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ANALYSIS OF HEAVY METAL CONTAMINATION ASSOCIATED WITH WASTE MANAGEMENT PRACTICES IN JALINGO LOCAL GOVERNMENT AREA (LGA), TARABA STATE

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A B S T R A C T

This study examines heavy metal contamination associated with waste management practices in Jalingo Local Government Area (LGA), Taraba State, Nigeria. Rapid urbanization and poor waste disposal have raised environmental and public health concerns due to heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), chromium (Cr), arsenic (As), nickel (Ni), and thallium (Tl). Soil samples were purposively collected from six riverside dumpsites at 0 m, 10 m, and 20 m distances. Digestion followed USEPA Method 3050B, and analysis was done using Atomic Absorption Spectrophotometry (AAS). Results revealed elevated heavy metal concentrations at 0 m, significantly exceeding World Health Organization (WHO) limits. Although levels declined with distance, Pb, Cd, and Hg remained above safe thresholds at 20 m. Seasonal trends showed higher concentrations during the dry season due to reduced water dilution. One-way ANOVA revealed statistically significant differences ($p < 0.001$) in metal concentrations across sampling distances for all metals, confirming the spatial impact of dumpsite leachates. The chi-square analysis (19.683) further indicated a strong inverse relationship between distance and contamination levels. These findings indicate the need for improved waste regulation, public sensitization, and investment in sustainable waste management systems to mitigate environmental risks and protect public health in Jalingo and similar urban centers.

1. Introduction

The increasing volume and poor management of solid waste in Nigerian cities, including Jalingo, have led to significant environmental and public health concerns. Solid waste not only contributes to flooding due to blocked drainage systems (Kawai and Tasak, 2016), but also serves as a source of air, land, and water pollution, breeding microbial pathogens and disease-carrying vectors (Alamgir *et al*., 2006). Among the most pressing concerns is the contamination of soil and water by heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), and chromium (Cr), commonly present in waste due to industrial activities and improper disposal methods (Jiang *et al*., 2019; Kadir *et al*., 2020). These toxic elements persist in the environment, bioaccumulate in living organisms, and cause long-term health effects such as organ damage and neurological disorders. In Jalingo, indiscriminate waste dumping and inefficient landfill management aggravate these risks, yet studies focusing on heavy metal contamination in waste-impacted environments remain limited (Ali *et al*., 2019).

This knowledge gap is particularly concerning, given that heavy metals are non-biodegradable and can accumulate in agricultural produce and water systems, entering the food chain. The lack of local data on their concentration in Jalingo hampers effective monitoring and response. Moreover, poor infrastructure and weak enforcement of waste management regulations further compound the issue (Oladapo *et al*., 2020). Critics of the current waste management framework in Nigerian cities have called for a paradigm shift toward waste recycling and sustainable practices (Benefit e*t al*., 2012; Oladapo *et al*., 2020). Proper assessment of heavy metal levels will not only guide environmental policy but also protect public health.

This study is justified as it contributes toward bridging the data gap and provides evidence-based insights to improve

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waste management strategies in Jalingo. It also supports the realization of global environmental objectives such as the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being) and SDG 6 (Clean Water and Sanitation). By integrating scientific evaluation with policy development, this research seeks to promote an environmentally resilient waste management framework for Jalingo LGA.
The aim of this study is to assess the extent of heavy metal contamination and evaluate waste management practices in Jalingo LGA.

2. Materials and Methods

This research was conducted in Jalingo Local Government Area (LGA), the administrative capital of Taraba State, Nigeria. Located between latitudes 8°54' to 9°01'N and longitudes 11°22' to 11°30'E. Jalingo is bordered by Lau LGA to the north, Yorro LGA to the east, and Ardo-Kola LGA to the south and west. It experiences a tropical savannah climate, characterized by a rainy season from April to October and a dry season from November to March (Oruonye & Abbas, 2010). These weather patterns greatly impact waste management practices in the area, particularly during the rainy season when flooding can exacerbate issues of waste overflow from poorly managed dumpsites.

