IRAQI BULLETIN OF GEOLOGY AND MINING (IBGM)\
IRAQ GEOLOGICAL SURVEY (GEOSURV-IRAQ)

*IBGM (**2025**, Vol 21; Issue 2)* *445-456*

ASSESSMENT OF HEAVY METAL POLLUTION IN THE AIR OF HILLAH CITY, IRAQ

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Type of the Paper (Article)
Received: 22/05/2025
Accepted: 07/10/2025
Available online: 27/12/2025

Abstract

Heavy metal pollution in the air creates significant environmental risks and health hazards because these substances stay in the environment while being toxic to living creatures and gradually increase their presence in the ecosystems. A research project measured the levels of zinc (Zn), chromium (Cr), cadmium (Cd), and lead (Pb) throughout Hillah city air based on data acquired from ten specific sampling stations. This research investigates whether human activities have negatively affected these heavy metal levels above their natural range. The research data were analyzed by comparison against crustal background values using accepted classification systems. The research data show that zinc (Zn), chromium (Cr), and lead (Pb), respectively, derive mainly from natural sources, yet cadmium (Cd) shows moderate levels of contamination stemming from human activities. Excessive Cr, Pb, and Cd levels relative to WHO standards emphasize the immediate requirement for pollution management systems. The region suffers from heavy metal contamination mainly because of industrial emissions, traffic density, illegal waste burning, and energy generation activities. Further research is needed to study seasonal heavy metal exposure patterns and development protocols that minimize human contact with pollutants.

Keywords: Heavy Metals; Air Pollution; Hillah city; Iraq.

1. Introduction

Air contamination is an urgent ecological problem because industrial processes, transport systems, and garbage incineration generate dangerous pollutants, which contain heavy metals, including Zn, Cr, Cd, and Pb. These chemicals represent important health dangers to ecosystems because they are toxic and persistent while accumulating in the biological systems (Duffus, 2002; Kabata-Pendias & Mukherjee, 2007; Muslim et al., 2022). According to Lazaridis (2011) and Hussain & Manii (2023), heavy metals have prolonged atmospheric retention potential besides their occurrence in fine particulate matter. Heavy metals travel through the atmosphere as gases, while aerosols and particles exist in the air. Still, fine

ISSN 1811-4539, EISSN 3005-3714
https://doi.org/10.59150/ibgm2102a24
IBGM: http://ibgm-iq.org/
Academic Scientific Journals: www.iasj.net

particles maintain the most severe health hazards because they stay suspended in the air for hours to weeks (Lazaridis, 2011). Studies show that exposure to elevated heavy metal particulates through inhalation leads to cancer development and brain injuries, congenital disabilities, and heart conditions (Panne et al., 2001; An et al., 2008; Hassan & Al-Shamma, 2019). High environmental contamination with Cd and Pb has led to increased spontaneous abortions in early pregnancies, according to Krasnodebski (1986). This study aims to extract the concentrations of Cd, Zn, Pb, and Cr in the air of the city of Hillah and compare them with the standards of the World Health Organization and with other local, Arab, and international concentrations.

2. Materials and Methods

2.1. Study Area

The study area is located in Hillah City, Babylon Governorate, Iraq. The city is 100 km south of Baghdad. Figure 1 shows the location map of the study area, and has a population of around 645016 people. Hillah City has an arid and semi-arid climate that brings hot, dry summers combined with cold, rainy winters. North-south traffic through Hillah plays a crucial role as this city acts as the link between Iraqi regions. The city receives about 151.8 mm of average rainfall annually (Hilal & Manii, 2024).

