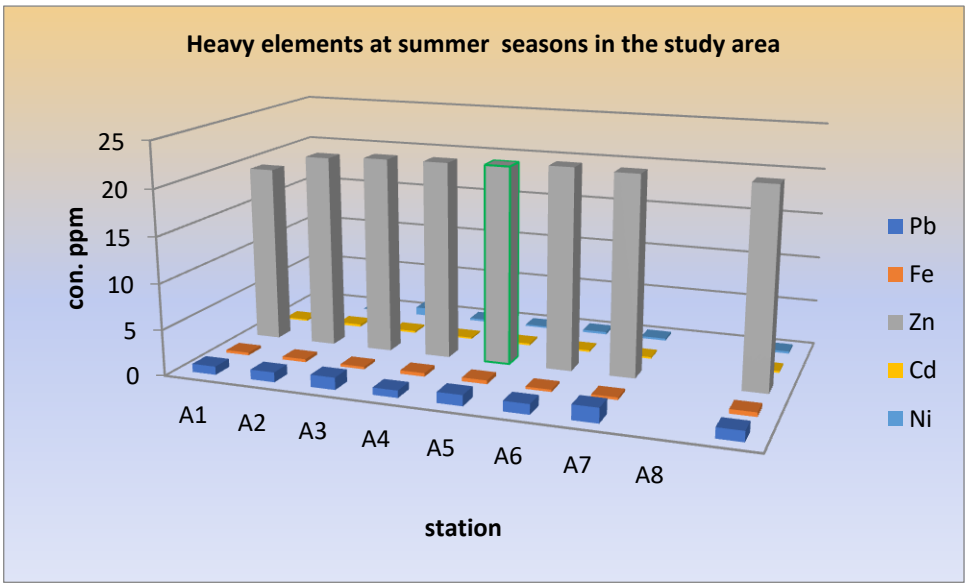



Figure (3.17) Heavy elements in summer seasons of the study area

## 3.6.Air Quality Index (AQI)

Air pollution refers to the contamination of the surrounding atmosphere due to the presence of chemical substances, gases, or particulate matter. This pollution not only poses risks to human health but also has detrimental effects on vegetation, animals, and food crops (Padula et al. 2019). To assess and evaluate the air quality, numerous monitoring programs have been implemented to gather extensive data on various air pollutants such as Total

Suspended Particles (TSP), CO, nitrogen oxides (NOx), sulfur dioxide ($SO_2$), and more. However, the sheer volume of data collected can make it challenging for the scientific community, policymakers, decision-makers, and the general public to comprehend the current state of air quality. To address this issue, the concept of the AQI has been introduced.

The AQI also known as the Air Pollution Index (API), serves as a standardized measure to determine the quality of the air in a particular area (Turner et al. 2020). By consolidating the data collected from various pollutants, the AQI provides a simplified and easily understandable indicator of air quality. It offers a comprehensive assessment of the air pollution levels, taking into account multiple pollutants and their corresponding concentrations. The AQI is typically reported on a scale that ranges from 0 to a maximum value, indicating the level of air pollution and associated health risks.

Using the AQI, individuals and communities can quickly and effectively comprehend the current air quality conditions and make informed decisions to protect their health and well-being. It helps raise awareness about the severity of air pollution and encourages actions to mitigate its harmful effects. Moreover, the AQI facilitates communication among scientists, policymakers, and the public, enabling better understanding and response to air quality issues.

It is important to note that air quality standards, pollutant thresholds, and the calculation of the AQI can vary between countries and regions, as they are based on local regulations and guidelines. Therefore, the specific parameters used to calculate the AQI and its corresponding index values may differ. In summary, the AQI provides a simplified and accessible means to assess and communicate the state of air pollution. By consolidating data from various pollutants, it facilitates understanding, raises awareness, and enables informed

decision-making regarding air quality issues.The mean objective of AQI is to measure the air quality with respect to its effects on human health. The index for each pollutant is calculated using the following expression (Bishoi et al. 2009).

$$IP = \frac{(I_{HI} - I_{LO})}{(BP_{HI} - BP_{LO})} (CP - BP_{LO}) + I_{LO} \quad \text{.....3-1}$$

$$\mathbf{AQI=Max\ (IP)\ .....3\text{-}2}$$

Where Ip = the index for pollutant p;

Cp = the rounded measured concentration of pollutant p

BPHi = the breakpoint that is greater than or equal to Cp

BPLo = the breakpoint that is less than or equal to Cp

IHi = the AQI value corresponding to BPHi

ILo = the AQI value corresponding to BPLo

AQI=Air quality index

The conversion of each pollutant's concentration to its corresponding numerical value for the AQI is not an easy linear process. Each category's breakpoint concentration does not follow a linear scale. By EPA, a break point concentration has been established. There are documented values for various breakpoint concentrations and air quality standards. It would be important to take local conditions into account while defining breakpoint concentrations. It is not practical to believe that the same AQI is true throughout the entire planet because different regions of the world have varied pollution patterns and meteorological conditions that affect the impact of air pollutants (Monteiro et al., 2017), where Table (3-7) represents breakpoint values according to US-EPA (2006) and (Saad et al., 2017) Pollutant concentration is converted in to a numerical index (AQI) which assumes value in the range of 0 to 500). The overall range is subdivided into

six ranges to which six categories of air quality correspond and it is divided into six levels of health concern as shown in Table (3-6).

Table (3.7) represents breakpoint values according to US-EPA (2006) and (Saad et al., 2017).

| TSP (µg/m3) | CO (ppm) | AQI | Category |
|---|---|---|---|
| BPlow – Bphigh | BPlow – Bphigh | Ilow - Ihigh | |
| 0-104 | 0.0-4.4 | 0-50 | Good |
| 105-264 | 4.5-9.4 | 51-100 | Moderate |
| 265-364 | 9.5-12.4 | 101-150 | Unhealthy for Sensitive Groups |
| 365-464 | 12.5-15.4 | 151-200 | Unhealthy |
| 465-524 | 15.5-30.4 | 201-300 | Very Unhealthy |
| 525-604 | 30.5-40.4 | 301-400 | Hazardous |
| 605-704 | 40.5-50.5 | 401-500 | Very Hazardous |
| >700 | ------ | >500 | Very Critical |

Table (3.8): AQI and health effect (EPA, 2009).

| Index | Level | General health effect |
|---|---|---|
| 0 - 50 | Good | None |
| 51 – 100 | Moderate | Few or non for general population |
| 101 - 200 | Unhealthy | A level that may have harmful impacts on patients and member of sensitive groups and also causes the general public un pleasant feeling. |
| 201 - 300 | Very unhealthy | Have a serious impact on patients and members of sensitive group in case of acute exposure. |
| 301 - 400 | Hazardous | A level which may need to teak emergency measures for patients and members of sensitive groups and have harmful impacts on the general public. |
| 401 – 500 | Very hazardous | Healthy people will experience reduced endurance in activities older and the sick people should remain indoors and avoid exercise. Healthy individuals should avoid out activities. |

### 3.6.1Air Quality Index (AQI) at winter season

The current study found that the values of the AQI. The table provides information about air quality measurements in the study area during the winter season. It includes various stations (A1, A2, A3, etc.) and

corresponding measurements for Total Suspended Particles (TSP), CO, Indoor Particulate (IP), and AQI.

The AQI is a numerical value that represents the overall air quality and is calculated based on the concentrations of different pollutants. The AQI scale ranges from 0 to 500, with higher values indicating poorer air quality and potential health risks. The table also includes qualitative descriptions of the air quality level, ranging from "Good" to "Very Hazardous."

Analyzing the data, we can draw the following conclusions about the air pollution in the study area during the winter season:

Station A1: The TSP measurement is extremely high 938.9671, indicating a very critical level of suspended particles. The Indoor Particulate (IP) level is also above 700, which is considered very critical. The CO level is moderate (6), leading to a moderate AQI of 66.

Station A2: The TSP measurement is still high 511.69, and the Indoor Particulate (IP) level is also in the very unhealthy range 279.29. The CO level is relatively low (1), resulting in an AQI of 11.36, which is considered good.

Station A3: The TSP measurement decreases further to 300.3, but the Indoor Particulate (IP) level is still in the unhealthy for sensitive groups range 118.471. The CO level and AQI are both at 0, which is considered good.

Station A4: The TSP measurement increases slightly 391.23, and the Indoor Particulate (IP) level is in the unhealthy range 163.982. The CO level is also at 1, resulting in an unhealthy AQI.

Station A5: The TSP measurement decreases significantly 234.74, and the Indoor Particulate (IP) level is in the moderate range 90.9827. The CO level is 4, leading to a moderate AQI.

Station A6: The TSP measurement is high >700, and the Indoor Particulate (IP) level is also in the very critical range. The CO level is 3, resulting in a very critical AQI of 34.090.

Station A7: The TSP measurement decreases to 555.55, but the Indoor Particulate (IP) level is still in the hazardous range 339.284. The CO level is 1, leading to a hazardous AQI.

Station A8: The TSP measurement is still high 694.44, and the Indoor Particulate (IP) level is in the very hazardous range 490.44. The CO level and AQI are both at 0, which is considered good.

Station A9: The TSP measurement decreases to 321.98, and the Indoor Particulate (IP) level is in the unhealthy for sensitive groups range 163.9825. The CO level and AQI are both at 0, which is considered good.

Station A10: The TSP measurement is the same as A4 391.23, and the Indoor Particulate (IP) level decreases to 124.7476, which is in the unhealthy range. The CO level and AQI are both at 0, which is considered good.

Overall, the air pollution in the study area during the winter season varies across different stations. Some stations experience very critical or hazardous levels of

Table (3.9) : AQI for study area for winter season

| Station | TSP | IP | CO | IP | AQI |
|---|---|---|---|---|---|
| A1 | 938.9671 | >700 | 6 | 66 | Very critical |
| | Very critical | | moderate | | |
| A2 | 511.69 | 279.29 | 1 | 11.36 | Very Unhealthy |
| | Very Unhealthy | | Good | | |
| A3 | 300.3 | 118.471 | 0 | 0 | Unhealthy for Sensitive Groups |
| | Unhealthy for Sensitive Groups | | Good | | |
| A4 | 391.23 | 163.982 | 1 | 11.363 | Unhealthy |
| | Unhealthy | | Good | | |
| A5 | 234.74 | 90.9827 | 4 | 45.45 | Moderate |
| | Moderate | | Good | | |
| A6 | 782.472 | >700 | 3 | 34.090 | Very critical |
| | Very critical | | Good | | |
| A7 | 555.55 | 339.284 | 1 | 11.363 | Hazardous |
| | Hazardous | | Good | | |
| A8 | 694.44 | 490.44 | 0 | 0 | Very Hazardous |
| | Very Hazardous | | Good | | |
| A9 | 321.98 | 163.9825 | 0 | 0 | Unhealthy for Sensitive Groups |
| | Unhealthy for Sensitive Groups | | Good | | |
| A10 | 391.23 | 124.7476 | 0 | 0 | Unhealthy |
| | Unhealthy | | Good | | |

Table (3.10) AQI for study area for summer season

| Station | TSP | IP | CO | IP | pb | Ip | AQI |
|---|---|---|---|---|---|---|---|
| A1 | 841.219 | >700 | - | - | - | | Very critical |
| | Very critical | | Good | | | | 1.01 |
| A2 | 1195.49 | >700 | 1.04 | 1.04 | 1.04 | | Very critical |
| | Very critical | | Good | | 1.10 | 1.10 | 1.10 |
| A3 | 843.881 | >700 | 1.13 | 1.13 | 1.13 | | Very critical |
| | Very critical | | Good | | - | - | - |
| A4 | 1125.176 | >700 | 1.36 | 1.36 | 1.36 | | Very critical |
| | Very critical | | Good | | 1.46 | 1.46 | 1.46 |
| A5 | 562.587 | 348.10 | 1.46 | 1.46 | 1.46 | | Hazardous |
| | Hazardous | | Good | | 1.43 | 1.43 | |
| A6 | 925.925 | >700 | - | - | - | | Very critical |
| | Very critical | | Good | | 1.01 | 1.01 | 1.01 |
| A7 | 849.256 | >700 | 1.04 | 1.04 | 1.04 | | Very critical |
| | Very critical | | Good | | 1.10 | 1.10 | 1.10 |
| A8 | 3043.171 | >700 | 1.13 | 1.13 | 1.13 | | Very critical |
| | Very critical | | Good | | - | - | - |
| A9 | 283.0856 | 109.9514 | 1.36 | 1.36 | 1.36 | | Unhealthy for Sensitive Groups |
| | Unhealthy for Sensitive Groups | | Good | | 1.46 | 1.46 | 1.46 |
| A10 | 601.557 | 396.938 | 1.46 | 1.46 | 1.46 | | Hazardous |
| | Hazardous | | Good | | 1.43 | 1.43 | |

### 3.6.2Air Quality Index (AQI) at summer season

The table provides information about air quality measurements in the study area during the summer season. Similar to the previous table, it includes various stations (A1, A2, A3, etc.) and measurements for Total Suspended Particles (TSP), Indoor Particulate (IP), CO, Lead (Pb), and AQI.

Here are some observations and conclusions about the air pollution in the study area during the summer season based on the provided data:

Station A1: The TSP measurement is high 841.219, and the Indoor Particulate (IP) level is above 700, indicating a very critical level of suspended particles. The CO level is not provided (-), but the AQI is marked

as very critical. Additionally, the presence of Pb (lead) is indicated, but no specific value is given.

Station A2: The TSP measurement is even higher 1195.49, and the Indoor Particulate (IP) level is above 700, indicating a very critical level of suspended particles. The CO level is 1.04, and the AQI is marked as very critical. Pb (lead) is present with a value of 1.10.

Station A3: The TSP measurement is similar to A1 843.881, and the Indoor Particulate (IP) level is above 700, indicating a very critical level of suspended particles. The CO level is 1.13, and the AQI is marked as very critical. No specific value for Pb (lead) is provided.

Station A4: The TSP measurement is high 1125.176, and the Indoor Particulate (IP) level is above 700, indicating a very critical level of suspended particles. The CO level is 1.36, and the AQI is marked as very critical. Pb (lead) is present with a value of 1.46.

Station A5: The TSP measurement decreases significantly 562.587, and the Indoor Particulate (IP) level is in the hazardous range 348.10. The CO level is 1.46, and the AQI is marked as hazardous. Pb (lead) is present with a value of 1.43.

Station A6: The TSP measurement is high >700, and the Indoor Particulate (IP) level is above 700, indicating a very critical level of suspended particles. The CO level is not provided (-), but the AQI is marked as very critical. Pb (lead) is present with a value of 1.01.

Station A7: The TSP measurement is similar to A1 849.256, and the Indoor Particulate (IP) level is above 700, indicating a very critical level of suspended particles. The CO level is 1.04, and the AQI is marked as very critical. Pb (lead) is present with a value of 1.10.

Station A8: The TSP measurement is significantly higher 3043.171, and the Indoor Particulate (IP) level is above 700, indicating a very critical level

of suspended particles. The CO level is 1.13, and the AQI is marked as very critical. No specific value for Pb (lead) is provided.

Station A9: The TSP measurement is relatively low 283.0856, and the Indoor Particulate (IP) level is in the unhealthy for sensitive groups range 109.9514. The CO level is 1.36, and the AQI is marked as unhealthy for sensitive groups. Pb (lead)

### 3.6.3 Comparison of the AQI at two seasons

Based on this information, we can compare the two chapters in terms of air pollution patterns and the impact of the power plant:

**a-Winter Season**

In the winter season, the air pollution levels vary across different stations. Some stations experience very critical or hazardous levels of air pollution, indicated by high TSP and Indoor Particulate (IP) measurements.

Station A1, which is likely closer to the power plant and in the direction of the prevailing winds, shows extremely high levels of TSP and critical Indoor Particulate (IP) levels. This suggests that the emissions from the power plant, likely fueled by fossil fuels, are contributing to the high pollution levels in that area.

The stations located further away from the power plant or not in the direction of the prevailing winds generally show lower pollution levels, with some stations even having good air quality.

**b-Summer Season**

In the summer season, the air pollution levels again vary across different stations. The TSP measurements generally remain high, but the IP levels appear to be consistently above 700, indicating very critical levels of suspended particles.

Station A5, which is likely in the direction of the prevailing winds, shows hazardous air quality, indicating the transport of pollutants from the power plant towards that location.

The stations located further away from the power plant or not in the direction of the prevailing winds also experience very critical air pollution levels, suggesting that the emissions from the power plant are likely affecting a wider area during the summer season.

Overall, the comparison of the two season suggests that the air pollution in the study area is influenced by the electric power plant operating on fossil fuels. The stations located closer to the power plant or in the direction of the prevailing winds experience higher pollution levels, while the stations further away or not in the path of the winds show relatively lower pollution levels. This indicates the impact of the power plant emissions on the local air quality, with the prevailing winds playing a role in the dispersion of pollutants.

# Chapter Four

# Assessment of Water and Plant pollution

# Assessment of Water and plant pollution

## 4.1 Preface

Water pollution is a significant global issue that varies in severity across different countries. The primary sources of water pollution are population centers and industrial activities (Connell, 1998). Power plants contribute to water pollution through the release of pollutants as gases or through wastewater that ultimately reaches surface and groundwater sources. The Al-Zubaydiya thermal power plant, for instance, withdraws cooling water and operational water from the Tigris River using underground outlet pipes. Drinking water is supplied through the plant's drinking water system, while cooling water is returned to the Tigris River via outlet pipes.

This chapter presents an analytical study of water samples collected from the Tigris River, both before and after the operation of the Al-Zubaydiya thermal power plant. Two surface water samples were chosen for analysis, focusing on measuring their physical, chemical properties, and trace elements. These results will be compared with international water standards to assess the water quality.

Figure (4-1) An image showing the Tigris River at the site of the water intake station

### 4.1.1 Physical parameters

#### 4.1.1.1 Temperature (C°)

Heat has an effect on the physical and chemical properties of water as it affects the determination of the locations of living organisms in the water (Larinier et al. 2010 and Araujo et al. 2000). It also causes an effect on vital activities such as respiration, hatching, movement, reproduction and growth (El-Gamal et al. 2009) and (Al-Mousawi 2016). It also caused an effect on the oxygen ratio, as the Mustapha (2008) study proved that the high temperature leads to a decrease in the dissolved oxygen in the water and is accompanied by an increase in the salinity concentration, and this deteriorates the quality of water and oxygen, which is one of the important factors for providing living things (Araujo et al. 2000).

The temperature of all samples water in winter season were range between 19 and 24 C° and in summer season ranged between 35 and 41 as showed in Tables (4.1) and (4.2).

Table (4.1) Physical and chemical parameter of water samples in winter season

| Samples | T C ° | pH | ECμs/cm | TDS ppm |
|---|---|---|---|---|
| Inside | 19 | 7.5 | 1428 | 1156 |
| Outside | 24 | 9.7 | 1483 | 1371 |
| Range | 19-24 | 7.5-9.7 | 1428-1483 | 1156-1371 |
| Mean | 21.5 | 8 | 1455.5 | 1263.5 |

Table (4.2) Physical and chemical parameter of water samples in summer season

| Sample | T C ° | pH | ECμs/cm | TDS ppm |
|---|---|---|---|---|
| Inside | 35 | 7.7 | 1594 | 1325 |
| Outside | 41 | 8.9 | 1620 | 1472 |
| Range | 35-41 | 7.7-8.9 | 1594-1620 | 1325-1472 |
| Mean | 43 | 7.82 | 1607 | 1398.5 |

### 4.1.2 Chemical Parameters

#### 4.1.2.1 Hydrogen number (pH)

Hydrogen ion concentration, often represented as pH, is a measure of the acidity or alkalinity of a solution. It is a logarithmic scale that quantifies the concentration of hydrogen ions ($H^+$) present in a solution. The pH scale ranges from 0 to 14, where a pH of 7 is considered neutral. Values below 7 indicate acidity, with lower numbers indicating higher acidity, while values above 7 indicate alkalinity, with higher numbers indicating greater alkalinity. The pH of a solution can has significant effects on various chemical and biological processes, including nutrient availability, enzyme activity, and the overall health of aquatic ecosystems. Regular monitoring of pH is essential in many scientific and environmental applications, such as water quality assessment, agriculture, and industrial processes (Attee, 2000). The pH is affected by several factors including, temperature, the presence of calcium carbonate and plants. , pH is measured directly in the field and indicates that the water of the studied area tends toward alkalinity. pH values of the winter season were detected range between 7.5 and 9.7 with the mean (8), while pH values in summer season were detected rang between 7.7 and 8.9 with the mean (7.82) (Tables 4.1 and 4.2).

#### 4.1.2.2 Electrical conductivity (EC)

Electrical Conductivity (EC) is defined as: a measure of the ability of a solution to conduct an electric current, and it is a measure of the salt content of water (Koren, 2005). It is usually useful to use this indicator to indicate the occurrence of any water quality problems; Suddenly high electrical conductivity in any aqueous medium indicates the presence of a source of dissolved ions affecting the medium (Mortimer, 2007).

The EC values in winter season were detected the range (1428-1483) µc/cm with mean 1455 µc/cm. In summer season the EC values were detected range 1594-1620 µc/cm with the mean 1607 µc/cm. EC is very important to know the quantity of dissolved salts in water, through which we can assess the water quality, and are also good evidence to determine the degree of mineralization of water (Detay, 1997).

In term of water mineralization, the water in winter and summer season are weakly mineralized water in .as (Table 4.3) shows Water classification based on electrical conductivity (Detay,1997).

The relationship of electrical conductivity and TDS is not standardized and to be meaningful, should be specified whenever TDS units are used as showed in Figures (4.2 and 4.3).

Table (4.3) Water classification based on electrical conductivity (Detay, 1997).

| EC(µc/cm) | Mineralization |
|---|---|
| <1000 | Very weakly mineralized water |
| 1000-2000 | Weakly mineralized water |
| 2000-4000 | Slightly mineralized water |
| 4000-6000 | Moderately mineralized water |
| 6000-10000 | Highly mineralized water |
| >10000 | Excessively mineralized water |

### 4.1.2.3 Total dissolved solid (TDS)

Total Dissolved Solids (TDS), it is one of the important measures of water quality that shows the concentration of chemical, organic and inorganic dissolved substances in water (Koran, 2005). The inorganic dissolved are usually the cations Calcium, Magnesium, Sodium and Potassium and the anions Carbonate, Bicarbonate, Chloride, Sulphate and, particularly in

groundwater, Nitrate, A certain level of these ions in water is necessary for aquatic life, changes in TDS concentrations can be harmful because the density of the water determines the flow of water into and out of an organism's cells (Davis and Dewiest, 1966) TDS is measured by the ppm or mg/l units (Boyd, 2000).

The Tables 4.1 and 4.2 showed TDS mean values 1263 ppm in the winter season, with range 1156-1371 ppm. In the summer season the mean values of TDS were detected 1398 ppm, with range 1 ppm. The relationship of electrical conductivity and TDS is not standardized and to be meaningful, should be specified whenever TDS units are used. When TDS levels exceed 1000 mg/l, it is generally considered unfit for human consumption. From Table 4.8, based on TDS, the two seasons water can be classified as fresh water according to Altoviski (1962); Todd (2007) and Drever (1997).

Table (4.4) Classification of water salinity according to the TDS (ppm).

| Altoviski (1962) | Drever (1997) | Todd (2007) | Water class |
|---|---|---|---|
| 0-1000 | < 1000 | 10-1000 | Fresh water |
| 1000-3000 | 1000-2000 | ----- | Slightly water |
| 3000-10000 | 2000-20000 | 1000-10000 | Slightly-Brackish water |
| 10000-100000 | ----- | 10000-100000 | Brackish water |
| ----- | 20000-35000 | ----- | Saline water |
| >100000 | >35000 | >100000 | Brine water |

### 4.2.1. Concentrations of ions

The chemical properties of water were measured in concentrations of ions (cations and anions). All samples were analyzed for major cations ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$), major anions ($SO_4^{=}$ and $Cl^{-}$), and minor anions ($NO^{-}$ and $PO^{3-}$). These chemical components provide good understanding of the chemistry of surface water in study area. These components are discussed below and showed in Tables 4.5 and 4.6.

