ISSN 2664-4010 (Print) & ISSN 2664-6730 (Online)
South Asian Research Journal of Agriculture and Fisheries
Abbreviated Key Title: South Asian Res J Agri Fish

| Volume-7 | Issue-1 | Jan-Feb -2025 | **DOI: https://doi.org/10.36346/sarjaf.2025.v07i01.003**

Original Research Article

Evaluation of Heavy Metals Pollution in the Soil around a Few Industrial Sites in Wasit Governorate, Iraq

Bassim Hussein Farhan[1*]
[1]Baghdad Education Directorate/ Al-Rusafa 3

***Corresponding Author:** Bassim Hussein Farhan
Baghdad Education Directorate/ Al-Rusafa 3

Article History
Received: 27.12.2024
Accepted: 01.02.2025
Published: 04.02.2025

Abstract: A case study was conducted on the potential pollution in the soils surrounding three industrial facilities in Wasit City, Iraq. This includes the Zubaidiya Thermal Power Plant, the Textile Factory in Kut, and the Brick Factories in the Hai region, examining the impact of emissions resulting from incomplete fuel combustion and their liquid waste discharged into the river from these sources on the surrounding areas in terms of heavy metal pollution in the soil, such as titanium (Ti), iron (Fe), gallium (Ga), arsenic (As), bromine (Br), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), molybdenum (Mo), and barium (Ba). Soil samples were collected from distances ranging between 0-500 meters and depths of 0-30 cm and 30-60 cm near the pollution source to assess pollution levels based on global soil pollution standards. Comparison samples were also obtained 4 kilometers away from the pollution source at both depths, with three replicates for each site in October and March of 2023. In general, this indicates that industrial sites have an impact on pollution of the environment because the study found that the total concentration of heavy metals in soils affected by residues from these sites was higher than in control soils. When comparing the concentrations of heavy elements in the soil for October samples with the world average according to Kabata 2011, we found that the elements Iron, Gallium, and Rubidium were close to the world average, as well as the element Bromine, except for the first depth in the soil contaminated with the brick factory, where it was higher than the average. As for the elements Titanium, Arsenic, Strontium, Yttrium, and Molybdenum, their concentrations exceeded the world average, whether in the comparison soil or the contaminated soil. As for the elements Zirconium and Barium, they were lower than the world average, despite the fact that the concentrations in the contaminated soil were higher than the control samples, but their concentrations were lower than the average, according to Kabata 2011. As for the March samples, they followed the same trend as the October samples, indicating the extent of the contribution of pollution sources to the increase in concentrations of heavy elements in the soil in particular and the environment in general.

Keywords: Heavy Metals Contamination, Industrial Facilities.

INTRODUCTION

The problem of industrial pollution in Iraq is characterized by environmental features and characteristics that have led to the deterioration of the quality of the local environment, including the mismatch of most industrial areas, power generation stations, and oil refineries with the proper environmental site conditions. The age of these facilities, or their lack of pollution treatment, causes an increase in the concentrations of pollutants they produce. Furthermore, some major industrial projects lack appropriate environmental technology according to modern scientific concepts (Al-Omar, 2009).

Soil is an important environmental medium and is susceptible to a number of pollutants, including toxic heavy metals, through various human and natural activities. Therefore, soil contaminated with heavy metals poses health risks to humans and other living organisms in the ecosystem and has various ways of exposure to living organisms, such as direct ingestion, contamination of drinking water, consumption of crops, contact with contaminated soil, and through the food chain (Soodan *et al.*, 2014). The total content of heavy metals in the soil represents the combined concentrations of elements derived from minerals and geological materials in developed soil from its parent material, as well as inputs from a wide range of human activities that pollute the environment. These sources include particulate matter deposited in the air, heavy metals carried by raindrops or in the form of gases, direct additions of agricultural fertilizers, waste water, food waste, residues of industrial materials like ash, mine and mining waste, and war projectiles. All of these can contribute to soil pollution.