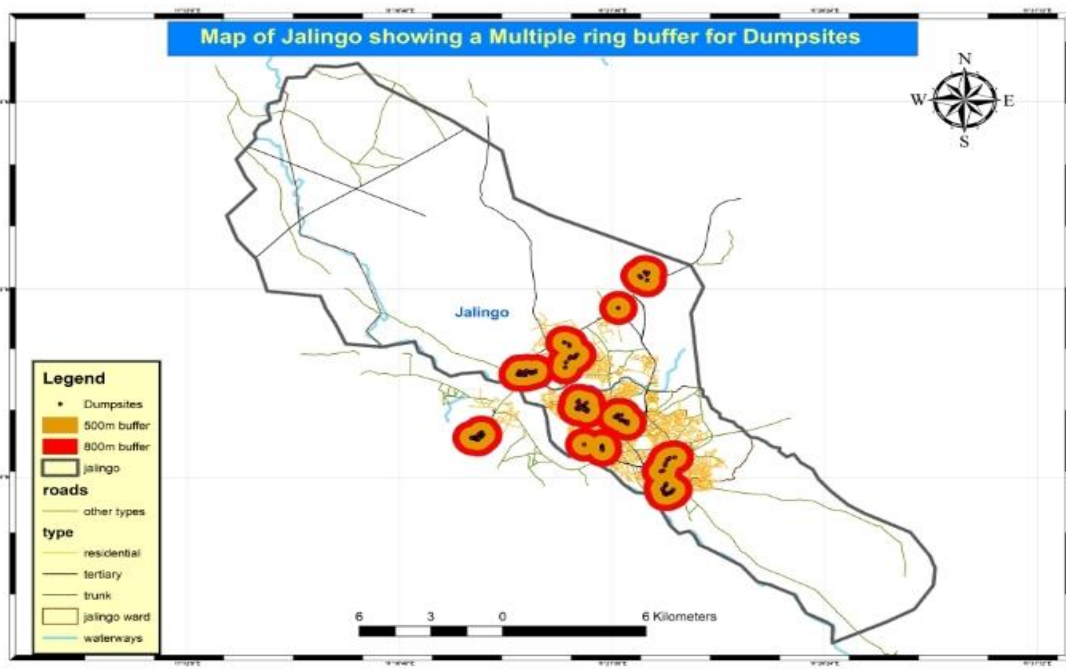

Figure 1: Map of Jalingo Metropolis Showing a Multiple Ring Buffer (Source field study, 2023).

The population, estimated to have increased significantly from the 140,000 recorded in 2006, predominantly engages in agriculture, commerce, and public service. Urbanization in Jalingo has led to a higher volume of waste, intensifying the demand for effective waste management infrastructure. Jalingo's dynamic socio-economic structure and the consequent environmental challenges make it an ideal location for this study.
This study assessed heavy metal contamination in Jalingo LGA through a descriptive design using quantitative methods. Soil samples were purposively collected from six major riversides associated with dumpsites, namely: Karofi, Kasuwan-bera, Mayo-gwoi, Nukkai, Gadan-bobboji and Sabongari. At each site, soil samples were taken at three distances from the dumpsite: 0 meters (directly at the dumpsite point of river comtact), 10 meters and 20 meters away, to determine the extent of metal dispersion in the surrounding environment (Scribbr, 2022). The sampling focused on top sediments most vulnerable to leachate infiltration and runoff.
In the laboratory, Soil samples were air-dried at room temperature, ground, and sieved through a 2 mm mesh to remove debris and obtain uniform particle sizes. A 1 g sub-sample of each was digested using a mixture of concentrated nitric acid (HNO_3) and perchloric acid ($HClO_4$), following the U.S. Environmental Protection Agency's Method 3050B for acid digestion of sediments, sludges, and soils (USEPA, 1996). The digests were filtered through Whatman No. 42 filter paper and diluted to a final volume of 50 mL with deionized water. The resulting solutions were stored in acid-washed polyethylene bottles prior to analysis.
Heavy metal concentrations of arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), and

thallium (Tl) were determined using Atomic Absorption Spectrophotometry (AAS) at specific wavelengths. Calibration standards were prepared from certified 1000 mg/L stock solutions, and calibration curves were constructed for quantification. Quality control measures including reagent blanks, duplicate samples, and spike recoveries were implemented to ensure precision and accuracy. Final results were expressed in mg/kg and compared with permissible limits recommended by the World Health Organization

Descriptive statistics (mean, standard deviation) were used to summarize the concentration levels, and one-way ANOVA was conducted to identify significant differences across the sampling distances.