Table (4.5) Concentrations of major ions in water samples in (ppm) for winter season

| Samples N. | Cations | | | | T.H | Anions | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | | $SO_4^{-2}$ | $Cl^{-}$ | $NO_3^{-}$ | $PO_4^{-}$ |
| Inside | 112.224 | 70.5 | 91.6 | 4.7 | 1340 | 314.386 | 152.1 | 12.5 | .64 |
| Outside | 134.6688 | 84.6 | 109.92 | 5 | 1620 | 377.2632 | 182.52 | 14.8 | 1.768 |
| Mean | 123.45 | 77.55 | 100.76 | 4.85 | 1480. | 345.82 | 167.31 | 13.65 | 1.20 |
| IQS,2009 | 150 | 100 | 200 | ——— | 500 | 400 | 350 | 50 | ——— |
| (WHO,2011) | 100 | 125 | 200 | 12 | 500 | 250 | 250 | 50 | 0.4 |

Table (4.6) Concentrations of major ions in water samples in (ppm) for summer season

| Samples N. | Cations | | | | T.H | Anions | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | | $SO_4^{-2}$ | $Cl^{-}$ | $NO_3^{-}$ | $PO_4^{-}$ |
| Inside | 134.6688 | 84.6 | 115.2 | 5.64 | 1408 | 387.2632 | 192.52 | 16.88 | 0.768 |
| Outside | 161.6026 | 101.52 | 131.904 | 6.768 | 1929.6 | 452.7158 | 219.024 | 19.36 | 1.9216 |
| Mean | 148.13 | 93.06 | 120.91 | 6.204 | 1668.8 | 419.98 | 205.77 | 18.12 | 1.34 |
| IQS, 2009 | 150 | 100 | 200 | — | 500 | 400 | 350 | 50 | ——— |
| (WHO, 2011) | 100 | 125 | 200 | 12 | 500 | 250 | 250 | 50 | 0.4 |

### 4.2.2 Major Cations

#### 1. Calcium ($Ca^{+2}$)

Calcium ranks fifth in terms of the natural abundance of chemical elements in the Earth's crust and, given the order of minerals, is third after aluminum and iron (Krieck et al., 2010). Calcium is an essential component of a healthy diet. Its deficiency leads to problems in the formation of bones and teeth, while an increase in its dose leads to the formation of kidney stones. (USDA, 2017). The initial concentration of calcium ($Ca^{++}$) in the internal water sample of the station was approximately 112.2 ppm. In the winter, the concentration in the water leaving the station was 134.4 ppm. However, during the summer, the concentration in the incoming water was 134.6, and the concentration in the water leaving the station increased to 161, which indicates an increase in different proportions for the water outside the station.

station and for the two seasons, as shown in Table (4-6) and exceeded the permissible limits of WHO (2018) for winter season.

**2. Magnesium ($Mg^{2+}$)**

Magnesium is found in relatively good abundance in the earth's crust, as it ranks eighth in terms of the abundance of chemical elements in it. Magnesium can be found in up to 60 different minerals, often in the form of carbonate, silicate, or sulfate minerals. It is more in union with water than calcium, while the two share being one of the causes of water hardness (Hem, 1989)

The initial concentration of $Mg^{++}$ in the internal water sample of the station was approximately 70.5 ppm . In the winter, the concentration in the water leaving the station was 84.6ppm. However, during the summer, the concentration in the incoming water was 84.6ppm, and the concentration in the water leaving the station increased to 101ppm which indicates an increase in different proportions for the water outside the station. station and for the two seasons, as shown in Table (4-6) The concentration of $Mg^{2+}$ is varied in different locations where with the permissible limits of WHO (2018) for the two seasons.

**3. Sodium ($Na^{+}$)**

Sodium does not exist freely in nature, and it is obtained from its compounds. There is a relatively large abundance of sodium, it is the sixth most abundant chemical element in the earth's crust, and is found in many minerals such as feldspar, sodalite, and halite. Sodium salts are distinguished by their great solubility in water, most notably sodium chloride salt, which is the main cause of seawater salinity (Abdul Kazem, 2012).

The initial concentration of $Na^{+}$ in the internal water sample of the station was approximately 91.6 ppm. In the winter, the concentration in the water

leaving the station was 109 ppm. However, during the summer, the concentration in the incoming water was 115ppm, and the concentration in the water leaving the station increased to 131 ppm, which indicates an increase in different proportions for the water outside the station. station and for the two seasons, as shown in table (4-6) The concentration of $Na^+$ is where with the permissible limits of WHO (2018) for the two seasons.

**4. Potassium ($K^+$)**

In its chemical properties, potassium is very similar to the element sodium, which precedes it in the group of alkali metals, in terms of ionization energy and the pattern of chemical reactions. Elemental potassium, for example, reacts violently with water, generating enough heat to ignite the hydrogen gas resulting from the reaction, burning with a lilac flame. Potassium is of vital importance to the human body at all levels of cells in the body. which help maintain resting voltage and signal transduction and normally regulate cell performance. (Hall et al., 2006).

The initial concentration of $K^+$ in the internal water sample of the station was approximately 4.7 ppm. In the winter, the concentration in the water leaving the station was 5 ppm. However, during the summer, the concentration in the incoming water was 5.6 ppm, and the concentration in the water leaving the station increased to 6.7 ppm which indicates an increase in different proportions for the water outside the station. station and for the two seasons, as shown in Table (4-6) The concentration of $K^+$ is where with the permissible limits of WHO (2018) for the two seasons. The relationship between these cations will show in Figure (4.2) and (4.3) for the two seasons.

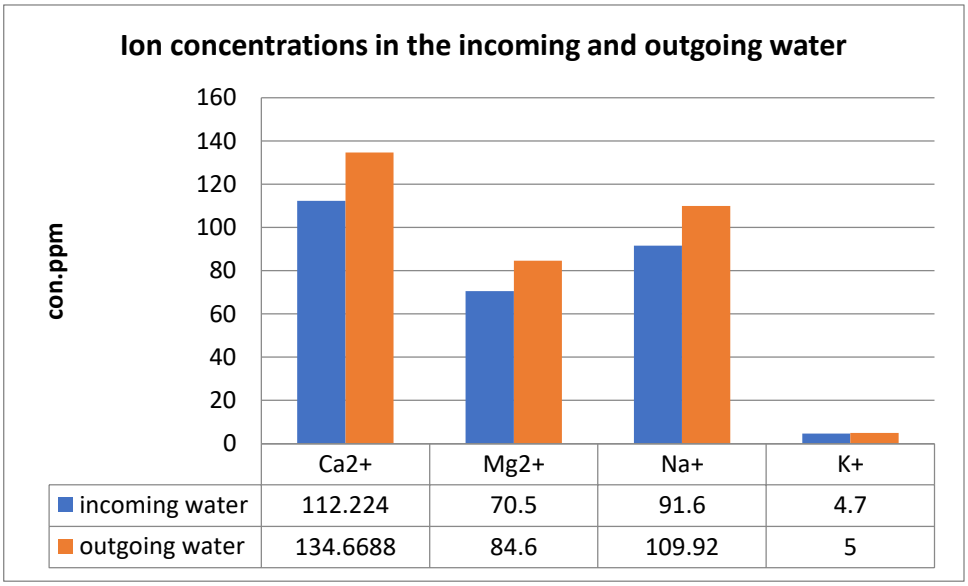



Figure (4.2) The relationship between cations in water sample for winter season

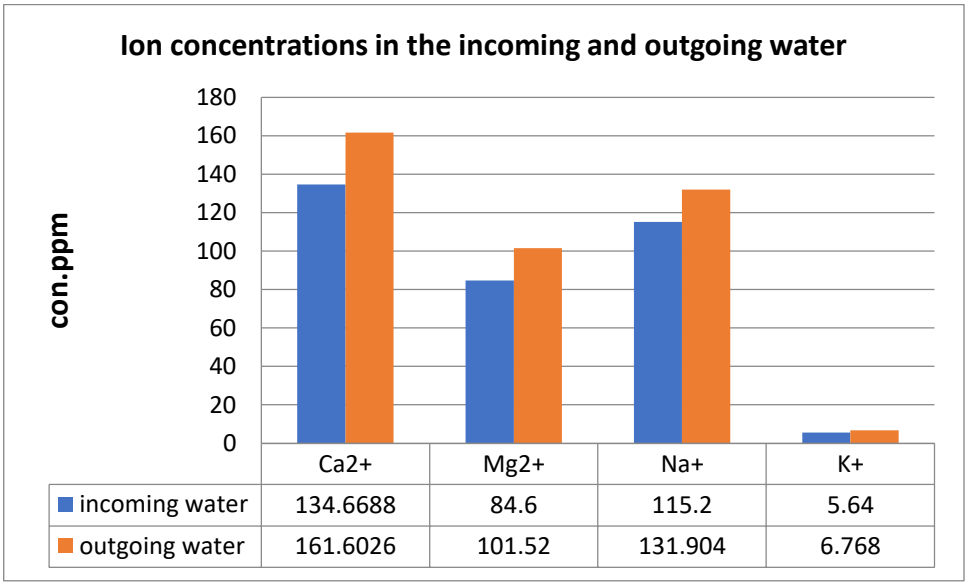



Figure (4.3) The relationship between cations in water sample for summer season

### 4.2.2.1 Total hardness (TH)

The total hardness is the concentration of calcium cations (Ca), magnesium (Mg) and polyvalent ions of iron, aluminum, tin and zinc (Mohammed 2015). Which leaves deposits on the walls of hot water pipes and boilers. The term water hardness is usually used to describe the state of water when the percentage of mineral salts in it is high, which is often in the

form of salts of calcium (Ca) and magnesium (Mg) and some polyvalent ions such as iron, aluminum, tin and zinc. The value of the hardness represents the total concentration of calcium and magnesium ions. It is expressed in terms of calcium carbonate ($CaCO_3$). The concentration of hardness varies according to the water resource, as surface water is less hard than groundwater, and this follows the geological characteristic of the land on which water flows or passes through (Mohammed 2015) (Table 4-7). It is found that all sampling stations fall within very hard water hardness kind for the two periods.. In this study, TH of water samples in During the summer, the water hardness measurements for the incoming and outgoing water at the plant were recorded as 1340 and 1620, respectively. In the winter, the hardness of the incoming water increased to 1408, while the outgoing water exhibited a higher hardness of 1929. These findings indicate an overall increase in water hardness during both seasons (Tables 4-5 and 4-6). The total hardness concentration was showed in figures (4.4) for the two seasons .

Table (4.7) Classifications of water hardness values in ppm units.

| Water Hardness | Bagley et al., 1997 | Manahan, 1994 | Todd, 2007 |
|---|---|---|---|
| Soft | 0 – 60 | 0 – 75 | 0-60 |
| Moderate | 61 – 120 | 75 – 150 | 60-120 |
| Hard | 121 – 180 | 150 – 300 | 120-180 |
| Very hard | > 180 | > 300 | >180 |

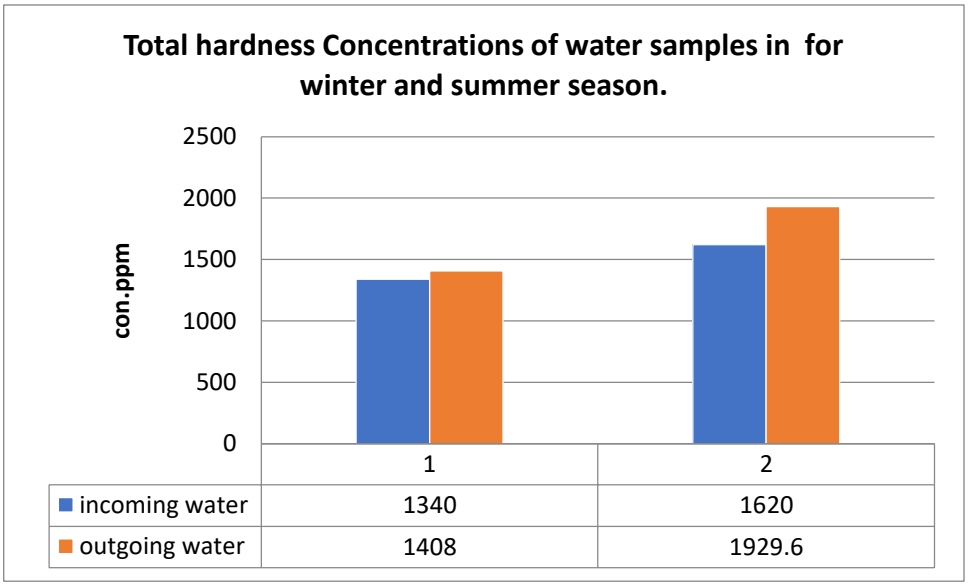



Figure (4.4) Total hardness Concentrations of water samples in (ppm) for winter and summer

### 4.2.2 Major Anions

#### 1- Sulphate ($SO_4^{-2}$)

Sulfate is one of the widespread elements in the earth's crust, and its concentration in the evening ranges from a few milligrams to several thousand milligrams per liter (1998, APIA). Gypsum, sodium sulfate and some rocks due to rainfall (Al-Eisi, 2009). One of the most common forms in which sulfur is found in natural waters is in the form of sulfate bonds combined with positive ions. And magnesium, and it is among the salt-producing substances, and it gives a salty taste to water when its concentration is more than (200) mg / liter (Abbawi Rahman, 1990). During winter, the concentration of sulphate in the incoming water to the station was approximately 314 parts per million (ppm) compared to the water leaving the station 377ppm. In the summer, the concentration of sulphate in the incoming water was around 387 ppm, while it increased to about 452 ppm in the water leaving the station. as shown in the Tables (4.5 and 4-6). Which exceeded the permissible limits of WHO (2011).

**2- Chloride ($Cl^-$)**

Chloride is found in surface waters in the form of sodium, calcium or magnesium salts. It may enter water through industrial flows, agricultural landslide water, and sewage waste. It increases in drinking water after treatment with chlorine (WHO, 1996). The importance of chloride in determining water quality is little because it does not adsorb on clay surfaces (Kovda, 1973). Allawi and Hammadi (1981) mentioned that the chloride ion does not have any effect on the physical properties of the soil, in addition to that it does not absorb into the soil complex, and therefore it enters into the assessment of the quality of irrigation water only through its direct effect on plants and agricultural crops. The concentration of chloride increases in the waters of the Euphrates River in the southern parts of Iraq. The water is considered chloride with the decline of the river (Salman, 1987). The concentration of chlorine in the water samples of the study area During the winter season, the concentration of chlorides in the water entering the plant was approximately 152 parts per million (ppm) in comparison to the water leaving the station 182. In the summer, the chlorides concentration in the incoming water was approximately 192 ppm, whereas it rose to approximately 219 ppm in the water leaving the station. compared to the permissible limits of WHO (2018). as shown in Tables 4-5, and 4-6.

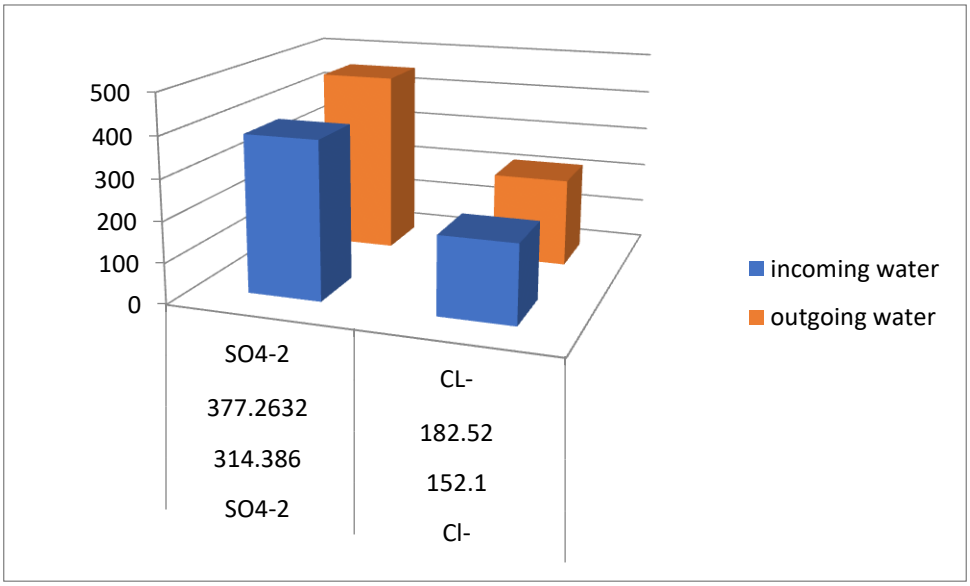



Figure (4.5) Anions Concentrations of water samples in (ppm) for two seasons.

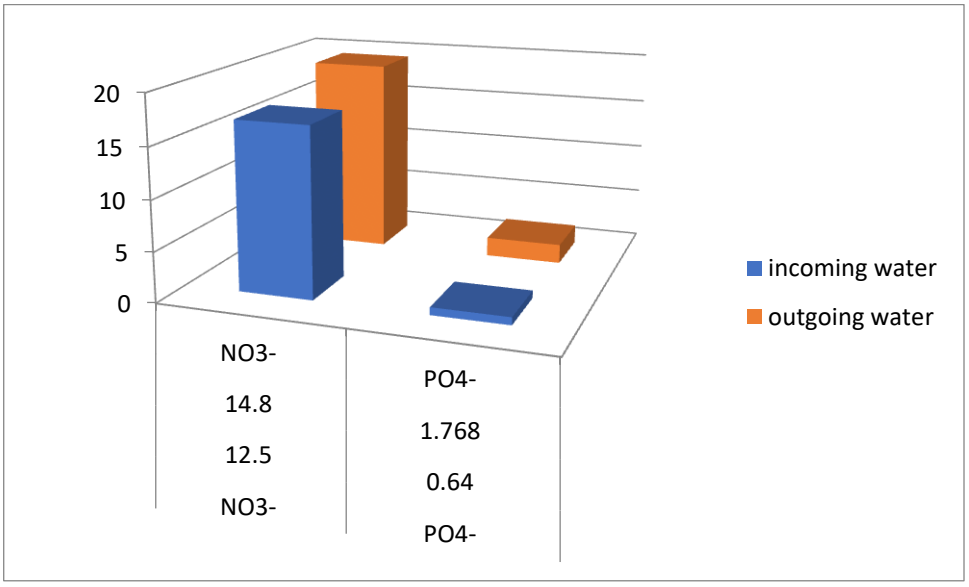



figure (4.6) phosphate and Nitrite Concentrations of water samples in (ppm) for two season.

### 4.2.2.1 Minor anions

#### 1- Nitrate ($NO_3^-$)

Nitrate is a naturally occurring compound that has many man-made sources. Nitrates are found in some lakes, rivers and groundwater. You cannot taste, smell, or see nitrates in the water. Consuming a lot of nitrates can be harmful - especially for babies, natural processes can cause low levels of

nitrates in drinking water - usually less than 3 mg/L. A health concern relates to nitrate levels greater than 10 mg/L. High levels of nitrates in water can be from runoff, seepage from fertilized soil, sewage, landfills, feedlots, sewage systems, or urban drainage. It can be difficult to determine the source of nitrates in drinking water because there are many possibilities. (Kris, 2017). In this study, In the winter season, the concentration of nitrates in the water entering the station was approximately 12.5 parts per million (ppm) compared to 14.8 the water leaving the station. During the summer, the nitrate concentration in the water was around 16.88 ppm, and it further increased to about 19.36 ppm in the water exiting the station. (Table 4-5 and 4-6). The concentrations were with acceptable limit of WHO (2011)

**2- Phosphate ($PO_4^{3-}$)**

Phosphates enter waterways from human and animal waste, phosphorus-rich bedrock, laundry and cleaning wastewater, industrial effluents, and fertilizer runoff. These phosphates become detrimental when they over-fertilize aquatic plants and increase the rate of natural eutrophication, which is sometimes called cultural eutrophication or accelerated eutrophication (Shaima et al., 2020). Phosphate comes in a number of different forms. In natural waters, it commonly presents as phosphate or the anion ($PO_4^{-3}$). In the environment, phosphorus is an essential element needed for life and, in most cases, it is also a "growth limiting" nutrient, because bioavailable phosphate is naturally present at very low levels in the environment (which is why it is an important component of fertilizer). Phosphate is usually held (adsorbed) on soil particles, bound into organic material, or part of mineral compounds. In lakes that are unproductive, the level of ortho-phosphate (aka phosphoric acid, $H_3PO_4$ and its salts) is typically 0.005 to 0.007 mg P/L. The following is a general (Fakhri and Waad, 2009).

In this study, In the winter season, the concentration of $po4^{-3}$ in the water entering the station was approximately 0.64 parts per million (ppm) compared to 1.76 the water leaving the station. During the summer, the phosphate concentration in the water was around 0.76 ppm, and it further increased to about 1.92 ppm in the water exiting the station (Table 4-5 and 4-6). These values are exceeded the permissible limits of WHO (2011). The relationship between these anions will show in Figures (4.5) and (4.6) for the two season.

### 4.2.3 Heavy Metals:

The term heavy metals refers to the metallic elements that have a density higher than 5.0 $g.cm^{-3}$, including Zn, Pb, Ni, Mo, Mn, Hg Fe, Cu, Cr, Co, Cd and As (SSSA 2008).The most important thing that distinguishes these pollutants from other pollutants is their high stability and their survival in the environment for a long time and the inability of the body to metabolize them, as well as that they do not transform, do not decompose, do not volatilize, and are not affected by sunlight (do not decompose lightly) when they are in the environment, but they combine to form diverse and complex compounds, (Al-Dahimi 2006). These elements become toxic in high concentrations, or be of limited biological value and have a toxic effect even in low concentrations such as lead, cadmium, nickel, chromium, mercury and others (Salman, 2006) and the presence of heavy metals in the environment is often evidence of their exposure to pollution (Sanchez 2008). Davies et al. (1991) indicated that the concentration of these elements depends on the temperature, salinity, pH and surface area of the organic and mineral materials present in the river. Heavy elements are present in aquatic environments either in a dissolved state, in suspended load, in bottom sediments, or within the crystalline structure of the minerals that make up river sediments. However, measuring their

concentrations in water for a long time does not give accurate indicators of pollution due to the variation in water expenditures and the instability of pollution sources, Therefore, the focus is on sediments, as the sediment particles whose size is less than (2 microns) contain high concentrations of heavy elements because they contain high percentages of clay minerals, which have a high adsorption capacity for these elements in the sedimentation environment (UNESCO, 1983).

The sources that can supply the aquatic environment with heavy elements and in different concentrations, they are either natural sources and include erosion and weathering of natural mineral rocks, forest fires, vegetable crops and storms (Fernandez-Leborans & Olalla-Herrero, 2000) or they are human sources and they represent all the sources arising from the activities of Man as industrial waste, such as the manufacture of fertilizers, textiles, batteries, leather, dyes, oil refineries, hospital waste, and others. Household waste has a significant impact on adding quantities of heavy metals to the German ocean (Ulmann et al., Al Saad and his group 2003). Sometimes heavy metal pollution results from the use of sewage water to irrigate agricultural crops, including rice crops (Abegunde & Adelekan 2011.)

Range and mean concentration of the elements shown in Tables (4-8 and 4-9) and it has been compared with according to Iraqi standards 2009 and WHO 2011.

Table (4.8) Concentrations of trace elements in ppm for the winter season water sample and comparing with IQS (2009) and WHO (2011) limits.

| Sample No. | Pb(ppm) | Zn(ppm) | Fe(ppm) | Cd(ppm) | Ni(ppm) |
|---|---|---|---|---|---|
| Inside | 0.7711 | 0.1739 | 1.9175 | 0.0752 | 0.2362 |
| Outside | 0.7951 | 0.2106 | 2.0517 | 0.0821 | 0.2637 |
| Ave. | 0.783 | 0.191 | 1.984 | 0.078 | 0.2495 |
| (IQS, 2009) | 0.01 | ——— | ——— | 1 | 0.02 |
| (WHO, 2011) | 0.01 | 0.003 | ——— | 2 | 0.02 |

Table (4.9) Concentrations of trace elements in ppm for the summer season water sample and comparing with IQS (2009) and WHO (2011) limits.

| Samples No. | Pb | Zn | Fe | Cd | Ni |
|---|---|---|---|---|---|
| | ppm | | | | |
| Inside | 0.9315 | 0.0825 | 2.2136 | 0.1152 | 0.3716 |
| Outside | 0.983 | 0.1217 | 2.3617 | 0.1307 | 0.4312 |
| Ave | 0.957 | 0.103 | 2.287 | 0.1225 | 0.401 |
| (IQS, 2009) | 0.01 | ——— | ——— | 1 | 0.02 |
| (WHO, 2011) | 0.01 | 0.003 | ——— | 2 | 0.02 |

UN: undetected

**1. Lead (Pb)**

Lead is a soft, malleable, bluish-white metal known for its poor heat conductivity and resistance to corrosion. Its ores, such as galena composed of lead sulfide (PbS), often contain sulfur, zinc, and copper. Galena finds application in mirror coatings and is also utilized in the production of blue pigments (Al-Saad et al. 2003).

In this study the concentration of lead in the water entering and leaving the Zubaidiya thermal plant was assessed (Tables 4-8 and Table 4-9). The concentration of lead in the incoming water during winter was approximately 0.77 ppm, while the outgoing water showed a concentration of around 0.79 ppm. In the summer, the concentration of lead in the incoming water was measured at 0.931 ppm, while the outgoing water exhibited a concentration of 0.983 ppm.

Comparing these lead concentrations with the limits set by the Iraqi Quality Standards (IQS) and WHO, it was observed that the concentrations exceeded the established limits, indicating a high level of pollution.

**2. Zinc (Zn)**

According to Khalil (2003), the recommended dietary intake of zinc varies based on age and gender, ranging from 4 to 15 mg/day for the general population. Pregnant women, however, have a higher requirement of 16 mg

per day. In terms of drinking water, the maximum permissible level of zinc is set at 5.0 mg/l, as stated by Al-Farhan (2003) and Khalil (2002).

In the context of the Zubaidiya thermal plant, the concentration of zinc in the incoming and outgoing water was assessed during winter and summer (as shown in Tables 4-8 and 4-9. In winter, the concentration of zinc in the incoming water was approximately 0.082 ppm, while the outgoing water exhibited a concentration of about 0.121 ppm. Similarly, in summer, the concentration of zinc in the incoming water was measured at around 0.1739 ppm, and the outgoing water showed a concentration of approximately 0.21 ppm.