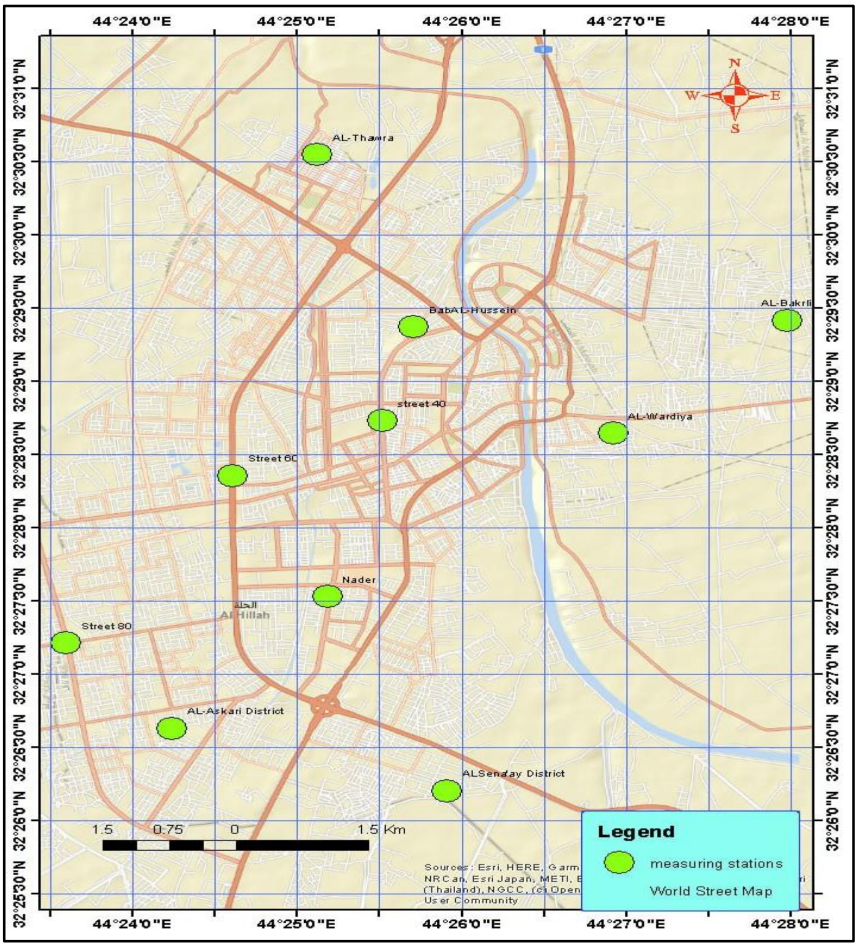

Figure 1. Air sampling stations of the study area in Hillah City, Iraq.

2.2. Sampling Procedures

Ten airborne dust sampling sites were selected throughout Hillah City, including places for commercial activities, industrial sites, residential areas, and traffic zones. The RADECO Sniffer device with attached fiber filters was used to conduct the sampling operations. The instrument operated 2 meters above the floor during one-hour sampling durations at each site selection. The atomic absorption spectrometry (AAS) technique enabled sample analysis of trace elements by demonstrating high sensitivity and reliable results, as shown in Table 1 (Silvia et al., 2004; Vasconcelos & Tavares, 1997).

Table 1. Range and mean of trace element concentrations in the air of the study area.

Station / Trace Element	City Type	Zn (μg/m³)	Cr (μg/m³)	Cd (μg/m³)	Pb (μg/m³)
ALSena'ay District	Industrial	0.378	2.562	0.253	1.140
Street 80	Traffic	0.929	6.435	0.257	1.155
AL-Askari District	Residential	0.857	1.837	0.297	2.419
AL-Thawra	Traffic	0.511	1.029	0.330	1.104
BabAL-Hussein	Commercial	1.801	0.639	0.342	1.706
Street 40	Traffic	0.811	1.379	0.4166	1.735
Street 60	Traffic	1.263	0.687	0.407	2.238
AL-Bakrli	Residential	1.2483	4.103	0.437	3.740
Nader Bridge	Traffic	1.324	1.593	0.573	2.583
AL-Wardiya	Residential	1.007	1.716	0.5115	2.779
Mean		1.013	2.198	0.382	2.059
Range		1.801 - 0.378	6.435 - 0.639	0.5115 - 0.253	3.740 - 1.104
WHO (1996) (μg/m³)		6	0.04	0.05	0.5

2.3. Crustal Earth Background Concentrations

2.4. Assumptions

A simple assumption was made that atmospheric particulate matter density is 1 g/cm³, permitting comparison of crustal concentrations (mg/kg) as shown in Table 2 and air concentrations (μg/m³) (Schroeder et al., 1987; Al-Bassam & Yousif, 2014). The aluminum (Al) was selected as a reference since it exists abundantly in nature with low human-made pollution levels.

Table 2. The crustal background concentrations of the elements were derived from published literature (Taylor & McLennan, 1985; Wedepohl, 1995):

Element	Crustal Concentration (mg/kg)
Zn	70
Cr	90
Cd	0.1
Pb	17

3. Results and Discussion

A table of trace element concentrations has been compiled from research in Iraq, Arab countries, and worldwide locations, as shown in Table 3, focusing on Zn, Cr, Cd, and Pb compared with the study area. A complete data evaluation will include findings from previous studies, pollution determinants identified by the World Health Organisation (WHO), and confirmed scientific records.

3.1. Explanation of Results

3.1.1. Zinc (Zn)

Zinc (Zn): The research area has moderate Zn levels (0.37 – 1.80 µg/m³) as shown in Figure 2 and Table 3 relative to Iraqi and Arab cities like Baghdad and Cairo. International cities, such as London, have lower Zn concentrations due to stronger air quality laws. The WHO does not have particular limits for zinc; however, greater quantities are commonly linked to industrial pollutants.

