Environmental and Health Impact of Heavy Metal Accumulation in (Hair - Nails) of Scavenger Workers at Some Landfill Sites in Baghdad City-Iraq

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Received: 20/10/2023

Accepted: 12/11/2023

Online: 16/05/2024

ABSTRACT

Background*:* Heavy metals are considered one of the most dangerous environmental pollutants due to their high toxicity, even at low concentrations, and their accumulation in various body tissues. Landfills contain various wastes rich in heavy metals, such as batteries, paints, and household and hospital waste, making them a major source of air, soil, and groundwater pollution. **Objective**: To analyze the level of accumulation of heavy metals in hair and nail samples of waste collectors. **Material and method:** Five main landfill sites in the city of Baghdad were chosen to collect hair and nail samples from waste collectors of both sexes for the winter and summer seasons to analyze the levels of metal concentrations (lead, cadmium, nickel, zinc, and copper). And the use of atomic absorption spectrometry (AAS). **Results**: Higher concentrations of lead, copper, and nickel were found in nail samples during the summer compared to the winter, indicating an increased risk of exposure to them. While zinc accumulation was much greater in winter samples. **Conclusions** The results highlight the health risks faced by landfill workers. A need to develop tailored strategies to control exposure to these emissions based on weather conditions and priority metals of concern identified through regular biological monitoring.

Keywords: Heavy metals, Scavengers, Landfills, Occupational exposure.

DOI: https://doi.org/10.24126/jobrc.2024.18.1.777

1-INTRODUCTION

Heavy metals such as lead, cadmium, copper, and zinc are among the most hazardous environmental pollutants due to their high toxicity, even at low concentrations. Chronic exposure to these elements leads to their gradual accumulation in different body organs and tissues, causing various health disorders (1). For example, continuous exposure to lead is associated with anaemia, hypertension, renal damage, and neurological disorders (2). Cadmium causes renal dysfunction and bone fragility (3,4), while excessive copper exposure leads to liver damage (5). Regarding nickel, studies have shown that chronic exposure can lead to allergic reactions in the skin as well as lung and nasal cancers (6). High zinc intake is also associated with low immune function and neurological disorders (8) Heavy metals cause negative effects on plants, as they change the water balance and absorption of nutrients, inhibit the process of photosynthesis, and also cause chlorine poisoning (8). Landfills contain industrial and domestic waste rich in heavy metal compounds (9), such as batteries, paints, and hospital waste, making them a major source of air, soil, and groundwater contamination by these metals (10,11). Therefore, waste scavengers are directly exposed to high levels of dust and fumes laden with toxic metals which poses a considerable health hazard, especially in the long term. Several previous studies have addressed the issue of environmental pollution by heavy metals and its serious health effects (12,13). In a recent study (14), the levels of cadmium, lead, and copper were evaluated in vegetable samples grown in contaminated soil, and the permissible limits were exceeded, posing health risks. Another study (15) found an association between heavy metal pollution, such as lead and cadmium, and male infertility. An experimental study (16) found high concentrations of heavy metals like aluminum and iron in vegetables exceeding safe levels, which may lead to non-cancer health risks due to long-term exposure to these elements. The toxic and cumulative effects of cadmium and lead on yeast were investigated in a study (17), elucidating the mechanisms of cell poisoning. The present study continues previous research to assess the prevalence of the landfills problem in Iraq. This research aims to assess the levels of some toxic heavy metals such as lead, cadmium, nickel, zinc, and copper in biological samples (hair and nails) of waste scavengers at some landfills in Baghdad, and compare measured metal concentrations depending on gender, old, and between winter and summer seasons. This will help determine the potential health risks to these workers and develop appropriate solutions to reduce their exposure to pollutants.

2- MATERIAL AND METHODS

This cross-sectional study was conducted on random samples of waste scavengers aged 18-50, working in 5 major landfill sites in Baghdad, Iraq (12 workers from each site). The landfill sites included were Al-Kadhimiya, Al-Shuala, Al-Adhamiya, Abu-Dsher, and Baghdad Al-Jadeeda. Hair and fingernail samples were collected from each participant during (January, February - June, and July - 2021). The hair specimens were taken and fingernail clippings were gathered from all ten fingers. The biological samples were analyzed to determine lead, cadmium, nickel, zinc, and copper content using atomic absorption spectrometry (AAS). This analytical technique measures the absorption of light passing through a cloud of vaporized analyte atoms to determine the concentration of metals present. Hair and nail samples were analyzed to estimate their content of lead, cadmium, nickel, zinc, and copper using Atomic Absorption Spectrometry (AAS). A series of standard solutions for the heavy metals were prepared by diluting the original 1000 micrograms/ml solutions using the dilution law. The hair and nail samples were washed to remove external contaminants, dried at room temperature, weighed, and digested with nitric acid and perchloric acid. After cooling, the digested solutions were diluted with deionized water and filtered. The absorption of the samples was measured using AAS with the specific hollow cathode lamps for each element and comparing the absorption to the calibration curves to determine the metal concentrations in the original specimens (18, 19).