Comparing these zinc concentrations with the limits set by WHO, it was found that the concentrations exceeded the established limits both in winter and summer, indicating elevated levels of zinc in the water.

**4. Iron (Fe)**

Iron in water can cause a change in color, turning it red-brown due to the presence of iron (III). This color change occurs when iron (III) accelerates the formation of iron oxide and hydroxide, which can absorb the effects of other minerals (Andac et al., 2009). The presence of iron in turbid water is primarily influenced by the dissolution or solubility of aerosol particles. Iron particles are commonly found in the atmosphere as a result of soil dust, fly ash from power plants and combustion engine exhaust, and industrial processes (Parazols et al., 2006).

In the case of the Zubaidiya thermal plant, the concentration of iron (Fe) in the incoming and outgoing water was examined during winter and summer (as shown in Tables 4-8 and 4-9). In winter, the concentration of Fe in the incoming water was approximately 1.917 ppm, while the outgoing water exhibited a concentration of about 2.051 ppm. Similarly, in summer, the

concentration of Fe in the incoming water was measured at around 2.213 ppm, and the outgoing water showed a concentration of approximately 2.361 ppm.

It is worth noting that the provided concentration values for Fe are within the normal range and do not indicate excessive levels. Iron is generally considered harmless unless present in large amounts, and its presence in water mainly affects its aesthetic qualities rather than posing significant health risks.

**4. Cadmium (Cd)**

Cadmium is classified as a heavy element due to its high atomic number 48, atomic mass 112.40, and density 8.64 mcg/m³. It possesses metallic properties such as conductivity, ductility, malleability, and cation formation (Its Compounds, 2004; Cadmium Watts 1998). Cadmium is relatively rare, with an average abundance in the Earth's crust of 0.16 micrograms, ranging from 0.1-0.5 micrograms in soils, 1 microgram per liter in rivers, and 1-10 micrograms per liter in groundwater (Watts, 1998; APHA, 1998).

The primary source of cadmium in the environment is human activities, particularly the combustion of fuels, oils, and household waste ash, which contribute to airborne cadmium (Hamza, 2005). Cadmium compounds in water can exist in dissolved or insoluble complexes, and these compounds demonstrate mobility and high stability in water, with a half-life exceeding 200 days (cadmium and its compounds, 2004).

In the case of the Zubaidiya thermal plant, the concentration of cadmium (Cd) in the incoming and outgoing water was analyzed during winter and summer (as shown in Tables 4-8 and 4-9). During winter, the concentration of Cd in the incoming water was approximately 0.072 ppm, while the outgoing water exhibited a concentration of around 0.0821 ppm. Similarly, in summer, the concentration of Cd in the incoming water was measured at approximately

0.115 ppm, and the outgoing water showed a concentration of about 0.1307 ppm.

Comparing these cadmium concentrations with the limits set by WHO, it is evident that the concentrations exceeded the established limits for both seasons, indicating higher levels of cadmium than recommended.

**5. Nickel (Ni)**

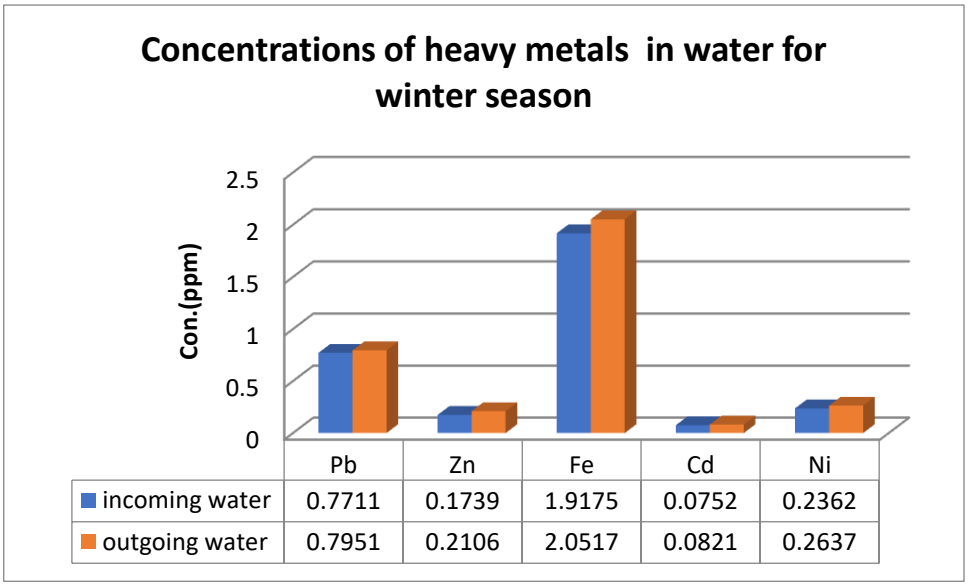
Nickel is considered an essential nutrient for certain microorganisms and plants that rely on enzymes containing nickel within their active sites. This metal plays a crucial biological role in bacteria, archaea, and fungi (Nickel, 2008). Numerous examples of nickel-containing enzymes exist, including urease, which catalyzes the hydrolysis of urea to produce ammonia and carbamates, and certain hydrogenase enzymes that rely on nickel and iron (Covacci, 1999).

Nickel can impact the synthesis of DNA and RNA by inhibiting strand duplication in DNA. It has been associated with various types of cancer, such as lung, skin, and nasal cavity cancer (Ciubar, & Bonoiu, 2006). In freshwater, the concentration of nickel ranges from 0.2 to 27 μg/l, while in seawater, it varies from 0.13 to 43 μg/l. Nickel is considered a toxic element for humans, and if its concentration exceeds the permissible limit of 0.02 mg/L, it can lead to several diseases, including nausea, gastrointestinal disorders, and lung cancer (WHO, 1996).

Regarding the Zubaidiah thermal plant, the concentration of nickel (Ni) in the incoming and outgoing water was assessed during winter and summer (as shown in Tables 4-8 and 4-9). In winter, the concentration of Ni in the incoming water was approximately 0.2362 ppm, while the outgoing water exhibited a concentration of around 0.0263 ppm. In summer, the concentration of Ni in the incoming water was measured at approximately

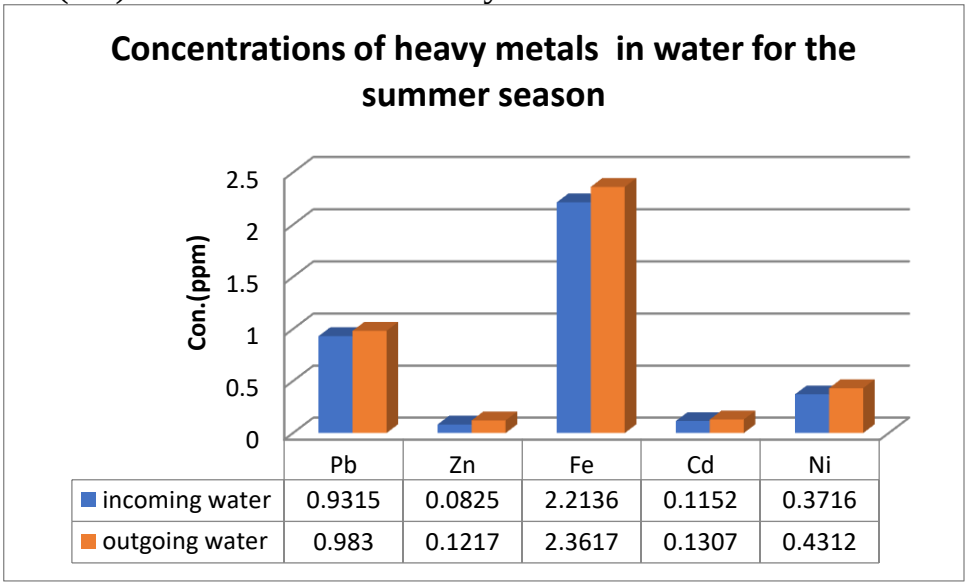
0.3716 ppm, and the outgoing water showed a concentration of about 0.4312 ppm.

Comparing these nickel concentrations with the limits set by the IQS and WHO, it was found that the concentrations exceeded the limits in winter and were below the limits in summer.




| | Pb | Zn | Fe | Cd | Ni |
|---|---|---|---|---|---|
| incoming water | 0.7711 | 0.1739 | 1.9175 | 0.0752 | 0.2362 |
| outgoing water | 0.7951 | 0.2106 | 2.0517 | 0.0821 | 0.2637 |

Figure (4.7) Concentrations of heavy metals water for the winter season




| | Pb | Zn | Fe | Cd | Ni |
|---|---|---|---|---|---|
| incoming water | 0.9315 | 0.0825 | 2.2136 | 0.1152 | 0.3716 |
| outgoing water | 0.983 | 0.1217 | 2.3617 | 0.1307 | 0.4312 |

Figure (4.8) Concentrations of heavy metals water for the summer season

## 4.2 Introduction of pollution plants

Pollution from heavy metals poses a significant threat to plant health and ecosystem functioning. The toxicity of heavy metals to plants depends on their availability and the plant's ability to absorb them. When these elements are present in high concentrations that are easily absorbed, they can compete with essential elements for plant uptake, leading to imbalances and hindering the function of chlorophyll and enzymes (Shah et al., 2009). This interference can negatively impact plant growth, both in terrestrial and aerial organs, and can even result in plant death (Shah et al., 2011).

While plants have the capacity to absorb and accumulate essential elements such as iron (Fe), magnesium (Mg), sodium (Na), and zinc (Zn), they can also accumulate non-essential and potentially toxic elements like aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb), and uranium (U) (Jadia and Fulekar, 2008). These non-essential elements do not have any known physiological function in plants. Heavy elements generally enter plants through the soil, water, or air (Shah et al., 2009). Uptake through the roots can occur through cation exchange processes or in the form of chelates, while foliar uptake can happen through stomata or surface interception (Kabata-Pendias and Pendias, 2001).

The ability of plants to absorb and accumulate heavy elements varies widely, not only between plant species but also within a single species, depending on the plant's genotype. Other factors such as soil characteristics, climatic conditions, and plant age and growth stage also influence the behavior of these elements (Kabata-Pendias and Pendias, 2001). The characteristics of the elements themselves also play a role in their uptake and movement within plants. According to Alloway's classification in 1999, some elements are slow-moving (Cr, Hg, Pb), while others are medium-moving (Co, Ni, Cu), and some are easily mobile (Cd, Mn, Zn, Mo).

This chapter focuses on an analytical study of plant samples collected near the Al-Zubaidiya thermal power plant. Five samples of wild reed plants were selected for the study and measurement of heavy metal concentrations in them.

### 4.2.1 Heavy metals in plant

Plants have the remarkable ability to absorb and accumulate certain elements from their surrounding environment, often in higher concentrations than what is present in the medium they grow in. This phenomenon is known as accumulation, and interestingly, it does not typically cause negative symptoms or harm to the plants themselves. To counteract the potential harmful effects of accumulated heavy metals, plants have developed various mechanisms to regulate the absorption and distribution of these elements, aiming to prevent or reduce their toxicity (Hassner et al., 1998).

One such mechanism involves plants binding toxic elements to the cell walls of their roots and leaves, effectively sequestering them away from sensitive sites within the cell. Another strategy is to store these elements in specialized compartments called vesicles (Memon et al., 2001). Additionally, many plant species exhibit resistance to heavy metals by fixing them in the root zone and reducing their transportability to the leaves. This is a common resistance feature observed in a majority of plant species (Pulford and Watson, 2003).

These adaptive strategies employed by plants help them cope with the presence of heavy metals and minimize their harmful effects. By regulating the absorption, distribution, and storage of these elements, plants can thrive even in environments contaminated with heavy metals. *Phragmites australis*, also known as common reed, is a tall perennial grass found in various habitats such as wetlands, marshes, and aquatic environments. It is known for its

adaptability and ecological significance in providing habitat and food sources for wildlife species.

In the present study, samples of Phragmites australis were collected from four different locations within the study area to analyze the concentrations of heavy elements. The results of the analysis are presented in the table below:

**A: Concentration Heavy metals in plant at winter season**

The concentrations of heavy elements in Phragmites australis samples collected during the winter season are presented in the table below. The concentrations are measured in milligrams per kilogram (mg/kg).

The mean concentrations of the heavy elements in the Phragmites australis samples are also provided. Permissible values of heavy elements in plants, according to WHO guidelines from 1996, are given in milligrams per kilogram (mg/kg). These values represent the maximum allowable concentrations for the respective elements in plants. These permissible values serve as guidelines to assess the heavy metal concentrations in plants and determine their potential impact on human health and the environment.

Table (4.10) Concentrations of Heavy Elements(mg/Kg) in Phragmites australis Samples for the winter season

| No. S | Pb | Cd | Zn | Fe | Ni |
|---|---|---|---|---|---|
| **P1** | 8.031 | 0.088 | 4.99 | 128.0 | 0.27 |
| **P2** | 7.791 | 0.099 | 73.02 | 172.51 | 0.55 |
| **P3** | 7.791 | 0.093 | 24.22 | 127.73 | 2.856 |
| **P4** | 7.951 | 0.11 | 59.26 | 114.91 | 1.868 |
| **P5** | 7.871 | 0.097 | 25.31 | 104.63 | 1.263 |
| **Mean** | 7.887 | | 37.36 | 129.56 | 1.213 |
| **Permissible value of plant mg/kg,WHO (1996)** | 2 | 0.02 | 0.6 | | 10 |
| **Habib et al., 2012** | 30 | 16 | | 211 | 45 |

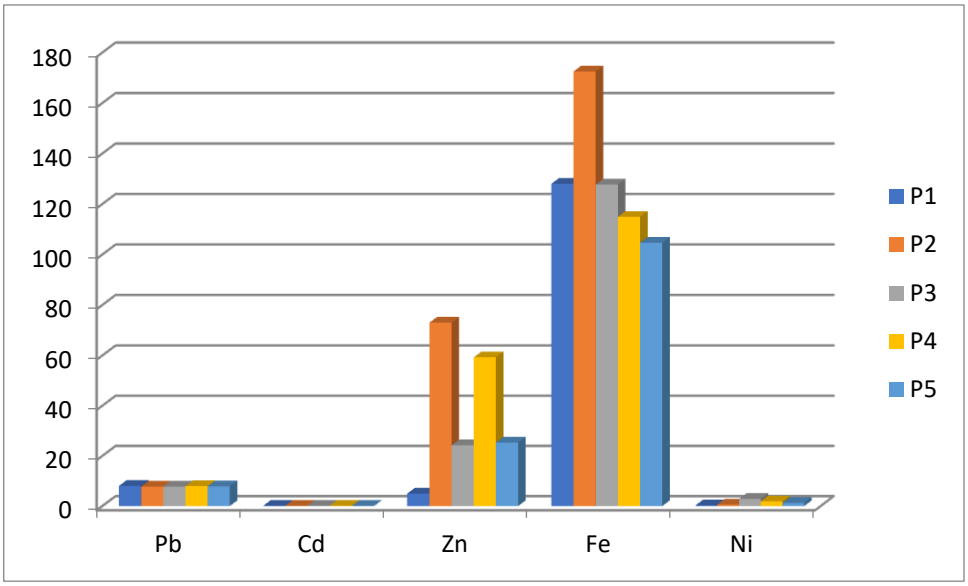



Figure (4.9) Concentrations of heavy metals (mg/Kg) in the leaves of a sample of wild reed plant for the winter season

**b. Concentration Heavy metals in plant at summer season**

In the summer season, the concentrations of heavy elements in Phragmites australis samples show variations at different stations. Let's compare these concentrations to the permissible limits set by WHO for each heavy metal:

**Lead (Pb)**

Permissible value by WHO: 2 mg/kg

Concentrations in Phragmites australis samples range from 7.311 to 9.043 mg/kg.

All samples exceed the WHO permissible limit for lead.

**Cadmium (Cd)**

Permissible value by WHO: 0.02 mg/kg

Concentrations in Phragmites australis samples range from 0.087 to 0.122 mg/kg.

All samples exceed the WHO permissible limit for cadmium.

**Zinc (Zn)**

Permissible value by WHO: 0.6 mg/kg

Concentrations in Phragmites australis samples range from 12.36 to 68.03 mg/kg.

All samples exceed the WHO permissible limit for zinc.

**Iron (Fe)**

There is no specific WHO permissible limit for iron in plants.

Concentrations in Phragmites australis samples range from 167.01 to 635.02 mg/kg.

**Nickel (Ni)**

Permissible value by WHO: 10 mg/kg Concentrations in Phragmites australis samples range from 0.55 to 4.312 mg/kg. All samples are within the WHO permissible limit for nickel.

Based on the data provided, it is evident that the concentrations of lead, cadmium, and zinc in Phragmites australis samples during the summer season exceed the WHO limits. This indicates potential contamination of the plants with these heavy metals. It raises concerns about the possible ecological and health risks associated with the consumption of these plants or their impact on the surrounding environment.

Further assessment and analysis are necessary to understand the potential implications of these elevated concentrations and their effects on human health and the ecosystem. Additionally, implementing measures to mitigate heavy metal pollution and monitor these areas is crucial to ensure environmental sustainability and public safety.

Table (4.11) Concentrations of Heavy Elements(mg/Kg) in Phragmites australis Samples for the summer season

| N.S | Pb | Cd | Zn | Fe | Ni |
|---|---|---|---|---|---|
| **P1** | 9.043 | 0.091 | 12.36 | 190.19 | 4.312 |
| **P2** | 7.977 | 0.120 | 65.11 | 167.01 | 0.55 |
| **P3** | 7.311 | 0.087 | 68.03 | 180.33 | 1.648 |
| **P4** | 8.150 | 0.122 | 49.65 | 635.02 | 1.895 |
| **P5** | 7.861 | 0.1158 | 34.11 | 227.83 | 1.840 |
| **Mean** | 8.068 | 0.107 | 45.852 | | |
| **Permissible value of plant mg/kg, WHO (1996)** | 2 | 0.02 | 0.6 | | 10 |

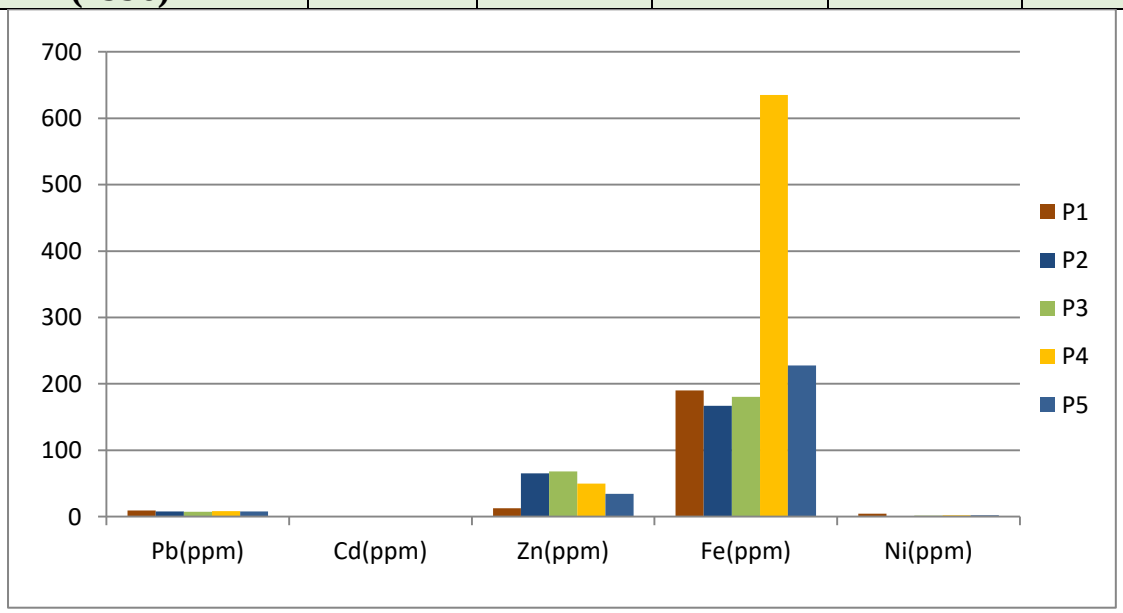



Figure (4.10) Concentrations of heavy metals (mg/Kg) in the leaves of a sample of wild reed plant for the summer season

**1. Lead (Pb)**

Plants tend to absorb lead in the soil and retain most of it in their roots. There are indications that the green parts of plants also distribute the lead absorbed from the soil, and it can also be transferred to other plant parts. Some plant species have the ability to contain high concentrations of lead. The intake of lead can be reduced through the roots of these plants, by increasing calcium and phosphorous to the soil. (Tamer, 2013). The pores in the leaves of plants allow the entry of $CO_2$, which the plant needs for

photosynthesis, and these pores release oxygen. Lead pollution leads to covering the surfaces of the leaves and reducing the amount of light that reaches them, and this results in weak plant growth or plant death due to a decrease in the rate of photosynthesis and inhibition of respiration. Some studies indicate that lead can also have genetic effects on plants. All these effects were monitored in isolated cells or in plants grown in a nutrient liquid containing (1-2 ppm) of lead, which represents the percentage of lead in the environment near smelting plants or transportation routes (Greene, 1993).

Lead (Pb) concentrations in wild reed plant samples ranges from 7.791 to 8.031) ppm with mean concentration of 7.877 mg/kg for winter season where the lowest concentration in station (P2 and P3) and the highest concentration in station (P1). The concentrations compared with many studies as shown in table (4.10). Pb concentration was more than studies WHO (1996) and more than other worldwide studies. When summer season the wild reed plant samples range from 7.311 to 9.043 mg/kg with mean concentration of 8.068 ppm where the lowest concentration in station (P3) and the highest concentration in station (P1). The concentrations compared with many studies as shown in Table 4.11. Pb concentration was more than studies WHO (1996) and more than other worldwide studies.

**2. cadmium**

The absorption of cadmium depends on the ability of plants to resist its toxic effects, as one of the researchers indicated that cadmium is toxic to most living organisms and is a human carcinogen, unlike metals such as iron (FE + 2) and copper (CU + 2). Also, the accumulation of cadmium in plants may cause many physiological, biochemical and structural changes. Cadmium accumulation alters the absorption of mineral nutrients by interacting with the water balance in the plant as it prevents the opening of stomata in plant

leaves. The exposure of plants to cadmium causes major damages at the cellular and physiological level to plants, as soil contamination with heavy metals is an important problem that hinders plant growth. The addition of cadmium in the nutrient media of wheat plants hindered the growth of the stem and roots, as the gas exchange reactions (photosynthesis and transpiration rates) decreased upon exposure to cadmium, which leads to a decrease in plant growth. (Rabah, 2022).

cadmium (Cd) concentrations in wild reed plant samples ranges from 0.088- 0.115 ppm with mean concentration of 9.898 mg/kg for winter season where the lowest concentration in station (P1) and the highest concentration in station (P4) . The concentrations compared with many studies as shown in table (4.10). Cd concentration was more than (WHO 1996). When summer season the wild reed plant samples range from 8.703- 12.24mg/kg with mean concentration of 10.749 mg/kg where the lowest concentration in station (P3) and the highest concentration in station (P2). The concentrations compared with many studies as shown in table (4.11). Cd concentration was more than local studies less than WHO (1996) and more than other worldwide studies.

**3. Zinc (Zn)**

Zinc enters the composition of enzymes that synthesize plant auxins. It also plays an important role in the process of oxidation of sugars in the data. It has a key role in the formation of chlorophyll and in the process of photosynthesis. Zinc deficiency leads to a decrease in the number of chloroplasts in the cell with its small size and clump, as the cytoplasm decreases, the nucleus is deformed and transformed Wood parenchyma cells to a grassy appearance with an increased calcium oxalate content. (Mohamed, 2018)

Zinc (Zn) concentrations in wild reed plant samples ranges from 4.99 to 73.02 mg/kg with mean concentration of 37.36 mg/kg for winter season where the lowest concentration in station (P1) and the highest concentration in station (P2). The concentrations compared with many studies as shown in Table 4.10. Zn concentration was less than WHO (1996). When summer season the wild reed plant samples range from 12.36 to 68.03 ppm with mean concentration of 45.852 mg/kg where the lowest concentration in station (P1) and the highest concentration in station (P3). The concentrations compared with many studies as shown in Table (4.11). Pb concentration was less than WHO (1996) and more than other worldwide studies.

**1. Iron (Fe)**

Iron is a low-moving element within the plant that is absorbed in the form of $Fe^{++}$. It is an intermediate in the formation of chlorophyll. It also enters the synthesis of cytochromes and is related to the formation of the enzyme peroxidase. Symptoms of iron deficiency are most noticeable on fruiting trees. The appearance of symptoms of deficiency of this element does not necessarily mean that it is not available in the soil. On the contrary, it has been found that some trees that suffer from its deficiency spread in iron-rich lands in the Zabadani region, for example, but it is in a form that cannot be absorbed. (Izraa, 2020).