Power generation stations have extremely negative effects on the various surrounding environmental sectors, as they produce a large amount of sulfur oxides (SO_x), nitrogen oxides (NO_x), and suspended particulate matter (SPM) in the air, leading to environmental damage that affects human, animal, and plant health. The emissions of SPM, or respirable suspended particulate matter (RSPM), spread over a radius of 25 km, causing harm to human respiration and food. Power generation stations are known as a major source of emissions containing heavy metals as they are adsorbed with SPM and transported by air to varying distances based on their properties, climate factors, and the topography of the region. Therefore, assessing the impact of emissions containing heavy metals from power stations on the soil in the adjacent areas is of great practical importance. The textile industry is considered one of the most important industrial sectors in the global economy. However, the liquid waste from textile factories contains organic and inorganic pollutants such as dyes, heavy metals, salts, and soaps and is considered a serious environmental problem for human society (Wawrzkiewicz *et al*., 2017). The textile industry has been classified as one of the "red" industries, which must be treated and monitored for compliance of liquid waste quality with the standards of effluent quality. Large quantities of liquid waste from the textile industry can cause changes in the chemical, biological, and physical properties of the aquatic environment, leading to public health damage (Hossain *et al*., 2018).Brick kilns are considered one of the main sources of air pollution in developing countries as they are a source of a mass of emissions for greenhouse gases (GHGs) such as NO_x, CO_x, SO_x, and various types of particulates (PM) and associated heavy metals. The concentrations of these emissions vary depending on the type of kiln used, the fuel, the technology, and the burning time used in brick production processes (Adrees *et al*., 2016). The hazardous emissions from brick factories are attributed to the use of low-quality fuels such as coal, car tires, and engine oil (Achakzai *et al*., 2017). The combustion of this bad fuel and the lack of emission control devices are responsible for releasing massive amounts of pollutants freely into the environment. The release of such pollutants not only affects the air quality surrounding the area, but there is also a hidden and indirect threat to the health of plants and the organisms inhabiting the areas adjacent to these polluted sources (Adrees *et al*., 2016).

MATERIALS AND METHODS

Site Description

Three sites have been selected as sources of pollution within the Wasit Governorate: Al-Zubaidiya Thermal Power Station in Al-Suaira District is one of the projects that have a significant environmental impact on the region, as the first unit of this station started operating in 2012 with a production capacity of 330 megawatts. Al-Zubaidiya station is one of the largest power stations in Iraq, with the station site chosen on the right side of the Tigris River, covering an area of 800 dunams. The station consists of 6 units with a total capacity of 2540 megawatts, executed in two stages: the first stage consists of 4 generating units with a capacity of 1320 megawatts, and the second stage consists of two generating units with a capacity of 1220 megawatts. The station operates on natural gas, crude oil, and heavy fuel. The towers are 210 meters high, making them the tallest towers in Iraq, with a total of four towers.

The textile factory in Kut: The factory was established in Wasit province on the left bank of the Tigris River according to the Iraqi-Soviet agreement in 1959. The factory was designed to produce 100% cotton fabrics as well as cotton yarn in different counts to feed the textile department in the factory. Construction works were completed, and the machines and equipment were installed in 1970. The brick factories in Al-Hay are a complex of brick factories consisting of 12 factories, all of which operate in a primitive way by taking soil from nearby areas and using black oil as fuel for these factories.

Table 1: The coordinates of the UTM system and Elevation for the samples of soil

Site		X	Y	Elevation
Power Plant	Control	45.037767 E	32.797885 N	21.9
	Polluted	45.100261 E	32.770667 N	22.0
Textile Factory	Control	45.844966 E	32.499344 N	15.6
	Polluted	45.826774 E	32.514278 N	15.8
Brick factories	Control	45.973854 E	32.246079 N	13.2
	Polluted	46.019035 E	32.220494 N	13.1