3.1.2. Chromium (Cr)

The study area detects chromium amounts that exceed the WHO recommended yearly threshold of 0.02 µg/m³ because of industrial contamination in Basra and Riyadh, as shown in Figure 3, and other Iraqi and Arab cities. International cities achieve low chromium concentrations through their successful emission control plans.

Table 3. Comparison of heavy metal concentrations in urban dust across different regions.

Element	Study Area (µg/m³)	Iraqi Cities (µg/m³)	Arab Cities (µg/m³)	International Cities (µg/m³)	WHO Guideline (µg/m³)	References
Zn	0.378–1.801	Baghdad: 2.1–3.5	Cairo: 4.6–7.8	London: 0.4–0.8	No specific guideline	Al Manmi et al.(2019) . El-Nahhal & Safi (2018)
	0.639–6.435	Basra: 1.5–4.2	Riyadh: 2.1–5.4	New York: 0.1–0.3	Annual mean: 0.025	WHO (2021), Al-Dabbas et al.(2017), Ewaid et al.(2020)
Cd	0.253–0.573	Mosul: 0.3–0.8	Amman: 0.2–0.7	Paris: 0.01–0.05	Annual mean: 0.005	Al-Saadi & Al-Tawash (2019), Al-Rashidi & Al-Haddad (2018), Zhang & Liu (2021)
Pb	1.104–3.740	Erbil: 1.8–3.1	Dubai: 0.9–2.4	Tokyo: 0.05–0.2	Annual mean: 0.5	Al-Shammari & Al-Mosuli (2020), Al-Awadhi & Al-Shemari (2017), Kim, Kabir & Jahan (2018)

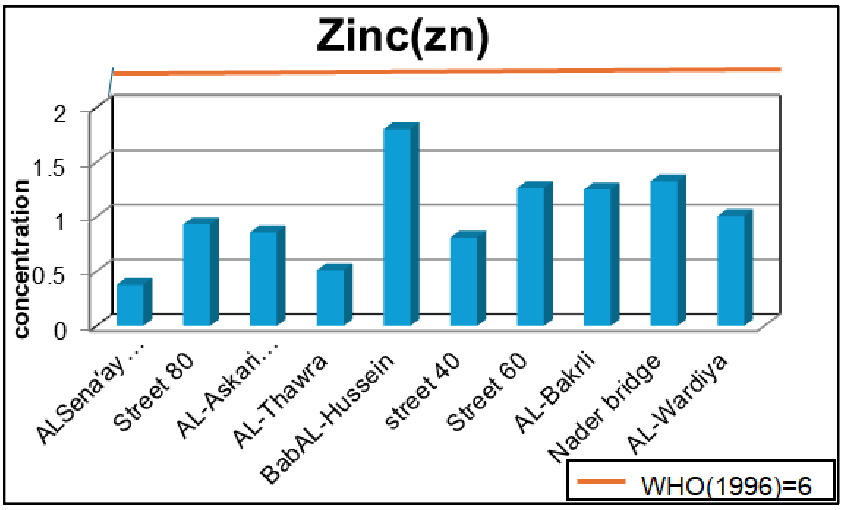

Figure 2. Graphical representation of zinc concentrations (µg/m³) in the air of the study area.

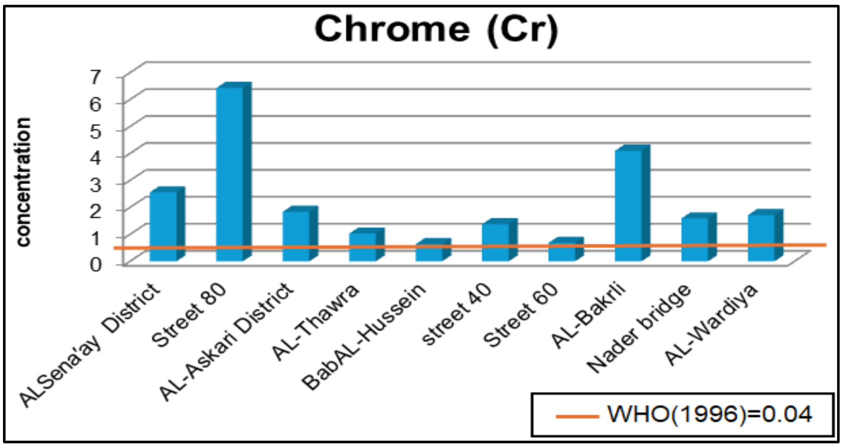

Figure 3. Graphical representation of chromium concentrations (µg/m³) in the air of the study area.