Iron (Fe) concentrations in wild reed plant samples ranges from 104.63 to 172.51 mg/kg with mean concentration of 129.51 mg/kg for winter season where the lowest concentration in station (P5) and the highest concentration in station (P2). The concentrations compared with many studies as shown in table (4.10). Fe concentration was less than the WHO (1996) and more than other worldwide studies. When summer season the wild reed plant samples range from 635.02 to 227.83 mg/kg with mean concentration of 165.77 mg/kg

where the lowest concentration in station (P2) and the highest concentration in station (P4). The concentrations compared with many studies as shown in Table 4.11. Fe concentration was less than WHO (1996) except for a station (p4) that was higher than aforementioned parameters.

**5.Nickel (Ni)**

The nickel element plays a major role in plant physiology, especially during seed germination, in addition to its great importance in the synthesis of urease, the enzyme that converts urea into aluminum (Havlin et al. 1999). Research has proven the importance of nickel in nitrogen metabolism in some plants. Studies have shown the nutritional importance of nickel for humans, as it enters the synthesis of nucleic acids (DNA and RNA) and thus is added to the list of minerals necessary for the body (AlSaad, 2006). The element is not sufficiently available for the requirements of plant growth, and toxicity usually occurs when the element is available in more than the plant needs, which in turn leads to the reduction of plant growth naturally (McCauley et al., 2003). The presence of these elements in a heterogeneous manner in the atmosphere It usually leads to damage to the natural and chemical components that are in contact with humans and which lead to the production of large quantities of safety minerals to the food chain (Baner Jee et al., 2004). Nickel is considered one of the toxic elements for most plants, and given what the Basra Governorate was exposed to to the damages of pollution with safety metals as a result of the war, we decided to study the effect of harmful concentrations of one of these toxic elements (nickel) on the growth of this plant, as well as its effect on the absorption of some other trace elements necessary for plant growth

Nickel (Ni) concentrations in wild reed plant samples ranges from 0.27-1.263 mg/kg with mean concentration of 2.138 mg/kg for winter season where the lowest concentration in station (P2) and the highest concentration in station (P3) . The concentrations compared with many studies as shown in table (4.10). Ni concentration was more than WHO(1996) and more than other worldwide studies. When summer season the wild reed plant samples ranges from 4.31- 1.840 mg/kg with mean concentration of 2.946 mg/kg where the lowest concentration in station (P2) and the highest concentration in station (P1). The concentrations compared with many studies as shown in table (4.11). Ni concentration was more than less than WHO (1996).

Upon reviewing the results of the current study near Zubaidiya Thermal Station, it is evident that the concentrations of heavy metals in the reed plant samples exceeded the permissible limits set by WHO. The study revealed higher levels of lead, cadmium, and nickel compared to the WHO limits. This signifies a concerning level of pollution in the study area, potentially posing risks to both the environment and human health. In contrast, the previous study conducted in the streets of Baghdad reported average concentrations of iron, lead, cadmium, and nickel, without explicitly mentioning their compliance with WHO limits. These contrasting findings underscore the variability of heavy metal pollution across different locations and emphasize the need for stringent monitoring and pollution control measures to safeguard ecosystems and human well-being.

### 4.2.2Polycyclic aromatic hydrocarbons in plant

Polycyclic aromatic hydrocarbons (PAHs) are a group of organic compounds consisting of fused aromatic rings. They are formed primarily through incomplete combustion of organic matter, such as fossil fuels, wood,

and tobacco (Huang et al., 2014). PAHs are widespread environmental pollutants and can be found in various media, including air, water, soil, and plants.

Plants have the ability to take up and accumulate PAHs from the environment. The uptake of PAHs by plants can occur through several pathways, including absorption from the soil, deposition from the atmosphere onto plant surfaces, and uptake through the roots (Li et al., 2013). Once inside the plant, PAHs can be translocated and distributed to different plant tissues, including leaves, stems, and roots (Hawthorne et al., 2012).

The presence of PAHs in plants can have significant implications for both the plants themselves and the ecosystems they inhabit. PAHs are known to have toxic effects on plants, including inhibition of photosynthesis, disruption of cell membranes, and interference with plant growth and development (Ding et al., 2016). Additionally, PAHs can be transferred through the food chain, as plants contaminated with PAHs can be consumed by herbivores and subsequently by higher trophic levels (Gupta et al., 2017).

The analysis of PAH concentrations in plants is crucial for understanding the extent of environmental contamination and assessing potential risks to human and ecological health. Researchers employ various techniques, such as extraction and chromatographic methods, to quantify PAH levels in plant samples (Khan et al., 2015). Monitoring PAH concentrations in plants can provide valuable information about the presence and distribution of these pollutants in the environment.

Overall, the study of PAHs in plants helps shed light on the environmental impact of these toxic compounds and aids in the development of strategies for pollution prevention and remediation. By understanding how PAHs accumulate in plants and their potential effects, scientists and policymakers

can work towards mitigating the risks associated with PAH pollution and safeguarding both the environment and human health.

Distribution of PAHs present in the wild reed plant located in the vicinity of the studied area show in table (4.12), noting that the polycyclic aromatic hydrocarbons were examined in the GC device. The table shows the concentrations of various PAHs in two samples (winter and summer) compared to the mean concentration reported by Yubo et al. in 2015. Overall, the results suggest that the level of pollution in both samples is high, with many of the PAHs having concentrations exceeding the maximum permissible limits set by regulatory agencies such as the Environmental Protection Agency (EPA).

Some specific observations include:

Acridine had a higher concentration in both samples compared to the mean reported by Yubo et al. in 2015, indicating a potentially higher level of pollution in the samples.

Acenaphthene had a higher concentration in the winter sample compared to the summer sample, but both samples had concentrations higher than the mean reported by Yubo et al. in 2015.

Anthracene had a higher concentration in the winter sample compared to the summer sample, but both samples had concentrations higher than the mean reported by Yubo et al. in 2015.Benzo(a)anthracene had a concentration in sample 3B that exceeded the maximum permissible limit set by the EPA.

Chrysene had a higher concentration in the winter sample compared to the summer sample, but both samples had concentrations higher than the mean reported by Yubo et al. in 2015. Fluranthene had a higher concentration in the winter sample compared to the summer sample, but both samples had concentrations higher than the mean reported by Yubo et al. in 2015.

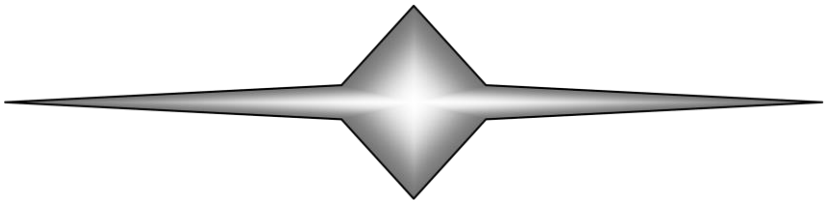
Indeno had a concentration only in sample 3A, indicating a potential source of pollution in that sample.Naphthalene had a concentration only in the winter sample, indicating a potential source of pollution in that sample.

Phenanthrene had a concentration only in the winter sample, indicating a potential source of pollution in that sample. Pyrene had a higher concentration in the winter sample compared to the summer sample, but both samples had concentrations higher than the mean reported by Yubo et al. in 2015. Overall, the results suggest that the level of pollution in both samples is high and that appropriate measures need to be taken to reduce the concentration of these harmful pollutants. Further investigation is needed to identify potential sources of pollution and to determine the impact of this pollution on the environment and public health.

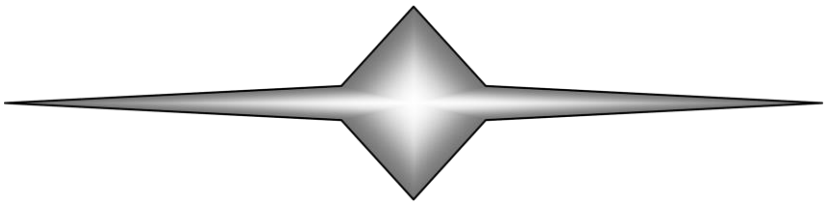
Table (4.12) The range and concentration of PAHs in each plant sample

| No | 16 PAHs | Name | 1 winter | 4 W | 1 summer | 4 S | Mean µg/kg | Yubo.et.al 2015µg/kg |
|---|---|---|---|---|---|---|---|---|
| 1 | Low molecular weight | Acenaphthene | 22.15 | 16.28 | 10.58 | 11.25 | 15.065 | 149.1 |
| 2 | | Acenaphthylene | 15.89 | 10.88 | 13.55 | 15.47 | 13.9475 | 46.4 |
| 3 | | Anthracene | 24.58 | 14.58 | 18.47 | 20.56 | 19.5475 | 435.2 |
| 4 | | Fluroene | 8.15 | UDL | UDL | UDL | 8.15 | 155.2 |
| 5 | | Naphthalene | 13.58 | UDL | UDL | UDL | 13.58 | 19.5 |
| 6 | Highi molecular weight | benzo( k ) Fluoranthene | 13.65 | 10.25 | 10.55 | 13.69 | 12.035 | 175 |
| 7 | | benzo ( g , h ) perylene | 9.25 | 6.25 | 7.48 | 9.58 | 8.14 | 84.1 |
| 8 | | benzo ( a ) pyrenen | 2.55 | 1.05 | 2.00 | 2.55 | 2.0375 | 65.6 |
| 9 | | Chrysene | 8.14 | 5.22 | UDL | 3.69 | 5.683333 | 595.9 |
| 10 | | dibenzo ( a , h ) anthracene | 15.64 | 10.69 | UDL | 8.55 | 11.62667 | 65.2 |
| 11 | | Fluranthene | 11.25 | 6.58 | UDL | 5.99 | 7.94 | 157 |
| 12 | | benzo( a ) anthracene | 12.48 | 9.65 | 10.25 | 13.66 | 11.51 | 108.2 |
| 13 | | Indeno | 12.65 | UDL | UDL | UDL | 12.65 | |
| 14 | | benzo( b) Fluoranthene | 11.08 | 9.44 | 8.58 | 10.58 | 9.92 | |
| 15 | | Phenanthrene | 9.58 | UDL | UDL | UDL | 9.58 | 157 |
| 16 | | pyrene | 12.44 | 9.33 | | | | 186.1 |

# Chapter Five



# Assessment of Soil pollution



# Assessment of Soil pollution

## 5.1 Preface

Pollution means all forms of quantitative or qualitative changes in the components of the soil in terms of its chemical, physical or biological characteristics, which result from the use of some chemicals, whether intentionally or unintentionally, and then spoil the basic components of the soil and change its composition, making it unsuitable for agriculture or It produces contaminated food harmful to humans, as is the case in the study area.( Attia, etal 2012).

This chapter included sampling and analysis of 20 samples of surface soil, and soil analysis included chemical analysis (pH, electrical conductivity, organic matter, sulfate, gypsum, hydrocarbons, heavy elements and XRF)

## 5. 1 pH

One of the key elements in determining the concentration of metals in the soil solution, their mobility, and their accessibility to plants is thought to be the soil pH. The intensity of heavy metal mobilization changes as hydrogen ion concentration rises. Metallic elements are substantially more mobile in extremely acidic soils than they are in neutral or alkaline-reacting soils. There is a chance of heavy metal complex anions with higher mobility and bioavailability in alkaline soils with a pH range. However, as the pH of the soil rises to between pH 6.5 and 7.5, plants' root uptake of metal often becomes less intense (Fijałkowski et al. 2012 ). The capacity of soils to collect elements on their surface from adsorption increases as soil pH rises. According to Bang and Hesterberg's (2004) assessment of North Carolina's coastal plains, With the lowering of the hydrogen function under 4.1-4 for Cu-

Pb and 5.2-4.6 for the element Zn, the solubility of the elements (Zn, Pb, Cu) rises. They also confirmed that as the hydrogen function is reduced toward acidity, the solubility of the elements increases. The pH range of the majority of natural soils is 4.5 to 8.5. (Pye, 2007). Due to the presence of calcium carbonate, magnesium salts, and sodium, the pH values of the surface soil samples used in **this investigation ranged from 7.4 to 8.5,** suggesting alkaline soil. The alkalis soils are located in the dry region of the planet and are found in lowlands or irrigated areas where the pH rises to 9.5 on the surface (Hesse, 1971). (table 5.1).

### 5.2.2 Electrical conductivity (EC)

The amount of moisture held by soil particles has an impact on the electrical conductivity of the soil. Sands have a low conductivity, compared to clays, which have a high conductivity. As a result, EC substantially corresponds with soil particle size and texture (Grisso et al., 2009). Surface soil samples' EC values ranged from 315 to 7310 c/cm, with a mean value of 2332.5 c/cm, as shown in (Table 5.1).

The amount of moisture held by soil particles has an impact on the electrical conductivity of the soil. Sands have a low conductivity, compared to clays, which have a high conductivity. As a result, EC substantially corresponds with soil particle size and texture (Grisso et al., 2009). Surface soil samples' EC values ranged from 12.65 to 65.5 c/cm, with a mean value of 35.362 c/cm, as shown in (Table 5.1).

Table (5.1) pH-EC parameters of soil samples.

| Soil sample | PH | EC(ds/cm) |
|---|---|---|
| 1 | 8 | 28.1 |
| 2 | 7.5 | 22.3 |
| 3 | 7.6 | 14.57 |
| 4 | 8.5 | 62.8 |
| 5 | 7.4 | 65.5 |
| 6 | 7.6 | 12.65 |
| 7 | 7.7 | 19.9 |
| 8 | 7.5 | 42.4 |
| 9 | 8.1 | 50 |
| 10 | 8.1 | 35.4 |
| Rang | 7.4-8.5 | 12.65-65.5 |
| Mean | 7.8 | 35.362 |

### 5.3.1 Calcium Carbonate

Carbonate minerals are among the most important soil components that play an important role in the development of soils in arid and semi-arid regions. They are found in the form of primary carbonate and secondary carbonate, and the latter is divided into pedogenic carbonate and uthigenic carbonate (Arnaud and Sudom, 1981; Khademi and Mermut, 1999). Khormali et al., 2006).

The source of calcium carbonate in the depth of the soil could be the result of wind deposition or weathering of carbonate-rich minerals, as well as the local redistribution of carbonate-rich water in low topographical locations to high, dry locations by capillary movement as a result of the nature of the prevailing climatic conditions (Netteton et al., 1990; Khresat 2001; Al-Husseini, 2005).

It is noted from the above table that the highest value of calcium carbonate was in S7 with a value of 46.8 and the lowest was in S3 with a value of 43.2.

### 5.3.2 Organic Matter

Organic matter: It is the remains of the decomposition of the dead bodies of plants and animals that live in the soil and on its surface, and the dung of living animals, which are the products of the dissolution of these materials through life processes, physical and chemical, for a long period of time, as well as the remains of agricultural crops such as roots, stems, leaves, green manure crops, and industrial organic fertilizers Which is made from crop residues, dead cells of microorganisms, and urea-fortified fertilizers (Ibrahim, Al-Shalash, 1976), and there are organic substances that are included in the composition of organic nutrients such as carbon, hydrogen, nitrogen, oxygen, phosphorus, sulfur, and other nutrients (Mahout, 1953). Its availability indicates a good soil structure (Al-Salem,1989), in addition to that the organic matter affects other physical properties in the soil such as increasing its ability to retain water and maintains soil heat and determines the ketone exchange capacity (Khaled, 1973).

It is noted from the above Table(5.2) that the highest value of organic matter was in S1 with a value of 12.153 and the lowest was in S7 with a value of 2.412.

### 5.3.3 Sulfites

One of the common elements in the crust of the earth is sulfate, and in the evening, its concentration varies from a few milligrams to several thousand milligrams per liter (1998, APIA). due to rainfall, gypsum, sodium sulfate, and certain rocks (Al-Eisi, 2009). Sulfate bonds paired with positive ions are one of the most prevalent ways that sulfur can be discovered in natural waterways. And magnesium, which is one of the components that produces salt, imparts a salty flavor to water when its content is greater than (200) mg/liter (Abbawi Rahman, 1990).It is noted from the above table that the

highest value of sulfate was in S5 with a value of 13.179 and the lowest was in S3 with a value of 0.13. While the gypsum had the highest value at S5 which amounted to 28.336 and the lowest value was at S3 with a value of 0.28.

Table (5.2) showing chemical analysis of soil sample in study area

| Soil sample | $CaCO_3$% | O.M | $SO_3$% | Gypsum% |
|---|---|---|---|---|
| **S1** | 45.8 | 12.153 | 2.948 | 6.338 |
| **S2** | 46.4 | 11.457 | 2.617 | 5.627 |
| **S3** | 43.2 | 5.226 | 0.13 | 0.28 |
| **S4** | 46.4 | 5.427 | 12.847 | 27.621 |
| **S5** | 45.8 | 3.417 | 13.179 | 28.336 |
| **S6** | 45.8 | 5.628 | 3.237 | 6.961 |
| **S7** | 46.8 | 2.412 | 0.708 | 1.523 |
| **S8** | 45 | 4.422 | 2.459 | 5.287 |
| **S9** | 46 | 4.221 | 2.087 | 6.637 |
| **S10** | 46.6 | 3.613 | 4.255 | 9.148 |

## 5.4 Heavy metals

The presence of heavy metals in soil serves as an indicator of environmental pollution (Hodges, 1973). Elevated levels of specific trace elements in the soil can result in diseases, as seen with high concentrations of lead found in the soil (Hodges, 1973). Conversely, deficiencies of certain components in the soil can also pose problems. For example, inadequate levels of manganese and copper in the soil have been associated with heart disease (Keller, 1976). The accumulation of heavy metals in soil signifies environmental pollution, and these pollutants can subsequently enter the food chain, leading to various diseases in humans. Industrial, domestic, and agricultural activities contribute to the production of these substances, which then enter water bodies through runoff (Forstner and Wittemann, 1981; Netkim et al., 1992).

Research indicates that the processes responsible for soil formation result in heterogeneity in the composition of constituent rocks, leading to variations

in the proportions of elements within the soil (Al_ Sultany, 2006). Soil pollution occurs due to increased concentrations of components, particularly trace elements. Several factors influence the distribution of heavy elements in sediments, including the chemical nature of the element, its physical properties, the presence of clay minerals (which adsorb elements and act as filters), the presence of organic matter (which aids in element chelation), and the soil's ecological pH (ec-pH) (Al_ Sultany, 2006). Additionally, regions with low rainfall and arid climates, as well as areas with stable chelation of metals, contribute to this phenomenon.

Table (5.3) provides a comparison of surface concentrations of heavy metals, measured in parts per million (ppm), with global and local guidelines and standards. This analysis offers valuable insights into the levels of heavy metals and the factors influencing their distribution in soil (Al-Sultany, 2006).

Table 5.3: concentration Heavy metals in soil sample at ppm

| St | Mn | Fe | Co | Ni | Cu | Zn | As | Sr | Zr | pb | Th |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **S1** | 580 | 25300 | 180 | 210 | 30 | 100 | 10 | 520 | 100 | 10 | 10 |
| **S2** | 530 | 25100 | 150 | 180 | 30 | 90 | 10 | 630 | 100 | 10 | 0 |
| **S3** | 670 | 28600 | 120 | 220 | 40 | 70 | 10 | 370 | 90 | 10 | 10 |
| **S4** | 580 | 27900 | 210 | 170 | 30 | 70 | 10 | 350 | 100 | 10 | 10 |
| **S5** | 630 | 29300 | 230 | 180 | 50 | 70 | 10 | 450 | 100 | 20 | 10 |
| **S6** | 600 | 23000 | 120 | 180 | 30 | 70 | 10 | 510 | …. | 10 | 10 |
| **S7** | 490 | 22500 | 150 | 180 | 40 | 70 | 10 | 340 | 110 | 10 | 0 |
| **S8** | 670 | 30300 | 180 | 210 | 40 | 70 | 10 | 410 | 100 | 10 | 10 |
| **S9** | 560 | 26000 | 130 | 180 | 30 | 70 | 10 | 350 | 80 | 10 | 0 |
| **S10** | 470 | 23300 | 120 | 160 | 30 | 70 | 0 | 690 | 80 | 10 | 0 |
| **S11** | 450 | 19400 | 100 | 130 | 20 | 70 | 0 | 320 | 100 | 10 | 10 |
| **S12** | 450 | 18900 | 80 | 130 | 30 | 130 | 10 | 660 | 90 | 20 | 0 |
| **S13** | 480 | 19500 | 80 | 170 | 30 | 70 | 10 | 460 | 80 | 10 | 10 |
| **S14** | 560 | 25700 | 250 | 150 | 40 | 70 | 10 | …. | 80 | 10 | 10 |
| **S15** | 620 | 27500 | 240 | 170 | 40 | 80 | 10 | 330 | 90 | 10 | 10 |
| **S16** | 620 | 28700 | 270 | 180 | 40 | 80 | 10 | 280 | …. | 20 | 10 |
| **S17** | 600 | 27300 | 150 | 190 | 30 | 80 | 10 | 270 | 100 | 10 | 10 |
| **S18** | 400 | 17700 | 100 | 140 | 20 | 70 | 0 | 430 | 80 | 10 | 10 |
| **S19** | 610 | 24900 | 150 | 220 | 30 | 70 | 10 | 350 | 90 | 20 | 10 |
| **S20** | 390 | 17600 | 120 | 130 | 30 | 50 | 10 | 340 | 70 | 10 | 0 |
| **Max** | 670 | 30300 | 270 | 220 | 50 | 130 | 10 | 690 | 110 | 20 | 10 |
| **Min** | 390 | 17600 | 80 | 130 | 20 | 50 | 0 | 270 | 70 | 10 | 0 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mean** | 548.00 | 24425.0 | 156.50 | 174 | 33 | 76 | 8.50 | 424.21 | 91.1 | 12. | 7 |
| **WHO, 2006** | | | | 30-75 | 50-140 | | | | | 50-300 | |
| ***Kabata-Pendias and Mukherjee, 2007** | | | 6.9 | 56 | 14 | | | | | 25 | |
| **Al_ Sultany, 2006** | | | 12.6 | 174.6 | 29.4 | | | | | 62.3 | |
| **Kirkuk Ali, L. A. A. (2013).** | | | | 38.1 | 6.6 | | | | | 10 | |
| **al-Maliky, 2005** | | ……. | | 111.4 | 91.9 | | | | | 153.7 | |
| **upper continental crust,Rudnick, R.L. and Gao, S. (2003)** | 950 | 56000 | 25 | 84 | 55 | 67 | 4.8 | 320 | 165 | 13 | 10.5 |

### 5.4.1 Manganese (Mn)

Manganese (Mn) is an essential micronutrient for plant growth and development, comprising approximately 0.08% of the earth's crust (Awad, 1987). It exists in various forms and three oxidation states, with divalent manganese ($Mn^{2+}$) being the most important form in soil. Divalent manganese is adsorbed onto the surfaces of clay minerals and organic matter, while manganese oxides contain both divalent and trivalent forms ($Mn^{3+}$, $Mn^{2+}$) that are highly stable. In alkaline soils with a pH higher than 8, the concentration of tetravalent manganese ($Mn^{4+}$) increases, and these oxides exhibit stability. These forms are not separate entities but undergo permanent transformations from one form to another based on oxidation and reduction processes influenced by soil acidity, organic matter content, microbial activity, and soil moisture (Al-Nuaimi, 2000).

Several factors, including pH and organic matter, affect manganese availability. Plants require only small amounts of readily available manganese, as high quantities can be toxic. Manganese availability increases as pH decreases, and in the pH range of 6-7, it prevents the excessive accumulation and aggregation of readily available manganese, thus avoiding toxicity. Acidic soils have high manganese availability due to the dissolution of manganese compounds under low pH conditions. The availability of manganese decreases in soils with high lime content, as high pH in lime soils leads to the adsorption of manganese onto carbonate mineral surfaces (Ahangar et al., 1995; Joshi and Dhir, 1983).