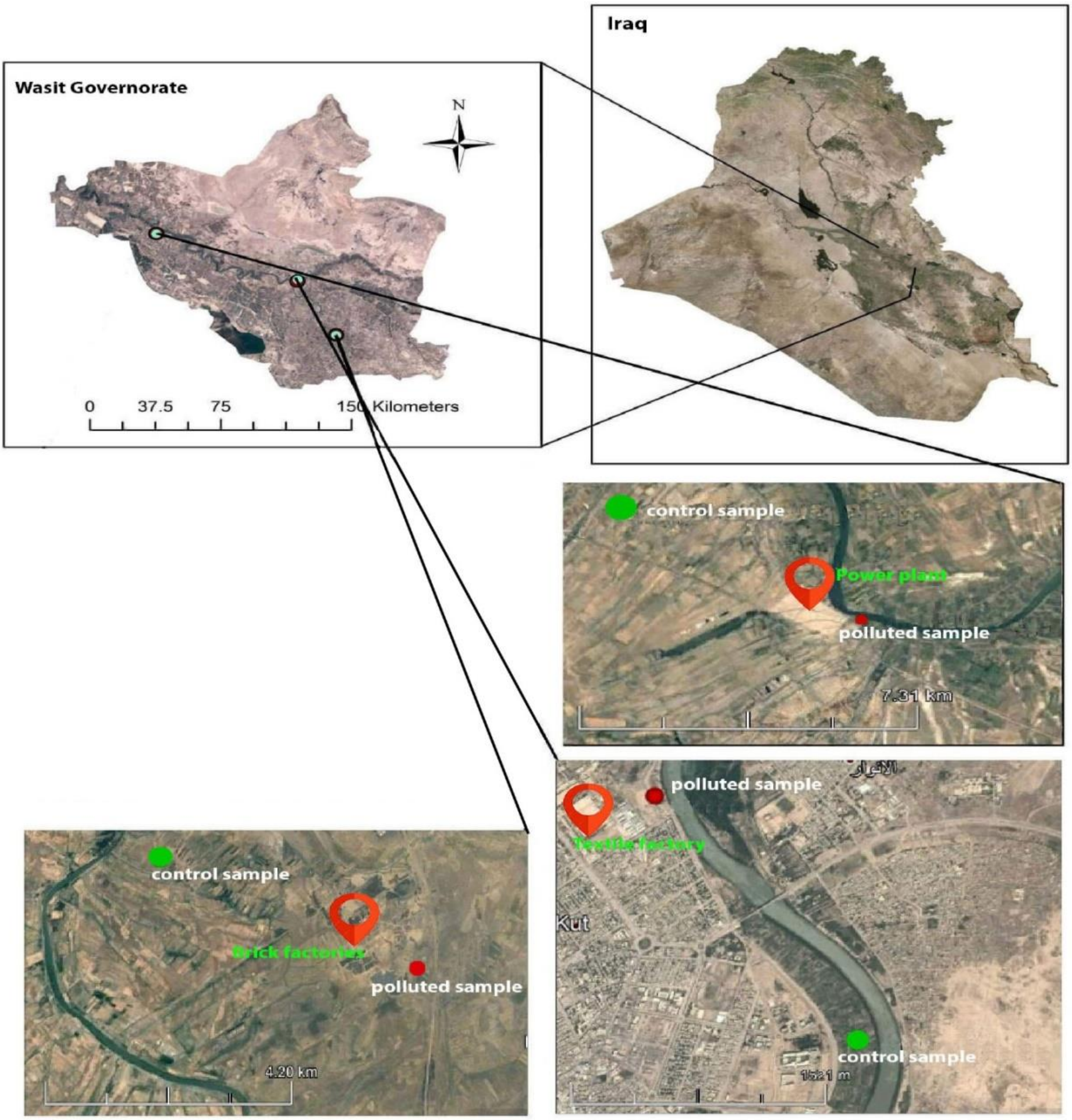

Fig. 1 : Study sites in Wasit governorate and soil sampling sites

Sample Collection

Soil samples were collected at a distance of 0–500 m from the pollution source and at two depths: 0–30 cm and 30–60 cm. Control samples were also taken at a distance of about 4 km from the same source and at similar depths, with three replicates for each site during the months of March and September. Considering the dominant wind direction for the power station and brick Factories, as well as the river direction for the textile factory site.