Statistical Analysis

The statistical analysis was performed using Statistical Analysis System (SAS - 2018) software to determine the effect of different factors on the study parameters. An independent samples t-test was used to compare means between two groups of quantitative data. One-way analysis of variance (ANOVA) was utilized to test differences between more than two groups, along with LSD post-hoc tests for pairwise comparisons. The chi-square test was used to compare percentages between categorical variables. Statistical significance was determined at p-values less than 0.05 and 0.01. The assumptions of normality and homogeneity of variance were checked for the ANOVA analysis (21).

3-RESULTS

Table 1 shows the average concentration of heavy metals in the air in all locations and seasons, along with the highest and lowest values measured for each metal. The results indicate a wide variation in heavy metal concentrations across the samples, with the minimum and maximum values for copper ranging from 0.005 to 2.685 mg/dL, respectively. Nickel had the lowest concentration of 0.004 ppm, while the highest reached 1.788 ppm. For zinc, the values varied between 2.2 and 60 ppm. This suggests there are different sources of heavy metal emissions at the dumpsites, leading to variable exposure levels for the workers.

Table 1 shows the concentrations of heavy metals measured in air samples collected from the landfill sites, along with the highest and lowest values for each metal. The results indicate a wide variation in heavy metal concentrations in the air samples, with the minimum and maximum values for Cu ranging from 0.005 to 2.685 mg/m3 respectively. Ni had the lowest concentration of 0.004 mg/m3, while the highest reached 1.788 mg/m3. For Zn, the values varied between 2.2 and 60 mg/m3. This wide range in the concentrations of heavy metals in air samples suggests the presence of different sources of emissions at landfill sites, such as the burning of plastics, batteries, paints, and other waste materials, leading to variable exposure levels for the workers. Control of emissions by segregation and safe disposal of hazardous waste materials could help mitigate exposure risks

Table 1 The Average concentration of heavy metals in the air in all locations and seasons

	Metals Conc. (mg/m^{3})				
	Cu	**Ni**	**Zn**	**Cd**	**Pb**
Mean	0.201	0.197	12.268	0.023	0.100
Std. Deviation	0.390	0.320	8.875	0.037	0.118
Minimum	0.005	0.004	2.200	0.001	0.005
Maximum	2.685	1.788	60.000	0.165	0.551
Mean	0.201	0.197	12.268	0.023	0.100

Figure (1, A) shows the results using the Descriptive plots technique, where individual plots are drawn for each metal, describing the distribution of values and dispersion around the mean. The results demonstrate wide variation in heavy metal values across the samples, with some outlier values evident in the zinc plots.
Figure (1, B), which utilizes the Boxplots method summarizes the metal results in box charts depicting the quartiles and minimum/maximum values, enabling easier comparison between pollution levels of the different metals. Marked differences in the degree of value dispersion are noticed between the metals, with zinc showing the highest concentration variance.

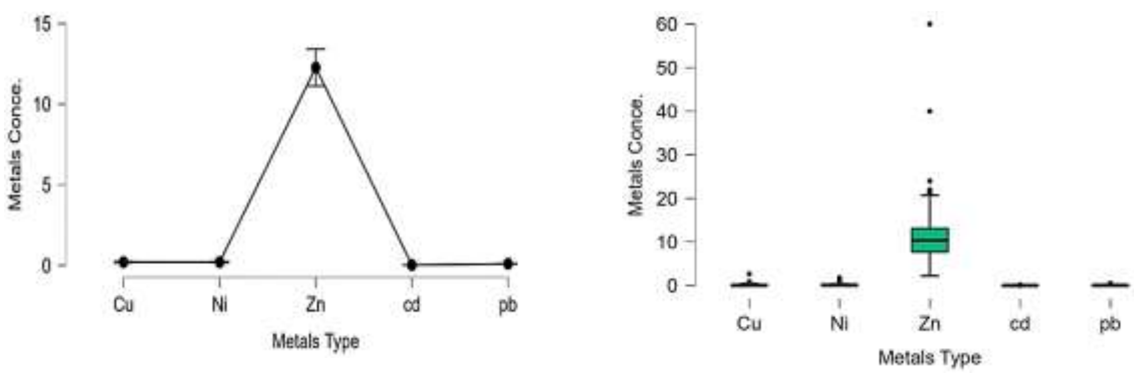

Figure (1) The concentrations and types of heavy metals using A) Descriptive plots technique, B) Boxplots method**.**

Table 2 shows the analysis of variance (ANOVA) testing results for differences in mean heavy metal concentrations by metal type. The ANOVA results indicate statistically significant differences at the 0.001 level between the mean concentrations by metal, with a p-value of less than 0.001. This signifies substantial variations in sample contamination levels by different heavy metals. For instance, the mean Zn concentration was much higher than the Pb mean concentration in the samples. Therefore, the statistical analysis findings suggest that the type of heavy metal has a large and statistically significant effect on the observed pollution levels in the biological specimens. This highlights the importance of identifying emission sources for each metal to develop suitable solutions for reducing exposure.