From the aforementioned Table(5.3), it can be observed that the highest manganese value (Mn) was recorded in samples S3 and S8, with a concentration of 670 ppm, while the lowest value was found in sample S20, with a concentration of 390 ppm Bottom of Form

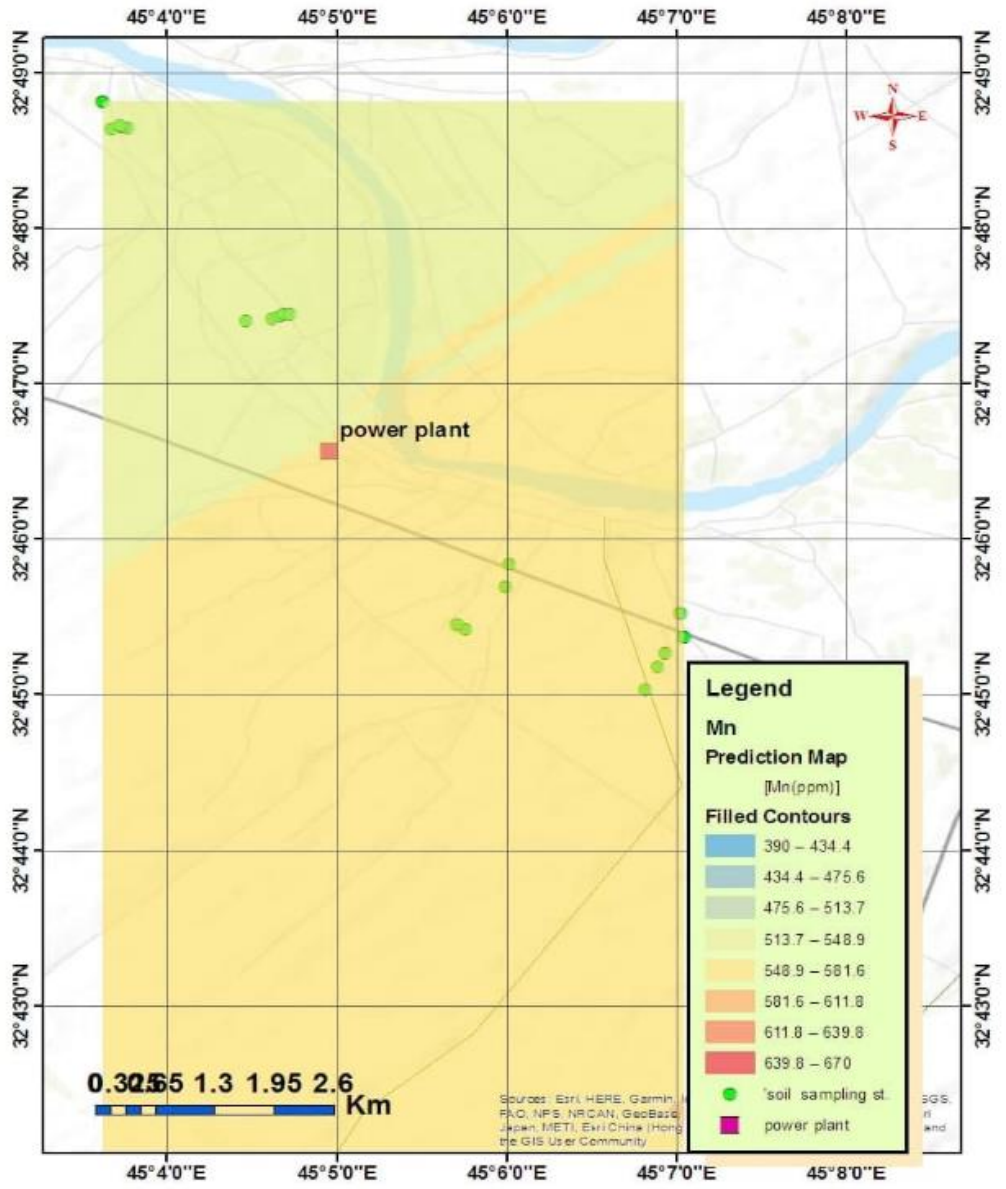



**Figure (5.1):** GIS Map showing geographical Distribution of Manganese (Mn)

### 5.4.2 Iron (Fe)

Iron occupies the fourth place after oxygen, silicon, and aluminum in terms of its abundance in the earth's crust, or its presence in it in the form of oxides, hydroxides and phosphates is 4.2%. Iron content ranges from 0.42% in sandy soils and to more than 5.58% in clay soils. The most important iron minerals are hematite ($Fe_2O_3$), machnite ($Fe_3O_4$), siderite ($FeCO_3$), pyrite $FeS_2$, limonite ($Fe_60_3.3H_2O$), and goethite FeOOH is one of the most important iron minerals in the soil. The total iron content of the soil is between -100,000 - 200 mg kg' (Sauchelli, V., 1969.).There are several factors that affect the readiness of the iron element, including the oxidation and reduction effort (Redox Potential), which controls the nature of the forms of iron ions and its dissolution in the soil, as the ferric ion is reduced to iron under wet conditions, which increases its readiness for plants and vice versa (Hassan et al., 1990), as well as the The chemical properties of soil, such as the presence of high proportions of lime, have an effect on iron availability (Al-Malik, 1986), and many studies have shown that the iron ion is under the control of other factors, including the degree of interaction (pH), the concentration of bicarbonate ions in the soil solution, the amount of irrigation water, and the availability of other elements. Such as phosphorous, copper, manganese, molybdenum, fedium and zinc (Al Rayes, 1982 and Jawad, 1988).

It is noted from the above table that the highest value of (Fe) was in S8 with a value of 30300ppm and the lowest was in S20 with a value of 17600ppm.

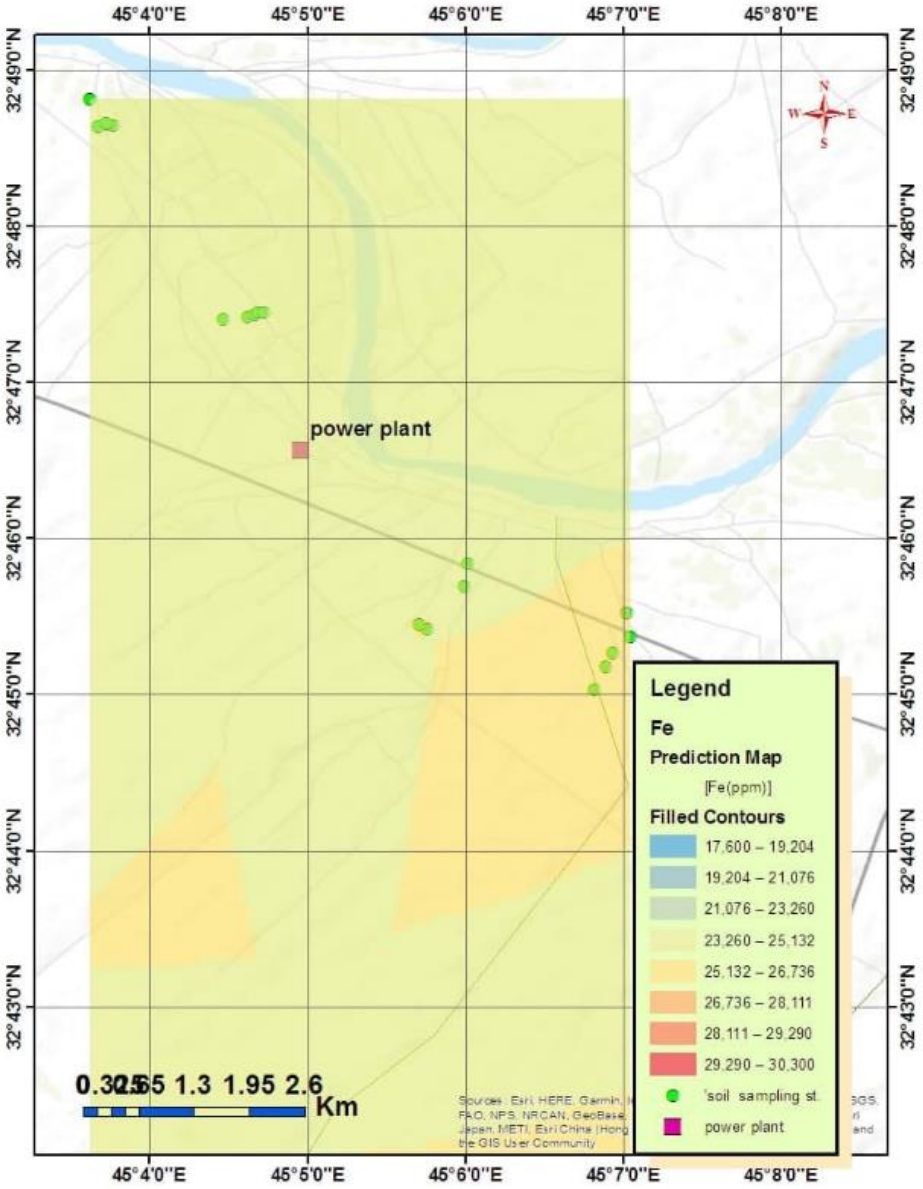



Figure (5.2): GIS Map showing geographical Distribution of Iron (Fe)

### 5.4.3 Cobalt (Co)

Cobalt (Co) in soils is primarily inherited from parent materials. Cobalt average values in surface soils around the world range from 4.5 to 12 (mg/kg), with organic soils and heavy loamy soils having the greatest average values and light sandy soils having the lowest average values Kabata-Pendias and Mukherjee (2007), with a mean value of 8.55 (ppm), cobalt concentrations in the investigated soils ranged from 1.43 (ppm) at S14 to 14.4

ppm at S1 (Table 5.3). It was higher than (Kabata, 2007) permitted limits. The elevated cobalt levels in the surface soil (Figure 5.3) are linked to agricultural practices and fuel burning (phosphate fertilizer). It is noted from the above table that the highest value of (Co) was in S16 with a value of 270 ppm and the lowest was in S12, S13 with a value of 80 ppm.

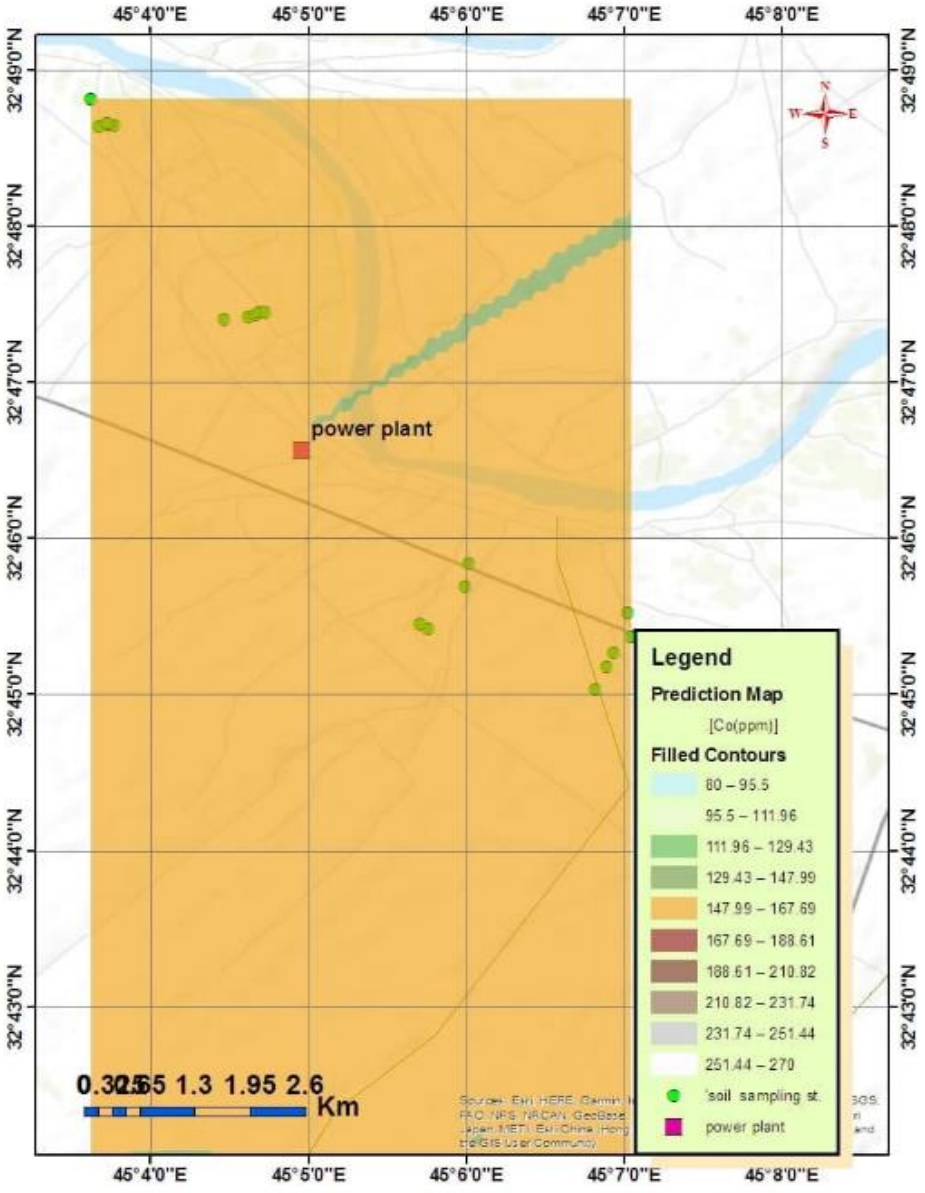



**Figure (5.3)** GIS Map showing geographical Distribution of Cobalt (Co)

### 5.4.4 Nickel (Ni)

Fe and Mn oxides have a high correlation with soil nickel (Ni). Additionally, clay minerals, especially montmorillonite, have a strong tendency to bind this metal (Dahn et al. 2003). Swedish arable soils have an average Ni concentration of 13 mg/kg, while loamy soils in Poland have an average Ni content of 18 mg/kg and Russian soils have an average Ni content of 28 to 34 mg/kg (Kabata-Pendias and Mukherjee, 2007). Ni values ranged from 108.7 ppm at S10 to 196.5 ppm at S15, with a mean value of 150.24 ppm between the two (Table 5.4). The regional distribution of elevated Ni contents (Figure 5.4) may be connected to agricultural operations and oil combustion (phosphate fertilizer). (Kabata-Pendias and Mukherjee, 2007).

It is noted from the above Table(5.3) that the highest value of Ni was in S3, and S19 with a value of 220 and the lowest was in S11 and S12 with a value of 130.

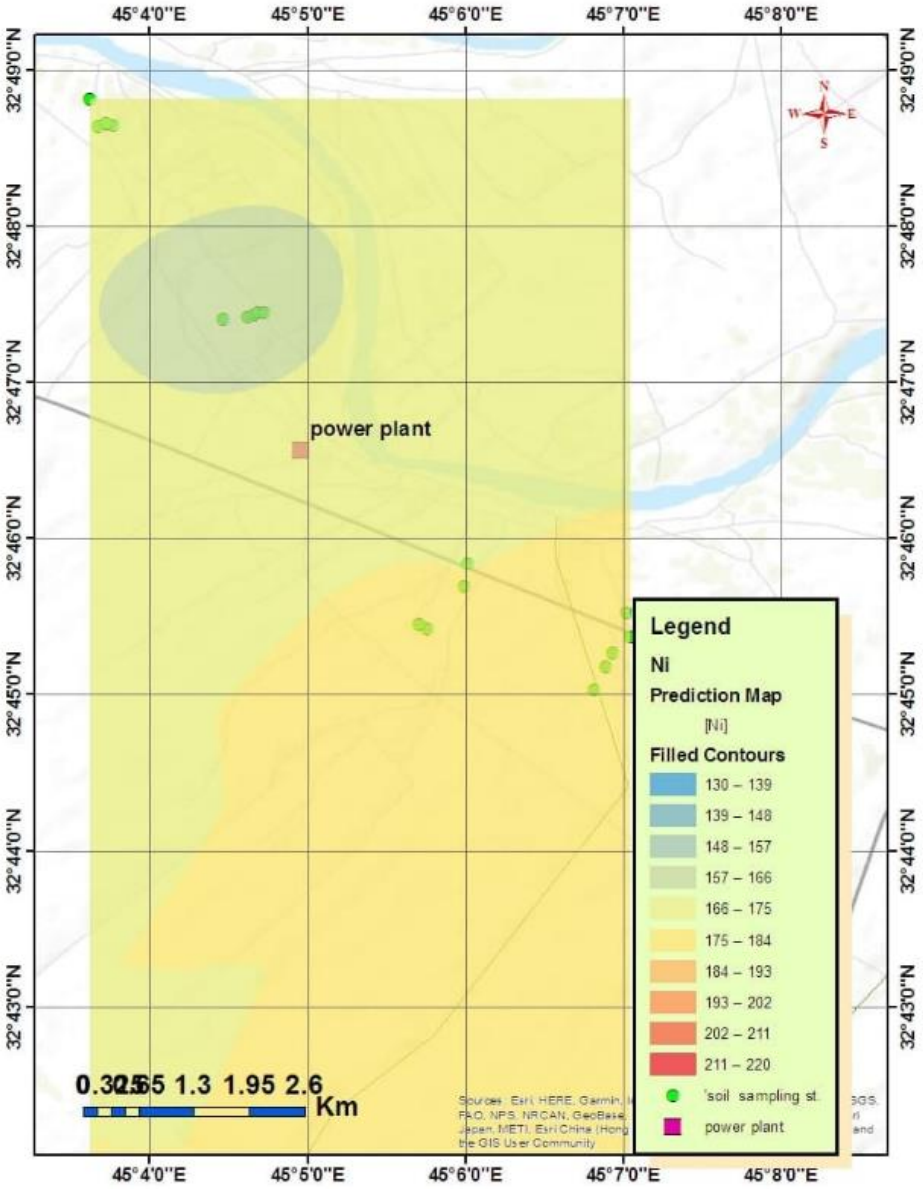



**Figure (5.4)** GIS Map showing geographical Distribution of Nickel (Ni)

### 5.4.5 Lead (Pb)

Parent rocks are the source of the natural Lead (Pb) content in soils. Its abundance in sediments depends on the amount of clay present, so argillaceous sediments have higher Pb contents than sands, sandstones, and limestones. Increased Pb contents in calcareous soils and organic soils have also been reported. Lead is not distributed uniformly in soil horizons and exhibits a strong association with hydroxides, particularly those of Fe and

Mn. Fe-Mn nodules and concretions may contain quantities of up to 20,000 mg.kg-1 of it (Kabata-Pendias and Sadurski, 2004). Additionally, it could be contained in phosphate or carbonate particles. Lead typically accumulates close to the soil surface, mostly as a result of soil organic matter (SOM) sorption. Pb mobilization is typically sluggish, but some soil characteristics, such increased acidity and the production of Pb organic compounds, may make Pb more soluble. Lead that has been desorbed into the soil solution may easily migrate from the upper to lower layers, causing groundwater poisoning (Alumaa et al., 2002). Table (5.3) shows that the highest lead element concentration in the soil was at site S1 51.085 ppm, while the lowest lead element concentration was at site S4 18.625 ppm, with a mean of 31.99 ppm. Note that both of these lead element concentrations were below the WHO limit (Table 5.4).

It is noted from the above Table(5.3) that the value of (Pb) was in (10) in most of the samples and the highest was in S5, S12, S16, and S19 with a value of 20.

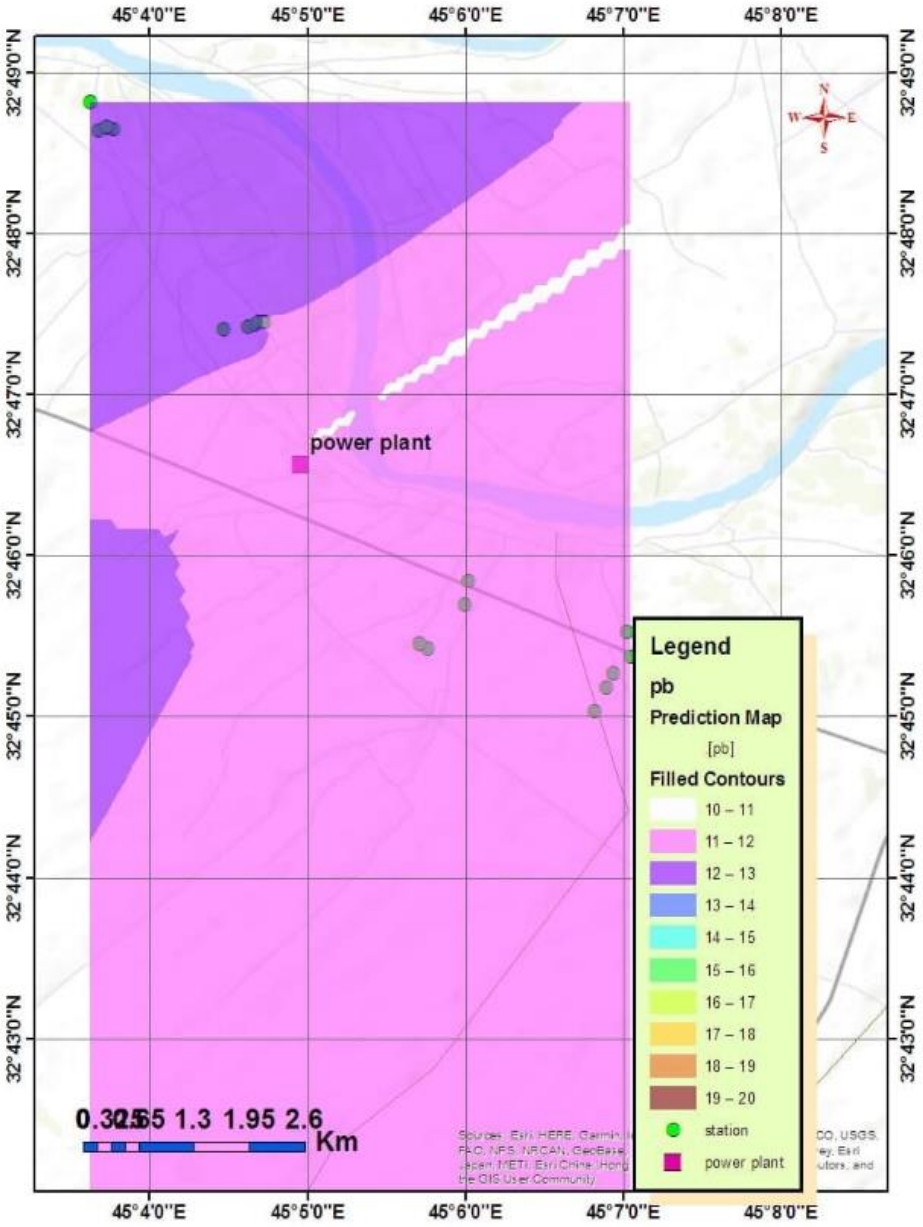



**Figure (5.5)** GIS Map showing geographical Distribution of Lead (Pb)

### 5.4.6 Copper (Cu)

According to reports, the average total copper (Cu) level in soils of all types typically ranges between 20 and 30 (mg/kg) (Alloway, 1995). Increased Cu levels in agricultural soils have been caused by a number of important sources, including fertilizers, sewage sludge, manures, agrochemicals, petroleum refineries, industrial by-product wastes, and the quality of irrigation flows (Kabata-Pendias and Mukherjee, 2007). Cu values ranged

from 8.345 ppm at S11 to 49.545 ppm at S19, with a mean value of 26.96 ppm between the two (Table 5.3). In comparison to other research, the mean copper content of surface soil is higher (Figure 5.6). It is noted from the above table that the highest value of Cu was in S5 with a value of 50 and the lowest was in S11, and S18 with a value of 20.

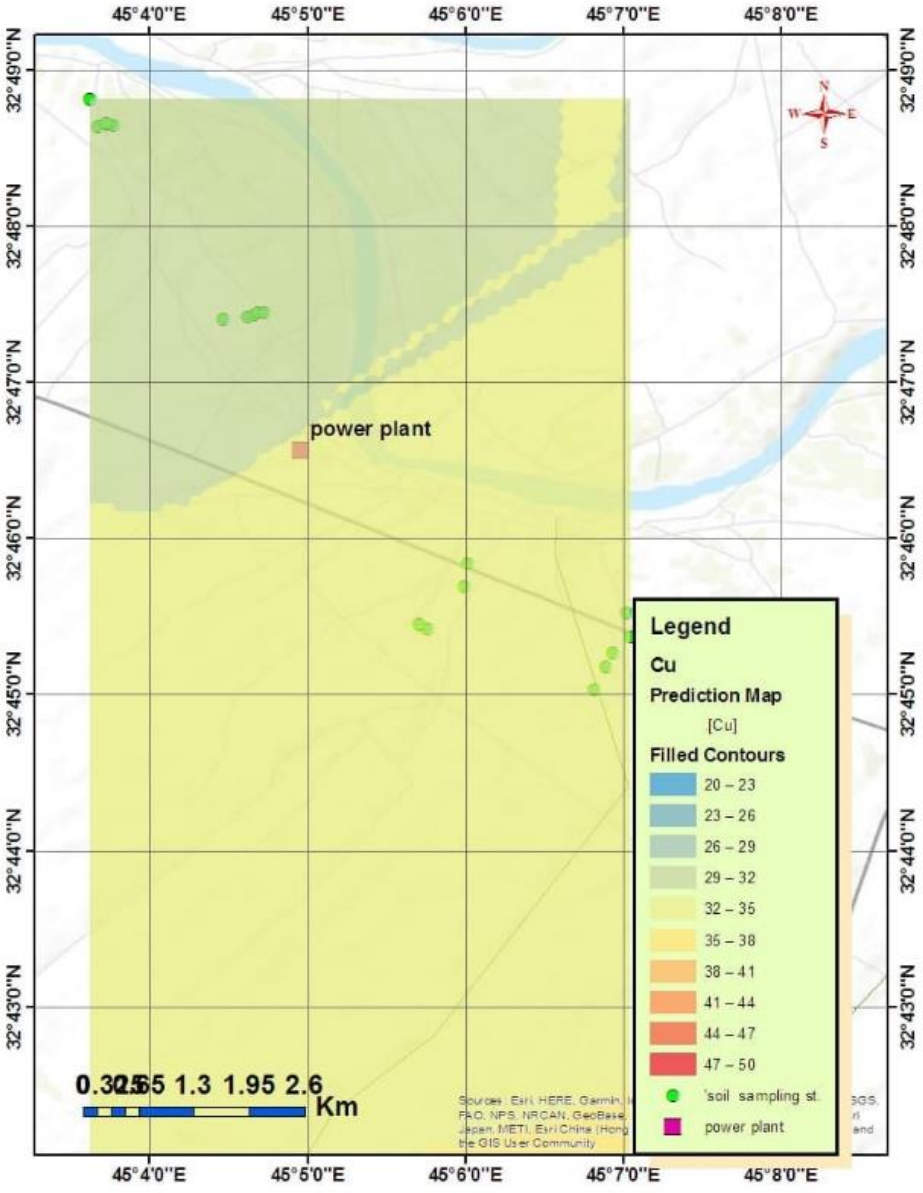



**Figure (5.6)** GIS Map showing geographical Distribution of Copper (Cu)

### 5.4.7 Zinc (Zn)

According to Kabata and Pendiase (2011), the average zinc content of the Earth's crust and world soil is 70 mg.kg-1. Zinc is commonly found in minerals such as Zincite ZnO, warzitep Zns, and sphaleirte ZnCO.