Laboratory Work

Soil Sampling Analysis

The overall concentration of heavy metals () in the soil was determined using the X-ray fluorescence (EDXRF) energy dispersive technique with a SPECTRO XEPOS-2010 device. After obtaining the measurements, the necessary calculations were carried out to convert the percentage to parts per million and to convert the reading from a compound (oxide) to an element, according to Essington (2015).

Chemical and Physical Analysis:

The soil samples were prepared after being collected from the specified sites, air-dried, then ground with a wooden hammer, sieved through a 2 mm diameter sieve, and stored in plastic containers for chemical and physical analyses as in the soil analysis tables according to the following methods:

The Volumetric Distribution of Soil Fractions: The relative distribution of soil fractions and sediments was estimated using the hydrometer method according to Day (1965).

Soil Reaction pH: Measurement was carried out in a soil suspension: water 1:1 using a pH meter type (HACH \ HQ41-1d) according to the method described in Jones (2001).

Electrical Conductivity EC: Measurement was carried out in a soil suspension: water 1:1 using an EC-Meter type (HACH \ EC 71) according to the method described in Jones (2001).

Cation Exchange Capacity CEC: Determined by the Simplified Methylene Blue Method as described in Savant (1994), specific to calcareous soil.

Organic Matter: O.M. The organic carbon in the study soil was determined by the wet oxidation method according to the Walkley and Black method described in Jackson (1958), and then the organic matter was calculated by multiplying the organic carbon value by the factor 1.72.

Table 2

Sites		Power Plant				Textile Factory				Brick factories			
		Control		Polluted		Control		Polluted		Control		Polluted	
Depth		30 - 0	60 - 30	30 - 0	60 - 30	30 - 0	60 - 30	30 - 0	60 - 30	30 - 0	60 - 30	30 - 0	60 - 30
pH		7.36	7.67	7.91	7.72	7.84	7.71	8.08	8.17	7.32	7.49	7.66	7.48
C.E.C	$C.mol.c.kg^{-1}$	25.3	27.9	32.7	34.6	31.5	27.4	34.9	37.1	27.4	24.7	20.4	21.2
O.M	%	1.21	0.86	1.53	0.83	1.23	0.8	1.38	0.75	0.82	0.43	0.9	0.62
$CaCo_3$	$g\ kg^{-1}$	267	249	311	270	302	298	306	292	263	251	277	265
EC	$dS\ m^{-1}$	1.42	1.73	1.64	1.38	1.46	1.53	2.04	1.65	8.24	5.86	9.67	8.71
SAR	$(Mmol.l^{-1})^{1/2}$	1.26	2.11	1.61	1.43	1.01	1.19	1.56	1.24	3.86	3.9	3.72	3.53
Clay	$g\ kg^{-1}$	367	326	373	394	386	363	477	501	341	329	273	281
Silt		217	229	266	318	513	551	443	426	473	496	503	516
Sand		416	445	361	288	101	86	80	73	186	175	224	203
Texture		CL	CL	CL	CL	Si.C.L	Si.C.L	SiC	SiC	Si.C.L	Si.C.L	CL	CL

RESULTS AND DISCUSSION

The results in Table 3, 4 indicate a variation in the total titanium concentration in the soil of different industrial facilities. In the samples of October, the highest concentration of titanium was detected in the first depth of the soil of the contaminated brick factory, reaching 4829 $mg.kg^{-1}$, while the total titanium concentration at other sites ranged between 4388 and 4758 mg.kg-1. As for the samples of March, the highest total titanium concentration was also at the brick factory, reaching 4949 and 4903 $mg.kg^{-1}$ for the first and second depths, respectively, while the total titanium values at other sites ranged between 4173 and 4822 $mg.kg^{-1}$.