3.1.3. Cadmium (Cd)

The research site demonstrates Cd concentrations (0.25 – 0.57 µg/m³) similar to those of other Iraqi municipalities and Arab cities, while exceeding the recommended WHO standard of 0.005 µg/m³ annual mean as shown in Figure 4. Due to stringent pollution regulations in Paris, the city exhibits minimal cadmium (Cd) concentrations.

3.1.4. Lead (Pb)

The World Health Organization established a 0.5 µg/m³ annual mean level for Lead contamination; however, examination findings in the study zone (1.10 – 3.74 µg/m³) exceed this standard, as shown in Figure 5.

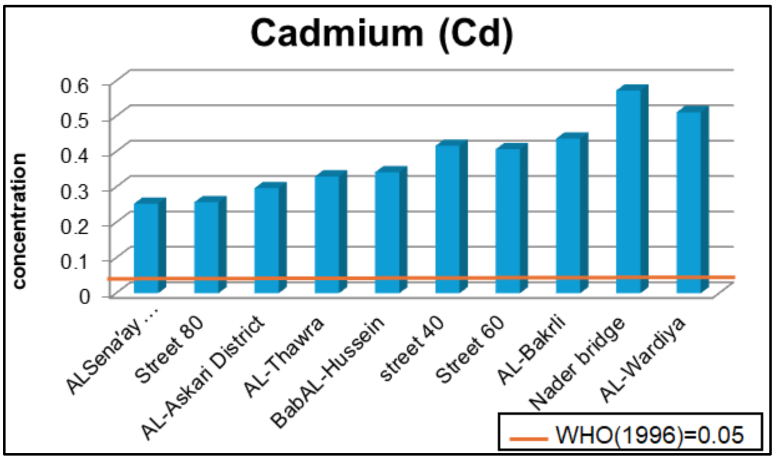

Figure 4. Graphical representation of cadmium concentrations(μg/m³) in the air of the study area.

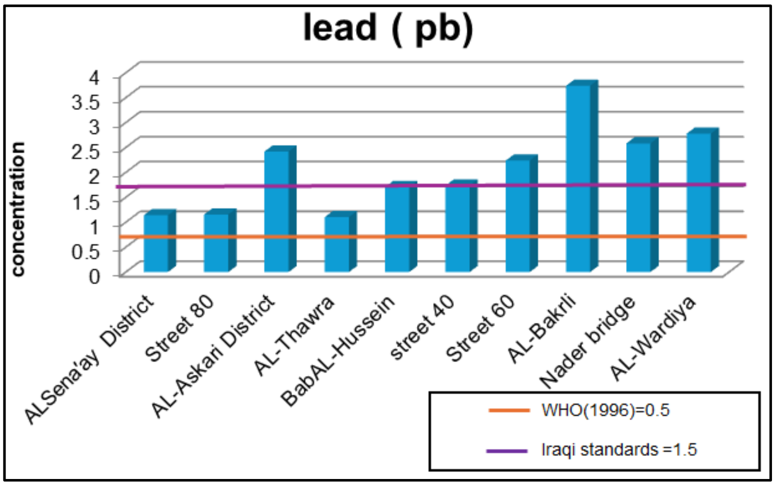

Figure 5. Graphical representation of lead concentrations (μg/m³) in the air of the study area.

4. Comprehensive Analysis Using Geostatistical Mapping

The atmospheric concentrations of zinc (Zn), chromium (Cr), cadmium (Cd), and lead (Pb) exist in the environment. Universal knowledge about how these pollutants spread in space allows scientists to identify contaminated zones while evaluating human exposure risks and developing suitable protection approaches. Geographic Information Systems processed data to create how heavy metals, Zn, Cr, Cd, and Pb, distribute in Hillah City through geostatistical mapping. These maps present extensive information about heavy metal pollution distribution throughout the city, allowing observers to better understand their origins and effects in the area. The heavy metals received geostatistical analysis through kriging interpolation to develop mapping visuals for their spatial distribution patterns. The distribution of heavy metals of Zn, Cr, Cd, and Pb throughout the city can be observed through these maps, which present spatial concentration data. The obtained results were assessed against both the World Health Organization (WHO) permissible limits and Iraqi standards to determine the degree of environmental pollution. Below, the spatial distribution patterns depicted in Figures 6 and 7 are discussed and analyzed.

