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REVIEW ARTICLE

Bibliometric analysis (VOSviewer): Analytical chemistry techniques for heavy metals and lead determination in Iraq: A review

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ABSTRACT

This review provides a comprehensive overview of heavy metal and lead analysis in environmental, drug, cosmetic, and food pollution samples, focusing on research conducted in Iraq. The explore of the co-occurrence of heavy metals and analytical chemistry techniques in published studies over the last ten years was achieved by using bibliometric analysis (VOS viewer) based on database from the Scopus. For determining heavy metal concentrations in different environmental samples, various analytical chemistry techniques were assesses in this review such as Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Atomic Absorption Spectrometry (AAS), and X-ray fluorescence (XRF). This study confirms the importance of development of efficient, selective, and sensitive techniques for heavy metal detection in Iraq to reduce their harmful impacts on human health and the environment.

Keywords: VOSviewer; heavy metals; analytical chemistry; bibliometric analysis; Iraq

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1. Introduction

Heavy metals are metallic elements with a relatively high atomic weight and density compared to other substances in the periodic table[1]. Heavy metals are found in soils, water, organism bodies, and all our biosphere[2]. Most of these metals, such as (As, Cd, Pb, Ni, and Hg), pose a significant health risk, even at low concentrations or when exposure exceeds permissible daily limits[3]. The negative health effects for human come from when elements are toxic. These toxic elements can bioaccumulate in human body, causing disorder with physiological functions or illness[4].

The risk control of elemental impurities in drug products is describes by International Council for Harmonization (ICH) Q3D guidelines. The risk assessment of elemental impurities includes manufacturing equipment, excipients, drug substance, utilities, and container closure system[5]. PDE is the permitted daily exposure limits of elemental impurities for pharmaceutical product[6]. The maximum elemental impurities consumption of oral drug dosage is 10 g day per day. ICHQ3D guideline classifies of elements to the four classes based on their potential to appear as contaminants in pharmaceutical products and their toxicity, they are[7-9]:

Class 1: elements of significant human toxicity (As, Cd, Pb, and Hg). These elements have no therapeutic benefit and found in drugs from raw materials like mined excipients.

Class 2: Elements of moderate human toxicity and divided into two subclasses: Class 2A includes (Ni, Co, and V) which are high presence element as impurities in drugs. Class 2B includes (Au, Ag, Ti, Se, Ru, Rh, Pt, Pd, Os, and Ir) which are low probability of presence element as impurities in drugs.

Class 3: Elements of low human toxicity, when administered via oral route, intramuscular, and intravenous route (Li, Cr, Sn, Cu, Mo, Ba, and Sb). The PDE limits exceeding of 500 µg/day.

Moreover, some of elements not classified in the above classes due to their low inherent toxicity include: Al, Zn, W, Ca, Na, Mn, K, Fe, B, and Mg. The classification of elements and their PDE limits for oral consumption according to the ICH Q3D guidelines are shown in **Table 1**.

Lead (Pb) a particularly hazardous heavy metal within this category. Lead, known as "*plumbum*" in Latin, and sometimes referred to as liquid silver, has an atomic number of 82 on the periodic table. Its presence in drug products can originate from commonly used minerals, raw materials, excipients, or metal reagents and catalysts employed in the synthesis of active pharmaceutical ingredients (APIs)[10,11].

The network data obtained from scientific literature databases (such as Scopus, Web of Science, and PubMed) can be used in VOSviewer software for bibliometric network analysis. It is used to create maps that provide a comprehensive understanding of the analytical chemistry techniques used for the determination of heavy metals in different complex samples and that show the linkage between scientific publications focusing on pollutants in soil, rivers, drugs, blood, and keywords of heavy metals through co-occurrence bibliographic analysis.

This review aims to provide an overview of heavy metal and lead analysis, especially within the context of Iraq using bibliometric analysis (VOS viewer) and to assess the analytical chemistry techniques such as AAS, ICP-OES, and ICP-MS used for determination of heavy metals.

Table 1. Element toxicity classification according to ICH Q3D guidelines.

Element	Oral PDE (µg/day)	Class (Toxicity)
Cd	5	1 strong
Pb	5	
As	15	
Hg	30	
Co	50	2A (Moderate)
V	100	
Ni	200	
Ti	8	2B (Moderate)
Au	100	
Pd	100	
Ir	100	
Os	100	
Rh	100	
Ru	100	
Pt	100	
Se	150	
Ag	150	
Li	550	3 (Moderate)
Sb	1200	
Ba	1400	
Mo	3000	
Cu	3000	
Sn	6000	
Cr	11000	

2. Methodology

This bibliometric study, conducted from 2015 to 2025, used the Scopus database to analyze the application of analytical chemistry techniques for the determination of heavy metals in Iraq. The analysis was structured depend on the following stages:

1. We focused on the co-occurrence network of (A) heavy metals and (B) analytical chemistry techniques used for their analysis in the world (**Figure 1**).The search strategy employed selected keywords from Scopus database, including ("heavy metals" AND "analytical chemistry techniques).
2. We studied the co-occurrence of analytical chemistry techniques specifically used for the analysis of lead metal in the world (**Figure 2**). The search used keywords including ("heavy metals" AND "analytical chemistry techniques" AND "lead").
3. We studied the global application of analytical chemistry techniques for the analysis of lead metal in pharmaceutical formulations over the last ten years (**Figure 3**).The search used keywords including ("heavy metals" AND "analytical chemistry techniques" AND "lead" AND "pharmaceutical formulations").
4. We focused on the analytical chemistry techniques used for the analysis of heavy metals in Iraq (**Figures 4, 5**, and **6**). The search used keywords including ("heavy metals" AND "analytical chemistry techniques" AND "Iraq").

2.1. Analytical chemistry techniques for analysis of heavy metals

In this study, we utilized the VOS viewer software tool to construct bibliometric networks for heavy metals and the analytical chemistry techniques used for their analysis[12-14]. **Figure 1**A shows the co-occurrence network of heavy metals found in research publications over the past ten years based on database from the Scopus. The big size of node corresponds to the more prevalent the heavy metal and the lines connecting the nodes represent the co-occurrence of these heavy metals. Moreover, **Figure 1**B shows the co-occurrence network of analytical chemistry techniques used for heavy metals analysis found in research publications over the past ten years. The big size of node corresponds to the more prevalent analytical chemistry techniques, such as Atomic Absorption Spectrometry (AAS) and Mass Spectrometry. The links between nodes indicate which techniques are frequently mentioned together, like AAS technique is strongly linked to spectrophotometry, and spectrometry techniques, indicating that these techniques are often used in conjunction with each other[15-17].