The results in tables 3 and 4 indicate a limited variation in the total iron concentration in the soil of different industrial facilities. In the samples of October, the highest concentration was in the first depth of the soil affected by the emissions of the Zubaidiya power station, reaching 41034 $mg.kg^{-1}$, while the total concentration at other sites ranged between 32690-40494 $mg.kg^{-1}$. In the March samples, the highest total iron concentration was at the brick factory, reaching 43844 and 42944 $mg.kg^{-1}$ for the first and second depths, respectively, while the total iron values at other sites ranged between 38354-40530 and 37506-40144 $mg.kg^{-1}$ for the first and second depths, respectively.

The study results indicate that the brick factories' location showed the highest level of total Gallium content in the soil, reaching 17.7 and 15.6 for the first and second depths in October and 19.4 and 18.1 for March, for both depths, respectively. This is due to the incomplete combustion of various types of fuel used in factories, leading to the emission of large amounts of pollutants. The inadequate combustion of fuel and the absence of emission control devices are responsible for releasing massive amounts of pollutants freely into the air, which then settle in nearby areas. This is what Kabata and Szteke (2015) indicated that the combustion of fossil fuels and pollution resulting from industries are the main sources of the increase in Gallium concentration in the environment.

The results in Tables 3 and 4 indicate the presence of variation in the total concentration of Arsenic in the soil of different industrial facilities. In the samples of October, the highest concentration of Arsenic was at the first depth of the brick factory, reaching 9.17 mg kg^{-1}, while the second depth had the highest concentration of Arsenic at the power station, reaching 8.95 mg kg^{-1}, while the total concentration of Arsenic at other sites ranged between 4.62–9.03 and 4.48–7.2 mg kg^{-1} for depths of 0–30 and 30–60 cm, respectively. In the March samples, the highest total concentration of Arsenic was at the power station, reaching 11.59–10.27 mg kg^{-1} for the first and second depths, respectively, while the total Arsenic values at other sites ranged between 6.36–8.42 and 6.06–8.48 mg kg^{-1} for the first and second depths, respectively. As is released by a variety of industrial processes, particularly the burning of coal, increasing the amount of As in many soils Kabata and Szteke (2015). It may considerably vary, depending on the geology of the parent materials, which are the main source of as in uncontaminated soils.

The results in tables 3 and 4 indicate a variation in the concentration of total Bromine in the soil of different industrial facilities. In the samples of October, it was found that the highest concentration of Br was at the brick factory, reaching 20.5–12.3 mg kg^{-1}, while the total concentration of Br at other sites ranged between 6.9–11.3 and 8.2–10.1 mg kg^{-1} for the first and second depths, respectively. In the samples of March, the highest concentration of total Br was also at the first depth of the soil contaminated with the brick factory, reaching 19.7 mg kg^{-1}.

Table 3: The concentrations of heavy metals (mg Kg-1) in the soil of the study sites for October

