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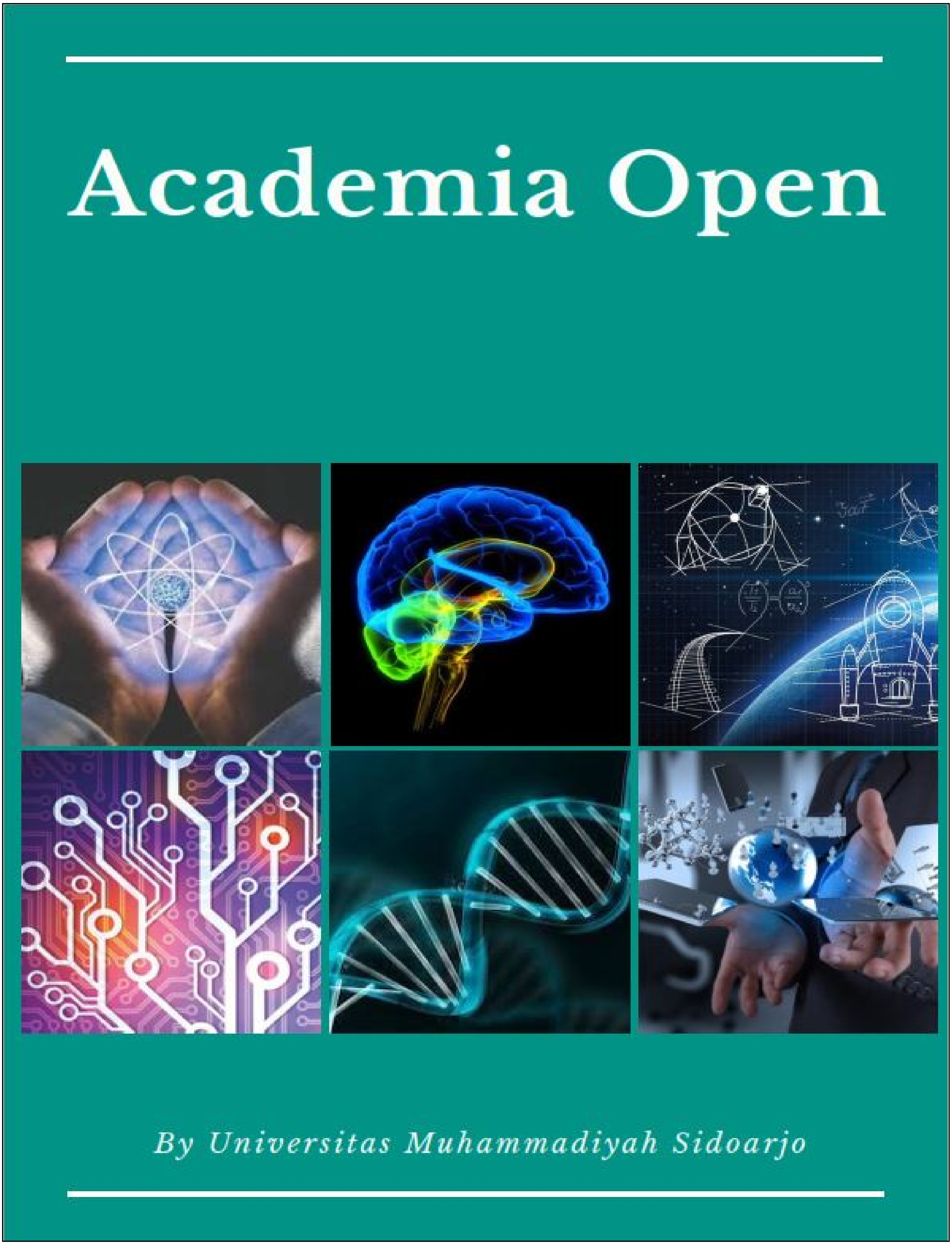

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Environmental and Health Impacts Resulting From Burning Solid Waste Near Residential Areas in Diyala Governorate, Iraq

Dampak Lingkungan dan Kesehatan Akibat Pembakaran Limbah Padat di Dekat Kawasan Pemukiman di Kegubernuran Diyala, Irak