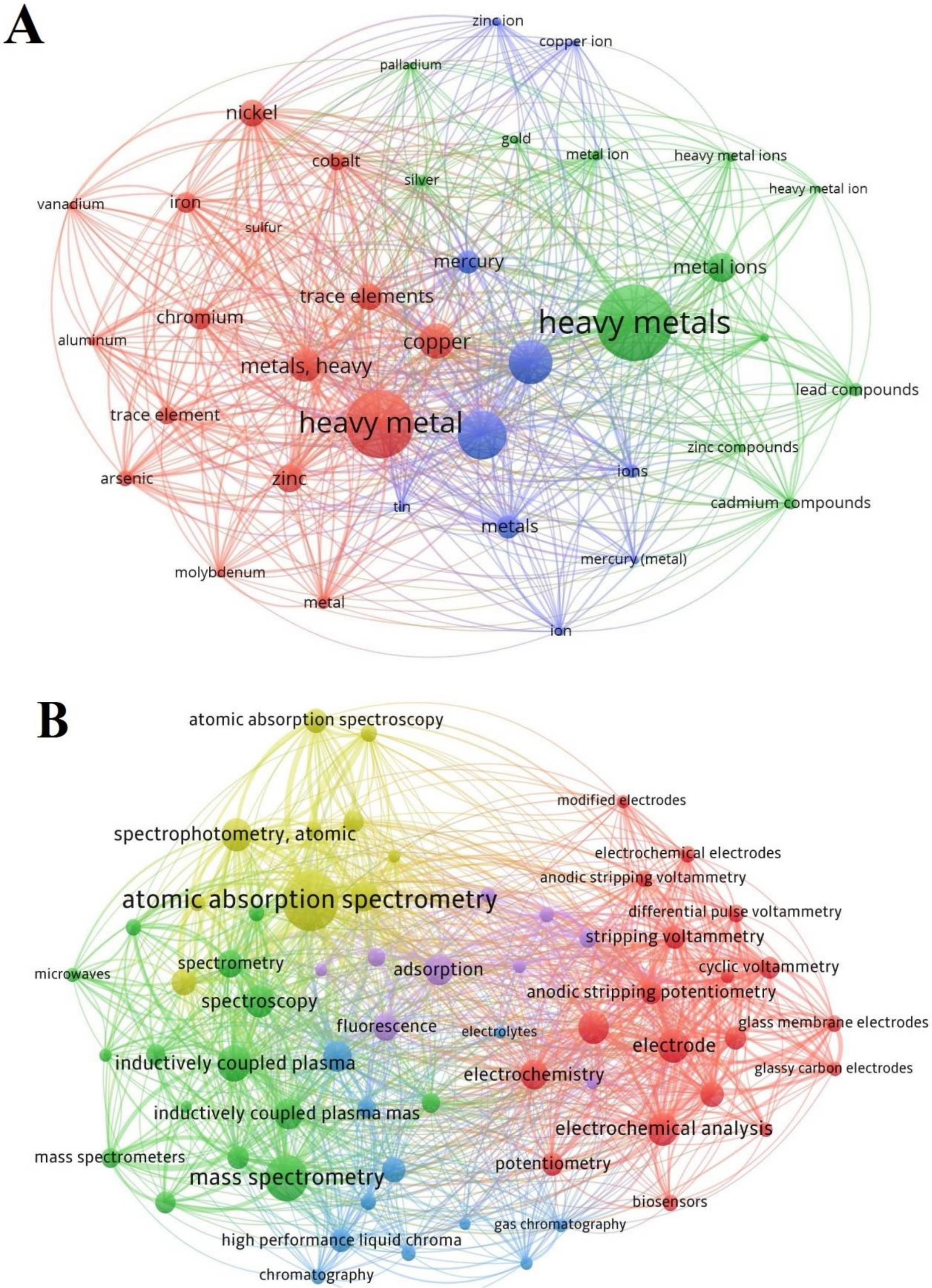

Figure 1. The co-occurrence network of (A) heavy metals and (B) analytical chemistry techniques used for analysis these heavy metals.

2.2. Analytical chemistry techniques for analysis of Lead metal

Figure 2 suggests that a variety of analytical chemistry techniques are used in the over ten year's studies related to lead analysis. The big node indicates prominence of chromatographic and spectroscopic techniques used for analysis lead.

Chromatographic techniques (ultra performance liquid chrom, liquid chromatography, chromatography, high pressure, and thin layer chromatography) are likely used for separating and quantifying lead species in complex matrices (water, soil, blood, urine, and samples tissues)[18-21]. Spectroscopic techniques (scanning electron microscopy, X ray diffraction, nuclear magnetic resonance SPE) are probably used for identifying and quantifying lead at trace levels[22,23]. Electrochemical methods (electrodes and electrochemical techniques) are likely used for determining lead concentrations based on its electrochemical properties[24,25]. Keywords related to the microfluidic analytical method appeared less frequently for lead analysis compared to terms associated with other techniques[26].

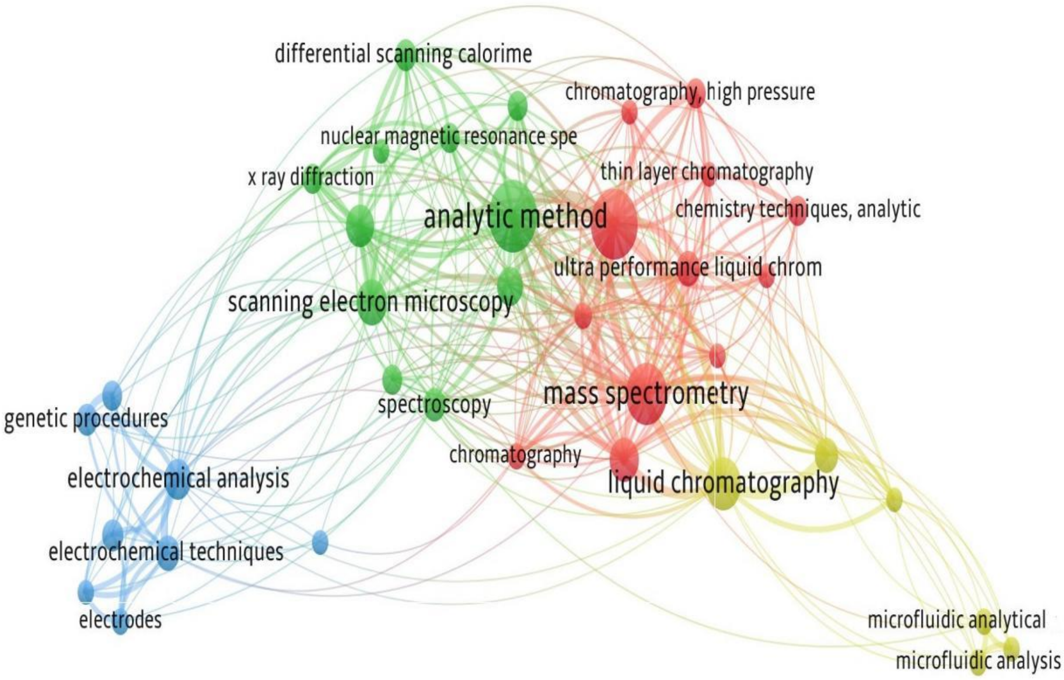

Figure 2. The co-occurrence network of analytical chemistry techniques used for analysis Lead metal.

Chromatographic techniques (essentially HPLC) are the most analytical tools used for lead analysis in pharmaceutical formulations over the past ten years as shown in **Figure 3**. This is due to their ability to separate and quantify lead species in complex matrices (such as blood, urine, serum, tissue, and comples pharmaceutical formulations), high sensitivity, and selectivity[27,28]. Spectroscopic techniques (such as FTIR, SEM, and XRD) play a significant role, but less than chromatographic method[29,30]. Electrochemical and biosensing techniques are less dominant, but they are also used for lead detection and quantification in pharmaceutical formulations[31,32].