All procedures followed ethical guidelines, with approval from the Taraba State Ministry of Urban Development and adherence to environmental research protocols aimed at minimizing ecological disturbances.

3. Results

Table 1: Annual Summary of Average Heavy Metal Concentrations in Stream Sediments at Different Distances from Dumpsites in Jalingo (April 2023–March 2024)

	Arsenic			Cadmium			Chromium			Lead			Mercury			Nickel			Thallium		
Month	0m	10m	20m	0m	10m	20m	0m	10m	20m	0m	10m	20m	0m	10m	20m	0m	10m	20m	0m	10m	20m
April	1	0.007	0.0045	7.2	0.14	0.08	3.2	0.021	0.014	20	0.095	0.052	4.5	0.16	0.012	2.5	0.065	0.05	0.015	0.008	0.005
May	1.05	0.0065	0.004	7.3	0.13	0.07	3.1	0.02	0.013	20.5	0.094	0.051	4.6	0.155	0.011	2.45	0.062	0.048	0.014	0.0075	0.0045
June	1.02	0.006	0.0038	7.1	0.125	0.075	3.05	0.019	0.012	20.1	0.091	0.049	4.55	0.158	0.01	2.4	0.06	0.047	0.013	0.008	0.0048
July	1.03	0.005	0.0039	6.9	0.12	0.065	3	0.018	0.011	19.9	0.09	0.048	4.48	0.15	0.009	2.35	0.058	0.046	0.0145	0.0078	0.0047
Aug	1.01	0.0055	0.0037	7	0.13	0.07	3.15	0.017	0.013	20.3	0.089	0.047	4.53	0.152	0.008	2.3	0.059	0.0485	0.014	0.007	0.0042
Sept	1.09	0.0058	0.004	7.15	0.135	0.072	3.08	0.019	0.0125	20.2	0.093	0.05	4.6	0.156	0.0095	2.48	0.06	0.049	0.0148	0.0075	0.0046
Oct	1.06	0.0055	0.0039	7.1	0.126	0.074	3.1	0.02	0.0135	20.15	0.091	0.049	4.57	0.154	0.009	2.42	0.063	0.048	0.014	0.0072	0.0045
Nov	1.07	0.0052	0.0041	7.25	0.129	0.078	3.2	0.0195	0.014	20.6	0.092	0.0485	4.59	0.155	0.0098	2.44	0.062	0.0485	0.0145	0.0075	0.0048
Dec	1.08	0.0058	0.0042	7.3	0.13	0.077	3.3	0.0185	0.0138	20.8	0.094	0.0495	4.61	0.157	0.0105	2.46	0.061	0.0495	0.015	0.008	0.0049
Jan	1.11	0.0062	0.0045	7.18	0.135	0.076	3.25	0.0175	0.0142	20.7	0.0935	0.05	4.6	0.158	0.011	2.43	0.0625	0.05	0.0148	0.0082	0.0047
Feb	1.1	0.006	0.004	7.12	0.13	0.075	3.1	0.02	0.013	20.5	0.0925	0.051	4.58	0.16	0.01	2.4	0.06	0.048	0.015	0.008	0.0045
Mar	1.12	0.0057	0.0041	7.14	0.132	0.073	3.15	0.019	0.0135	20.4	0.0918	0.05	4.55	0.157	0.0095	2.45	0.061	0.049	0.0145	0.0079	0.0046