Research by Huang and Jin (2008) has shown that agricultural operations can increase the zinc content of surface soils, with little difference in zinc content between agricultural soils and greenhouse soils. The zinc content in these soils ranged between 57-82 mg.kg-1.

The presence of zinc in soil is determined by factors such as parent material, soil formation processes, and chelating material. The clay fraction, particularly when it contains gibbsite and vermiculite, has a significant impact on soil zinc content (Kuupien et al., 2008). Zinc in soil is present in various forms, including free and complex ions $Zn^{2+}$ and the cationic formula $ZnOH^{+}$, $ZHCO^{+}$, $ZnCl^{+}$, and the anionic formula $ZnO^{2-}$, $Zn(OH)_3^{-}$, $ZnCl^{-}$ (Kabata-Pendiace and Sadurski, 2004).

The highest value of zinc 130 mg.kg-1 was found in S12, while the lowest value 50 mg.kg-1 was found in S20.

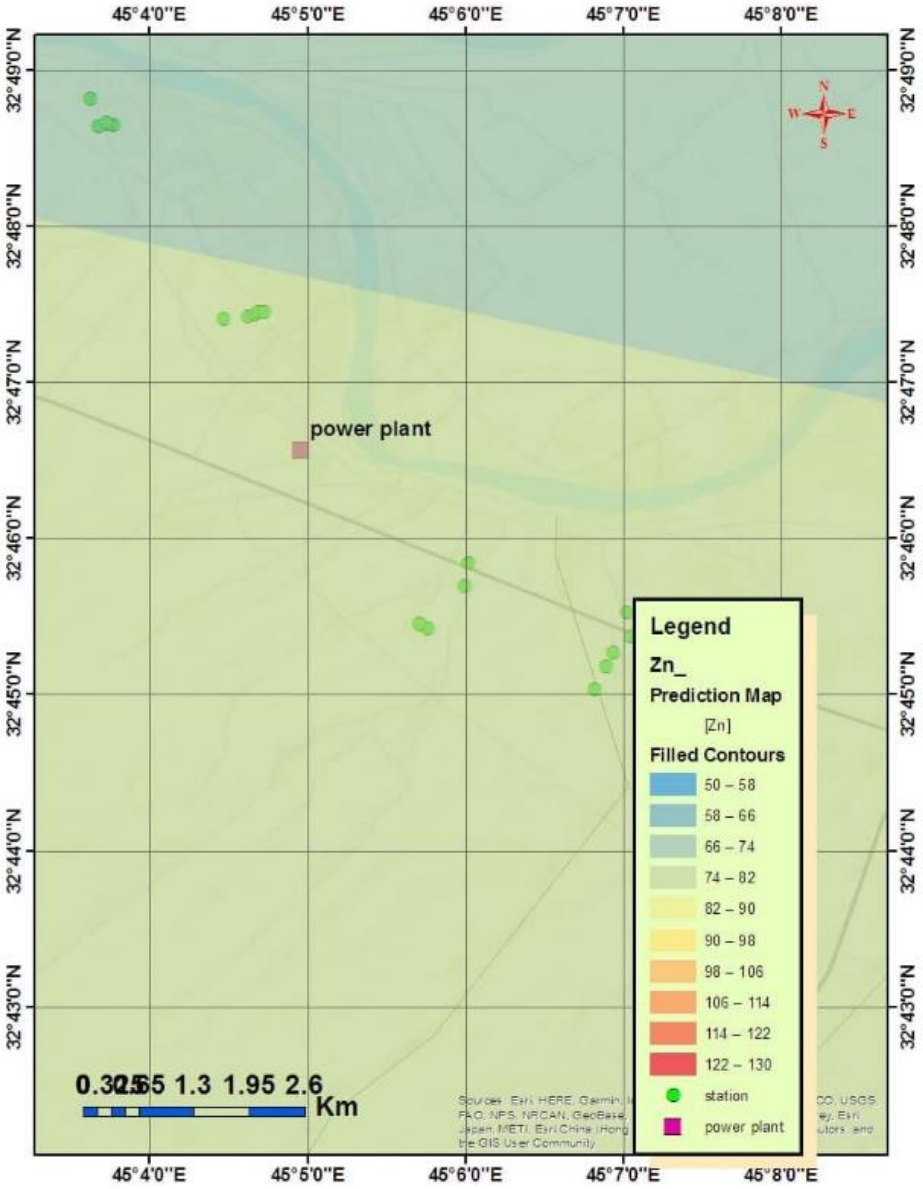



**Figure (5.7)** GIS Map showing geographical Distribution of Zinc (Zn)

### 5.4.8 Arsenic (As)

Element 33, arsenic, has a lengthy and sinister history; the word "arsenic" has come to mean "poison." The Borgia dynasty of Italy utilized arsenic as their preferred poison for political killings in the 15th and 16th century. Some people even claim that the arsenic-laced wine that was provided to Napoleon while he was in exile caused his death. The National Poisoning Data System (NPDS) of the American Association of Poison Control Centers (AAPCC)

reports that in 2015, exposure to non-pesticide arsenic resulted in the deaths of 1 patient and significant effects in 3 others. On the other hand, industrial effluent causes tens of thousands of people to suffer from the deadly effects of arsenicals in numerous nations worldwide. Arsenic, a natural component of the human body, is delivered to various organs by the blood (Rasheed, Slack and Kay, 2016).

It is noted from the above Table(5.3) that the value of As was in 10 in most of the samples and the least was in S10, S11, S18 with a value of 0.

### 5.4.9 Strontium (Sr)

Strontium is a chemical element in the periodic table, with atomic number 38. It is an alkaline-earth metal (bigenc.ru, 2019). Strontium is found in the minerals celestite and strontium and combines immediately with oxygen, nitrogen and hydrogen. Strontium nitrite ($Sr[NO_3]^2$) burns with a crimson flame, and is used in flashing lights and display crackers. It was discovered by Adair Crawford of Ireland in 1790 (Murray, 1977). Strontium is an alkaline earth metal. Strontium is a soft, silvery-white metallic element that is highly chemically reactive. The metal forms a dark oxide layer when exposed to air. Strontium has physical and chemical properties similar to those of its vertical neighbors in the periodic table, calcium and barium. It is found naturally in the minerals celestine and strontianite, and is mostly extracted from these minerals (Ropp, 2012).

It is noted from the above Table(5.3) that the highest value of Sr was in S10 with a value of 690 and the lowest was in S17 with a value of 270.

### 5.4.10 Zirconium (Zr)

Zirconium is widely distributed in nature. The principal ores are zircon ($ZrO_2.SiO_2$) and elipidite ($Na_2ZrSi_6O15.3H_2O$). Many different methods, such

as: ion selective electrode (Arid, 2008), inductively coupled plasma isotope dilution-mass spectrometry (ICPIDMS) (Dimer and Heumann,1999), high performance liquid chromatography (HPLC) (Xin and Xianzhong, 2004), stripping voltammetry (Domenech-Carbo et al., 2004) (Li et al.,2007).

It is noted from the above Table(5.3) that the highest value of Zr was in S7 with a value of 110 and the lowest was in S20 with a value of 70.

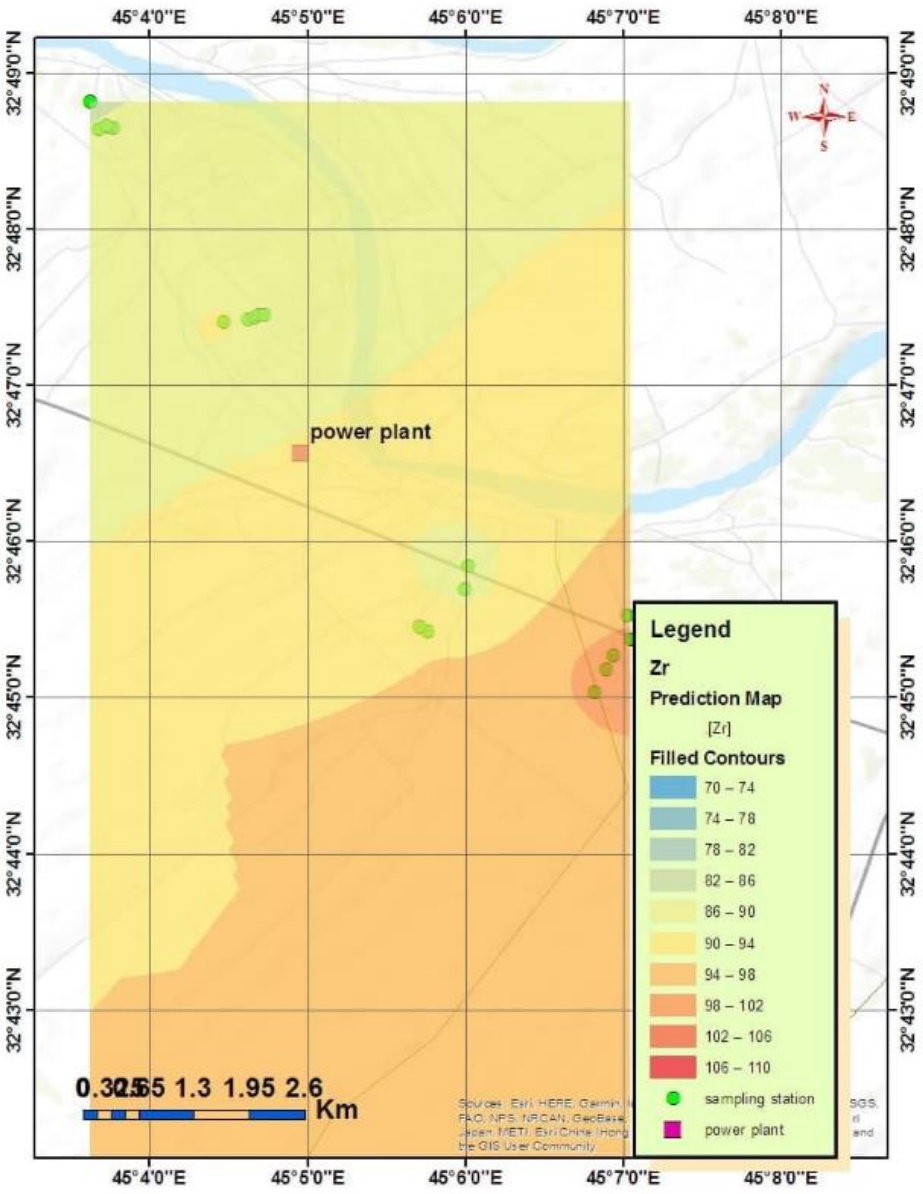



**Figure (5.8)** GIS Map showing geographical Distribution of Zirconium (Zr)

### 5.4.11 Thorium (Th)

Thorium is a chemical element of the periodic table and has the symbol Th, and the atomic number is 90. Since it is a metal with slight radioactivity, and it is found naturally, it is one of the alternative nuclear fuels to uranium. Thorium is present in trace amounts in most rocks and soils, but it is present three times more than uranium, and is present in an amount equal to that of lead. Soils generally contain an average of 6 parts per million (ppm) thorium. Thorium is present in several minerals, the most famous of which is monazite, which contains approximately 12% of thorium oxide. There is a natural stock of this mineral in many countries. 232Th decays very slowly (its half-life is about three times that of Earth), but there are other isotopes of thorium produced from the serial decay of uranium. Most of them have a short half-life and are radioactive, but they are minuscule when compared to $^{232}$Th. (National Library of Medicine, 2019).

It is noted from the above Table(5.3) that the value of Th was in 10 in most of the samples and the least was in S2, S7, S9, S10, S12, S20 with a value of 0.

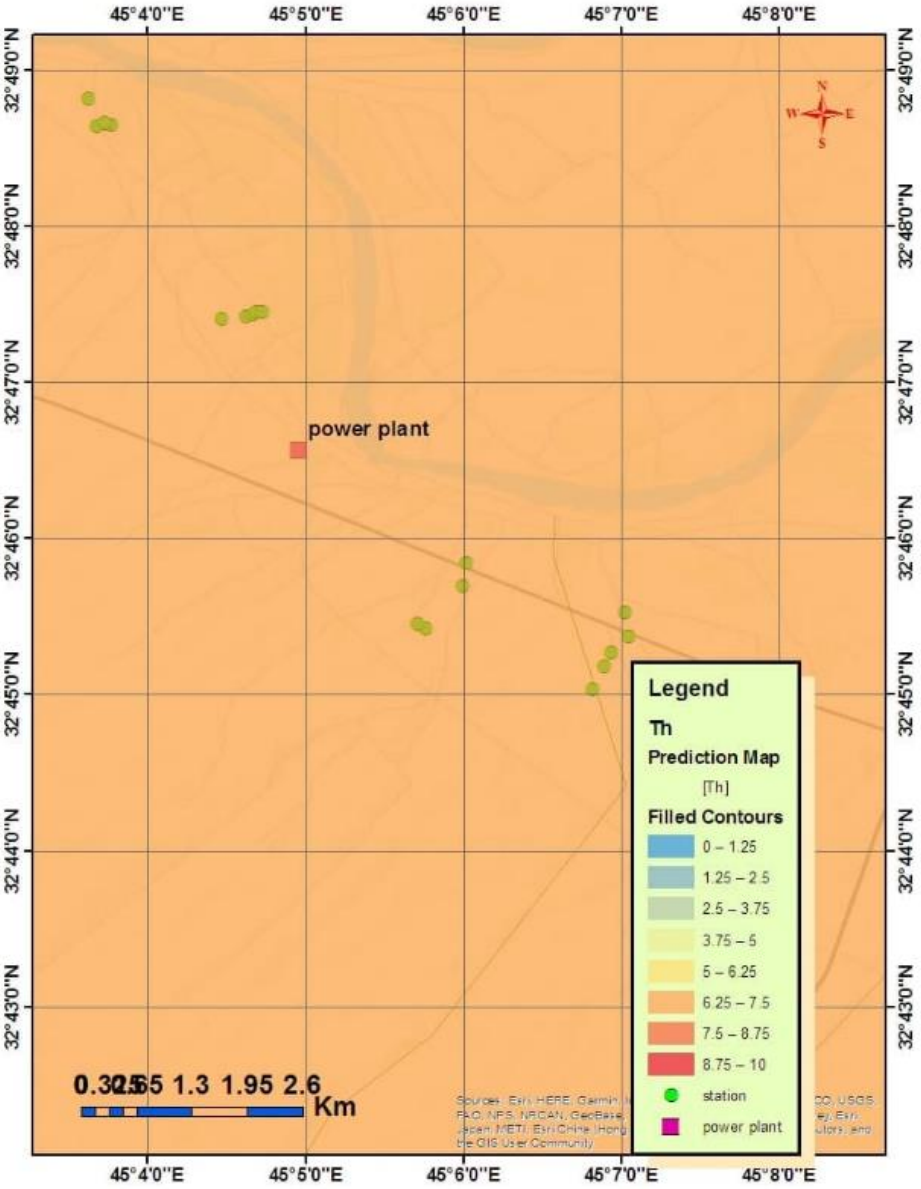



**Figure (5.9)** GIS Map showing geographical Distribution of Thorium (Th)

## 5.5. Measurements Depends

The accuracy of the measurements depends on a variety of factors, such as the quality and method used for conducting the analysis, the devices and tools used in the analysis, the extent of their consumption and for the anomaly, the extent to which the devices are contaminated with other components of previous solutions, the chemicals, their purity, their weights, and

concentrations, as well as the person who is the analyst and his experience (Al-sultany,2006)

**- Precision**

The [coefficient of variation] is a measure of the precision of a set of findings relative to the arithmetic mean, and its value is dependent on the analytical method used and the number of sample analyses conducted. Stanton (1966) reported that a confidence level of 68% is associated with a coefficient of variation ranging from 5% to 15%. Analytical precision, as defined by Maxwell (1968), refers to the consistency and agreement of values obtained from repeated measurements of the same sample. The degree of precision is reflected in the closeness of the values to the mathematical mean. Statistical calculation can be used to determine precision, with a standard confidence level of 95% within a range of 5-25%, as reported by Shaw (1969). The [formula for coefficient of variation] can be found in [Table], which provides a summary of precision statistics for the analytical method used in this study. It's important to note that the accuracy of the measurements can vary for different heavy metals. For example, metals like Cu, As, Rb, Zr have a standard deviation of 0.00, indicating no variability in the measurements. On the other hand, metals like Co and Pb have higher standard deviations, suggesting more variability in the measurements.

Overall, these calculations help assess the accuracy and reliability of the measurements, providing insights into the precision of the data obtained for each heavy metal.

$$Precision = \frac{s}{x`} \quad \text{.....5.1}$$

$$S = \sqrt{\frac{\sum \left(X - X`\right)^2}{n-1}} \quad \ldots\ldots\ldots\ldots 5.2$$

Where:

S = standard deviation

X = the concentration for one read

X´= the arithmetic average of readings

n = the number of readings for each sample

* The Precision at 68% is S / X' * 100

* The Precision at 95% is 2S / X' * 100

Table (5.4) Measurements Depends of Heavy metals

| metal | x1 | x2 | x3 | x (average) | stander devotion | p.at 68% | p.at 95% |
|---|---|---|---|---|---|---|---|
| **Fe** | 25700 | 25400 | 25600 | 25566.67 | 152.75 | 0.60 | 1.19 |
| **Co** | 250 | 130 | 90 | 156.67 | 83.27 | 53.15 | 106.30 |
| **Ni** | 150 | 160 | 170 | 160.00 | 10.00 | 6.25 | 12.50 |
| **Cu** | 40 | 40 | 40 | 40.00 | 0.00 | 0.00 | 0.00 |
| **Zn** | 70 | 80 | 70 | 73.33 | 5.77 | 7.87 | 15.75 |
| **As** | 10 | 10 | 10 | 10.00 | 0.00 | 0.00 | 0.00 |
| **Rb** | 50 | 50 | 50 | 50.00 | 0.00 | 0.00 | 0.00 |
| **Sr** | 370 | 360 | 370 | 366.67 | 5.77 | 1.57 | 3.15 |
| **Zr** | 80 | 80 | 80 | 80.00 | 0.00 | 0.00 | 0.00 |
| **Pb** | 10 | 20 | 10 | 13.33 | 5.77 | 43.30 | 86.60 |
| **Mn** | 560 | 530 | 570 | 553.33 | 20.82 | 3.76 | 7.52 |

## 5.6. Analysis of grain size

The texture of soil has a significant impact on its ability to hold and exchange materials in the soil solution, with finer soils having a greater capacity to adsorb cations like lead and nickel compared to coarser soils (Meuser, 2010; van der Perk, 2006). Clay minerals in the soil can adsorb negative and positive ions from water solutions, with some ions being exchanged for others (Grim, 1968). Heavy metals can accumulate on the surface of clay minerals through adsorption and aggregation, or can propagate within the crystalline structure of the minerals, a slow process. Alternatively, heavy metals can precipitate within the internal structure of the clay minerals.

The texture of the soil samples analyzed was determined using the Folk classification (1974), and the results showed that the samples were primarily composed of clay, silt, and a small amount of sand. Based on this classification (Grim, 1968; Folk, 1974).

Table (5.5): Classification of soils of study area on sand-silt-clay

| soil sample | Sand% | Silt% | Clay% | Soil type |
|---|---|---|---|---|
| S1 | 28 | 59.3 | 12.7 | Sandy silt |
| S2 | 51.7 | 42.2 | 6.1 | Silty sand |
| S3 | 32.2 | 54.5 | 13.3 | **Sandy silt** |
| S4 | 28 | 58.1 | 13.9 | Sandy silt |
| S5 | 38.4 | 49.1 | 12.5 | Sandy silt |
| S6 | 26.7 | 53.9 | 19.4 | Sandy silt |
| S7 | 54.8 | 34 | 11.2 | Sandy silt |
| S8 | 28.3 | 52.2 | 19.5 | Silty sand |
| S9 | 30.8 | 59.1 | 10.1 | Sandy silt |
| S10 | 42.7 | 40.1 | 17.2 | Silty sand |

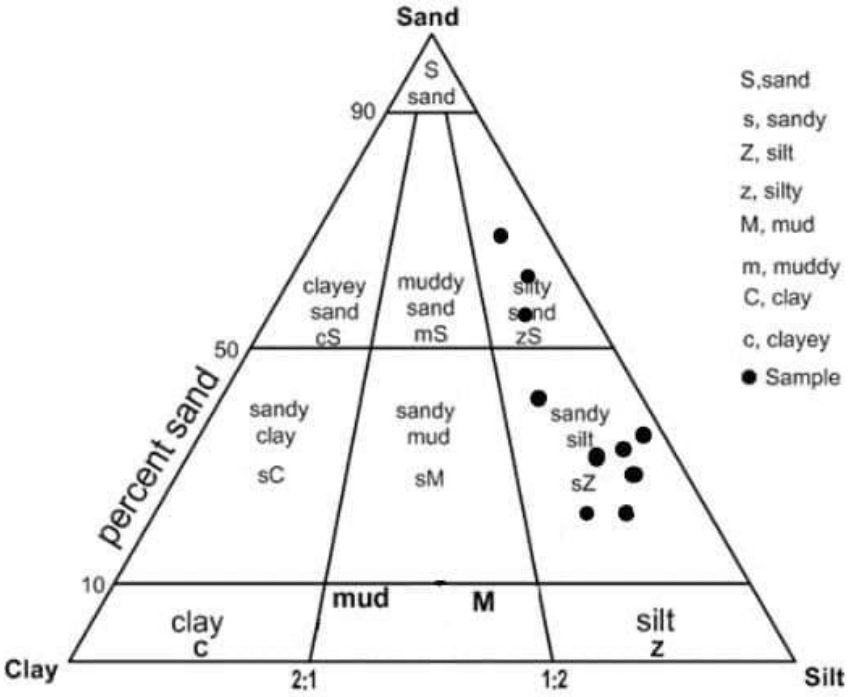



Figure (5.10) soil classification according to Folk classification (1974)

## 5.7 X-ray diffraction pattern

We use of an X-ray diffraction pattern device to obtain x-ray diffraction pages, then diagnose the types of clay minerals, and to confirm the diagnosis, the modern method was used through the diagnostic program designed by the International Society for X-ray Data (ICDD, 2016), and the program is a A database of minerals found in nature, and when the profile of the sample examined in the XRD device is entered into the program, the program will compare the profile with the database, and then perform the diagnosis and determine the percentages of minerals in the sample examined. As Figur 4.1 (a,b,c,d)

### 5.7.1 Clay mineral

**a- Kaolinite**

Kaolinite has various characteristics, including:

A- The (001) plane has a spacing of 7.1 angstroms, while the (002) plane has a spacing of 3.57 angstroms, both of which exhibit a series of reflections.

B- The crystalline structure of kaolinite collapses at 550 degrees, resulting in the loss of its characteristic reflections. However, distinguishing chlorite from kaolinite can be difficult, especially when the fundamental reflections (14) angstrom (100) for chlorite are indistinct. Although chlorite does not show any heating effect, it may experience slight water loss, which enhances the intensity of the reflection. In contrast, when heated to 550, kaolinite loses its crystallinity (Grim, 1968).

**b- Montmorillonite**

Montmorillonite is a common clay mineral belonging to the smectite group. It is known for its expansive properties and ability to swell and shrink with changes in moisture content. Montmorillonite typically exhibits

characteristic alkaline reflections in X-ray diffraction (XRD) patterns, which can be used to identify its presence in a sample (Moore, & Reynolds, Jr. (1997).

The alkaline reflections of montmorillonite are observed at specific 2 Theta angles in XRD analysis. These reflections arise from the spacing between the layers of the mineral's crystal structure. Montmorillonite has a unique crystal structure composed of stacked layers, with water molecules and exchangeable cations located between these layers. The specific 2 Theta angles and d-spacing values for the alkaline reflections of montmorillonite can vary depending on factors such as the composition, degree of hydration, and structural variations within the montmorillonite group. These values are typically found in the low-angle region of XRD patterns, ranging from approximately 5° to 10° (Velde, 1995)

**c- Illit**

The [001] base reflection at 10 can be used to differentiate it, as reported by Thorez in 1976. The negative reflections remain unaffected by the ethylene treatment, while the other reflective series also shows a [002] level at 5 angstroms, which may extend to 9.9 angstroms due to the presence of Montmorillonite. When heated, Montmorillonite loses the water molecules between its layers and intensifies the light's reflection. (Brown, 1961).

Kaolinite is a 1:1 dominant mineral, while Illit is 1:2, but it is not expanded, leading to a reduction in its access to the water table. The access is further restricted by the presence of rare or hazardous elements. The dominant minerals in the soil include Kaolinite, Illit, and the 14A group, which includes minerals such as montmorillonite and chlorite, with a higher montmorillonite ratio than chlorite. A group exhibits a small shoulder, which highlights the

significance of the small amounts of these minerals and their relevance to the brick industry. (Thorez, 1976; Brown, 1961).