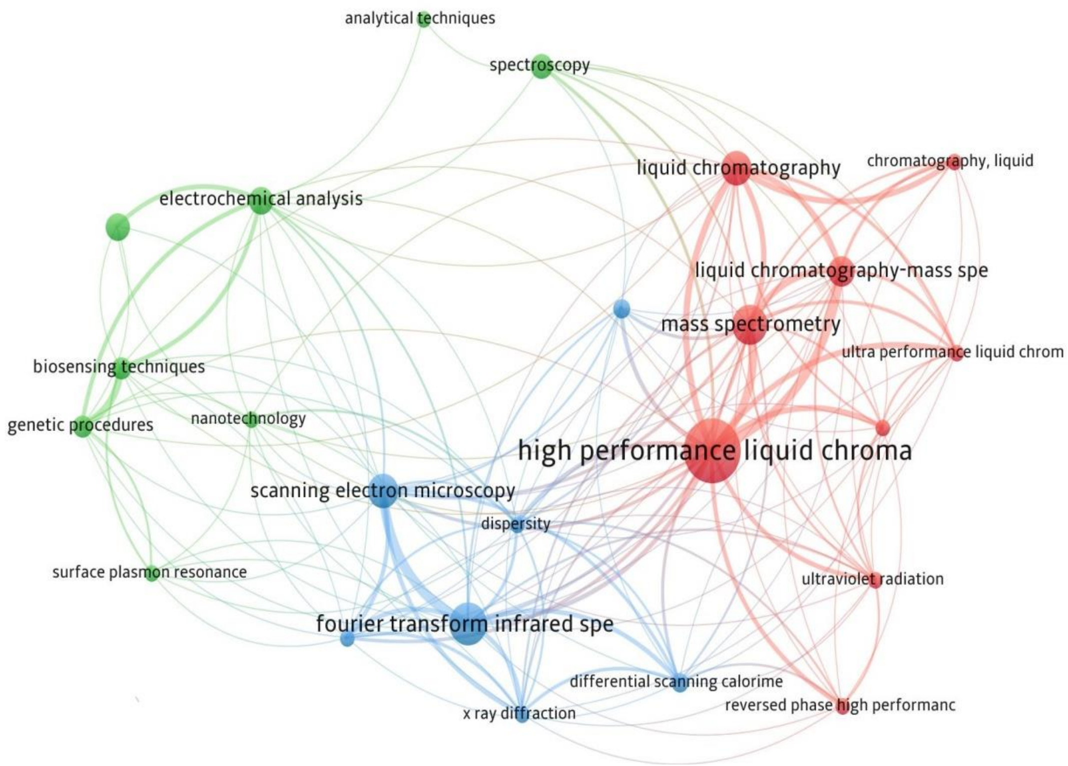

Figure 3. The co-occurrence network of analytical chemistry techniques used for analysis Lead metal in pharmaceutical formulations over the last ten years.

2.3. Analytical chemistry techniques for analysis of heavy metals in Iraq

In the past ten years, only two studies, utilizing AAS, analyzed zinc, iron, and lead in medicinal plant-derived pharmaceutical samples (solid and liquid) and determination (Ni, Co, Fe, Pb, Cd and Cr) by using AAS in Aspirin tablets available in Iraqi markets[63,59]. Therefore, this study will be focuses on the analytical chemistry techniques used for heavy metal analysis in different samples in Iraq. **Figure 4** shown the co-occurrence network related to the analysis of heavy metals within research publications from Iraq over the past ten years. Nodes such as Cd, Hg, Cr, Ni, Cu, Ar, and Pb, indicates these heavy metals are the most frequently studied in Iraq[33, 34].

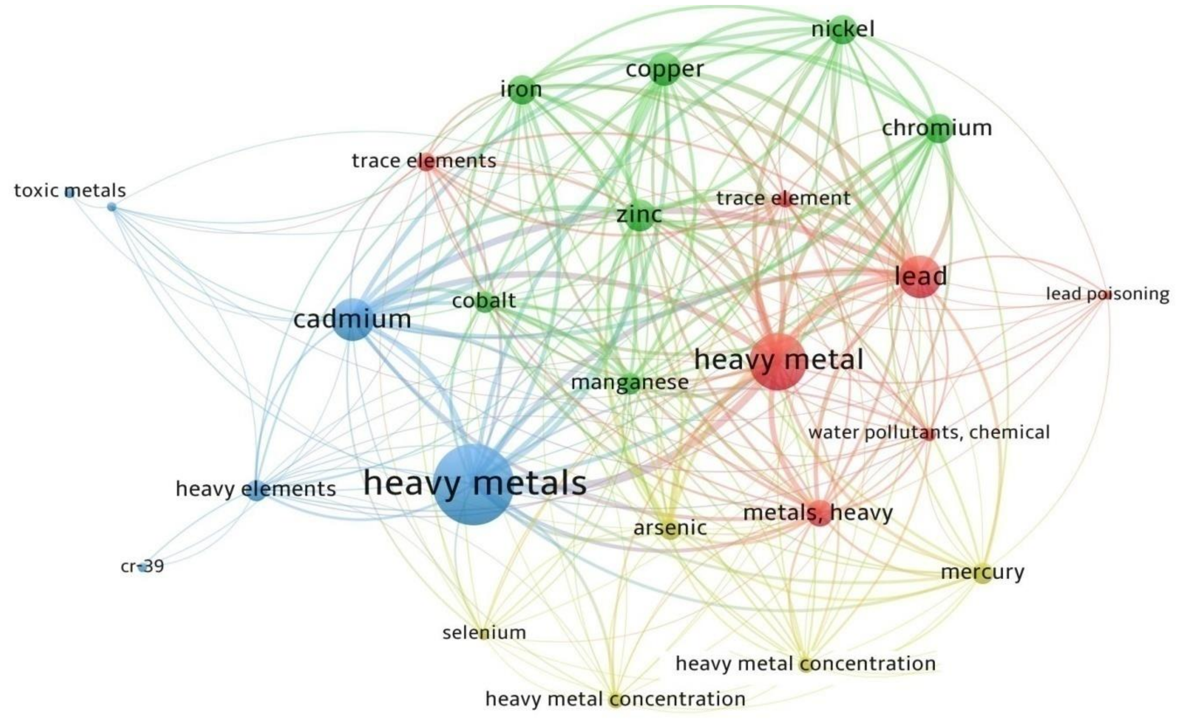

Figure 4. Heavy metals analysis in Iraq over the last ten years.

Figure 5 demonstrates the dominance of water pollution in Iraq, particularly concerning heavy metals. The figure highlights that pollution in rivers, drinking water, lakes, groundwater, and wastewater, including the Tigris and Euphrates rivers, is a major concern. Additionally, soil pollution, dust, air pollution, and specific sources like animals, crude oil, and the petroleum industry are also mentioned as contributing to pollution[35-39].