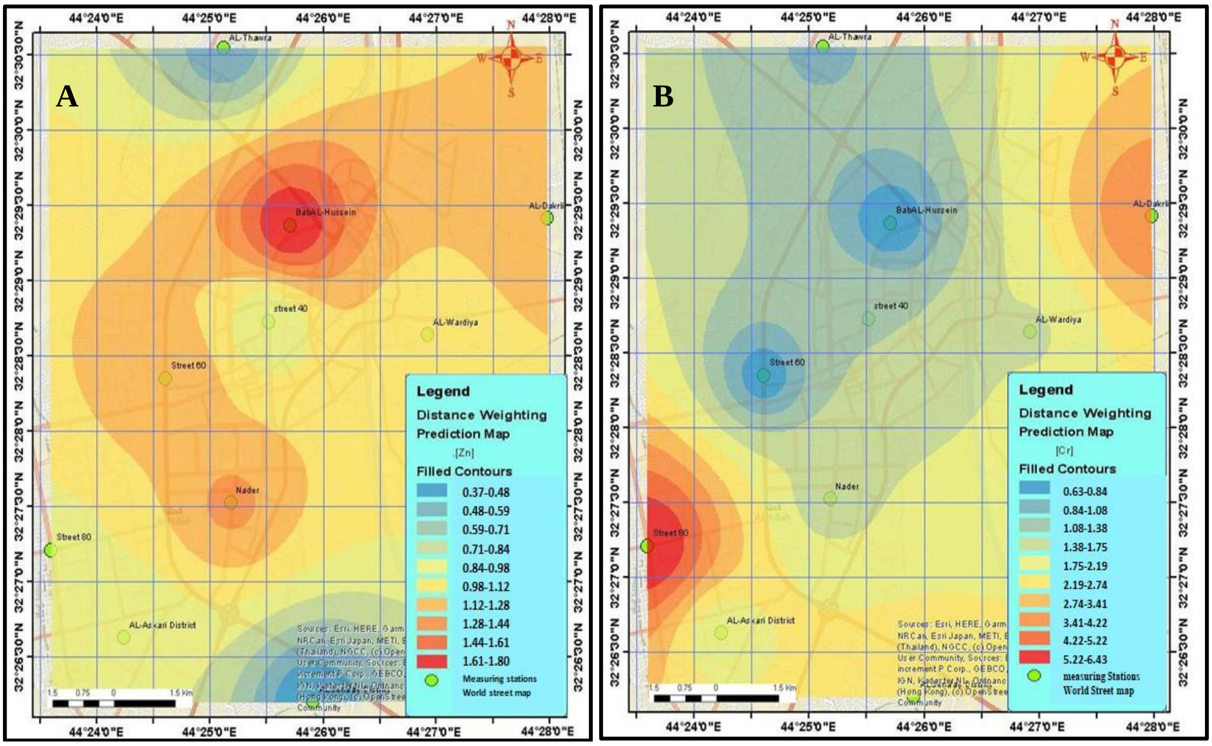

Figure 6. Spatial distribution of Zinc (Zn) concentrations (µg/m³) in the picture (A)and Spatial distribution of chromium (Cr) concentrations (µg/m³) in the picture (B)in the air of Hillah. City, generated using geostatistics (GIS).