Table (2) ANOVA testing for the mean of heavy metal concentrations across metal type

pollutants	**Sum of Squares**	**Df**	**Mean Square**	**F**	**P**
Metals Type	7073.040	4	1768.260	111.867	6.725e-58
Residuals	4663.029	295	15.807		
Note. Type III Sum of Squares					

Table 3 presents descriptive statistics of the heavy metal concentrations measured in hair and nail samples. It provides an overview of the means, standard deviations, and minimum/maximum values recorded for each metal in both sample types. Table 3 presents descriptive statistics of the heavy metal concentrations measured in hair and nail samples. It provides an overview of the means, standard deviations, and minimum/maximum values recorded for each metal in both sample types.

Table (3). The Average, lowest, and highest value and standard deviation for all elements combined.

	Metals Conc.	
	Hair (mg/dL)	**Nail (mg/dL)**
Mean	2.663	2.453
Std. Deviation	6.231	6.318
Minimum	0.004	0.001
Maximum	40.000	60.000

The results indicate a significant variation in concentrations of the samples, with the lowest and highest values in hair samples ranging from 0.004 to 40 mg/dL, respectively. The nail samples recorded a minimum concentration of 0.001 mg/dL and a maximum of 60 mg/dL. This wide variance suggests the workers are exposed to vastly different levels of toxic metals, warranting further in-depth studies to understand the causes of this variation and develop suitable solutions to control exposure and mitigate health effects. Figure 3 presents a boxplot comparing the distribution of heavy metal concentrations measured in hair and nail samples. This technique visually compares central tendency and dispersion between the two data sets in an easily understood graphical format. The results show an overall similarity between the two distributions, ranging from less than 1 mg/dL to over 40-60 mg/dL. However, the nail samples exhibited greater dispersion of the value and higher outliers. This suggests that nails may be more sensitive in reflecting both current and past exposure levels to heavy metals compared to hair (Being in contact with elements during waste turning, collecting, and transporting). Thus, greater attention should be given to monitoring nail contamination to assess exposure risks better.

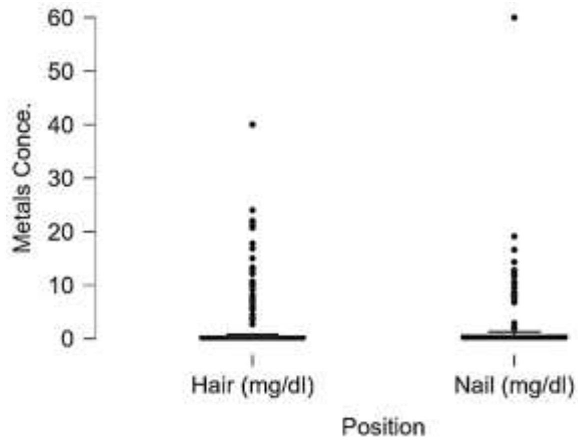

Figure (3) The concentrations of heavy metals in hair and nails by Boxplots method

Table (4). The heavy metal concentrations in males and females (by gender)

	Metals Conc.	
	Female	**Male**
Mean	2.597	2.528
Std. Deviation	5.988	6.487
Minimum	0.001	0.004
Maximum	40.000	60.000

The results indicate no clear differences between the genders regarding heavy metal pollution levels. Both males and females exhibited a wide range of concentrations from less than 1 mg/dL to over 40-60 mg/dL. This suggests that workers of both genders are exposed to approximately the same degree of toxic metals in the workplace environment. The wide dispersion and high upper range of concentrations in both groups underscores the need for continued biomonitoring and exposure control measures. Targeted interventions based on identified exposure pathways are essential to mitigate health risks. The boxplot in Figure 4 provides a visual comparison (boxplot) of the heavy metal concentration distributions between males and females. The results show substantial overlap in the distribution patterns, with both genders exhibiting a wide range from less than 1 mg/dL to over 40-60 mg/dL. The medians are similar around 2-3 mg/dL, and the upper quartiles are alike near 10 mg/dL. However, a slightly greater dispersion and more outliers are noticeable in the male group.

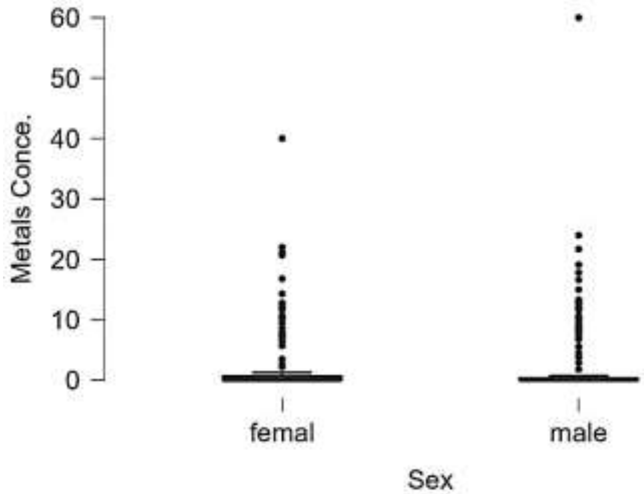

Figure (4) The concentrations of heavy metals in males and females (by gender)

The relationship between heavy metal concentrations and metal types in hair and nail samples categorized by gender was studied in Figure 5. The results show an overall similar pattern between the genders regarding accumulation profiles of the various metals. Both males and females exhibited the highest concentrations for Zn and the lowest for Cd. A markedly elevated average for Pb was noticed compared to Cu and nickel across the samples.