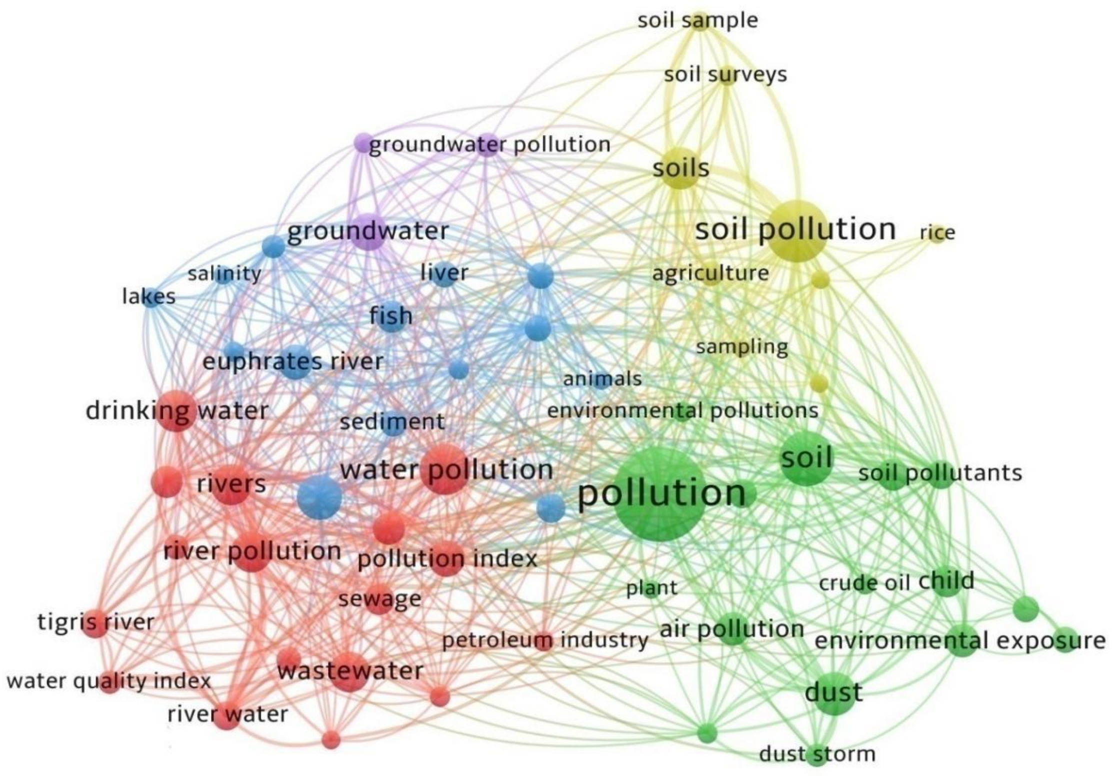

Figure 5. Pollutant samples with heavy metals in Iraq over the last ten years.

The largest node size indicated that the Atomic Absorption Spectrometry (AAS) and Flame Atomic Absorption Spectrometry (FAAS) are the most analytical tools used for determination of heavy metals in Iraqi land space over the past ten years as shown in **Figure 6**. This could be due to factors like its cost-effectiveness, accessibility, and suitability for analyzing heavy metals prevalent in the Iraqi region. This makes it a more accessible option for many laboratories in Iraq, and it is well-suited for the determination of many heavy metals commonly found as pollutants in soil, reivers, drugs, blood, and other matrices pollutant in Iraq. The other techniques (such as X-ray Diffraction, ICP, and X-ray diffraction) play a significant role, but less than AAS and FAAS methods. Finally, Scanning electron microscopy (SEM) was used to investigate the surface morphology of pollutant materials. **Table 2** shows a summary of analytical chemistry techniques such as AAS, XRF, and ICP-MS used to determine heavy metals in various samples from different regions of Iraq.

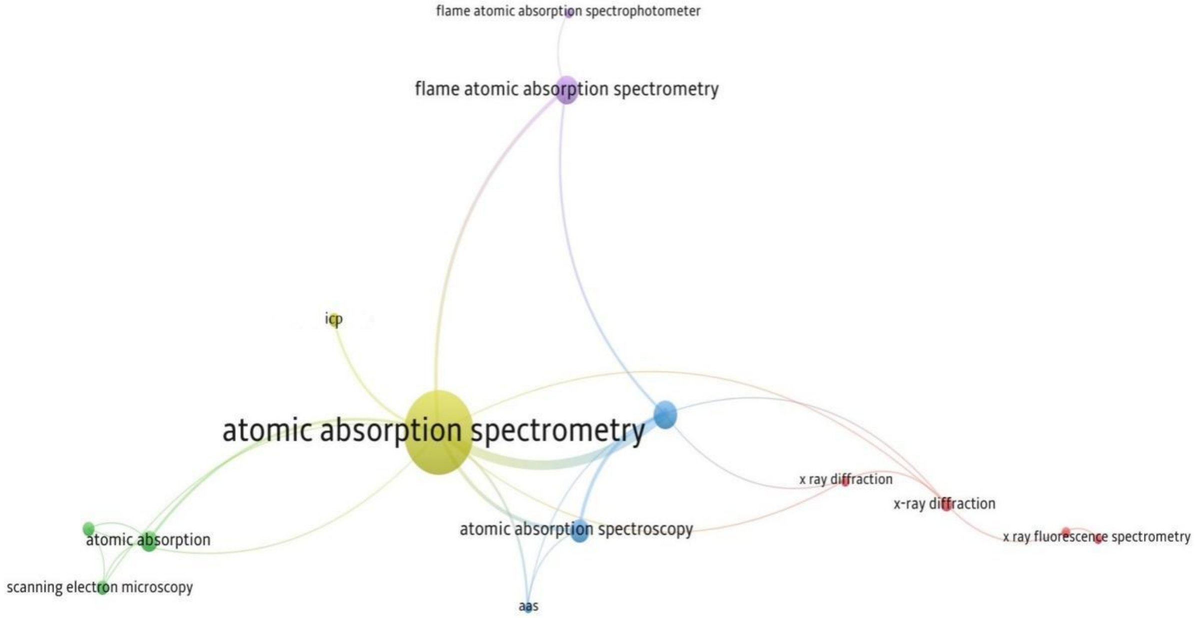

Figure 6. The co-occurrence of analytical chemistry techniques used for determination heavy metals in Iraq over the last 10 years.

Table 2. Analytical chemistry techniques used to determination of heavy metals in Iraq.