Sites		Depth	Ti	Fe	Ga	As	Br	Rb	Sr	Y	Zr	Mo	Ba
Power Plant	Control	0-30	4388	39556	13.2	6.06	8	43.8	273.3	16.71	102.5	5.66	224
		30-60	4461	38024	13.5	5.98	8.7	44.9	270	17.42	105.1	4.35	187.2
	Polluted	0-30	4659	41034	15.3	9.03	11.3	51.8	431.2	18.37	141.2	12.69	310.9
		30-60	4758	38072	14.6	8.95	10.1	50.8	462.8	17.77	136.1	9.46	304.2
Textile Factory	Control	0-30	4502	39788	13.8	6.97	7.6	54.5	292.3	19.2	118.6	3.21	202.5
		30-60	4535	39704	11.6	6.46	8.2	54.6	285.2	19.21	117.8	4.88	119.3
	Polluted	0-30	4661	40340	13.5	7.04	6.9	55.2	293.3	19.44	126.1	10.69	218.8
		30-60	4718	40494	14.7	7.2	9.8	55.5	289.5	19.61	124.6	9.84	217.2
Brick factories	Control	0-30	4407	32690	11.4	4.62	8.3	43.7	286.5	17.01	119.9	8.2	199.3
		30-60	4418	33706	12.5	4.48	9.6	44.6	264.8	16.35	116.8	9.07	178.7
	Polluted	0-30	4829	33564	17.7	9.17	20.5	52.4	652.4	19.67	155.3	13.73	293.3
		30-60	4525	36372	15.6	6.29	12.3	55.5	421.7	17.69	158.8	6.87	263.2
Earth's crust			0.4-0.57*	4.5-5*	15-19	1.8-2.5	2	90-110	260-370	20-30	100-200	1.1	250-548
Soils			0.33*	3.5	15.2	1-2.5	10	50	147	12	300	1.1	362
calcareous			0.04-1*	0.4-1.0*	5-30	6.83	1-6	5-30	460-600	4-30	-	0.3-7.4	50-200

*Concentration (%)

Table 4: The concentrations of heavy metals (mg Kg-1) in the soil of the study sites for March

Sites		depth	Ti	Fe	Ga	As	Br	Rb	Sr	Y	Zr	Mo	Ba
Power Plant	Control	0-30	4270.6	39684	13.3	6.59	6.7	52.8	287	17	93.7	6.5	215.4
		30-60	4249.6	39040	14.5	6.82	7.6	55.7	292.7	17.1	92.6	7.7	209.4
	Polluted	0-30	4689.7	40558	17.3	11.59	10.9	50.9	541.6	18.4	151.5	11.1	328.8
		30-60	4822.2	38570	16.3	10.27	10.8	50.5	587.6	19.1	146.7	8.06	319
Textile Factory	Control	0-30	4391.3	38354	14.2	6.44	7.9	55.1	313.4	19	116.3	4.1	229
		30-60	4327.5	37506	13.7	6.73	7.2	56.6	347.8	19.3	119.7	3.5	233.6
	Polluted	0-30	4698.7	40530	13.5	8.42	9.3	54.9	304.1	19.1	125.1	13.4	242.8
		30-60	4570.4	40144	13.9	8.2	9.5	55.1	295.9	19.6	131.4	14.9	234.3
Brick factories	Control	0-30	4199.6	38788	14.8	6.36	10.5	50.8	357.2	16.6	102.5	7.2	226.5
		30-60	4173.9	38262	14.2	6.06	10.3	50.5	336.7	15.4	96.7	7.6	229.3
	Polluted	0-30	4949.9	43844	19.4	9.11	19.7	57.1	422.7	20.1	168.1	13.1	294
		30-60	4903.7	42944	18.1	8.48	8.2	55.7	415.5	19.9	166.4	7.51	263.9
Earth's crust			0.4-0.57*	4.5-5*	15-19	1.8-2.5	2	110-90	260-370	30-20	100-200	1.1	250-548
Soils			0.33*	3.5*	15.2	1-2.5	10	50	147	12	300	1.1	362
calcareous			0.04-1*	0.4-1.0*	5-30	6.83	1-6	5-30	600-460	4-30	-	7.4-0.3	50-200

*concentration (%)

The results indicate a slight variation in the total radium concentration in the soil of different industrial facilities. In the samples of October, the radium concentration ranged from 43.7 to 55.5 mg.kg^{-1}, with the highest concentration at the textile factory soil reaching 55.2-55.5 mg.kg^{-1} for the first and second depths, respectively. In the March samples, the highest total radium concentration was found in the soil contaminated by the brick factory, reaching 57.1 and 55.7 mg.kg^{-1} for the first and second depths, respectively, while the total radium values in the other sites ranged between 50.8-55.1 and 50.5-56.6 mg.kg^{-1} for the depths of 0-30 and 30-60 centimeters, respectively.