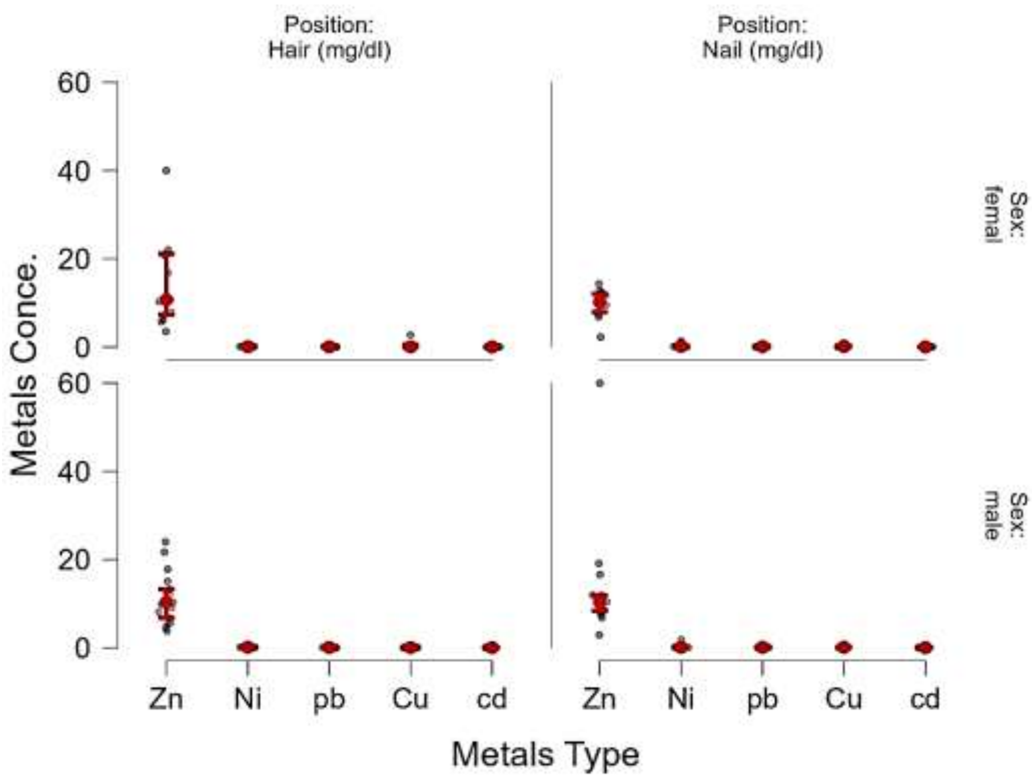

Figure (5) The relationship between the concentration of heavy elements and the types of heavy metals in hair, nails, and gender (male and female).

These findings indicate comparable conditions and degrees of exposure for workers of both genders to the emission sources of heavy metals at the work sites. This highlights the importance of adopting an inclusive approach to pollution control without discrimination between the sexes. In summary, the figure visually depicts the analogous heavy metal accumulation patterns in male and female workers. The post hoc tests were conducted to make pairwise comparisons between mean concentrations of the different metal types, Table 5. The results demonstrate a large statistically significant difference between the mean Zn concentration and the other metals, with p-values below 0.001 in the pairwise comparisons with Cu, Ni, Cd, and Pb. For instance, the difference between the mean Zn and Pb concentrations was 12.168 mg/dL, with a p-value of 6.679e-13. In contrast, p-values were greater than 0.05 between the remaining metal pairs, indicating no significant differences among them. Therefore, these statistical findings confirm that Zn pollution levels differ markedly from the other elements, warranting preventative and remedial efforts to focus on Zn.

Table (5). Comparison of the concentration of the heavy metal with the concentrations of other heavy metals

		Mean Difference	**SE**	**T**	**$P_{\text{- value}}$**
Cu	Ni	0.003	0.726	0.005	1.000
	Zn	-12.068	0.726	-16.625	6.679e-13 ***
	cd	0.177	0.726	0.245	0.999
	pb	0.100	0.726	0.138	1.000
Ni	Zn	-12.071	0.726	-16.629	6.679e-13 ***
	cd	0.174	0.726	0.240	0.999
	pb	0.097	0.726	0.134	1.000
Zn	cd	12.245	0.726	16.869	6.679e-13 ***
	pb	12.168	0.726	16.763	6.679e-13 ***
cd	pb	-0.077	0.726	-0.106	1.000

*** p < .001

Note. P-value adjusted for comparing a family of 5

Table 6 presents the analysis of variance (ANOVA) testing for differences in heavy metal concentrations between the study sites. The high p-value of 0.770 indicates no statistically significant differences between the sites, as it is greater than the 0.05 significance level. Table 6 presents the analysis of variance (ANOVA) testing for differences in heavy metal concentrations between the five landfill sites included in the study. The results demonstrate no statistically significant differences in metal concentrations between the sites, as evidenced by the high p-value of 0.770 which is greater than the 0.05 significance level. The ANOVA findings indicate that the variability in metal levels within each landfill site is much higher than between sites. This suggests that exposure risks depend more on localized factors within a particular dump site than just the location. The results highlight the need to conduct in-depth exposure characterization and develop tailored interventions for each landfill site.