**d- chlorite**

Chlorite is a common clay mineral found in various geological settings. It is characterized by its layered structure and typically exhibits basal reflections in X-ray diffraction (XRD) analysis. The basal reflections of chlorite correspond to the spacing between the layers of its crystal structure.

The presence of chlorite can be identified through XRD analysis by observing the characteristic 2-Theta angles associated with its basal reflections. These angles typically fall within the range of 7° to 8°, indicating the presence of chlorite in the sample (Deer et al. 2013).

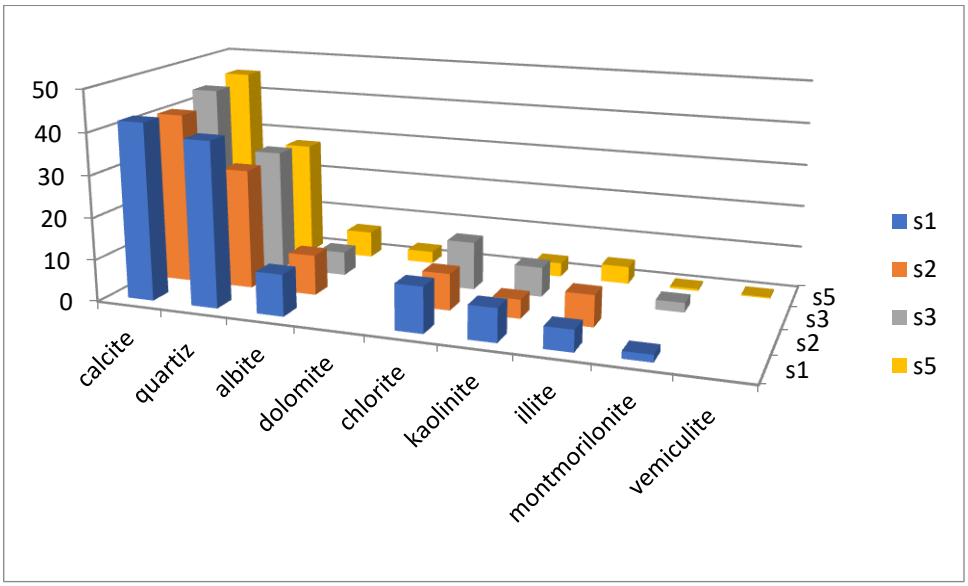



Figure (5-10) The figure illustrates the distribution of minerals in soil samples from four different sites within the study area, as determined by X-ray diffraction analysis. The percentage composition of various minerals in the soil samples is depicted in the graph.

The specific 2 Theta angles and d-spacing values for chlorite can vary depending on factors such as the chemical composition and structural variations within the chlorite group. It's worth noting that chlorite exists in different varieties, such as clinochlore, chamosite, and sudoite, each with

slightly different crystal structures and corresponding XRD pattern (Moore, & Reynolds, (1997).

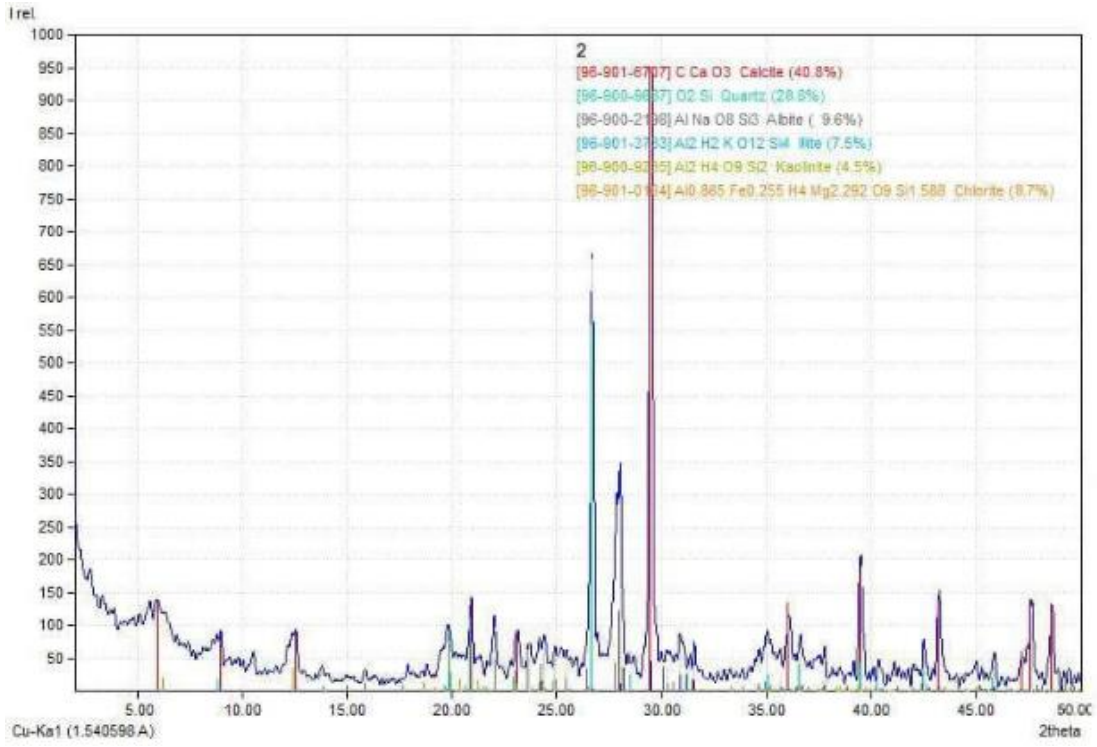



Figure (5.11: A) Determination of Clay Minerals by XRD Scale

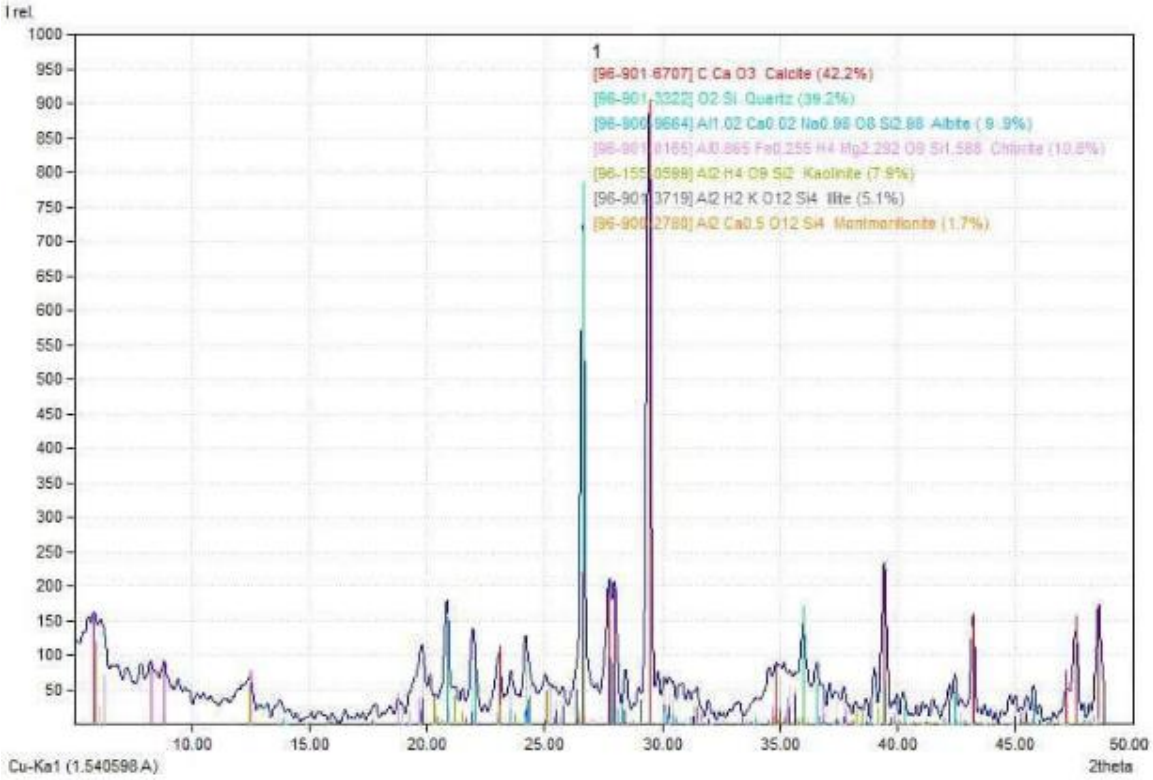



Figure (5.11: B) Determination of Clay Minerals by XRD Scale

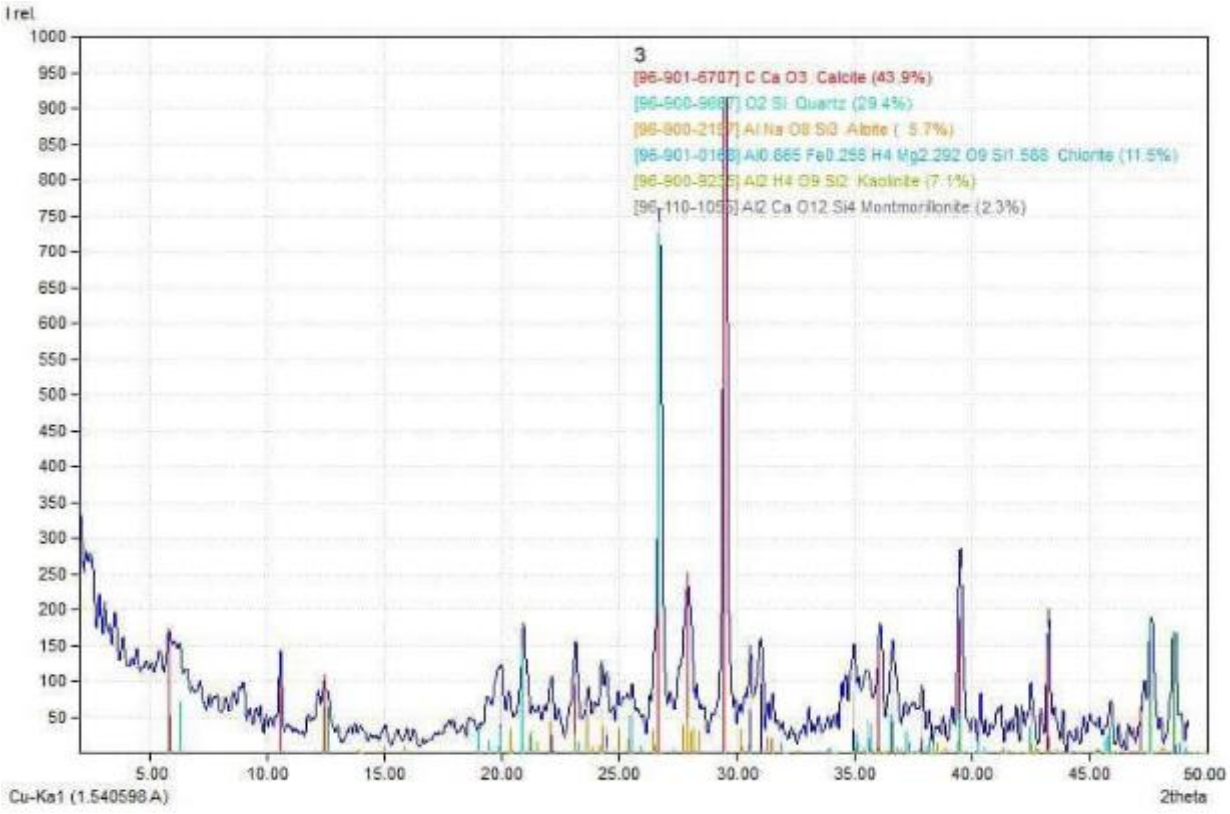



Figure (5.11: C) Determination of Clay Minerals by XRD Scale

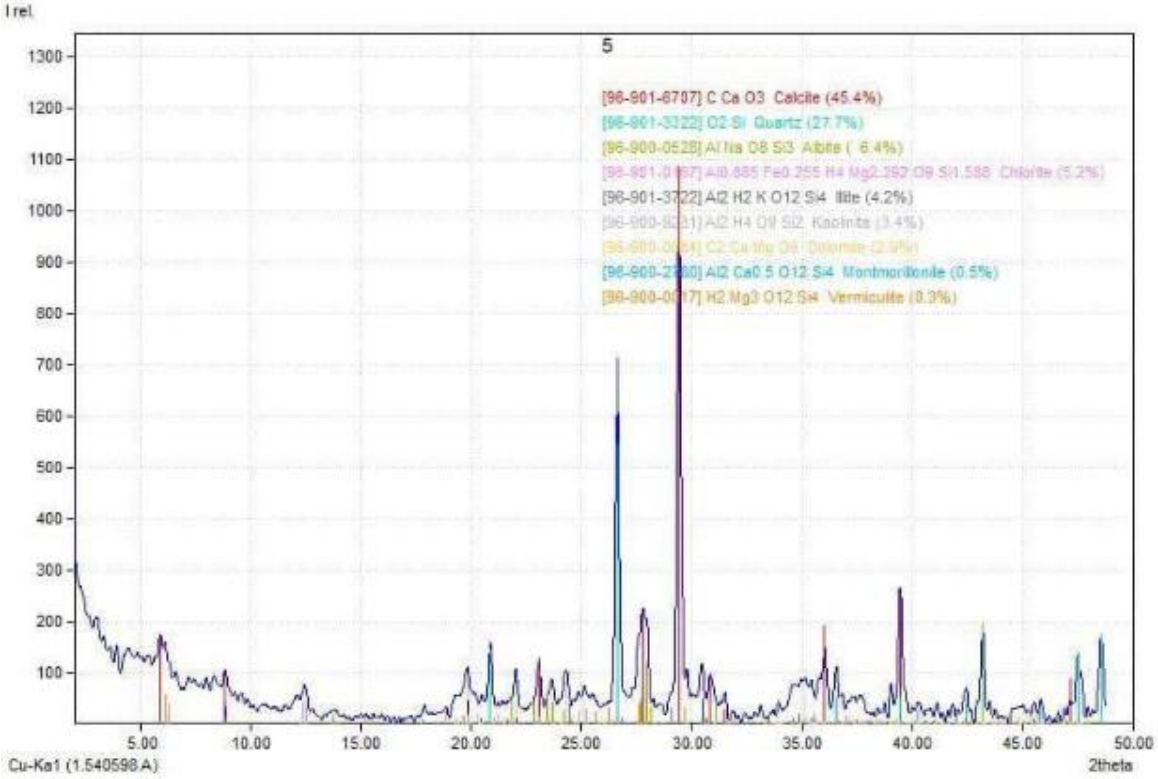



Figure (5.11: D) Determination of Clay Minerals by XRD Scale

## 5.8. Poly cyclic aromatic hydrocarbons (PAHs)

Hydrogen and carbon are organized as two or more fused benzene rings in linear, angular, or cluster patterns to generate polycyclic aromatic hydrocarbons (PAHs) (Eisler, 2007; Ravindra et al, 2007). Although PAHs are present everywhere in nature as a result of volcanic activity, microbial synthesis, and terrestrial vegetation, the amounts created by these natural processes are negligible in comparison to those created by forest fires and other anthropogenic sources. Coke production in the iron and steel industry, catalytic cracking in the petroleum industry, the production of carbon black and asphalt, the generation of heat and power, controlled refuse incineration, open burning, and emissions from internal combustion engines used in transportation are anthropogenic activities linked to significant PAH production (Eisler, 2007; Baird and Cann, 2012).

Before being deposited on soils, plants, or marine and inland waters with atmospheric precipitation, PAHs released into the air can travel over great distances (Van Jaarsveld et al, 1997). Depending on the mode of exposure and the kind of PAHs, human exposure to PAHs has been linked to an increased risk of developing cancer in a number of organs, including the lung, bladder, stomach, and skin (CCME, 2008). Due of their potential to cause cancer and mutations in humans as well as the fact that they are regularly present in the environment, PAHs have attracted a lot of attention. The presence of 16 PAHs on the U.S. EPA's list of 188 harmful air pollutants serves as an illustration of this (Li, 2009).

Low molecular weight PAHs (LMWPAHs) and high molecular weight PAHs (HMWPAHs) are two categories into which PAHs are frequently subdivided (Figure 5.10). The basic structure of LMWPAHs typically consists of two to three benzenoid rings (six-sided aromatic rings of carbon). HMWPAHs often have four or more benzenoid rings in their chemical

structures. Because the hydrophobicity, propensity for bioaccumulation, resistance to biodegradation, and overall environmental persistence of PAHs generally increase with increasing molecular weight, it is useful to distinguish between various PAHs based on their molecular weight. Due to their greater water solubility, LMWPAHs like naphthalene have a tendency to be more immediately harmful to aquatic creatures than HMWPAHs (CCME, 2008).

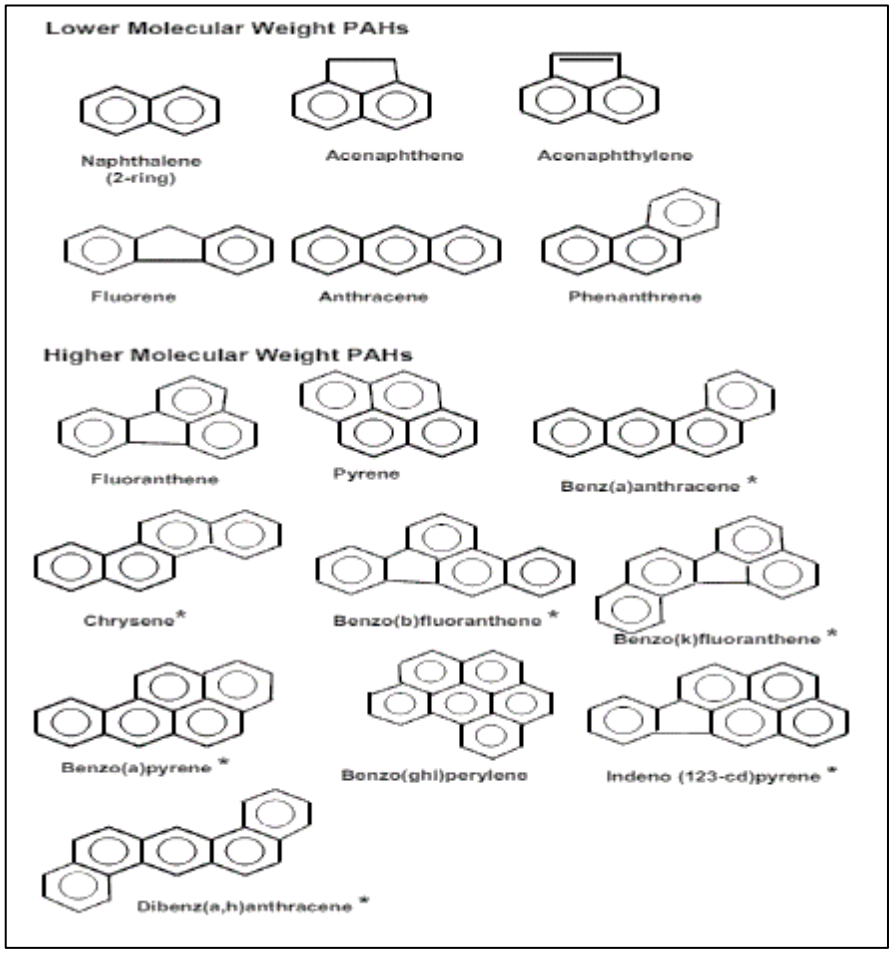



Figure 5.12: Structure of sixteen commonly evaluated PAHs (CCME, 2008). (Those indicated with an asterisk (*) were of particular interest based on possible carcinogenicity)

### 5.8.1 Concentration of polycyclic aromatic hydrocarbons (PAHs)

was measured in soil samples from two sites, S2 and S3. When comparing these concentrations with the study conducted by Mahmood in 2015 (Mahmood, 2015), variations in concentration levels were observed.

In the current study, Acenaphthene exhibited a higher concentration compared to Mahmood's study, where it was lower (Mahmood, 2015). Similarly, Anthracene showed higher levels in the current study than in Mahmood's study (Mahmood, 2015).

However, Mahmood's study reported lower concentrations for several compounds compared to the fixed concentrations in the current study. These compounds include Acridine, Acenaphthylene, benzo (a) anthracene, benzo (k) fluoranthene, benzo (g,h) perylene, benzo(a)pyrene, Chrysene, dibenzo (a,h) anthracene, Fluorene, Indeno, Naphthalene, Phenanthrene, and Pyrene (Mahmood, 2015).

The total concentrations of ∑ 17 PAHs in sites S4 and S3 were measured as 403.83 µg/kg and 531.97 µg/kg, respectively. Comparing these concentrations with the classification by Baurmard et al., (1998) for sediment contamination levels by PAHs (Baurmard et al., 1998), the following observations can be made:

Site S4: The total concentration of 403.83 µg/kg falls within the low contamination level range 0-199 µg/kg according to Baurmard et al. (1998). This suggests a relatively lower level of PAH contamination at this site.

Site S3: The total concentration of 531.97 µg/kg exceeds the low contamination level but falls within the moderate contamination level range 100-1000 µg/kg according to Baurmard et al. (1998). This indicates a moderate level of PAH contamination at this site.

It's important to note that the classification by Baurmard et al. (1998) at LÓPEZ, etall, 2020) is specifically based on sediment contamination levels by PAHs and may not directly correspond to other environmental media or specific regulations (Baurmard et al., 1998).

Bottom of Form

**Table (5.6): Concentration of PAHs(µg/kg)**

| No | Name | S4 (µg/kg) | S3 (µg/kg) | Mean (µg/kg) | Mahmood Mean2015 (µg/kg) |
|---|---|---|---|---|---|
| 1 | Acenaphthene | 36.98 | 42.56 | 39.77 | 15.3 |
| 2 | Acenaphthylene | 25.99 | 33.69 | 29.84 | 29.5 |
| 3 | Anthracene | 33.56 | 39.89 | 36.725 | 6.6 |
| 4 | benzo(a) anthracene | 15.89 | 24.58 | 20.235 | 13.6 |
| 5 | benzo(b) Fluoranthene | 20.69 | 31.58 | 26.135 | |
| 6 | benzo(k) Fluoranthene | 35.98 | 44.15 | 40.065 | 11.7 |
| 7 | benzo ( g , h ) perylene | 13.69 | 20.65 | 17.17 | 11 |
| 8 | benzo (a) pyrenen | 5.89 | 11.25 | 8.57 | 13.2 |
| 19 | Chrysene | 19.55 | 29.87 | 24.71 | 21.1 |
| 10 | dibenzo (a , h ) anthracene | 33.65 | 36.98 | 35.315 | 13.1 |
| 11 | Fluranthene | 24.89 | 40.56 | 32.725 | |
| 12 | Fluroene | 19.58 | 22.58 | 21.08 | 25.4 |
| 13 | Indeno | 20.65 | 29.87 | 25.26 | |
| 14 | Naphthalene | 22.89 | 30.69 | 26.79 | 20.6 |
| 15 | Phenanthrene | 27.98 | 33.69 | 30.835 | 18.2. |
| 16 | Pyrene | 30.69 | 39.80 | 35.245 | 12.2 |
| | ∑ 16 PAHs | 403.83 | 531.97 | | |

## 5.9 Soil Quality Index(SQI)

The Soil Quality Index (SQI) is a numerical value that represents the overall health and fertility of a soil. It takes into consideration various physical, chemical, and biological factors that are important for soil health and productivity. The SQI is calculated based on the measurement of several indicators such as soil structure, organic matter content, pH, nutrient availability, and the presence of harmful chemicals or contaminants. The higher the SQI value, the better the soil quality is considered to be. The SQI can be used to assess the potential for soil degradation and to identify areas where soil conservation practices are needed. It can also be used to compare the soil quality of different sites, to monitor changes in soil quality over time, and to evaluate the effectiveness of soil management practices. There is no

standard method for calculating the SQI, as different approaches can be used depending on the goals of the assessment and the resources available (Zhang et al., 2012).

Using common pollution measuring indices like the contamination factor (Cf), pollution load index (PLI), and index of geo-accumulation, the levels of enrichment or contamination of the trace elements in soil and sediments were assessed (I-geo).

**A- The pollution load index (PLI) and contamination factor (CF)**

Contamination Factors are used to calculate the Pollution Load Index (PLI) (CF). The degree of metal contamination in soil and river sediment samples is categorized using this CF. the result of dividing each metal's concentration by two. According to Issa and Qanbar (2016), the pollution load index (PLI) of the location is determined by taking the n-root of the n-CFs that were obtained for all metals. Hakanson (1980) first created the PLI, which is normally as follows:

CF = C metal / C background …….(1)

PLI= √(CF1xCF2xCF3x…xCFn) ……..(2)

Where:

CF = Contamination factor, n = Number of metals.

C metal = Metal concentration in polluted sediments.