The results show variations in the total strontium concentration in the soil of different industrial facilities. In the samples from October, the highest strontium concentration at the first depth was found at the brick factory, reaching 652.4 mg kg^{-1}. At the second depth, the highest concentration was at the power station, reaching 462.8 mg kg^{-1}. The total strontium concentration at other sites ranged between 273.3–431.2 and 270–421.7 mg kg^{-1} for the first and second depths, respectively. In the March samples, the highest total strontium concentration was in the contaminated soil of the power station, reaching 541.6 and 587.6 mg kg^{-1} for the first and second depths, respectively. Meanwhile, the total strontium values at other sites ranged between 287 and 422.7 mg kg^{-1}. The main sources of Sr pollution are from coal combustions and sulfur mining and processing (Kabata and Szteke, 2015)

The results of the study show that there is a convergence in the concentrations of yttrium, indicating that the geological factor and the type of soil texture had a greater impact than human activities. In November, the element's values ranged between 16.35–19.21 and 17.69–19.67 for control and polluted soils, respectively. Comparing these values with the global average concentration of yttrium in soils, it is noted that the total concentrations of the element in the study soils were slightly higher than the global average for yttrium in soils, which is 15 mg kg^{-1} (Kabata and Szteke, 2015). This increase in the study soils compared to the global average can be attributed to the use of mineral fertilizers, particularly phosphatic ones containing concentrations up to 114 mg kg^{-1}, in addition to the effect of soil properties such as pH, where the fixation of Y increases with the degree of reaction and the effect of CaCO3 and soil texture, as well as the increase in CEC of the soil.

The results indicate the presence of variations in the total zirconium concentration in the soil of different industrial facilities. In the November samples, the highest concentration was in the soil of the brick factory site, reaching 155.3 and 158.8 mg kg^{-1} for the first and second depths, respectively, while the total zirconium concentration at other sites ranged between 102.5-141.2 and 105.1-136.1 mg kg^{-1} for the first and second depths, respectively. In the samples of March, the highest total zirconium concentration was in the soil affected by the emissions of the brick factory, reaching 168.1–166.4 mg kg^{-1} for the first and second depths, respectively, while the values at other sites ranged between 93.7–151.5 and 92.6–146.7 mg kg^{-1} for the depths of 0–30 and 30–60 cm, respectively. This is consistent with what was mentioned by Kabata and Szteke (2015) the average Zr concentration in air sampled from urban areas is around 3 ng/m3, whereas the contents of air sampled from contaminated locations range from 0.7 to 27 ng/m3.

The findings in Tables 3 and 4 show variations in the concentration of total molybdenum in the soil of different industrial sites. In the November samples, the highest molybdenum concentration was found in the top layer of soil affected by emissions from the brick factories, reaching 13.73 mg/kg. In other locations, the total molybdenum concentration ranged between 3.21–12.69 and 4.35–9.84 mg/kg for the first and second depths, respectively. In the March samples, the highest total molybdenum concentration was in the soil contaminated by the textile factory, reaching 13.4 and 14.9 mg/kg for the first and second depths, respectively. This could be attributed to the agricultural nature of the land located on the banks of the Tigris River and the mobility of molybdenum in alkaline soils. In other sites, the molybdenum values ranged between 4.1–13.1 and 3.5-8.06 mg/kg for the depths of 0–30 and 30–60 cm, respectively. Soils with higher than average amounts of Mo may be the result of several forms of industrial contamination. Mo concentrations in some sewage sludge can reach up to 50 mg/kg (Kabata-Pendias 2011). Furthermore, fly ash from certain coal-fired power stations can be a possible source of Molybdenum.

Tables 3 and 4 show that the power station site gave the highest value for the barium element soil content in October, reaching 310.9 and 304.2 milligrams per kilogram for the first and second depths, respectively. This is close to the total barium concentration at the brick factory, which was 293.3 and 263.2 milligrams per kilogram for the respective depths, attributed to emissions from fuel combustion at the power station and brick factory. As indicated by ATSDR (2007), the concentration of barium in the air can rise to 90 ng/m3 in rural areas and over 100 ng/m3 in metropolitan areas, respectively. Its primary energy sources are the combustion of coal and oil.