Table (6). ANOVA analysis of Metals Concentrations according to Landfill sites.

Cases	Sum of Squares	df	Mean Square	F	P
Sites	71.651	4	17.913	0.453	0.770
Note. Type III Sum of Squares					

The flex plot visualizes the relationship between heavy metal concentrations and metal types categorized by gender, Figure 6. The plot illustrates substantial overlap in the distribution patterns between males and females for each metal type. Both genders follow similar trends, with the highest median concentrations observed, which are Zn>Pb>Ni>Cd. This suggests comparable exposure risks for male and female workers regardless of metal type, affirming the lack of variability between sites evidenced in the ANOVA test. While zinc displays the highest median, the wide dispersion of all metals underscores the need for continual monitoring and control measures. The priority metals may differ within the micro-areas of an individual landfill.

In summary, the flex plot offers a visual depiction confirming that metal levels do not appear to exhibit broader location-based trends. It highlights the need for localized exposure assessment and remediation planning focusing on specific sources and activities.

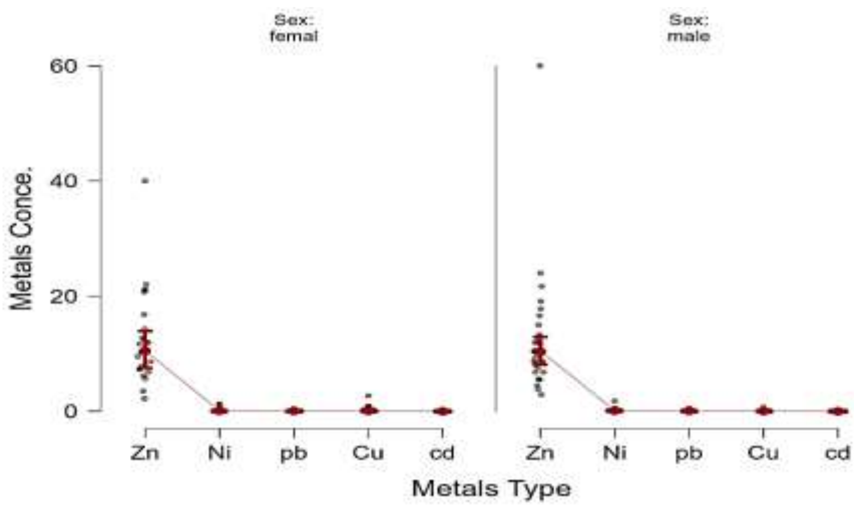

Figure (6). The relationship between the concentration of heavy elements and sex (male and female).

Analysis of Variance According to Landfill Site

The statistics in Table 7 demonstrate Pb concentrations quantified in hair and fingernail samples gathered from refuse collectors at five landfill locations in Baghdad during the winter and summer months. The findings reveal substantially higher Pb levels in both nail and hair specimens from all sites in the summer compared to the winter, as denoted by ($P \leq 0.05$)

Table (7). The levels of Pb in the hair and nails of Scavenger (Al- pick up) in the sites of landfills / Baghdad city for the winter and summer season

	Landfill sites	Mean ± SE of Pb		p-value
		Winter	Summer	
Nail (mg/ dl)	Kadhimia landfill	0.052 ±0.017	0.586 ±0.256	0.043 *
	Shualaa landfill	0.109 ±0.028	1.581 ±0.34	0.038 *
	Adhamiya landfill	0.172 ±0.080	0.835 ±0.192	0.040 *
	Abu Dashir landfill	0.119 ±0.022	0.607 ±0.132	0.033 *
	Baghdad Aljadeeda landfill	0.107 ±0.049	1.367 ±0.35	0.024 *
	LSD value	0.133 NS	0.892 *	---
Hair (mg/ dl)	Kadhimia landfill	0.108 ±0.05	2.43 ±1.36	0.024 *
	Alshuela landfill	0.098 ±0.056	1.751 ±0.59	0.034 *
	Adhamiya landfill	0.164 ±0.078	1.001 ±0.267	0.0328 *
	Abu Dashir landfill	0.038 ±0.022	0.435 ±0.131	0.013 *
	Baghdad Aljadeeda landfill	0.034 ±0.010	0.565 ±0.118	0.023 *
	LSD value	0.146 NS	1.678 *	---
*** (P≤0.05).**				

For example, the mean Pb content in nail clippings from Al-Shaula landfill was 0.109 mg/dL in winter versus 1.581 mg/dL in summer (p-value 0.038). Similarly, hair Pb concentrations were markedly elevated in the summer period across the sampling sites based on p-values below 0.05. Significantly, the detected Pb levels surpassed the maximum permissible exposure limits set by agencies such as OSHA at 0.05 mg/m^3. The considerably lower p-values for nail and hair samples in summer signify increased lead volatility and exposure risk for landfill laborers under high-temperature conditions. Further inquiries are imperative to fully elucidate the factors influencing seasonal variations in Pb exposure for these waste collectors.