C Background = world surface soil average given by (Kabata-Pendias and Pendias, 2001) The Contamination Factor was classified according to Hakanson, 1980 into:

Table (5.7) The Contamination Factor was classified according to Hakanson, 1980

| CF Value | Pollution |
|---|---|
| $CF < 1$ | Low |
| $1 \leq CF \geq 3$ | Moderate |
| $3 \leq CF \geq 6$ | Considerable |
| $CF > 6$ | Very high |

The PLI value was classified according to Hakanson, 1980 into:

Table (5.8) The PLI value was classified according to Hakanson (1980)

| PLI Value | Pollution |
|---|---|
| 0 | Perfection |
| <1 | Baseline Level |
| >1 | Polluted |

The results of the surface samples showed that the CF values for most of the elements such as: Cr, Cu, Mn, Zn for the samples in the study area are ≥1, indicating a the calculated Pollution Load Index (PLI) values provide an overall assessment of the pollution load at each site, taking into account the contamination factors (CF) for all elements. Based on the PLI values, we can evaluate the state of the area and the sites:

The area and sites are classified as polluted based on the PLI values exceeding 1, according to Hakanson's classification (Hakanson, 1980).

The PLI values range from 1.3896 to 2.4667, indicating varying degrees of pollution across the sites. Site S5 has the highest PLI value of 2.4667, indicating the highest pollution load among the sites, requiring immediate attention and remediation measures.

Sites S10 and S20 have the lowest PLI values of 1.7241 and 1.3896, respectively, indicating a relatively lower pollution load compared to other sites.

Sites S6, S11, S12, and S18 have PLI values below 2, indicating a moderate pollution load, but continuous monitoring and preventive measures are necessary.

Several sites (S1, S3, S4, S8, S13, S14, S15, S16, S17, and S19) have PLI values ranging from 2.0405 to 2.4684, indicating a considerable pollution load, requiring remediation efforts.

The burning of fossil fuels at the power plant, such as gas or oil, releases particulate matter and various combustion by-products that can contain heavy metals and other toxic substances. These emissions can be transported by air currents and deposited onto the surrounding land and water bodies, leading to contamination.

near the station and in the surrounding areas.

Implementing emission control technologies and transitioning to cleaner energy sources can help mitigate the pollution caused by the burning of fossil fuels. This includes the adoption of renewable energy sources like solar, wind, and hydroelectric power, as well as the use of advanced pollution control measures at the station.

In conclusion, the emissions from burning fossil fuels at the power plant likely play a significant role in the increased pollution levels observed in the area. Taking measures to reduce emissions and promote cleaner energy alternatives is crucial for minimizing the environmental and health impacts associated with fossil fuel combustion.

Continuous monitoring and reassessment of the pollutant levels and PLI values are important for tracking the effectiveness of pollution control measures and evaluating progress over time.

The calculated PLI values serve as a valuable tool for environmental management, helping authorities and stakeholders prioritize actions, allocate resources effectively, and implement targeted remediation strategies.

In summary, the area shows varying levels of pollution across the sites, with some sites experiencing higher pollution loads than others. The PLI values highlight the need for immediate remediation measures and continuous monitoring to mitigate environmental impact and protect the well-being of the ecosystem and human populations in the affected area.as shown in Table (5.9

Table (5.9): CF and PLI values of heavy elements in the Study area for Soil samples

| SAMPLE | CF Mn | CF Fe | CF Co | CF Ni | CF Cu | CF Zn | CF As | CF Sr | CF Zr | CF Pb | CF Th | **PLI** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S1 | 0.61 | 0.45 | 7.20 | 2.50 | 0.55 | 1.49 | 2.08 | 1.63 | 0.61 | 0.77 | 0.95 | 1.8 |
| S2 | 0.56 | 0.45 | 6.00 | 2.14 | 0.55 | 1.34 | 2.08 | 1.97 | 0.61 | 0.77 | 0.00 | 0.8 |
| S3 | 0.71 | 0.51 | 4.80 | 2.62 | 0.73 | 1.04 | 2.08 | 1.16 | 0.61 | 0.77 | 0.95 | 1.6 |
| S4 | 0.61 | 0.50 | 8.40 | 2.02 | 0.55 | 1.04 | 2.08 | 1.09 | 0.61 | 0.77 | 0.95 | 1.5 |
| S5 | 0.66 | 0.52 | 9.20 | 2.14 | 0.91 | 1.04 | 2.08 | 1.41 | 0.91 | 1.54 | 0.95 | 1.7 |
| S6 | 0.63 | 0.41 | 4.80 | 2.14 | 0.55 | 1.04 | 2.08 | ... | 0.61 | 0.77 | 0.95 | ... |
| S7 | 0.52 | 0.40 | 6.00 | 2.14 | 0.73 | 1.04 | 2.08 | 1.06 | 0.91 | 0.77 | 0.00 | 1.0 |
| S8 | 0.71 | 0.54 | 7.20 | 2.50 | 0.73 | 1.04 | 2.08 | 1.28 | 0.61 | 0.77 | 0.95 | 1.7 |
| S9 | 0.59 | 0.46 | 5.20 | 2.14 | 0.55 | 1.04 | 2.08 | 0.97 | 0.61 | 0.77 | 0.00 | 1.0 |
| S10 | 0.49 | 0.42 | 4.80 | 1.90 | 0.55 | 1.04 | 0.00 | 2.16 | 0.61 | 0.77 | 0.00 | 0.0 |
| S11 | 0.47 | 0.35 | 4.00 | 1.55 | 0.36 | 1.04 | 0.00 | 1.00 | 0.61 | 0.77 | 0.95 | 0.7 |
| S12 | 0.47 | 0.34 | 3.20 | 1.55 | 0.55 | 1.94 | 2.08 | 2.06 | 1.21 | 0.77 | 0.00 | 1.2 |
| S13 | 0.51 | 0.35 | 3.20 | 2.02 | 0.55 | 1.04 | 2.08 | 1.44 | 0.61 | 0.77 | 0.95 | 1.1 |
| S14 | 0.59 | 0.46 | 10.00 | 1.79 | 0.73 | 1.04 | ... | 0.97 | 0.61 | 0.77 | 0.95 | ... |
| S15 | 0.65 | 0.49 | 9.60 | 2.02 | 0.73 | 1.19 | 2.08 | 0.84 | 0.61 | 0.77 | 0.95 | 1.3 |
| S16 | 0.65 | 0.51 | 10.80 | 2.14 | 0.73 | 1.19 | 2.08 | 0.88 | 1.21 | 0.77 | 0.95 | ... |
| S17 | 0.63 | 0.49 | 6.00 | 2.26 | 0.55 | 1.19 | 2.08 | 0.84 | 0.61 | 0.77 | 0.95 | 1.3 |
| S18 | 0.42 | 0.32 | 4.00 | 1.67 | 0.36 | 1.04 | 0.00 | 1.34 | 0.61 | 0.77 | 0.95 | 0.6 |
| S19 | 0.64 | 0.44 | 6.00 | 2.62 | 0.55 | 1.04 | 2.08 | 1.16 | 1.21 | 0.77 | 0.95 | 1.4 |
| S20 | 0.41 | 0.31 | 4.80 | 1.55 | 0.55 | 0.75 | 2.08 | 1.06 | 0.42 | 0.77 | 0.00 | 0.5 |
| | | | | | | | | | | | | |
| CF class | ●Low pollution ●Moderate pollution ●Considerable pollution ●Very high pollution | | | | | | | | | | | |

**B- Index of geo-accumulation (I geo)**

I geo was used to assess the level of anthropogenic influence on the concentration of heavy metals in the soil. Müller categorizes the geo-accumulation index (I geo) into the following seven groups:

Table (5.10) The I-geo was calculated using Muller and Abrahim & Parker (1981)

| $I_{geo}$ | $I_{geo}$ grade | Pollution |
|---|---|---|
| < 0-0 | 0 | Unpolluted |
| 0-1 | 1 | Unpolluted to Moderate |
| 1-2 | 2 | Moderate Polluted |
| 2-3 | 3 | Moderate to high Polluted |
| 3-4 | 4 | High Polluted |
| 4-5 | 5 | High to Extremely Polluted |
| 5-6 | >5 | Extremely Polluted |

The I-geo was calculated using Muller and Abrahim & Parker (1981), method as follows:

Igeo=log2(Cn/(1.5Bn))……. ( )

Where:Cn: is the concentration of element ‘n’

Bn: is the geochemical background value in this study, consider Bn=world surface soil average given by (Kabata-Pendias and Pendias., 2001 ) .

The factor 1.5 is incorporated in the relationship to account for possible variation in background data due to lithogenic effect.

For surface samples I -geo values ≤0 of the elements such as; Based on the I-geo values calculated for heavy elements in the study area, the pollution potential can be summarized as follows:

The study area exhibits varying degrees of pollution for different heavy elements, indicating the influence of human activities on the environment. Site S10 shows severe pollution for Cu, Zn, Pb, and Th, suggesting potential sources such as industrial activities or waste disposal. S6 and S14 have lower contamination levels for Zr compared to the background, indicating relatively

less pollution in those areas. Mn and Fe show minimal pollution across all sites, suggesting natural background concentrations. S19 demonstrates moderate pollution for Ni and Sr, potentially caused by anthropogenic sources like industry or agriculture. S11 and S18 show moderate pollution for Co, likely originating from industrial activities. The I-geo values for As indicate low pollution levels across all sites. as show in Table (5.11) and Figure (5.13).

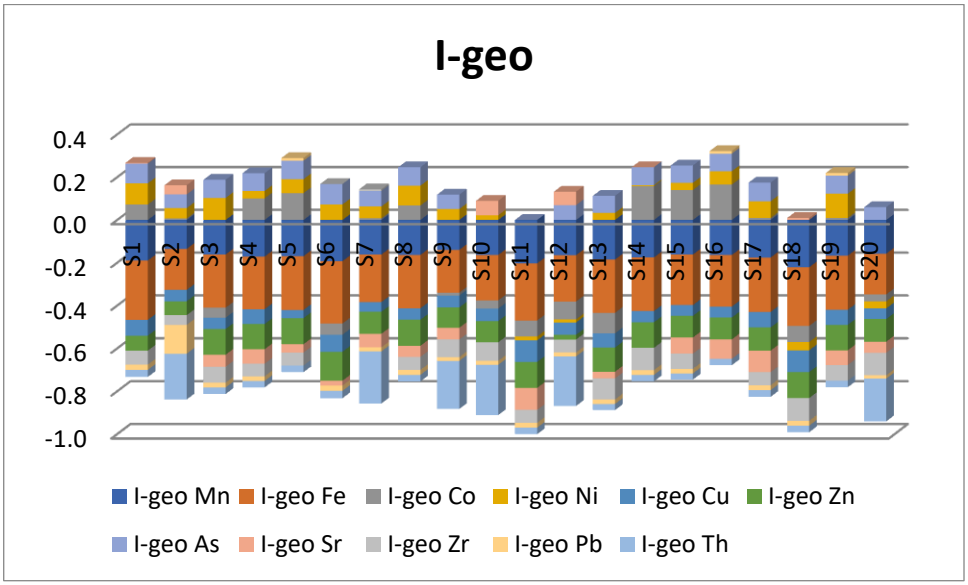


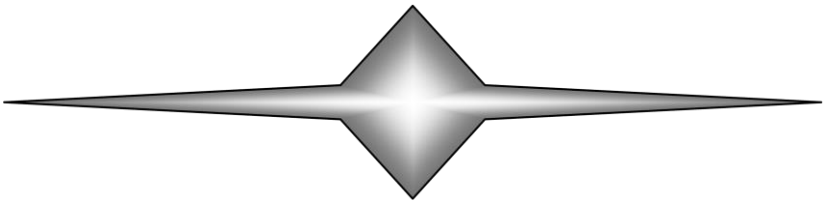

Figure (5.13): I-geo values of heavy elements in the Study area for surface samples

Table (5.11) I-geo values of heavy elements in the Study area for soil samples

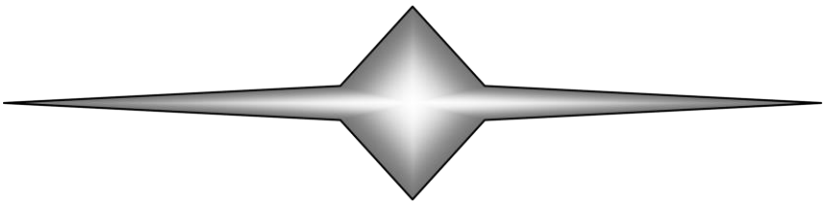
| N.S | Mn | Fe | Co | Ni | Cu | Zn | As | Sr | Zr | Pb | Th |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S1 | -1.95 | -2.85 | 0.74 | 1.02 | -0.76 | -0.72 | 0.95 | 0.04 | -0.67 | -0.25 | -0.34 |
| S2 | -2 | -2.85 | 0.1 | 0.72 | -0.79 | -0.96 | 0.95 | 0.64 | -0.67 | -2 | -3.17 |
| S3 | -1.8 | -2.78 | -0.52 | 1.15 | -0.59 | -1.34 | 0.95 | -0.63 | -0.83 | -0.25 | -0.34 |
| S4 | -1.95 | -2.8 | 1.15 | 0.39 | -0.79 | -1.34 | 0.95 | -0.77 | -0.67 | -0.25 | -0.34 |
| S5 | -1.86 | -2.77 | 1.38 | 0.72 | -0.42 | -1.34 | 0.95 | -0.43 | -0.67 | 0.14 | -0.34 |
| S6 | -1.91 | -2.89 | -0.52 | 0.72 | -0.79 | -1.34 | 0.95 | -0.22 | .... | -0.25 | -0.34 |
| S7 | -2.1 | -2.9 | 0.1 | 0.72 | -0.59 | -1.34 | 0.95 | -0.82 | 0.1 | -0.25 | -3.17 |
| S8 | -1.8 | -2.74 | 0.74 | 1.02 | -0.59 | -1.34 | 0.95 | -0.57 | -0.67 | -0.25 | -0.34 |
| S9 | -1.97 | -2.83 | -0.19 | 0.72 | -0.79 | -1.34 | 0.95 | -0.77 | -1.17 | -0.25 | -3.17 |
| S10 | -2.21 | -2.87 | -0.52 | 0.29 | -0.79 | -1.34 | -∞ | 0.92 | -1.17 | -0.25 | -3.17 |
| S11 | -2.25 | -2.96 | -0.83 | -0.2 | -1.12 | -1.34 | -∞ | -1.14 | -0.67 | -0.25 | -0.34 |
| S12 | -2.25 | -2.97 | -1.14 | -0.2 | -0.79 | -0.3 | 0.95 | 0.86 | -0.83 | -0.25 | -3.17 |
| S13 | -2.2 | -2.96 | -1.14 | 0.39 | -0.79 | -1.34 | 0.95 | -0.37 | -1.17 | -0.25 | -0.34 |
| S14 | -1.97 | -2.82 | 1.78 | 0.05 | -0.59 | -1.34 | 0.95 | .... | -1.17 | -0.25 | -0.34 |
| S15 | -1.89 | -2.76 | 1.64 | 0.39 | -0.59 | -1.18 | 0.95 | -0.88 | -0.83 | -0.25 | -0.34 |
| S16 | -1.89 | -2.78 | 1.91 | 0.72 | -0.59 | -1.18 | 0.95 | -1.05 | .... | 0.14 | -0.34 |
| S17 | -1.91 | -2.77 | 0.1 | 0.85 | -0.79 | -1.18 | 0.95 | -1.09 | -0.67 | -0.25 | -0.34 |
| S18 | -2.44 | -3.02 | -0.83 | -0.43 | -1.12 | -1.34 | -∞ | 0.1 | -1.17 | -0.25 | -0.34 |
| S19 | -1.88 | -2.85 | 0.1 | 1.28 | -0.79 | -1.34 | 0.95 | -0.77 | -0.83 | 0.14 | -0.34 |
| S20 | -2.5 | -3.02 | -0.52 | -0.52 | -0.79 | -1.68 | 0.95 | -0.82 | -1.67 | -0.25 | -3.17 |

| I- geo Class | Unpolluted | Unpolluted to Moderate | Moderate polluted | Moderate to high | high polluted |
|---|---|---|---|---|---|

# Chapter Six



# Conclusions and Recommendations



# 6. Conclusion Recommendations

## 6.1 Conclusion

### 6.1.1 air pollution

- The concentration of Total Suspended Particles (TSP) in the study area exceeded the allowable limits established by both the Iraqi Standards (2008) and WHO (1996) during both winter and summer seasons.
- The rate of CO concentration is less than the WHO (1996) and NAAQS standards, while the $CO_2$ concentration is higher than international standards during both seasons.
- The rate of concentration of VOC is less than global determinants, and the average LEL concentration is zero compared to the WHO limit of 15.5 PPM.
- The average lead values during winter and summer are higher than the limits set by WHO (1996), while it was within Iraqi national determinants.
- The average concentration of cadmium is high compared to both Iraqi and World Health Organizations.
- The average concentration of nickel in the atmosphere is slightly exceed the limits set by the WHO (1996).
- The AQI appears to be unhealthy in some locations and very critical in others during winter, and most locations are in the critical area during summer due to high TSP values.
- most of the locations are in the critical area due to the high TSP values.

### 6.1.2. Water Pollution

- Heavy metal concentrations in water samples from Tigris River (Zn, Pb, Fe, Ni) were higher than Iraqi national and WHO standards during winter and summer seasons.
- Water pollution in the study area is a concern due to the high heavy metal concentrations found in the Tigris River.
- Further measures should be taken to reduce the discharge of pollutants into the river and ensure the safety of the water for human and environmental health.
- Plant pollution
- The wild reed plant in the study area showed higher concentrations of heavy metals such as Pb, Ni, and Cd during the winter season compared to international standards.
- However, the concentrations of Fe and Zn in the plant were within the limits set by WHO.
- The average total concentrations of PAHs in the wild reed plant during both winter and summer seasons were within the natural limits set by Yubo et al. in 2015.

**Soil pollution**

- XRD analysis showed that the soil in the study area contains various mineral like calcite, quartz, albite and clay minerals, including, illite, kaolinite, montmorillonite, and chlorite.
- XRF analysis revealed the presence of several heavy metals in the soil, some of which exceeded the limits set by WHO.
- The heavy metals detected in the soil samples included lead, cadmium, chromium, nickel, zinc, and copper.

- The concentration of lead in the soil samples exceeded the limits set by WHO and the Iraqi standards, while the concentration of cadmium exceeded the Iraqi standards.
- Chromium, nickel, and copper were detected at levels within the limits set by WHO, while zinc was detected at levels both within and exceeding these limits.
- The presence of these heavy metals in the soil could pose a risk to human health, particularly through direct contact or ingestion of contaminated soil.
- The Soil Quality Index (SQI) assessment, based on various physical, chemical, and biological factors, revealed varying degrees of pollution and contamination in the study area. The Pollution Load Index (PLI) values indicated different pollution loads across the sites, with Site S5 showing the highest pollution load and Sites S10 and S20 exhibiting relatively lower pollution loads. Several sites had considerable pollution loads, while others had moderate pollution levels.
- The Index of geo-accumulation (I-geo) analysis demonstrated the influence of human activities on the concentration of heavy metals in the soil. Different heavy elements showed varying pollution potentials across the sites. Severe pollution was observed at Site S10 for Cu, Zn, Pb, and Th, suggesting industrial activities or waste disposal as potential sources. Some sites showed lower contamination levels for certain elements compared to the background, indicating relatively less pollution. Mn and Fe exhibited minimal pollution, likely due to natural background concentrations. The I-geo values for As indicated low pollution levels across all sites.

**Recommendation**

- Based on the information provided about soil, air, and water pollution in the study area, the following recommendations can be made:
- Develop and implement a comprehensive pollution control strategy that targets the sources of pollution in the area, particularly the power plant.
- Regular monitoring of air quality should be conducted, with a focus on suspended particles, heavy metals, and volatile organic compounds (VOCs). The results of these tests should be made available to the public and appropriate measures should be taken to address any areas of concern.
- Water pollution in the Tigris River should be addressed by implementing strict regulations on industrial wastewater discharge and by monitoring the river water quality.
- Regular soil testing and monitoring should be conducted in the study area to determine the level of contamination and identify potential health risks. Appropriate measures should be taken to remediate any areas of concern.
- A health impact assessment should be conducted to evaluate the potential health risks to the local population and workers in the power plant.
- Public education and awareness campaigns should be initiated to raise awareness of environmental issues and the importance of pollution control.
- The power plant should invest in renewable energy sources to reduce its environmental impact and carbon footprint.
- Efforts should be made to promote sustainable agricultural practices in the area, including the use of organic fertilizers and crop rotation.

- The government should enforce strict regulations and penalties for industries that violate environmental laws and regulations.
- By implementing these recommendations, the study area can improve its environmental quality, promote sustainable development, and protect the health and well-being of its residents.

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واشارت قيم مؤشر حمل التلوث (PLI) الى احمال تلوث مختلفة في المواقع المدروسة حيث اظهر موقع رقم 5 اعلى حمل تلوث والمواقع 10 تظهر اقل احمال تلوث

اظهر تحليل مؤشر التراكم الجغرافي ( I-GEO) تأثير الأنشطة البشرية على تركيز المعادن الثقيلة في التربة ,اظهرت العناصر الثقيلة المختلفة احتمالات تلوث متفاوتة عبر المواقع ,لوحظ تلوث شديد في المحطة 10

## المستخلص

تقع منطقة الدراسة شمال مدينة الكوت ، وسط محافظة واسط (قضاء الزبيدية) ، حيث توجد واحدة من أكبر محطات الطاقة الكهربائية (محطة الطاقة الحرارية) ، والتي يوجد حولها العديد من القرى. منذ وقت طويل. تطلق هذه المحطة العديد من الملوثات (العناصر النزرة والهيدروكربونات العطرية متعددة الحلقات). في شكل غازات ومواد صلبة وسوائل للبيئة المحيطة. حيث تحتاج جودة الهواء والماء والتربة والنبات إلى تقييم بيئي مستمر ، فقد تم تحديد 10 محطات لأخذ عينات الهواء خلال موسمي الشتاء والصيف ، ومحطتين لأخذ عينات المياه على نهر دجلة خلال فصلي الشتاء والصيف. و 5 محطات لأخذ عينات القصب البري خلال الموسمين 20 و 20 محطة أخذ عينات التربة للتقييم البيئي لهذه الدراسة.

أظهرت الدراسة أن معدل تركيز الجسيمات العالقة في الهواء كان أعلى من المحددات العراقية والمحددات الدولية خلال فصلي الشتاء والصيف ، وأن تركيزات غاز أول أكسيد الكربون (المركبات العضوية المتطايرة) كانت ضمن الحدود الطبيعية للعالم. منظمة الصحة والمحددات العراقية خلال الموسمين بينما كانت تركيزات غاز ثاني أكسيد الكربون أعلى من المحددات العراقية والعالمية خلال الموسمين أما تركيزات (LEL)كانت صفرا.

كان متوسط تركيز العناصر الثقيلة (Pb، Cd، Fe، Zn، Ni) أعلى من المحددات العراقية ومحددات منظمة الصحة العالمية.

متوسط قيم (pH) والأيونات الرئيسية والثانوية في فصلي الشتاء والصيف لنهر دجلة ضمن الحدود الطبيعية ، باستثناء الفوسفات والمغنيسيوم والكالسيوم والمواد الصلبة ، أعلى من المحددات العراقية والمحددات الدولية. كانت تراكيز العناصر الثقيلة في عينات المياه الداخلة والخارجة من المحطة (الرصاص ، الحديد ، الزنك) أعلى. من المحددات العراقية والمحددات الصحية العالمية باستثناء (الكادميوم والنيكل) داخل الحدود العراقية والحدود الصحية العالمية.

وكان متوسط التركيزات الاجمالية للهيدروكاربونات العطرية متعددة الحلقات في نبات القصب البري خلال فصلي الشتاء والصيف ضمن الحدود الطبيعية

اظهر نبات القصب البري في منطقة الدراسة تركيزات اعلى من المعادن الثقيلة مثل الرصاص والنيكل والكادميوم خلال فصل الشتاء مقارنة بالمعايير الدولية وكانت تراكيز الحديد والنيكل ضمن الحدود التي وضعتها منظمة الصحة العالمية.

أظهر تحليل الأشعة السينية لعينات التربة مجموعة واسعة من معادن الكوارتز والكالسيت والطين (الألبايت والكلوريت والكاولينيت والمونتموريلونيت).

حيث أظهرت نتائج التحليل الطيفي للأشعة السينية (XRF) ان التربة في منطقة الدراسة تحتوي على معادن ثقيلة بعضها تجاوزت الحدود التي وضعتها منضمة الصحة العالمية تضمنت المعادن الثقيلة المكتشفة في عينات التربة الرصاص والنيكل والكادميوم والحديد والنحاس والكروم والزنك اظهر مؤشر جودة التربة (SQI ) بناءا على عوامل فيزيائية وكيميائية وبيولوجية مختلفة درجات متفاوتة من التلوث

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قسم علم الأرض التطبيقي

# دراسة الاثر البيئي لمحطة توليد الزبيدية على البيئة المحيطة بمحافظة واسط شرق العراق

رسالة

مقدمة الى مجلس كلية العلوم - جامعة بابل وهي جزء من متطلبات الحصول على درجة الماجستير في العلوم/ علم الأرض التطبيقي

**من قبل**

**صفا حسام حسين حسون**

**بكالوريوس علوم علم الارض التطبيقي- جامعة بابل**

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بأشراف

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