Analytical Chemistry Techniques	Metal	Region	Sample	Year	Ref.
Flame Atomic Absorption Spectrophotometer (FAAS)	lead, cadmium, copper and iron	Shatt Al-Arab	water	2023	34
X-ray fluorescence (XRF)	lead , aluminium , chromium, nickel , and arsenic	Sulaymaniyah Governorate	concrete blocks	2025	35
Inductively coupled plasma mass spectrometry (ICP-MS)	As, Cd, Co, Cr, Ni, Pb	Al-Qayarah city	soil samples	2024	36
Flame Atomic Absorption Spectroscopy (FAAS)	Zn, Co, Cu, Pb, Cd, Cr, Fe, and Ni	Anbar Province	soil of oil installations	2024	37
Flame atomic absorption spectroscopy (FAAS)	zinc, copper, nickel, lead, and cadmium	Karbala	tap water samples	2024	38
Atomic Absorption Spectrometry (AAS)	lead, zinc, cadmium, nickel, copper, and chromium	Nine cities in Iraq (Basra, Najaf , Kirkuk , Baghdad , Hillah, Diwaniyah, Samawah, Kut, Amarah)	dust storms	2023	39
Flame atomic absorption spectroscopy (FAAS)	Cadmium, lead, Copper, Zinc, and Iron	Al-Hawizeh Marshes, Misan Province	liver tissues of three migratory bird (Anas platyrhynchos, A. crecca, and A. acuta)	2023	40

Analytical Chemistry Techniques	Metal	Region	Sample	Year	Ref.
Atomic Absorption Spectrometry (AAS)	Cu, Hg, Zn, Cd, Pp	Al-Diwaniyah Governorate	blood samples	2024	41
Atomic Absorption Spectrometry (AAS)	Iron, Copper, Manganese, Cobalt, Nickel, Cadmium and Copper	Baiji in Salah al-Din Governorate	Tigris River, Groundwater, and sewage drain	2022	42
Inductively coupled plasma optical emission spectroscopy	Fe, Mn, Ni, Cu, Zn, Hg, Al, Ba, Se, and As	Diyala-Sirwan river	wastewater discharge on water river	2021	43
Atomic Absorption Spectrometry (AAS)	lead	Kalak city, Erbil	Cowpea seeds and soil	2015	44
Atomic Absorption Spectrometry (AAS)	Ni, Zn, Co, Cr, and Pb	Al-Najaf refinery	soil	2025	45
Atomic Absorption Spectrometry (AAS)	Zn, Pb, Cd, Cu, Co, and Fe	Great Musaiyab, Babylon	water samples	2024	46
Atomic Absorption Spectrometry (AAS)	Nickel, Cadmium, and Lead in the liver and small intestine tissues of Marbled Teal.	Al-Dalmaj marsh	Liver and small intestine tissues of Marbled Teal.	2024	47
Atomic Absorption Spectrometry (AAS)	Mercury and Lead	Baghdad	Blood samples	2024	48
Atomic Absorption Spectrometry (AAS)	cadmium, lead, zinc, and mercury	Al-Hindiyah District, Al-Hindiyah District,and Al-Kifl District	Euphrates River	2024	49
Atomic Absorption Spectrometry (AAS)	Fe, Mn, Cd, Co, As, Hg, Pb, and Se	the vicinity brought on by the Erbil Steel Factory	Rainfall	2024	50
Atomic Absorption Spectrometry (AAS)	Ni, Cu, Cd, Pb, and Co	Maysan Refinery, Al-Masharah	Groundwater	2024	51
Flame atomic absorption spectroscopy (FAAS)	Cu, Zn, Pd, Cd, Mn, Mg, Ni, and Fe	Baghdad	Blood samples of fast-food workers	2024	52
Inductively Coupled Plasma Emission Spectrometry (ICP-AES)	Lead	Diyala River, AL Rustamiya, Karbala, Babylon, and AL-Rashdiya	Cyprus papyrus, Tigris and Euphrates rivers	2024	53
Energy dispersive X-ray fluorescence (EDXRF)	Cd, Pb, Ni, Cu, and Zn	Kurdistan	Milk powder	2025	54
X-ray fluorescence (XRF)	Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Cd, Sb, Hg, and Pb	Left Side of Mosul	Street Dust	2024	55
Flame Atomic Absorption Spectroscopy (FAAS)	Fe, Pb, Cu, Cr, and Zn	Basra	Water and blood samples	2020	56
X-ray fluorescence (XRF)	Cr, Co, Zn, Ni, Cu, Pb, Cd, and Zr	Kut	Tigris River sediments	2019	57
X-ray fluorescence (XRF)	Cr, Ni, Pb, Cd, and As	Okab industry- west of Mosul City and Karama Industry-East of Mosul City	Soil	2020	58
Atomic Absorption Spectrometry (AAS)	Nickel, Cobalt, Iron, Lead, Cadmium and Chromium	Iraqi markets	Aspirin tablets	2018	59
X-ray fluorescence (XRF)	Ti, Cr, Sr, Fe, Zn, Cu and Pb	Baghdad and ThiQar	Soil	2023	60
Inductively Coupled Plasma Emission Spectrometry (ICP-AES)	lead, mercury, and cadmium	Iraqi markets	Natural pharmaceutical products (NPPs)	2022	61
Atomic Absorption Spectrometry (AAS)	arsenic, mercury and cadmium	Iraqi markets	Rice types	2018	62
Atomic Absorption Spectrometry (AAS)	Zinc, iron, and lead	Iraqi markets	Drugs samples from medicinal plants (solid and liquid)	2023	63
Atomic Absorption Spectrometry (AAS)	Aluminum, Copper, Iron, Zinc,	Samaraa Drug Industry	Samaraa Drug Industry Water	2022	64

Analytical Chemistry Techniques	Metal	Region	Sample	Year	Ref.
	Manganese, and Chromium				
Atomic Absorption Spectrometry (AAS)	Cu, Fe, Zn, Pb,	drugs industry of Samarra	piped water	2021	65
X-ray fluorescence (XRF)	Fe, Co, Ni, Cu, Zn and Pb	Diwaniyah city-Qadisiyah Governorate	Road-side dust samples	2018	66
Atomic Absorption Spectrometry (AAS)	Cd, Ni, and Pb	areas near the fuel stations in Karkh District of Baghdad and sides of the highway between Ramadi and Rutba	Roadside dust	2015	67
Flame Atomic Absorption Spectroscopy (FAAS)	Cu, Ni, Cr, Pb, and Cd	Kurdistan	Soil and legume seeds samples	2016	68
Flame Atomic Absorption Spectroscopy (FAAS)	Pb	Sulaimani	lipsticks	2015	69
Atomic Absorption Spectrophotometer (AAS)	Pb, Cd and Cu	Naseriya markets	Medicinal plants	2019	70
Atomic Absorption Spectrophotometer (AAS) and Inductively coupled plasma mass spectrometry (ICP-MS)	As, Hg, Cd, and Pb	river and marine environmental of Basra	sediment samples	2019	71
X-ray fluorescence (XRF)	As, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, Se, Th, U, V, and Zn	Abu-Ghraib Land, Baghdad	plant samples of vegetables(carrot, onion, eggplant, cucumber, and okra)	2024	72
X-ray fluorescence (XRF)	Se, Sb, Te, Hg, Cd, Bi, U, Ni, Mo and As	Baiji and Salah Al-Din General Hospitals in Salah Al-Din	Dust Samples	2024	73
X-ray fluorescence (XRF)	Fe, Co, Ni, Cu, Zn and Pb	East of Baghdad	Streets dust	2021	74
Inductively coupled plasma mass spectrometry (ICP-MS)	Cu, Cr , Ni , Pb, As, Co, and Cd	Kirkuk City	Khasa River	2020	75
Inductively Coupled Plasma Emission Spectrometry (ICP-AES)	Arsenic, Cadmium and Lead	Al Delmaj Marshes	Water,Sediments and Fish	2019	76
Inductively coupled plasma mass spectrometry (ICP-MS)	Cd, Pb, Hg, Cr, Cu and Zn	Basra	blood, serum and hair of breast cancer patients	2021	77

Table 2. (*Continued*)

3. Conclusion

The bibliometric analysis (VOSviewer) based on data from Scopus revealed that Cd, Hg, Cr, Ni, Cu, As, and Pb are the most frequently investigated heavy metal contaminants in the Iraqi region, and that an appearing emergency issue in water pollution includes the Tigris and Euphrates rivers, groundwater, lakes, wastewater, and drinking water. The VOSviewer revealed that analytical chemistry techniques used for heavy metal determination in Iraq like AAS and FAAS. While other techniques are used less prevalent in iraq such as ICP, X-ray Diffraction and X-ray fluorescence (XRF). The analyses of pharmaceutical samples are limited number of studies (just one) in Iraq, which is led to increase the research into pharmaceutical samples. Finally, the evaluation of various environmental samples need to more comprehensive research of heavy metal contamination in Iraq.