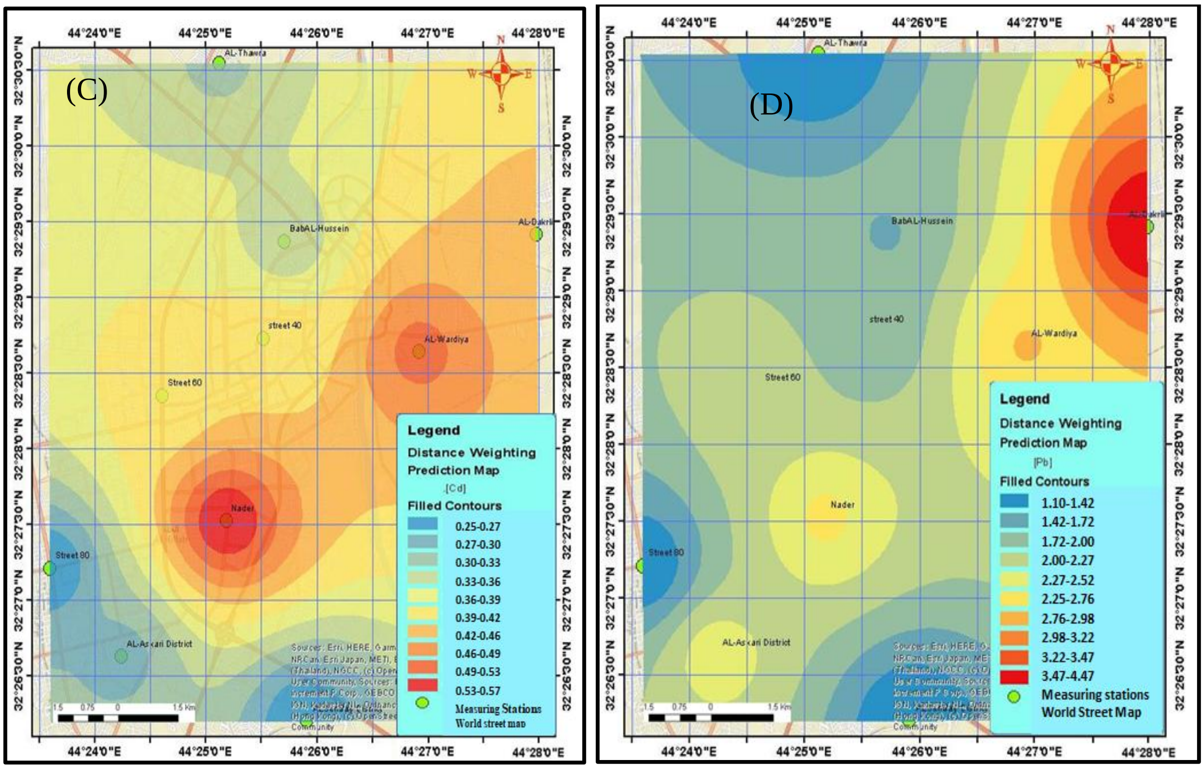

Figure 7. Spatial distribution of Cadmium(Cd) concentrations (µg/m³) in the picture(C) and Spatial distribution of lead (Pb) concentrations (µg/m³) in the picture(D) in the air of Hillah City, generated using geostatistics (GIS).

4.1. Zinc (Zn)

4.1.1. Spatial Distribution

Zn concentrations are generally low throughout Hillah City, with isolated maxima in commercial and industrial districts, according to the GIS map. Bab Al-Hussein, a commercial and busy neighborhood with many companies and workshops, has the highest Zn content (µg/m³). Moderate zinc levels are seen in residential neighborhoods like AL-Wardiya and AL-Bakrli, most likely as a result of lower traffic density and industrial activities.

4.1.2. Key Observations

Below the WHO-recommended limit of 6 µg/m³ stands the average zinc concentration in Hillah City at 1.01 µg/m³. Industrial activities and transportation emission products resulting from tire wear and brake pad abrasion create most of the zinc pollution in the region.

4.1.3. Outcome

The acceptable Zn levels found in the city should prompt focused monitoring efforts and intervention methods for controlling concentrations in industrial and commercial areas.

4.2. Chromium (Cr)

4.2.1. Spatial Distribution

The Cr pollution hotspots located in Street 80 appear as the most significant areas on the GIS map because this major road has the highest recorded Cr concentration at 6.43 µg/m³. The residential area AL-Bakrli exhibits increased Cr levels because residents conduct illegal waste burning and implement energy generation procedures. The Cr concentration in Street 60 and Nader Bridge falls within the moderate range because vehicular emissions and road wear contribute to this amount.

4.2.2. Key Observations

Hillah City's average chromium concentration level is 2.19 µg/m³, substantially surpassing the WHO-established safe level of 0.04 µg/m³. Analysis of Cr distribution reveals that industrial activities, together with fuel combustion and traffic sources, drive Cr pollution throughout the city.

4.2.3. Outcome

The areas with dense traffic flow and industrial sites in Hillah City present a major health threat due to Cr pollution. The protection of public health requires both more stringent emissions regulations and continuous chromium measurement systems.

4.3. Cadmium (Cd)

4.3.1. Spatial Distribution

The GIS map shows a variable distribution of Cd, whereby Nader Bridge and AL-Wardiya stand as the locations with the highest detection levels due to traffic congestion and unauthorized waste disposal activities. Cambrian played a major role in raising Cd concentrations at AL-Bakrli, which is located amidst power facilities and waste dumping sites.

4.3.2. Key Observations

The Hillah City average concentration of Cd amounts to 0.38 µg/m³, while the WHO established a maximum threshold of 0.05 µg/m³. The geographical data show that human activities such as industrial discharges, illegal waste disposal, and power production have strong effects on Cd pollution levels.

4.3.3. Outcome

The medium level of Cd contamination in Hillah City creates health risks because this substance is dangerously toxic and continues to accumulate in ecosystems. The control and enforcement of waste regulations, combined with pollution emission regulations, must be strictly implemented to fight Cd contamination.

This section may be divided into subheadings. It describes the research study's outcomes; the results should be presented clearly and concisely.

4.4. Lead (Pb)

4.4.1. Spatial Distribution

The Pb GIS map shows AL-Bakrli and Street 60 as major pollution areas because these locations host high traffic vibration points and industrial operations. The structural complexity of the Nader Bridge has been associated with heightened Pb concentrations because it serves as a connecting point between different governorates. Pb measurements in AL-Wardiya residential district have moderate levels that exceed the natural background.

4.4.2. Key Observations

Approximate measurements of Pb in Hillah City reached 2.05 µg/m³, surpassing the established WHO threshold (0.5 µg/m³) and Iraqi regulation (1.5 µg/m³). Pb distribution throughout the city confirms that vehicles, industries, and unauthorized waste incineration, all together, contribute to Pb contamination.