Table 8 presents the Cd levels in hair and nail samples of waste scavengers at the five landfill sites during winter and summer. The results show significant seasonal differences in Cd concentrations only in nail samples from the Baghdad Al-Jadeeda landfill, as indicated by the p-value of 0.0147 which is less than 0.05, (P≤0.05).

Table (8). The levels of Cd in the hair and nails of Scavenger (Al- pick up) in the sites of landfills / Baghdad city for the winter and summer season

	Landfill sites	Mean ± SE of Cd		p-value
		Winter	Summer	
	Kadhimia landfill	0.042 ±0.029	0.026 ±0.006	0.089 NS
Nail (mg/ dl)	Alshuela landfill	0.017 ±0.00	0.040 ±0.010	0.077 NS
	Adhamiya landfill	0.086 ±0.051	0.084 ±0.028	0.0971 NS
	Abu Dashir landfill	0.041 ±0.032	0.086 ±0.038	0.0592 NS
	Baghdad Aljadeeda landfill	0.028 ±0.00	0.291 ±0.224	0.0147 *
	LSD value	0.183 NS	0.263 *	---
	Kadhimia landfill	0.041 ±0.012	0.054 ±0.018	0.087 NS
Hair (mg/ dl)	Shualaa landfill	0.109 ±0.034	0.0559 ±0.02	0.079 NS
	Adhamiya landfill	0.063 ±0.014	0.072 ±0.023	0.083 NS
	Abu Dashir landfill	0.0167 ±0.009	0.041 ±0.009	0.069 NS
	Baghdad Aljadeeda landfill	0.034 ±0.009	0.039 ±0.011	0.098 NS
	LSD value	0.072 *	0.061 NS	---
*** (P≤0.05).**				

For instance, the mean Cd level in nails at the Baghdad Al-Jadeeda landfill was 0. For instance, the mean Cd level in nails at Baghdad Al-Jadeeda landfill was 0.028 mg/dL in winter compared to a higher concentration of 0.291 mg/dL in summer. However, no significant seasonal variations were observed in Cd levels of hair samples across the sites, as evidenced by p-values smaller than 0.05. Notably, theCd levels exceeded the permissible exposure limit set by occupational health organizations such as OSHA at 0.05 mg/m^3. The significantly lower p-value for nail samples from the Baghdad Al-Jadeeda landfill indicates increased Cd exposure in summer compared to winter for workers at this particular site. Meanwhile, the lack of significant differences in hair cadmium levels between seasons highlights the need for further investigation into factors influencing Cd accumulation in biological samples. The increased nail Cd content in summer could potentially be attributed to heightened vaporization and dispersion of this heavy metal under high-temperature conditions. Further studies are required to fully investigate the factors influencing metal exposure in these waste workers. Table 9 illustrates the Cu content in hair and nail samples collected from waste scavengers at the five landfill sites during winter and summer. Significant seasonal variations were evident in nail copper levels across four of the five sites, as denoted by LSD values below 0.05.

Table (9). The levels of Cu in the hair and nails of Scavenger (Al- pick up) in the sites of landfills / Baghdad city for the winter and summer season

	Landfill sites	**Mean ± SE of Cu**		**p-value**
		Winter	Summer	
Nail (mg/ dl)	Kadhimia landfill	0.229 ±0.100	0.375 ±0.140	0.192 NS
	Shualaa landfill	0.123 ±0.042	1.272 ±0.21	0.031 *
	Adhamiya landfill	0.133 ±0.050	0.741 ±0.145	0.046 2 *
	Abu Dashir landfill	0.226 ±0.145	1.656 ±0.45	0.032 5 *
	Baghdad Aljadeeda landfill	0.211 ±0.114	1.797 ±0.58	0.036 4 *
	LSD value	0.287 NS	0.974 *	---
Hair (mg/ dl)	Kadhimia landfill	0.115 ±0.055	0.830 ±0.385	0.025 3
	Alshuela landfill	0.176 ±0.120	1.304 ±0.25	0.039 1 *
	Adhamiya landfill	0.213 ±0.099	1.058 ±0.23	0.034 7 *
	Abu Dashir landfill	0.470 ±0.443	0.593 ±0.092	0.093 NS
	Baghdad Aljadeeda landfill	0.108 ±0.082	0.646 ±0.192	0.043 1 *
	LSD value	0.625 NS	0.741 NS	---

*** (P≤0.05).**

The mean Cu concentration in nail samples from Al-Shaula landfill was 0.123 mg/dL in winter versus a higher level of 1.272 mg/dL in summer (p-value 0.031). However, hair Cu levels showed significant seasonal differences only at Al-Shaula, Adhamiya, and Baghdad Al-Jadeeda landfills based on p-values below 0.05. It is worth highlighting that the observed copper levels exceeded permissible occupational exposure limits set by OSHA at 1 mg/m^3.The significantly higher p-values for nail samples in summer indicate increased copper exposure risk for landfill workers under hot conditions leading to enhanced volatilization. The variability in hair copper accumulation warrants further investigation to understand influencing factors. Table 10 shows the Ni levels measured in hair and nail samples of waste scavengers at the five landfill sites during the winter and summer seasons. The results indicate significant differences in Ni concentrations between seasons in nail samples from Adhamiya and Baghdad Al-Jadeeda landfills based on p-values below 0.05.