Declaration of competing interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Data availability

Data will be made available on request.

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References

1. Mitra, S., Chakraborty, A. J., Tareq, A. M., Emran, T. B., Nainu, F., Khusro, A., ... & Simal-Gandara, J. (2022). Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity. Journal of King Saud University-Science, 34(3), 101865.
2. Upadhyay, R. (2022). Heavy metals in our ecosystem. In Heavy Metals in Plants (pp. 1-15). CRC Press.
3. Witkowska, D., Słowik, J., & Chilicka, K. (2021). Heavy metals and human health: Possible exposure pathways and the competition for protein binding sites. Molecules, 26(19), 6060.
4. Aleluia, A. C. M., de Souza Nascimento, M., dos Santos, A. M. P., dos Santos, W. N. L., Júnior, A. D. F. S., & Ferreira, S. L. C. (2023). Analytical approach of elemental impurities in pharmaceutical products: a worldwide review. Spectrochimica Acta Part B: Atomic Spectroscopy, 205, 106689.
5. Finotti Cordeiro, C., Lopardi Franco, L., Teixeira Carvalho, D., & Bonfilio, R. (2024). Impurities in Active Pharmaceutical Ingredients and Drug Products: A Critical Review. Critical Reviews in Analytical Chemistry, 1-21.
6. Aleluia, A. C. M., de Souza Nascimento, M., dos Santos, A. M. P., dos Santos, W. N. L., Júnior, A. D. F. S., & Ferreira, S. L. C. (2023). Analytical approach of elemental impurities in pharmaceutical products: a worldwide review. Spectrochimica Acta Part B: Atomic Spectroscopy, 205, 106689.
7. Radić, I., Runje, M., Cvetnić, M., Halužan, M., Jeličić, M. L., Miloloža, M., ... & Bolanča, T. (2021). Validation of the ICP-MS method for determination of trace elements provided by ICH Q3D guideline in fosamprenavir calcium. Kemija u industriji: Časopis kemičara i kemijskih inženjera Hrvatske, 70(11-12), 701-709.
8. Torres, S., Boetzel, R., Gatimu, E., Gomes, D. Z., King, F., Kocks, G., ... & Teasdale, A. (2022). ICH Q3D drug product elemental risk assessment: The use of an elemental impurities excipients database. Journal of Pharmaceutical Sciences, 111(5), 1421-1428.
9. Satoh, M., Motokawa, K., Uesawa, Y., Ishikawa, Y., Maeda, H., Iida, K., ... & Nishizawa, K. (2021). Study of the compatibility of oral magnesium oxide preparations sold in Japan with the ICH-Q3D guideline for elemental impurities. Drug Discoveries & Therapeutics, 15(5), 227-235.
10. Annar, S. (2022). The characteristics, toxicity and effects of heavy metals arsenic, mercury and cadmium: A review. Int. J. Multidiscip. Educ. amazonaws. com.
11. Khatun, J., Intekhab, A., & Dhak, D. (2022). Effect of uncontrolled fertilization and heavy metal toxicity associated with arsenic (As), lead (Pb) and cadmium (Cd), and possible remediation. Toxicology, 477, 153274.
12. Li, B., Hu, K., Lysenko, V., Khan, K. Y., Wang, Y., Jiang, Y., & Guo, Y. (2022). A scientometric analysis of agricultural pollution by using bibliometric software VoSViewer and Histcite™. Environmental Science and Pollution Research, 29(25), 37882-37893.
13. Hirawan, D., Oktafiani, D., Fauzan, T. A., Luckyardi, S., & Jamil, N. (2022). Research trends in farming system soil chemical: A bibliometric analysis using VOSviewer. Moroccan Journal of Chemistry, 10(3), J-Chem.
14. Zhang, K., Liu, F., Zhang, H., Duan, Y., Luo, J., Sun, X., ... & Li, D. (2024). Trends in phytoremediation of heavy metals-contaminated soils: a web of science and CiteSpace bibliometric analysis. Chemosphere, 352, 141293.
15. Benhander, G. M. (2024). Mapping Research Landscape: Bibliometric Analysis of Microextraction Techniques in Drug Analysis Using Scopus Database. Analytical and Bioanalytical Chemistry Research, 11(2), 211-225.
16. Saxena, K. (2024). Study of Poly (amidoamine) Based Dendrimers as Adsorbents for Heavy Metals Removal Through Bibliometric Analysis. Indonesian Journal of Limnology, 5(1), 49-63.
17. Shi, D., Xie, C., Wang, J., & Xiong, L. (2021). Changes in the structures and directions of heavy metal-contaminated soil remediation research from 1999 to 2020: A bibliometric & scientometric study. International Journal of Environmental Research and Public Health, 18(14), 7358.
18. Carbonell-Rozas, L., Lara, F. J., & García-Campaña, A. M. (2024). Analytical methods based on liquid chromatography and capillary electrophoresis to determine neonicotinoid residues in complex matrices. A comprehensive review. Critical Reviews in Analytical Chemistry, 54(7), 2554-2582.
19. Muhammad, N., Hussain, I., Ali, A., Noureen, L., He, Q., Subhani, Q., ... & Zhu, Y. (2024). Ion chromatography: A comprehensive review of sample preparation methods for analysis of halogens and allied nonmetals in critically challenging inorganic matrices. Journal of Chromatography A, 465311.
20. Lata, S., & Ansari, N. G. (2024). Analytical Techniques for Heavy Metal Analysis. In Heavy Metal Contamination in the Environment (pp. 180-202). CRC Press.
21. Muhammad, N., Lao, L., Intisar, A., Cui, H., & Zhu, Y. (2019). Simultaneous determination of fluoride and chloride in iron ore by steam distillation followed by ion chromatography. Chromatographia, 82(12), 1839-1844.
22. Muhammad, N., Zia-ul-Haq, M., Ali, A., Naeem, S., Intisar, A., Han, D., ... & Wei, B. (2021). Ion chromatography coupled with fluorescence/UV detector: A comprehensive review of its applications in pesticides and pharmaceutical drug analysis. Arabian Journal of Chemistry, 14(3), 102972.