4.4.3. Outcome

Pb pollution in Hillah City is a significant concern, particularly in areas with high traffic density and industrial activity. Urgent measures, such as promoting cleaner fuels and improving public transportation, are needed to reduce Pb exposure risks**.**

5. Conclusion

The research showed considerable differences in how much of heavy metals in the study area. The recorded concentrations of Cr at 2.19 µg/m³, together with Pb at 2.05 µg/m³ and Cd at 0.38 µg/m³, exceeded WHO permissible limits, illustrating substantial human activities as sources of heavy metal pollution in the city. The average Zn content at 1.01 µg/m³ fell below the WHO established maximum level of 6 µg/m³, thus demonstrating low environmental and health risks from Zn exposure. The Geographic Information Systems (GIS) generated geostatistical maps displayed comprehensive patterns of heavy metal pollution throughout Hillah City. The maps pointed out particular hotspots where pollutants reached their peak levels, and both traffic congestion areas and industrial facilities alongside illicit waste disposal sites exposed these high-risk zones. Tire wear and road abrasion from heavy traffic resulted in Street 80 becoming the area with the maximum Cr concentration of 6.43 µg/m³. AL-Bakrli recorded the greatest Pb levels (3.74 µg/m³) because it serves as a residential area that simultaneously supports energy generation initiatives and experiences more vehicular activity. AL-Wardiya registered the highest Cd levels (0.51 µg/m³), which indicates that residential zones are affected by both illegal waste burning and individual vehicle emissions.

The accumulation of heavy metals in Hillah City happens mainly because of expanding population numbers, accompanied by growing automotive activity and industrial smoke pollution, and the practice of disposing of trash through burning and the process of electricity generation. Hillah City experiences increased pollution through human-made sources due to its arid climate, which allows dust to re-launch and extends airborne fine particles. Heavy metal concentrations exceed levels from rainy seasons because dry seasons create optimal conditions for atmospheric pollutant reduction. The elevated concentrations of Cr, Pb, and Cd in Hillah City present serious health threats to its residents. Both short-term and long-term metal contaminant exposure lead to respiratory diseases, along with neurological damage, reproductive abnormalities, and carcinogenic effects. People who inhale high levels of particulate heavy metals risk serious health problems, which cause cardiovascular diseases and result in abortion during early pregnancy.

The research shows an immediate requirement to tackle heavy pollution from metal contaminants in Hillah City. Public health needs urgent action to control the high Cr, Pb, and Cd concentrations alongside the acceptable Zn levels. To address health risks from exposure, it is necessary to combine stronger emission standards with better waste practices and the promotion of energy sources that minimize pollution. Air quality assessment programs and heavy metal measurement protocols need to operate regularly throughout time for researchers to monitor environmental trends caused by pollution and evaluate the success of cleanup strategies. The implementation of pollution hotspot resolution alongside sustainability measures will enable Hillah City to achieve a wholesome urban setting for its population.

References

Al Manmi, D. A. M., Abdullah, T. O., Al-Jaf, P. M., & Al-Ansari, N. (2019). Soil and groundwater pollution assessment and delineation of intensity risk map in Sulaymaniyah City, NE of Iraq. *Water, 11*(10), 2158. https://doi.org/10.3390/w11102158

Al-Awadhi, J. M., & Al-Shemari, H. (2017). Heavy metal contamination in urban dust of Dubai, UAE. *Environmental Monitoring and Assessment, 189*(5), 218

Al-Bassam, K. S., & Yousif, M. A. (2014). Geochemical distribution and background values of some minor and trace elements in Iraqi soils and recent sediments. *Iraqi Bulletin of Geology and Mining, 10*(2), 109–156.

Al-Dabbas, M. A., Abdul Razzaq, S., & Maiws, S. O. (2017). Evaluation of soil pollution and chemical weathering in the Yusufiya and Dujaila areas of Iraq using environmental pollution factors. *Iraqi Geological Journal, 50*(2), 72–84.

Al-Rashidi, M. S., & Al-Haddad, A. (2018). Heavy metal pollution in urban dust of Kuwait City. *Atmospheric Pollution Research, 9*(4), 684–693.

Al-Saady, Y. I., & Al-Tawash, B. S. (2019). Hydrochemical characteristics and environmental evaluation of surface and groundwater quality at Al-Tarmiyah Area, Baghdad, Iraq. *Iraqi Journal of Science, 60*(5), 1055–1068. https://ijs.uobaghdad.edu.iq/index.php/eijs/article/view/443

Al-Shammari, A. M., & Al-Mosuli, R. K. (2020). Heavy metal contamination in urban dust of Mosul City, Iraq. *Environmental Geochemistry and Health, 42*(1), 291–302.