Table 1 results indicate that heavy metal concentrations in stream sediments near dumpsites in Jalingo are significantly elevated, with values exceeding WHO permissible limits, especially at 0 m. The highest contamination levels are observed for Lead, Cadmium, and Mercury, which pose serious environmental and health risks. A clear pattern of decreasing concentration with increasing distance from the dumpsites is observed, with substantial reductions at 10 m and further declines at 20 m. However, despite this decline, certain metals, particularly Cadmium, Lead, and Mercury, remain above safe limits even at 20 m, suggesting persistent contamination. Seasonal variations also influence the concentration levels, with higher values recorded in the dry season (December–March), likely due to reduced water volume and sediment dilution, while slightly lower levels are observed during the rainy season (April–September) due to increased water flow. These data show the long-term impact of dumpsites on water quality, emphasizing the need for improved waste management strategies and continuous monitoring to mitigate heavy metal pollution in Jalingo's water bodies.

Table 2: Heavy Metal Concentrations in Stream Sediments at Different Distances from Selected Dumpsites in Jalingo

Heavy Metal	WHO Acceptable Limit (mg/kg)	Distance (m)	1	2	3	4	5	6
Arsenic	0.01	0	0.697	0.972	1.102	0.925	1.902	1.205
		10	0.009	0.004	0.005	0.003	0.008	0.005
		20	0.008	0.003	0.005	0.003	0.006	0.004
Cadmium	0.003	0	8.7356	2.3425	6.4702	1.8107	6.2239	4.691
		10	0.2596	0.0899	0.1464	0.0644	0.2562	0.1524
		20	0.1655	0.0155	0.1654	0.0144	0.0433	0.0704
Chromium	0.05	0	5.867	2.199	3.055	1.682	5.857	3.55
		10	0.038	0.014	0.02	0.011	0.038	0.023
		20	0.025	0.004	0.025	0.004	0.008	0.011
Lead	0.01	0	25.489	12.376	13.481	9.421	22.679	14.522
		10	0.096	0.047	0.051	0.035	0.085	0.055
		20	0.092	0.045	0.049	0.034	0.082	0.052
Mercury	0.006	0	6.13	2.175	3.45	1.675	5.79	3.6
		10	0.17		0.16		0.011	0.19
		20	0.016		0.17			
Nickel	0.02	0	3.303	3.071	1.588	2.3	1.988	1.679
		10	0.09	0.082	0.042	0.061	0.046	0.054
		20	0.087	0.078	0.04	0.059	0.051	0.043
Thallium	0.0001	0	0.016	0.009	0.009	0.007	0.015	0.01
		10						
		20						

KEY: Study sites; 1 = Karofi, 2 = Kasuwan-bera, 3 = Mayo-gwoi, 4 = Nukkai, 5 = Gadan-bobboji, 6 = Sabongari

Table 2 shows variations in heavy metal concentrations across the six study sites and at different distances within the stream. At 0 m, all heavy metals exceeded WHO acceptable limits, suggesting high contamination levels, while a decline was observed at 10 m and 20 m, indicating possible dilution or natural attenuation. Among the heavy metals, cadmium recorded the highest concentration at Karofi (0 m) with 8.7356 mg/kg, which is 2,911 times above the WHO limit of 0.003 mg/kg. Similarly, lead at Karofi (0 m) reached 25.489 mg/kg, exceeding the WHO threshold (0.01 mg/kg) by 2,548 times. Mercury was also highly concentrated at Karofi (0 m) with 6.13 mg/kg, surpassing the WHO limit (0.006 mg/kg) by 1,021 times. GadanBobboji (0 m) had the highest arsenic concentration at 1.902 mg/kg, 190 times above the standard. Nickel and thallium followed a similar trend, with their highest values recorded at Karofi (0 m), indicating severe pollution in this area. On the other hand, Nukkai (20 m) had the lowest concentrations for arsenic, cadmium, chromium, lead, and thallium, though some values still exceeded WHO limits. Overall, Karofi (0 m) emerged as the most contaminated site, while Nukkai (20 m) showed the lowest pollution levels, reflecting variations in waste disposal practices, industrial activities, and environmental factors across locations.