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Abstract

General Background: Rapid development, population growth, and improper disposal of municipal solid waste are prevalent issues in developing countries, leading to significant environmental and health challenges. **Specific Background:** In Iraq's Diyala Governorate, the absence of integrated waste management exacerbates pollution through waste burning and heavy metal contamination, posing risks to nearby residential areas. **Knowledge Gap:** While previous studies have addressed waste management in developing countries, there is limited research on how local waste disposal practices impact air, soil, and water quality in specific areas of Diyala. **Aims:** This study evaluates the air quality and levels of heavy metals in soil and water near five landfill sites in Diyala Governorate: Kanaan, Al-Khalis, Baladruz, Khanaqin, and Hamrin, aiming to assess the pollution levels and the potential health risks to nearby communities. **Results:** The findings reveal significant differences across the sites, with the highest pollutant concentrations in Kanaan for air (40±445.8), soil (22.18±35.64), and water (3.037±3.146), while Hamrin recorded the lowest concentrations. All sites demonstrated statistically significant differences ($P < 0.05$). **Novelty:** This study provides the first comprehensive analysis of the environmental impact of waste disposal practices in Diyala, linking pollutant concentrations with specific landfill sites. **Implications:** The results underscore the need for improved waste management strategies, including monitoring, waste sorting, and recycling initiatives, to mitigate the negative effects on public health and the environment, particularly in areas near waste dumps.

Highlights:

1. Pollution levels vary significantly across Diyala's landfill sites.
2. Kanaan site has the highest air, soil, and water contamination.
3. Better waste management is needed to reduce environmental and health risks.

Keywords: Municipal waste, environmental pollution, heavy metals, Diyala Governorate, landfill impact

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Introduction

Waste management is considered one of the important pollution problems facing developing countries, and one of the environmental issues of great importance in many countries. Improper disposal and burning of solid waste, in addition to the lack of an integrated solid waste management program, will lead to significant environmental and health risks. (1) Iraq has also witnessed a noticeable increase in population growth, especially in recent years with urban expansion, in addition to an increase in industrial activities. All of these factors have helped to increase the amount of solid waste in cities with high population density, where the use of burning waste to dispose of it is considered one of the most common methods (2), and the process of burning solid waste emits many pollutants into the air, such as fine particulate matter (PM10). And PM2.5), volatile organic and inorganic compounds in the air (VOCs), in addition to gases such as carbon monoxide (CO) and nitrogen dioxide (NO2), which are highly toxic (3), and all of these pollutants have an impact on air quality and increase the effects environmental impact on the ecosystem in addition to the risk of respiratory and heart diseases (4),Some studies have also indicated that the process of burning waste in the air leads to major problems in urban cities in Iraq, where it is estimated that approximately 50% of this waste is burned in an irregular manner (5), This may reflect weak infrastructure in waste management and the lack of effective systems to dispose of this waste in a sustainable manner. In addition, the process of burning waste often takes place in or near residential areas, and this may directly expose residents to high levels of dangerous pollutants (6), As for the environmental impact of the process of burning waste, it causes the release of large quantities of gases such as methane and carbon dioxide, which increase climate change and global warming (7), The soil and water surrounding incineration sites are also exposed to contamination with chemicals that have long-term harmful effects on biodiversity and human health (8), and groundwater can be polluted as a result of the leakage of heavy metals from waste dumps, including cadmium, mercury, and lead, which may lead to freshwater pollution (9), As for health, research has shown that the risk of continuous exposure to pollutants produced by burning waste may cause chronic diseases such as heart disease, asthma, and lung cancer (10), Continuous exposure to polluted air also has effects on human behavior and psychological health (11), In conclusion, the current study, which was conducted in Diyala Governorate / Iraq, aims to know the health and environmental effects of burning solid waste in or near residential areas. Research methodologies are used to collect data, including interviews with local residents and analysis of air, soil and water samples. And work to provide recommendations to reduce reliance on burning as a means of disposing of waste and develop its proper management.