Table 10. The levels of Ni in the hair and nails of Scavenger (Al- pick up) in the sites of landfills / Baghdad city for the winter and summer season

	Landfill sites	Mean ± SE of Ni		p-value
		Winter	Summer	
Nail (mg/ dl)	Kadhimia landfill	0.107 ±0.024	0.099 ±0.025	0. 083 NS
	Shualaa landfill	0.213 ±0.071	0.384 ±0.14	0.080 NS
	Adhamiya landfill	0.187 ±0.046	0.527 0.23	0.0142 *
	Abu Dashir landfill	0.695 ±0.385	0.441 ±0.118	0.054 NS
	Baghdad Aljadeeda landfill	0.793 ±0.269	0.0126 ±0.002	0.0251 *
	LSD value	0.534 *	1.012 *	---
Hair (mg/ dl)	Kadhimia landfill	0.195 ±0.044	0.148 ±0.021	0.074 NS
	Shualaa landfill	0.165 ±0.025	0.154 ±0.045	0. 078 NS
	Adhamiya landfill	0.042 ±0.010	0.1017 ±0.02	0.086 NS
	Abu Dashir landfill	0.113 ±0.045	0.071 ±0.018	0.065 NS
	Baghdad Aljadeeda landfill	0.104 ±0.014	0.083 ±0.016	0.075 NS
	LSD value	0.095 *	0.103 NS	---

*** (P≤0.05).**

In particular, the mean Ni level in nail samples from Al-Adhamiya landfill was 0.187 mg/dL in the winter compared to 0.527 mg/dL in the summer (p-value 0.0142). However, no significant seasonal variations were found in hair nickel levels across the sites, as evidenced by p-values greater than 0.05. Notably, the detected Ni concentrations exceeded the occupational exposure limit of 1 mg/m^3 set by organizations like the ACGIH. The increased nail Ni content observed during the summer suggests heightened vaporization and exposure risk for landfill workers under high temperatures. Further studies are needed to elucidate factors affecting metal accumulation patterns in the biological samples of these waste scavengers. The data in Table 11 demonstrates Zn concentrations measured in hair and nail samples collected from waste pickers at five landfill areas in Baghdad during the winter and summer. The results exhibit significantly elevated Zn levels in both nail and hair samples from all sites in the winter compared to summer, as shown by p-values under 0.05. In one case, the average Zn content in nail clippings from Al-Shaula landfill was 11.30 mg/dL in the winter versus only 0.0119 mg/dL in the summer (p-value 0.0253). Likewise, hair Zn levels were markedly higher in the winter months across the sampling locations based on p-values below 0.05. Notably, the detected Zn concentrations, especially in the winter specimens, surpassed the maximum allowable occupational exposure limit of 10 mg/m3 established by regulatory bodies such as OSHA.

Table 11. The levels of Zn in the hair and nails of Scavenger (Al- pick up) in the sites of landfills / Baghdad city for the winter and summer season

	Landfill sites	Mean ± SE of Zn		p-value
		Winter	Summer	
Nail (mg/ dl)	Kadhimia landfill	9.36 ±0.52	0.0105 ±0.001	0.0142 *
	Shualaa landfill	11.30 ±1.39	0.0119 ±0.001	0.0253 *
	Adhamiya landfill	8.56 ±0.74	0.0115 ±0001	0.0284 *
	Abu Dashir landfill	17.72 ±8.83	0.012 ±0.001	0.0173 *
	Baghdad Aljadeeda landfill	11.35 ±0.94	0.0074 ±0.002	0.0115 *
	LSD value	11.77 NS	0.0042 NS	---
Hair (mg/ dl)	Kadhimia landfill	13.31 ±2.56	0.0115 ±0.003	0.0179 *
	Shualaa landfill	13.96 ±3.16	0.0309 ±0.015	0.0168 *
	Adhamiya landfill	8.65 ±0.77	0.0105 ±0.002	0.0271 *
	Abu Dashir landfill	14.05 ±5.84	0.0707 ±0.018	0.0196 *
	Baghdad Aljadeeda landfill	14.40 ±2.49	0.0191 ±0.006	0.0199 *
	LSD value	9.881 NS	0.032 NS	---

*** (P≤0.05).**

The considerably lower p-values for nail and hair samples in the winter indicate that colder conditions may restrict zinc volatilization, resulting in increased accumulation. Additional studies are imperative to fully elucidate the factors impacting these landfill employees' seasonal variations in zinc exposure

4-DISSCUSION

This study provided evidence of significantly higher exposure to certain heavy metals among landfill waste scavengers in Baghdad during summer compared to winter.