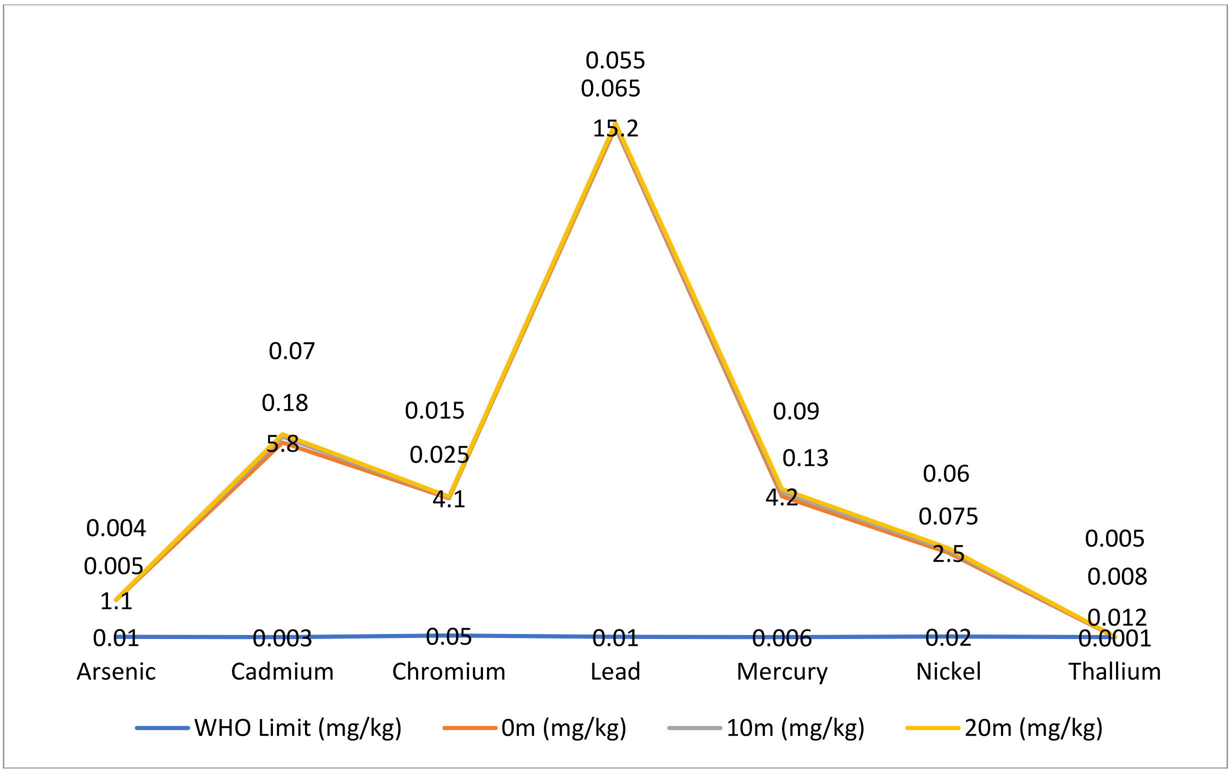

Figure 2: Graphical representation of heavy metal concentration levels against the WHO permissible limit.

Figure 2 reveals that among the metals studied, lead showed the highest concentration at 0 m (15.2 mg/kg), exceeding the WHO limit (0.01 mg/kg) by 1,520 times. Cadmium followed, recording 5.8 mg/kg, which is 1,933 times above its WHO standard (0.003 mg/kg). Mercury was next at 4.2 mg/kg, surpassing the acceptable limit (0.006 mg/kg) by 700 times. Chromium had a concentration of 4.1 mg/kg, exceeding its WHO guideline (0.05 mg/kg) by 82 times. Nickel recorded 2.5 mg/kg, which is 125 times above the permissible level (0.02 mg/kg). Arsenic was found at 1.1 mg/kg, exceeding its limit (0.01 mg/kg) by 110 times, while thallium had the lowest concentration at 0.012 mg/kg, 120 times above the WHO threshold (0.0001 mg/kg).