Methods

Study area

Diyala Governorate, with its center in the city of Baqubah, is considered one of the important governorates in Iraq, as it is located to the northeast of Baghdad Governorate. Its area is about 17,685 square kilometers. It is characterized by diverse landscapes, mountainous terrain, valleys and fertile agricultural lands. Its climate is dry, hot in summer and mild in winter. It faces challenges. It is significant in managing environmental issues, including improper disposal and burning of solid waste. Due to the lack of an integrated waste management system, which increases pollution problems, the selected landfill sites are distributed in different areas of Diyala Governorate, including (Kanaan, Khanaqin, Al-Khalis, Baladruz, and Hamrin). The sites were identified based on reports of waste burning and their proximity to Residential areas, which poses a threat to the environment and public health (12).

Selection of study sites.

The sites were chosen due to their proximity to residential areas with different levels of waste disposal activities, and based on the reports of the Diyala Governorate Environment Directorate and information received from local residents, five main sites were identified: Canaan Landfill (33°42′58.2″N, 44°43″ 14.8″E), Khanaqin landfill (34°47′46.6″N, 45°17′47.4″E), Al-Khalis landfill (33°54′12.6″N, 44°31′18.3″E), Baladruz landfill (34 °02′56.7″N, 45°02′05.7″E), and the Hamrin dump (34°22′46.3″N, 45°23′08.7″E). The sites were chosen to represent the diversity of environments in the governorate, and to evaluate the impact of human activities, especially waste burning, on air, water, and soil (13).

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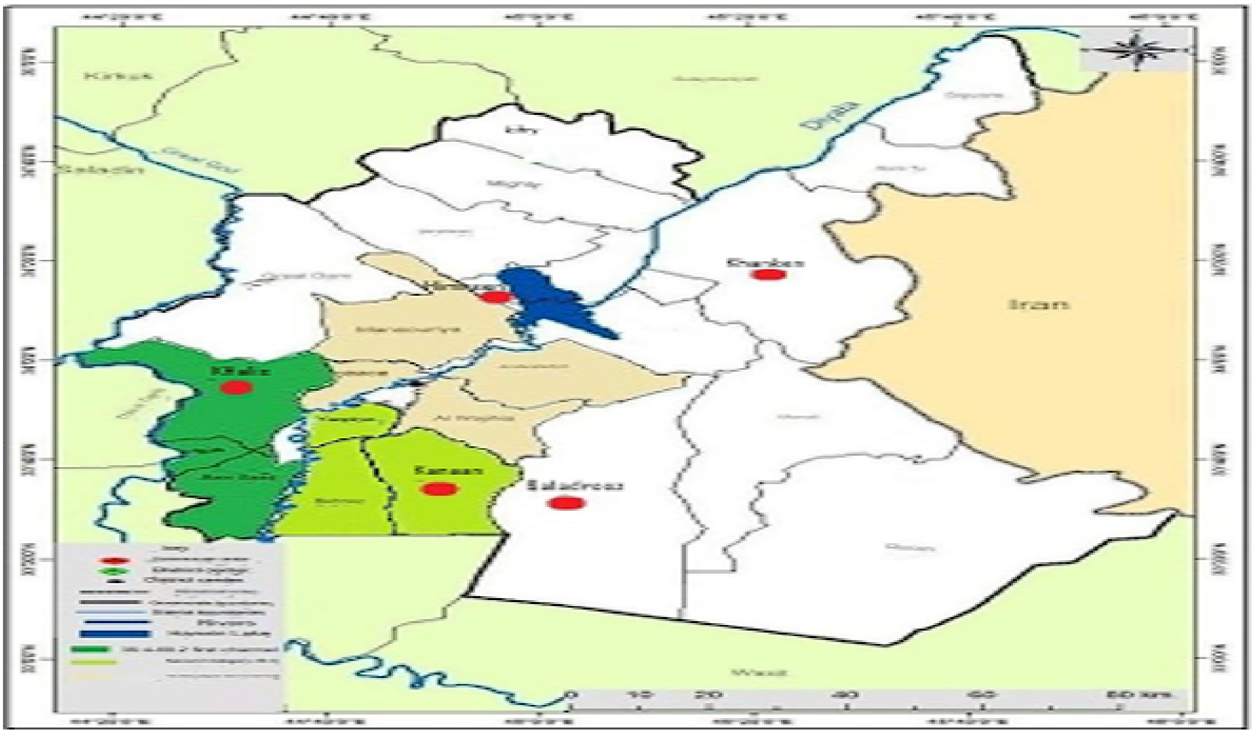

Figure 1. *the Study area*

Collect samples.