23. Golgoli, T., Ghanemi, K., & Buazar, F. (2024). Cysteine-functionalized selenium nanoparticles for efficient extraction and preconcentration of cadmium, copper, lead, and zinc ions from environmental water samples. Journal of Molecular Liquids, 393, 123680.
24. Ding, Q., Li, C., Wang, H., Xu, C., & Kuang, H. (2021). Electrochemical detection of heavy metal ions in water. Chemical communications, 57(59), 7215-7231.
25. Ding, R., Cheong, Y. H., Ahamed, A., & Lisak, G. (2021). Heavy metals detection with paper-based electrochemical sensors.
26. Lace, A., & Cleary, J. (2021). A review of microfluidic detection strategies for heavy metals in water. Chemosensors, 9(4), 60.
27. D'Atri, V., Barrientos, R. C., Losacco, G. L., Rudaz, S., Delobel, A., Regalado, E. L., & Guillarme, D. (2025). Trends in Pharmaceutical Analysis: The Evolving Role of Liquid Chromatography. Analytical Chemistry.
28. Sharma, S., Singh, N., Ankalgi, A. D., Rana, A., & Ashawat, M. S. (2021). Modern trends in analytical techniques for method development and validation of pharmaceuticals: A review. J. Drug Deliv. Ther, 11, 121-130.
29. Lin, S. Y. (2021). Current and potential applications of simultaneous DSC-FTIR microspectroscopy for pharmaceutical analysis. Journal of Food and Drug Analysis, 29(2), 182.
30. Fahelelbom, K. M., Saleh, A., Al-Tabakha, M. M., & Ashames, A. A. (2022). Recent applications of quantitative analytical FTIR spectroscopy in pharmaceutical, biomedical, and clinical fields: A brief review. Reviews in Analytical Chemistry, 41(1), 21-33.
31. Buledi, J. A., Shah, Z. U. H., Mallah, A., & Solangi, A. R. (2022). Current perspective and developments in electrochemical sensors modified with nanomaterials for environmental and pharmaceutical analysis. Current Analytical Chemistry, 18(1), 102-115.
32. AYDOĞMUŞ, Z., & Asfoor, A. (2022). Electroanalytical methods for determination of antiviral drugs in pharmaceutical formulation and biological fluids: a review. Chinese Journal of Analytical Chemistry, 50(10), 100063.
33. Hudhaifa, A. H., Aljumaily, M. M., & Al-Obaidi, M. A. (2024). Mono and competitive adsorption of Zn, Cu and Mn in different calcareous soils. REVISTA DE AGRICULTURA NEOTROPICAL, 11(3), e8543-e8543.
34. Jarjees, F. Z., & Darwesh, D. A. (2024). Human Health Risk Assessment of Toxic Heavy Metals in Commercially Available Rice at Local Markets in Erbil, within the Kurdistan Region of Iraq. Zanco Journal of Pure and Applied Sciences, 36(3), 95-108.
35. Al-Darraji, J., Alshami, I., & Ankush, M. (2023). Effect of Some Heavy Metals in the Industrial Flows on Shatt al-Arab River. Egyptian Journal of Aquatic Biology and Fisheries, 27(3), 801-814.
36. Othman, H. Q., & Hussein, Z. A. (2025). Radiological impacts of natural radioactivity and heavy metal of building material factories in Sulaymaniyah Governorate, Iraq. International Journal of Environmental Analytical Chemistry, 1-24.
37. Baddi, I., Al-Mallah, A., & Omer, F. (2024). An assessment of heavy metals soil Pollution and health risk around industrial district in Qayarah area, Northern Iraq. Iraqi National Journal of Earth Science, 24(2), 72-0.
38. Samir, B. A., & Kosaj, A. D. (2024). International Journal of Environmental Impacts. Journal homepage: http://iieta.org/journals/ijei, 7(2), 329-338.
39. Hasan, A. A., Al-Alawy, I. T., & Kadhim, H. A. (2024). Water Quality Assessment and Evaluation of the Human Health Risk of Tap Water Use in the Karbala Governorate, Iraq. Radiochemistry, 66(5), 764-773.
40. Jaafar, B. I., & Kadhum, S. A. (2023, November). Bioaccessibility and Distribution of Heavy Metals in Particles from a Dust Storm in Iraq. In IOP Conference Series: Earth and Environmental Science (Vol. 1259, No. 1, p. 012040). IOP Publishing.
41. Hussein, S. M., Jazza, S. H., & Najim, S. S. (2023). Bioaccumulation of heavy metals in liver tissues of three Anas species in Al-Hawizah marshes, southern Iraq. International Journal of Aquatic Biology, 11(2), 98-103.
42. Ghazi, A. M., & Marhoon, K. A. (2024, July). Determination of Heavy Metals Concentration in the Blood Samples of some Farmers at Al-Diwaniyah Governorate/Iraq. In IOP Conference Series: Earth and Environmental Science (Vol. 1371, No. 2, p. 022023). IOP Publishing.
43. Hammash, S. M., & Abed, M. F. (2022). Environmental Evaluation of the Surface Water, Ground Water and Wastewater using Pollution Indices at the Landfill Site, Southern Baiji, Salah Al-Din Northern iraq. The Iraqi Geological Journal, 105-112.
44. Issa, H. M., & Alshatteri, A. H. (2021). Impacts of wastewater discharge from Kalar city on Diyala-Sirwan river water quality, Iraq: pollution evaluation, health risks of heavy metals contamination. Applied Water Science, 11(4), 73.
45. Hamdy, S. M. A., Al Obiady, A. H. M. J., & Al Mashhady, A. A. M. (2015). Effects of lead pollution on soil and plants around the powered generators. Iranian Journal of Science, 39(3), 341-343.
46. Basha, N. T., & Issa, M. J. (2025). Determine the Pollution Indices of the Soil Near the Najaf Refinery in the Middle of Iraq. Iraqi Journal of Science, 219-229.
47. Al-Zubaydi, J. H., Al-Sultani, N. K., & Al-Amar, H. A. (2024, July). Hydrological Study of the Great Musaiyab Project Babylon Governorate in Middle of Iraq. In IOP Conference Series: Earth and Environmental Science (Vol. 1371, No. 8, p. 082005). IOP Publishing.