At 10 m, heavy metal concentrations showed a significant reduction. Lead remained the most concentrated at 0.065 mg/kg, still above its limit but much lower than at 0 m. Cadmium was measured at 0.18 mg/kg, chromium at 0.025 mg/kg, and mercury at 0.13 mg/kg, all showing notable declines. Nickel and arsenic recorded 0.075 mg/kg and 0.005 mg/kg, respectively, while thallium was at 0.008 mg/kg.

By 20 m, concentrations continued to decline, with lead at 0.055 mg/kg, cadmium at 0.07 mg/kg, and mercury at 0.09 mg/kg, suggesting a gradual dispersal of contaminants. Chromium (0.015 mg/kg) and nickel (0.06 mg/kg) were also reduced, while arsenic (0.004 mg/kg) and thallium (0.005 mg/kg) had the lowest recorded values.

Based on concentrations relative to WHO limits, lead ranked highest, followed by cadmium, mercury, nickel, chromium, and arsenic, while thallium had the lowest concentration.

4. Discussion

The One-way ANOVA and Chi-square tests performed on heavy metal concentrations at various distances from dumpsites in Jalingo LGA provides significant information on the extent and distribution of soil contamination. The findings demonstrate high levels of toxic metals such as arsenic, cadmium, lead, chromium, and mercury, which notably exceeded the World Health Organization (WHO) acceptable limits, at locations closest to the dumpsites (0 meters). These elevated levels of contamination raise substantial environmental and public health concerns for the local communities, especially those residing in proximity to the waste disposal areas.

From the results, it was observed that metal concentrations decreased with increasing distance from the dumpsites. However, the extent of reduction varied for different metals, with some contaminants persisting even at distances of 10 to 20 meters. The One-way ANOVA results revealed statistically significant differences ($p < 0.001$) in concentrations for all heavy metals across the three distances, with very high F-statistics (for example, Lead: F = 343.598; Cadmium: F = 206.063). Lead and Cadmium exhibited high levels at 0 meters, particularly at sites 1 (Karofi) and 5 (Gadan Bobboji), with lead concentrations reaching 25.489 mg/kg and cadmium concentrations peaking at 8.7356 mg/kg. Chi-square analysis ($X^2 = 19.683$, df = 2, p = 0.0000532) further revealed a highly significant relationship between distance from dumpsite and exceedance of WHO heavy metal limit, with 100% of samples at 0 m exceeding the limits and progressively fewer violations at 10 m and 20 m, confirming that proximity to dumpsites directly affects contamination levels.

In terms of reduction rates, arsenic concentrations were found to reduce sharply as the distance from the dumpsite increased. At 10 meters, arsenic levels were drastically reduced to values near or below the WHO acceptable limit (0.01 mg/kg) across most sites. This was similar for chromium, where concentrations dropped from an initial 5.867 mg/kg at 0 meters at site 1 to 0.038 mg/kg at 10 meters, demonstrating a steep decline in contamination with distance.

On the other hand, cadmium and lead concentrations showed a more gradual decline, with cadmium remaining above the WHO threshold even at 10 meters at certain locations, such as site 3 (Mayo Gwoi) and site 5 (Gadan Bobboji). Lead, in particular, demonstrated a persistent contamination risk, as values at 10 meters and 20 meters continued to exceed acceptable levels across most sites. This persistence is indicative of its tendency to remain in the environment, raising concerns about its long-term effects on soil and groundwater quality.