Samples were collected via a high-flow air pump (high-volume air sampler) through fiberglass or quartz filters that collect airborne particles such as PM2.5 and PM10. It was operated for a specific period of time, ranging from 24-48 hours, to collect a large amount of air and transport it to the laboratory.

Then soil samples were collected from different depths using a shovel or probe to dig a specific depth of 0-30 cm. They were placed in the bag, writing the date and place from which the sample was taken. Then the samples were saved and sent to the laboratory.

Then, water samples were collected from areas close to sources of pollution using sterile plastic bottles with a capacity of 250 ml. They were left to fill and then closed tightly. The date and place from which the sample was taken were written. The samples were preserved by adding concentrated nitric acid and then transported to the laboratory.

Chemical analysis.

We weighed the air before and after the analysis process using an accurate balance, then we calculated the particle concentrations using (Mettler Toledo XP6 Analytical Balance) based on the added mass and the air collected.(14).

As for the soil samples, the samples were dried in a drying oven at a low temperature (about 40 degrees Celsius), and then ground using a ceramic mortar. 1 gram of soil samples were taken, 1:3 ml of nitric acid was added and left for 24 hours, then the mixture was placed on the Hot Plate for 45 minutes. These steps were done inside a Chamber Hood Fume device, type VK-15Fe, then the solution was transferred. Quantitatively, the volume was transferred to a volumetric flask and the volume was completed to 100 ml by adding deionized distilled water, and then transferred to the ICP-OES device to measure the heavy elements (15).

As for water samples, the device was calibrated using standard solutions, and the samples were injected into the [ICP-OES] device, to measure the light emission intensity of each element at specific wavelengths and calculate the concentrations of the elements using calibration curves (16).

Statistical analysis.

SPSS statistical program was used to analyze the data and calculate the average concentrations and standard deviation for each site. An ANOVA test was conducted to calculate the significant differences between the different sites of the waste dumps

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Result and Discussion

Result

mxm	min	CO 2 (PPM)	SO 2 (PPM)	NO 2 (PPM)	PM10 (PPM)	PM2.5 (PPM)	Location
460	29	409	81	29	460	271	Khalis
426	64	426	89	64	381	366	Kan'an
501	35	390	72	35	501	206	Baladruz
340	28	340	67	28	460	110.5	Hamrin
427	44	415	83	44	427	100.3	Khanaqin

Table 1. *Air Pollution Concentrations at Five Landfill Sites*

The results of Table (1) showed that the Khalis site recorded the highest concentration of (PM10) reaching (460 ppm) and the lowest concentration of (NO2) reaching (26 ppm) on average, while the Kan'an site recorded the highest concentration of (CO2) reaching (426 ppm). The lowest concentration in (NO2) was (64ppm), while the Baladruz site recorded the highest concentration in (PM10) which reached (460 ppm) and the lowest concentration in (NO2) was (35ppm). The results of the concentrations of the Hamrin site, where the highest concentration reached (CO2 reached (340ppm), while the lowest concentration in (NO2) was (28ppm), while the results of the Khanaqin site showed the highest concentration in (PM10) reaching (472 ppm) and the lowest concentration in (NO2) reaching (44 ppm).

mxm	min	(Ni) (ppm)	(Cr) (ppm)	(Cd) (ppm)	(Pb) (ppm)	(Cu) (ppm)	(Zn) (ppm)	Location
51.05	0.23	12.10	51.05	0.23	14.1	17.21	10.24	Khalis
62.37	0.89	49.97	62.37	0.89	17.02	47.02	37.51	Kan'an
35.18	0.11	35.18	22.40	0.11	13.6	8.72	13.41	Baladruz
27.01	0.08	10.01	27.01	0.08	10.3	8.02	8.06	Hamrin
53.44	0.17	21.37	53.44	0.17	15.40	18.06	21.08	Khanaqin