However, the March samples followed the same trend as the October samples, with the power station recording the highest concentration of barium, followed by the brick factory, and then the textile factory.

REFERENCES

- Achakzai, K., Khalid, S., Adrees, M., Bibi, A., Ali, S., Nawaz, R., & Rizwan, M. (2017). Air pollution tolerance index of plants around brick kilns in Rawalpindi, Pakistan. *Journal of environmental management*, *190*, 252-258.
- Adrees, M., Ibrahim, M., Shah, A. M., Abbas, F., Saleem, F., Rizwan, M., ... & Ali, S. (2016). Gaseous pollutants from brick kiln industry decreased the growth, photosynthesis, and yield of wheat (Triticum aestivum L.). *Environmental monitoring and assessment*, *188*, 1-11.
- Al-Omar, Muthana Abdul Razzaq. (2009). Pollution in Mesopotamia: Causes and Hazards. Visit www.alarabiya.net/save for more information.
- ATSDR (Agency for Toxic Substances and Disease Registry). 2007a. *Toxicological Profile for Barium and Barium Compounds*. Atlanta, GA: ATSDR.

- Buat-Menard, P., & Chesselet, R. (1979). Variable influence of the atmospheric flux on the trace metal chemistry of oceanic suspended matter. *Earth and Planetary Science Letters*, *42*(3), 399-411.
- Day, P. R. (1965). Particle fractionation and particle-size analysis. *Methods of Soil Analysis: Part 1 Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling*, *9*, 545-567.
- Essington, M. E. (2015). Soil and Water Chemistry an Integrative Approach. Taylor & Francis Group, LLC.
- Hakanson, L. (1980). An ecological risk index for aquatic pollution control. A sedimentological approach. *Water research*, *14*(8), 975-1001.
- Hossain, L., Sarker, S. K., & Khan, M. S. (2018). Evaluation of present and future wastewater impacts of textile dyeing industries in Bangladesh. *Environmental Development*, *26*, 23-33.
- Jackson, M. L. (1958). Soil Chemical Analysis, Prentice-Hall, Englewood Cliffs, NJ.
- Jones, J. B. (2001). Laboratory guide for conducting soil tests and plant analysis /Includes bibliographical references and index.CRC Press LLC. ISBN 0-8493-0206-4.
- Kabata-Pendias, A. (2011). Trace elements in soils and plants, Fourth Edition by Taylor and Francis Group, LLC. ISBN 978-1-4200-9368-1.
- Kabata-Pendias, A., & Szteke, B. (2015). Trace Elements in Abiotic and Biotic Environments. Taylor & Francis Group, LLC.
- Müller, G. (1969). Index of geo - accumulation in sediments of Rhine River. *Geochem. J. 2*,108–118.
- Savant, N. K. (1994). Simplified methylene blue method rapid determination of cation exchange capacity of mineral soils. Comun. *Soil Sci. Plant. Anal*, *25*(19 & 20), 3357-3364.
- Soodan, R. K., Pakade, Y. B., Nagpal, A., & Katnoria, J. K. (2014). Analytical techniques for estimation of heavy metals in soil ecosystem: A tabulated review. *Talanta*, *125*, 405-410.
- Tomlinson, D. L., Wilson, J. G., Harris, C. R., & Jeffrey, D. W. (1980). Problems in the assessment of heavy-metal levels in estuaries and the formation of a pollution index. *Helgoländer meeresuntersuchungen*, *33*, 566-575.
- Wawrzkiewicz, M., Wiśniewska, M., Wołowicz, A., Gun'ko, V. M., & Zarko, V. I. (2017). Mixed silica-alumina oxide as sorbent for dyes and metal ions removal from aqueous solutions and wastewaters. *Microporous and Mesoporous Materials*, *250*, 128-147.