The results demonstrated considerably elevated lead, copper, and nickel levels in nail samples of workers during summer, indicating increased volatilization and bioavailability of these metals under high temperatures. This is consistent with findings by (20), who also found increased lead and cadmium accumulation under high-temperature conditions.

Meanwhile, zinc accumulation patterns showed an opposite trend, with markedly higher levels observed in winter nail and hair specimens. This implies zinc volatility and exposure risks are greater in cold conditions, aligning with results noted by (15) that reported limited zinc dispersion under high temperatures.

In some samples, the measured concentrations of metals exceeded recommended safe occupational exposure limits, underscoring the risks that landfill scavengers face with heavy metal exposure throughout the year. Significant variations were also found between the different metals, with zinc exhibiting the highest contamination burden compared to other elements based on statistical analysis, similar to trends observed in an earlier study (21).

The findings point to the need for stringent exposure control strategies tailored to weather conditions. Stricter measures may be required in summer to reduce lead, copper, and nickel volatilization, while added protections could be beneficial in winter to mitigate zinc exposure threats. Moreover, the considerable seasonal variations highlight the importance of regular biomonitoring of landfill employees to identify priority metals of concern year-round, as noted in previous research (17).

Overall, the study emphasizes that seasonal fluctuations and temperature extremes affect bioaccumulation patterns, necessitating appropriate interventions to minimize heavy metal exposure risks for waste scavengers throughout the year. Further research can provide insights into specific sources and mechanisms influencing accumulation.

The statistical analysis showed no significant differences in heavy metal concentrations between the five landfill sites included in the study ($p > 0.05$). This indicates that exposure risks depend more on specific activities and micro-environmental factors rather than simply the location. Significant within-site variations suggest the need for localized exposure assessments and control measures tailored to each dumpsite. The results also revealed no clear differences between genders in heavy metal accumulation levels. Both male and female workers exhibited wide ranges of metal concentrations, underscoring the need for gender-inclusive biomonitoring and exposure prevention strategies. The findings imply that employees of both sexes face comparable heavy metal hazards at the work sites.

5. CONCLUSION

This study demonstrated considerable seasonal variations in heavy metal exposure patterns among landfill waste scavengers in Baghdad, with higher lead, copper, and nickel levels in summer and elevated zinc accumulation in winter. The frequent exceeding of occupational limits underscores the year-round mental hazards faced by these workers. The findings highlight the need for tailored exposure control strategies based on weather conditions and priority metals of concern identified through regular biomonitoring. Adoption of stringent measures is critical to safeguard the health of this vulnerable population against heavy metal threats throughout the year.

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الأثر البيئي والصحي لتراكم المعادن الثقيلة في (الشعر - الأظافر) لعمال النظافة في بعض مواقع طمر النفايات في مدينة بغداد-العراق

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الخلاصة

خلفية عن الموضوع: تعتبر المعادن الثقيلة من أخطر الملوثات البيئية بسبب سميتها العالية حتى بتراكيز منخفضة، وتراكمها في أنسجة الجسم المختلفة. تحتوي مدافن النفايات على نفايات متنوعة غنية بالمعادن الثقيلة، مثل البطاريات والدهانات والنفايات المنزلية والمستشفيات، مما يجعلها مصدراً رئيسياً لتلوث الهواء والتربة والمياه الجوفية.**الهدف من الدراسة:** تحليل مستوى تراكم المعادن الثقيلة في عينات الشعر والأظافر لجامعي النفايات .**المواد وطرق العمل:** تم اختيار خمسة مواقع رئيسية لمدافن النفايات في مدينة بغداد لجمع عينات الشعر والأظافر من جامعي النفايات من الجنسين لموسمي الشتاء والصيف لتحليل مستويات تراكيز المعادن (الرصاص، الكادميوم، النيكل، الزنك، نحاس). واستخدام مطياف الامتصاص الذري.(AAS) **النتائج:** تم العثور على تركيزات أعلى من الرصاص والنحاس والنيكل في عينات الأظافر خلال فصل الصيف مقارنة بفصل الشتاء، مما يشير إلى زيادة خطر التعرض لها. بينما كان تراكم الزنك أكبر بكثير في العينات الشتوية.**الاستنتاج:** تسلط النتائج الضوء على المخاطر الصحية التي يواجهها عمال مدافن النفايات. الحاجة إلى وضع استراتيجيات مصممة خصيصًا للتحكم في التعرض لهذه الانبعاثات بناءً على الظروف الجوية والمعادن ذات الأولوية المثيرة للقلق والتي تم تحديدها من خلال المراقبة البيولوجية المنتظمة.

الكلمات المفتاحية: خميرة *Candida albicans*، تفاعل البوليميز المتسلسل، درجة الحرارة، الرقم الهيدروجيني، ثنائي اوكسيد الكربون.