Table 2. *Concentrations of heavy metals in the soil of five waste landfill sites*

The results of Table (2) showed that the Khalis site recorded the highest concentration of (Cr) amounting to (51.05) and the lowest concentration of (Cd) amounting to (0.23), while the Kan'an site recorded the highest concentration of (Cr) amounting to (62.37). The lowest concentration of (Cd) was (0.89), while the Baladruz site recorded the highest concentration of (Ni) of (35.18) and the lowest concentration of (Cd) was (0.11), while the results of the Hamrin site concentrations had the highest concentration of (Cr) of (0.11). (27.01), and the lowest concentration of (Cd) was (0.8). As for the Khanaqin site, the highest concentration of (Cr) was (53.44) and the lowest concentration of (Cd) was (0.17).

mxm	min	(Ni) (ppm)	(Cr) (ppm)	(Cd) (ppm)	(Pb) (ppm)	(Cu) (ppm)	(Zn) (ppm)	Location
4.22	0.13	1.12	4.22	0.13	1.22	0.87	2.44	Khalis
9.09	0.42	1.90	9.09	0.42	2.44	2.01	3.02	Kan'an
5.65	0.09	0.84	5.65	0.09	1.42	1.03	2.51	Baladruz
1.41	0.05	0.55	1.12	0.05	0.89	0.22	1.41	Hamrin
6.84	0.12	0.77	6.84	0.12	1.39	1.09	2.29	Khanaqin

Table 3. *Concentrations of heavy metals in the surface water of five landfill sites*

The results of Table (3) showed that the Khalis site recorded the highest concentration of (Cr) amounting to (4.22) and the lowest concentration of (Cd) amounting to (0.13), while the Kan'an site recorded the highest concentration of (Cr) amounting to (9.09). The lowest concentration of (Cd) was (0.42), while the Baladruz site recorded the highest concentration of (Cr) of (35.18) and the lowest concentration of (Cd) was (0.09), while the results of the Hamrin site concentrations had the highest concentration of (Zn) of (0.09). (1.41), and the lowest concentration of (Cd) was (0.05). As for the Khanaqin site, the highest concentration of (Cr) was (6.84) and the lowest concentration of (Cd) was (0.12).

Concentration	Locations					p-value
	Khalis	Kan'an	Baladruz	Hamrin	Khanaqin	
air mean± st d	210.76±100	445.8±40	40±14.85	78.4±8.82	396±33.92	2.58E-07

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soil mean±std	18.65±21.47	35.64±22.18	15.57±11.34	10.88±10.09	21.68±16.68	0.004729
water mean±std	1.666±1.456	3.146±3.037	1.923±1.990	0.706±0.527	2.083±2.437	0.000784

Table 4. *Average concentration, standard deviation, and p- value, in air, soil, and water, for five landfill sites.*

The results in Table (4) indicate that the highest average concentration and standard deviation in air, soil and water was in the Canaan site, reaching (40±445.8), (22.18±35.64), and (3.037±3.146), compared to the other sites, and the lowest average. The concentration and standard deviation recorded for air, soil, and water at the Hamrin site were (8.82±78.4), (10.09±10.88), and (0.527±0.706).

While the p-values for air, soil and water were less than 0.05, which indicates that there are significant differences between the concentrations of the five sites.