48. Al-Obeidi, L. A. A., & Al-Hamadawi, H. A. (2024). Assessment of heavy metals on some tissues of Marbled Teal, Marmaronetta Angustirostris in Al-Dalmaj Marsh, Iraq. International Journal of Aquatic Biology, 12(1), 25-32.
49. Ghaidan, H. Q., & Al-Dhamin, A. S. A. (2024). Detection of Some Heavy Metals (Mercury and Lead) Pollutants and their Association with Type 2 Diabetes Mellitus (T2DM) in Baghdad, Iraq. Iraqi Journal of Science, 6353-6370.
50. salman obaid AL-khazraji, S., & Al-Fatlawy, H. J. J. (2024). The Concentration of Some Heavy Metals in Phragmites Australis and Ceratophyllum. Demersum Plants in the Euphrates River, Iraq. Pak. J. Life Soc. Sci., 22, 2881-2903.
51. Salih, Z. R., Othman, B. A., & Aweez, S. J. (2024). Assessment of heavy metals in rainfall as an indicator of air pollution from Erbil Steel Factory in Iraq. Environmental Monitoring and Assessment, 196(3), 319.
52. Khalefah, A. R. M., Omran, I. I., & Al Waily, M. J. (2024). Environmental Impact of Petroleum Refinery Effluent on Groundwater Pollution: A Case Study of Maysan Refinery, Iraq. Salud, Ciencia y Tecnología-Serie de Conferencias, (3), 844.
53. Al-Fartusie, F. S., Mohammed, M. A., Thani, M. Z., Kader, S., & Khadim, R. M. (2024). Evaluation of Heavy Metal and Specific Trace Elements Levels Among Fast-Food Workers and Their Susceptibility to Atherosclerosis. Biological Trace Element Research, 1-10.
54. Ibraheem, A. G., Jawad, M. M. H. M., & Aqeel Lami, A. M. A. (2024). Evaluation of Lead, Copper and Iron Concentrations in Cyprus papyrus and Rivers in Iraq. Asian Journal of Water, Environment and Pollution, 21(5), 49-55.
55. Qadr, H. M., Ibrahim, M. H., & Hassan, H. Y. (2025). Determination of potentially toxic heavy metals in milk powder marketed in Kurdistan of Iraq. Journal of Trace Elements and Minerals, 100219.
56. Almola, M. A., Al-Ahmady, K. K., & Mhemid, R. K. S. (2024). An Investigation of Microplastic Occurrence and Heavy Metals Concentrations in Street Dust on the Left Side of Mosul City, Iraq. Journal of Ecological Engineering, 25(9).
57. Al-Lami, A. M. A., Abbas, Z. R., & Alshammary, A. G. (2020). Study of water pollution problem in Basra city of Iraq: a case study.
58. Al-Mayyahi, S. O. M., & Al-Zamili, H. A. A. (2019, July). Assessment of some heavy metals contamination in sediments of Tigris River in Kut City, Wasit Governorate, Iraq. In Journal of Physics: Conference Series (Vol. 1234, No. 1, p. 012076). IOP Publishing.
59. Znad, S. R., & Al-Sinjary, M. N. (2020). Assessment of heavy metal pollution of industrial zones in mosul city. Plant Archives, 20(2), 256-263.
60. Saeed, A. M., Hamzah, M. J., & Ahmed, N. Q. (2018). Quantitative assay of aspirin and (salicylic acid and heavy metals as impurates) in iraqi's market aspirin tablets using different analytical methods. Int J App Pharm, 10(5), 167-172.
61. Hussain, H. A., Abdullah, S. A., & Al Maliki, A. A. (2023, July). Predicting of heavy metals in some areas of Iraq using spectral analysis techniques. In IOP Conference Series: Earth and Environmental Science (Vol. 1202, No. 1, p. 012009). IOP Publishing.
62. Mahdi, H. J. (2022). Evaluation of the Pharmaceutical and Microbial Safety, as well as the Reliability, of Some Natural Pharmaceutical Products Available in Iraq. Archives of Razi Institute, 77(4), 1465-1471.
63. Abu-ALmaaly, R. A., Karm, I. F. A., & Alsaffar, N. M. A. (2018). Nutrient value and contamination by arsenic, mercury and cadmium in rice types available in local markets. Journal of Pharmaceutical Sciences and Research, 10(7), 1761-1764.
64. Lawi, D. J., Abdulwhaab, W. S., & Abojassim, A. A. (2023). Health risk study of heavy metals from consumption of drugs (solid and liquid) samples derived from medicinal plants in Iraq. Biological Trace Element Research, 201(7), 3528-3540.
65. Khaleel, L. R., Al-Hermizy, S. M., & Abbas, M. N. (2022). Statistical Indicators for Evaluating the Effect of Heavy Metals on Samaraa Drug Industry Water Exposed to the Sun and Freezing. Tropical Journal of Natural Product Research, 6(12).
66. Alsamaraay, R. T. A., Jabbar, R. A. A., & Alshawany, T. M. (2021, May). Quality study of the piped water of state company for drugs industry of Samarra and matching with the Iraqi and international drinking specification. In Journal of Physics: Conference Series (Vol. 1879, No. 2, p. 022032). IOP Publishing.
67. Al-Dabbas, M. A., Mahdi, K. H., Al-Khafaji, R., & Obayes, K. H. (2018, May). Heavy metals characteristics of settled particles of streets dust from Diwaniyah City-Qadisiyah Governorate-Southern Iraq. In Journal of Physics: Conference Series (Vol. 1003, No. 1, p. 012023). IOP Publishing.
68. Awadh, S. M. (2015). Cd, Ni, and Pb distribution and pollution assessment in roadside dust from Baghdad City and Western Iraqi Desert. Arab J Geosci 8: 315–323.
69. Dalaram, I. S., Nabil, R. H., & Dina, A. S. (2016). THE RELATIONSHIP OF HEAVY METALS CONTENTS IN SOILS TO THEIR CONTENT IN LEGUME SEEDS USED IN FAMOUS TRADITIONAL FOOD IN KURDISTAN REGION-IRAQ. Slovak Journal of Food Sciences/Potravinarstvo, 10(1).
70. Sayyadi, A., & Ioannidu, S. (2015). Determination of lead content in the most popular brands of lipsticks in Sulaimani, Iraq. Journal of the Indian Chemical Society, 92(11), 1625-1628.

71. Sadoon, M. A., & Ali, S. A. (2019). ASSESSMENT OF HEAVY METALS LIKE LEAD, CADMIUM AND COPPER IN MEDICINAL PLANTS COLLECTED FROM MARKET OF NASERIYA CITY, IRAQ. Plant Archives, 19(2), 2357-2358.
72. Abdulnabi, Z. A., Altememi, M. K., Hassan, W. F., Al-Khuzaie, D. K. K., & Saleh, S. M. (2019). Assessing of some toxic heavy metals levels and using geo accumulation index in sediment of Shatt Al-Arab and the Iraqi Marine region. Baghdad Science Journal, 16(2), 323-331.
73. Ali, N. A., & Abdullah, E. J. (2024). Accumulation, Bioavailability, and Health Risk of Heavy Metals in Some Plants Obtained from Abu-Ghraib Land, Baghdad, Iraq. The Iraqi Geological Journal, 187-200.
74. AL-Shammary, A. G., & Al-Jomaily, M. (2024). Evaluation of environmental and pollution indices of heavy metals of dust samples in Baiji and Salah Al-Din General Hospitals in Salah Al-Din Governorate/Iraq. Iraqi National Journal of Earth Science, 24(1), 17-0.
75. Jassim, H. H., Salman, I. M., & Al-Khafaji, R. M. N. (2021). Sedimentological and heavy metals characteristics of streets dust in some areas east of Baghdad for 2020. The Iraqi Geological Journal, 117-125.
76. Kareem, D. O., Ibrahim, A. A., & Ibrahiem, O. S. (2020). Heavy metal and radon gas concentration levels in Khasa River in Kirkuk City (NE Iraq) and the associated health effects. Arabian Journal of Geosciences, 13(19), 1023.
77. Joda, B. A., Alheloo, H. S., Al-Mankosh, H. J., & Maitham, S. A. (2019, August). Determination of heavy metals arsenic, cadmium and lead in water, sediments and fish from Al Delmaj Marshes-Iraq. In AIP Conference Proceedings (Vol. 2144, No. 1). AIP Publishing.
78. Khalaf, E. A., Abduljaleel, S. A., & Al-Jassani, H. M. (2021). Appraisal of trace elements and heavy metals levels in breast cancer patients of Basrah Province. Toxicology International, 28(2), 8-14.