The findings of this study are consistent with previous research conducted in other parts of Nigeria, showing a nationwide challenge in managing heavy metal contamination from unregulated waste disposal. For instance, a study by Adeleke *et al*. (2018) in Lagos reported lead concentrations of 18.76 mg/kg near dumpsites, comparable to the levels observed in Jalingo's Karofi and Gadan Bobboji dumpsites, where lead concentrations reached as high as 25.489 mg/kg. Similarly, cadmium levels reported by Adebiyi and Oyewole (2020) in Ibadan (4.97 mg/kg) align with the high cadmium levels recorded in this study, particularly at Karofi (8.7356 mg/kg). Globally, cities with inadequate waste management systems, such as Accra, Ghana, and Mumbai, India, have experienced similar issues. Kwarteng and Adjei (2019) reported lead concentrations as high as 24.5 mg/kg in Accra's dumpsites, which mirrors the findings in Jalingo. These parallels indicate a more global issue in the developing world, where weak regulatory frameworks and insufficient waste management practices lead to elevated levels of heavy metal contamination.

The results of this research also align with evidence from leachate-impacted environments. Kanmani and Gandhimathi (2013) identified open dumpsites as major sources of heavy metal migration into soils through leachate percolation, while Mahmood *et al.* (2014) similarly demonstrated soil contamination near Rawalpindi. Unlike these studies, which focused primarily on leachate movement through direct soil contact, the present study examined sediments collected from rivers at varying distances from the dumpsite. The observed reduction in heavy metal concentrations with distance reflects the influence of dilution, where contaminants are dispersed and transported downstream by flowing water. This creates an even greater risk, as dilution facilitates rapid and wide dispersal of heavy metals, potentially exposing distant communities and ecosystems to pollution far beyond the immediate dumpsite environment.

The elevated concentrations of heavy metals such as cadmium, lead, and arsenic near the dumpsites further highlight the dangers posed by these pollutants to both terrestrial and aquatic environments. In Gadan Bobboji, for instance, arsenic reached a hazardous level of 1.902 mg/kg, alarmingly higher than the WHO threshold of 0.01 mg/kg. The persistence of these metals in soils not only exposes residents to health risks through direct contact, inhalation of contaminated dust, or ingestion of food crops cultivated on polluted soils, but also threatens downstream ecosystems through runoff and sediment transport. Aquatic organisms in nearby rivers and streams are particularly vulnerable as they may accumulate toxic metals, thereby transferring contaminants into the food chain. This contamination disrupts ecological balance and places local communities at risk of chronic exposure through fish consumption and water use. Moreover, essential soil microbes involved in nutrient cycling may also be impaired, reducing soil fertility and agricultural productivity in the long term.

In summary, the results reveal a pressing environmental and health concern in Jalingo LGA, where the proximity of dumpsites to rivers highlights the cumulative effects of poor waste management and the potential risk of food chain contamination. This emphasizes the urgent need for remediation efforts and stronger regulatory measures to protect soil quality, secure water resources, and minimize long-term threats to both human and ecosystem health.

5. Conclusion

The study revealed significant contamination of soil sediments in water bodies near waste disposal sites in Jalingo LGA, with heavy metals like lead, cadmium, and arsenic exceeding WHO limits. These toxic elements pose severe health risks to residents and threaten aquatic wildlife by disrupting reproduction, impairing growth, and causing biodiversity loss. Sediment contamination extends these hazards, as heavy metals persist in the environment, leading to long-term ecological imbalances. Contamination levels were highest near dumpsites and remained above safe limits even at farther distances, highlighting the persistent threat of waste leachates.

6. Recommendations

(i). Strengthen Enforcement of Waste Disposal Regulations: Environmental authorities should rigorously implement waste management laws and ensure regular monitoring of soil and water sources around dumpsites to curb heavy metal contamination and protect public health.
(ii). Promote Sustainable and Integrated Waste Management Practices: Government and stakeholders should invest in waste sorting, recycling initiatives, and engineered landfill systems to reduce hazardous waste exposure and prevent leachate infiltration into surrounding ecosystems.
(iii). Enhance Public Awareness and Community Participation: Comprehensive public education campaigns should be conducted to inform residents about the health risks associated with heavy metals and encourage active community involvement in environmental protection efforts.
(iv). Support Remediation Efforts and Further Research: There is a need for increased funding towards the remediation of contaminated sites, as well as support for academic and scientific research to develop effective methods for detecting, managing, and reducing heavy metal pollution.

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