Discussion

The above results indicated that there were differences between the five sites in terms of pollutant concentrations, and this could be attributed to several factors, such as the size of the landfill, its management methods, or the type of waste, as the sites showed high rates of air pollution resulting from burning waste and its negative effects on human health and the environment. As a result of the population increase in these areas, their proximity to residential areas, and the incomplete burning method. Not the sound. This is consistent with a study on environmental pollution in Iraq that indicates that areas near oil fields suffer from high levels of air pollution due to gas burning operations. This indicates that pollution in Iraq is greatly affected by industrial and oil operations (17). Another study conducted in northern China indicated that burning municipal solid waste significantly contributes to the spread of heavy metals into the surrounding soil, which increases health risks to local residents, including cancerous and non-cancerous risks (18). On the contrary, a study conducted at the Matwal landfill in the city of Dhaka, Bangladesh, showed that the results indicated that the landfill did not have a significant impact on the ambient air quality, and this confirms the need for continuous monitoring to ensure the safety of the environment and the health of the community (19). As for the results of soil pollution, they indicated the presence of high concentrations of heavy metals in the dumps of the five sites, as the highest concentrations of chromium (Cr) showed in sites such as Canaan, Al-Khalis, and Khanaqin, with low concentrations of cadmium (Cd) in all sites due to the increase in industrial waste. Agricultural and domestic, as well as chromium is considered more stable in the soil compared to other elements, unlike cadmium, which is less stable. This is consistent with a study conducted in the city of Fallujah in Iraq, indicating the presence of high levels of pollution with heavy metals in the soil, due to industrial and human activities. (20), Another study conducted in Iraq/Erbil also indicated a high pollution index for heavy metals in surface soil samples, as a result of improper disposal of solid waste on site (21), A study was also conducted in Iraq / Sulaymaniyah Governorate, and the results of analysis of soil samples collected from sites close to landfills showed an increase in the percentage of heavy metals such as nickel and cadmium, due to the leakage of these metals from batteries and plastic materials (22), While a study in Malaysia showed that there is a clear deterioration in soil quality in unsanitary landfills (23). While the results of water pollution in the landfill of the current study showed the presence of pollution in all sites with differences from one site to another, as the Kan'an site recorded the highest concentration of nickel (Ni), chromium (Cr) and lead (Pb), due to improper disposal of waste. Industrial products that contain these elements. Chromium is considered one of the dangerous heavy metals that can affect aquatic life and human health if found in high concentrations. This is consistent with a study conducted on samples of bottled water and groundwater in Iraq in the Kurdistan region in the city of Zakho. The concentrations of heavy metals such as chromium (Cr) and nickel (Ni)) and lead (Pb) for some sites exceeded the permissible limit set by the World Health Organization (WHO) for drinking water. In other locations, it was within the acceptable limit (24). Another study conducted in Iraq, in Anbar Governorate, showed that the average concentrations of lead (Pb), nickel (Ni), and chromium (Cr) had exceeded the maximum permissible limit in most of the study stations, which indicates serious contamination in drinking water. The reason is due to human and industrial activities (25). Another study focused on the impact of the leachate resulting from the Bu Ngan landfill on both groundwater resources and the quality of surface runoff water, as the results showed that the leachate and drainage samples contain a higher percentage of heavy metals compared to groundwater samples (26). In a study of the Ghazipur landfill site. Low levels of Cd, Cr and Pb were observed. In groundwater (27), A study conducted in the Saravan landfill, the northern province of Iran, has also emerged on the evaluation of chemical quality and the danger of heavy metals in groundwater sources, that the leakage of the substance lifted from the waste dumps with high concentrations of chrome, lead, and manganese, is a potential source of groundwater pollution (28). This study shows the importance of conducting a comprehensive assessment of the environmental risks resulting from burning solid waste landfills, especially In areas near residential areas that suffer from large population growth. The results obtained affect the quality of air, soil, and surface water due to emissions resulting from waste burning and heavy metal pollution. These pollutants pose a threat to the environment, as well as a direct threat to the health of local residents.

Conclusion

The current study indicates that burning waste contributes significantly to air pollution with fine particles and toxic

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gases, which pose health and environmental risks to humans and living organisms near waste dump sites, including respiratory problems. Burning waste also leads to the release of other air pollutants such as nitrogen oxide (nitrogen oxide). NOx) and sulfur dioxide (SO2), which contribute to acid rain and smog formation and release greenhouse gases such as carbon dioxide and methane, which drive climate change. Pollution of soil and surface water with heavy metals poses a threat to human health and the ecosystem, as they can leak into the food chain through absorption by plants, and then transmit to humans when ingested, which requires continuous monitoring and evaluation of these sites. Therefore, this current study emphasizes the management of soil and surface water with heavy metals. Waste properly and take preventive measures to reduce the negative effects of landfills on human health and the environment and work to re-encourage waste sorting and recycling to reduce the amount of waste that is thrown into landfills.