An, J., Zhou, Q., Liu, W., & Ren, L. (2008). Horizontal distribution and levels of heavy metals in the biggest snowstorm in a century in Shenyang, China. *Journal of Environmental Sciences, 20*(7), 846–851. https://doi.org/10.1016/S1001-0742(08)62136-1

Duffus, J. H. (2002). Heavy metals: A meaningless term? *Pure and Applied Chemistry, 74*(5), 793–807.

Safi, J., El-Nahhal, Y., & Safi, M. (2018). Particle size distribution and hydraulic conductivity in coastal non-agricultural land in Gaza Coastal Plain. *International Journal of Geosciences, 9*(10), 619–633. https://doi.org/10.4236/ijg.2018.91003.

Ewaid, S. A., Al-Kasser, A., Al-Gizzi, H., Hassan, W., & Al-Saad, H. (2020). Air pollution in the southern part of Iraq and its health risks.

Hassan, R. A., & Al-Shamma, A. (2019). Environmental change detection using remote sensing and GIS techniques in the area around Al-Ahdeb oilfield, Wasit Governorate, Iraq. *Iraqi Bulletin of Geology and Mining, 15*(1), 123–133.

Hilal, R. R., & Manii, J. K. (2024). Dust storm effects on air quality and particulate matter pollution in Babylon Governorate, Iraq. *Iraqi Geological Journal, 57*(1D), 233. https://doi.org/10.46717/igj.57.1D.17ms-2024-4-27

Hussain, S. H., & Manii, J. K. (2023). Monitoring and distribution of some air pollutants levels around Al-Zubaydiah Electrical Power Plant in Wasit Governorate, Iraq. *Iraqi Geological Journal, 56*(2C), 335. https://doi.org/10.46717/igj.56.2C.0ms-2023-9-6.

Kabata-Pendias, A., & Mukherjee, A. B. (2007). *Trace elements from soil to human*. Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-540-32708-0

Kim, K.-H., Kabir, E., & Jahan, S. A. (2018). Exposure to heavy metals and its impact on human health: A review. *Environmental Science and Pollution Research, 25*(3), 2043–2058.

Krasnodębski, Z. (1986). *Rozumienie ludzkiego zachowania: rozważania o filozoficznych podstawach nauk humanistycznych i społecznych*. Warszawa: Państwowy Instytut Wydawniczy.

Lazaridis, M. (2011). *First principles of meteorology and air pollution*. Springer Science + Business Media.

Muslim, R. I., Al-Mayyahi, S. O., & Al-Ghasham, N. A. (2022). Employment of trace elements in environmental geochemistry studies to assess the pollution for selected areas in Iraq. *Iraqi Bulletin of Geology & Mining, 18*(2), 75–91.

Panne, U., Neuhauser, R. E., Theisen, M., Fink, H., & Niessner, R. (2001). Analysis of heavy metal aerosols on filters by laser-induced plasma spectroscopy. *Spectrochimica Acta Part B: Atomic Spectroscopy, 56,* 839–850.

Schroeder, W. H., Dohson, M., Kane, D. M., & Johnson, N. D. (1987). Toxic trace elements associated with airborne particulate matter: A review. *Journal of the Air Pollution Control Association, 33*, 1267–1285. https://doi.org/10.1080/00022470.1983.10465668

Silvia, P. J., & Phillips, A. G. (2004). Self-awareness, self-evaluation, and creativity. *Personality and Social Psychology Bulletin, 30*(8), 1009–1017.https://doi.org/10.1177/0146167204264073

Taylor, S. R., & McLennan, S. M. (1985). *The continental crust: Its composition and evolution*. Blackwell Scientific Publications.

Vasconcelos, M. T. S. D., & Tavares, H. M. F. (1997). Atmospheric metal pollution (Cr, Cu, Fe, Mn, Ni, Pb and Zn) in Oporto City derived from results for low-volume aerosol samplers. *Science of the Total Environment, 212*, 11–20.https://doi.org/10.1016/S0048-9697(97)00322-7

Wedepohl, K. H. (1995). The composition of the continental crust. *Geochimica et Cosmochimica Acta, 59*(7), 1217–1232. https://doi.org/10.1016/0016-7037(95)00038-2

World Health Organization. (1996). *Air quality guidelines for Europe* (2nd ed.). Copenhagen: WHO Regional Office for Europe.

World Health Organization. (2021). *Air quality guidelines: Global update 2021. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. Geneva: World Health Organization.

Zhang, L., & Liu, Y. (2021). Heavy metal contamination in urban dust of major Chinese cities: A review. *Environmental Pollution, 268*, 115774.