References

1. . A. Elyasari, "Estimation of Environmental Damages from Open-Air Burning of Solid Waste Using Endpoint Approach in Life Cycle Assessment," IOP Conference Series: Materials Science and Engineering, vol. 1090, no. 012088, 2021. doi: 10.1088/1757-899X/1090/1/012088.
2. . G. Jumaha, Z. Jasem, and M. Alshweikh, "Evaluation of Selected Landfill Sites Using Landfill Site Rating Method (Diyala Governorate as a Case Study)," IOP Conference Series: Materials Science and Engineering, vol. 737, no. 012202, 2020. doi: 10.1088/1757-899X/737/1/012202.
3. . K. Das, "Utilizing Plastic Waste in Construction Materials: A Review," in Emerging Technology for Sustainable Development, J. K. Deka, P. S. Robi, and B. Sharma, Eds. Singapore: Springer, 2024, vol. 1061, Lecture Notes in Electrical Engineering, pp. 255-270. doi: 10.1007/978-981-99-4362-3_15.
4. . World Health Organization (WHO), "Air Pollution and Child Health: Prescribing Clean Air," World Health Organization, 2018.
5. . Ministry of Environment, Iraq, "National Environmental Strategy and Action Plan for Iraq (2013-2017)," 2013.
6. . United Nations Environment Programme (UNEP), "Waste Management Outlook for West Asia," United Nations Environment Programme, 2016.
7. . Intergovernmental Panel on Climate Change (IPCC), "Climate Change 2014: Synthesis Report," Intergovernmental Panel on Climate Change, 2014.
8. . P. J. Landrigan, R. Fuller, N. J. R. Acosta, O. Adeyi, R. Arnold, A. B. Baldé, et al., "The Lancet Commission on Pollution and Health," The Lancet, vol. 391, no. 10119, pp. 462-512, 2018. doi: 10.1016/S0140-6736(17)32345-0.
9. . A. Ghanim, "Environmental Pollution and Health Risks in Iraq," Journal of Environmental Studies, vol. 30, no. 2, pp. 123-130, 2019. doi: 10.1016/j.jes.2019.04.001.
10. . International Agency for Research on Cancer (IARC), "Outdoor Air Pollution," IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, vol. 109, 2016.
11. . S. Galea, J. Ahern, S. Rudenstine, Z. Wallace, and D. Vlahov, "Urban Built Environment and Depression: A Multilevel Analysis," Journal of Epidemiology and Community Health, vol. 59, no. 10, pp. 822-827, 2011. doi: 10.1136/jech.2005.033084.
12. . Wikipedia Contributors, "Diyala Governorate," Wikipedia, The Free Encyclopedia, 2024. [Online]. Available: https://en.wikipedia.org/wiki/Diyala_Governorate [Accessed: Aug. 18, 2024].
13. . G. F. Jumaha, Y. I. Jasem, and Z. M. Alshweikh, "Evaluation of Selected Landfill Sites Using Landfill Site Rating Method (Diyala Governorate as a Case Study)," IOP Conference Series: Materials Science and Engineering, vol. 737, no. 012202, 2020. doi: 10.1088/1757-899X/737/1/012202.
14. . D. Majumdar and S. Ganguly, "Air Pollution from Municipal Solid Waste Management Techniques," in Waste Management and Resource Efficiency, S. Ghosh, Ed. Singapore: Springer, 2019, pp. 789-801. doi: 10.1007/978-981-10-7290-1_92.
15. . M. R. Carter and E. G. Gregorich, Eds., Soil Sampling and Methods of Analysis, 2nd ed., Boca Raton, FL: CRC Press, 2008. doi: 10.1201/9781420005271.
16. . S. Chowdhury, M. A. J. Mazumder, O. Al-Attas, and T. Husain, "Heavy Metals in Drinking Water: Occurrences, Implications, and Future Needs in Developing Countries," Science of The Total Environment, vol. 569-570, pp. 476-488, 2016. doi: 10.1016/j.scitotenv.2016.06.166.
17. . H. H. ALDelfi, "Iraq's Contemporary Environmental Problems, Their Causes, and Sustainability," in Selected Studies in Environmental Geosciences and Hydrogeosciences, A. Kallel et al., Eds. Cham: Springer, 2023, pp. 345-359. doi: 10.1007/978-3-031-43803-5_24.
18. . W. Ma, L. Tai, Z. Qiao, L. Zhong, Z. Wang, K. Fu, and G. Chen, "Contamination Source Apportionment and Health Risk Assessment of Heavy Metals in Soil Around Municipal Solid Waste Incinerator: A Case Study in North China," Science of The Total Environment, vol. 631-632, pp. 348-357, 2018. doi: 10.1016/j.scitotenv.2018.03.011.
19. . A. Matuszewska, M. Owczuk, and K. Biernat, "Current Trends in Waste Plastics' Liquefaction Into Fuel Fraction: A Review," Energies, vol. 15, no. 8, p. 2719, 2022. doi: 10.3390/en15082719.
20. . A. J. Specht, I. C. Lindsay, and E. M. Wells, "Spatial Distribution of Heavy Metal Contamination in Soils of Fallujah, Iraq," Exposure and Health, 2024. doi: 10.1007/s12403-024-00645-5.
21. . S. Y. Jalal and D. A. Darwesh, "Spatial Distribution of Heavy Elements in Erbil's Municipal Landfills by Using GIS," Baghdad Science Journal, vol. 21, no. 3, pp. 867-893, 2024. doi: 10.21123/bsj.2023.8382.
22. . H. Gökçekuş, Y. Kassem, and M. K. Musa, "Environmental Impact of Municipal Solid Waste Landfill in

ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

North of Iraq," International Journal of Innovative Technology and Exploring Engineering (IJITEE), vol. 9, no. 3, pp. 756-762, 2020. doi: 10.35940/ijitee.C8412.019320.

23. . M. Hussein, K. Yoneda, Z. Mohd-Zaki, A. Amir, and N. Othman, "Heavy Metals in Leachate, Impacted Soils, and Natural Soils of Different Landfills in Malaysia: An Alarming Threat," Chemosphere, vol. 248, p. 128874, 2020. doi: 10.1016/j.chemosphere.2020.128874.
24. . H. Salim, H. Abdo, F. Buni, I. Kareem, M. Najeeb, and B. Hussen, "Estimation and Correlation Analysis of Heavy Metals of Some Well Water in Zakho City, Iraq," Science Journal of University of Zakho, vol. 5, no. 2, pp. 205-209, 2017. doi: 10.25271/2017.5.2.369.
25. . M. Ramal, A. Jalal, and U. Abdulhameed, "Heavy Metal Assessment in Taps Drinking Water of Ramadi City Using Water Quality Indices, Anbar Province, Iraq," International Journal of Sustainable Development and Planning, vol. 16, no. 7, pp. 1287-1296, 2021. doi: 10.18280/ijsdp.160715.
26. . N. M. Z. Nursetiawan, N. F. M. K. Shaylinda, S. N. A. Amani, M. S. Mohd-Salleh, and M. S. Shahar, "Investigation of Heavy Metals Pollution in Piyungan Landfill Underground and Surface Water," IOP Conference Series: Earth and Environmental Science, vol. 498, no. 1, 012080, 2020. doi: 10.1088/1755-1315/498/1/012080.
27. . P. Kumari, A. Kaur, and N. C. Gupta, "Extent of Groundwater Contamination Due to Leachate Migration Adjacent to Unlined Landfill Site of Delhi," Environmental Claims Journal, vol. 31, no. 2, pp. 160-175, 2018. doi: 10.1080/10406026.2018.1543825.
28. . Z. Kazemi, M. H. Arani, M. Panahande, M. Kermani, and Z. Kazemi, "Chemical Quality Assessment and Health Risk of Heavy Metals in Groundwater Sources Around Saravan Landfill, the Northernmost Province of Iran," International Journal of Environmental Analytical Chemistry, vol. 103, pp. 6577-6595, 2021. doi: 10.1080/03067319.2021.1958800.

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