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Hematological Parameters, Blood Heavy Metal Levels, and Socio-Demographic Risk Factors among Occupational Metal Scrap Workers in Benin City, Nigeria: A Cross-Sectional Study

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ABSTRACT

Background: Heavy metals such as lead, chromium, cadmium, and nickel are widely distributed in the environment due to rapid industrial growth and poor waste management. Occupational metal scrap workers are particularly vulnerable.
Methods: A cross-sectional analytical investigation was conducted in the Iya-Ero area in Benin City, Nigeria. Fifty (50) male volunteers were enrolled: thirty (30) occupational metal scrap workers and twenty (20) age-matched, non-exposed controls. Complete blood counts and blood heavy metal levels (lead, chromium, cadmium, and manganese) were measured. Independent t-tests and Pearson correlation analyses were utilized for statistical evaluation.
Results: The white blood cell count was significantly higher in the exposed group (6.90±1.70 x 10^3/μL) compared to the control group (4.93±1.60 x 10^3/μL) ($p < 0.05$). The percentage of lymphocytes was significantly lower in the exposed group (42.80±8.59%) than in the control (45.90±7.50%) ($p < 0.05$). Blood lead (3.00±0.90 μg/dL vs 0.65±0.15 μg/dL) and chromium (1.61±0.40 μg/dL vs 0.60±0.13 μg/dL) levels were significantly elevated in the exposed group ($p < 0.01$).
Conclusion: Occupational metal scrap workers in Benin City demonstrated significantly higher blood lead and chromium levels, accompanied by altered white blood cell counts. These findings suggest potential inflammatory responses associated with occupational exposure. Large-scale longitudinal studies will be needed to ascertain the findings from this research work in order to promote more informed health interventions in occupational exposed subjects.

Keywords: Occupational exposure; Heavy metals; Hematological parameters; Metal scrap workers; Benin City.

INTRODUCTION

Heavy metals (for example lead, chromium, cadmium, and nickel) have a wide distribution in the geographical space. This wide distribution is linked to the fast growth of different types of industries and the resultant attributes of poor management of solid waste generated (1, 2). These heavy metals elicitss marked risks that could be linked to occupation and public health due to the fact that in variation to several natural poisons, they are hard to breakdown in the biological system. Rather, these agents undergo bioaccumulations in the tissues and organs of human and other related living things over a long timeline (3). As this process progresses, the affected living things suffer enormous metabolic challenges which could complicate existential capability. The level of occupational exposure in industries, semi-formal and informal work placements normally occurs through direct ingestion, physical contact with the skin, and/or inhalation of dust and fumes contaminated with such components (4, 5).

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This long timeline of exposure to these agents could lead to chronic multi-organ toxicity as a result of cellular damage, oxidative stress, and the significant drop in some important antioxidant enzymes (5). A group of occupationally exposed workers at imminent risk might include unorganized waste handlers as observed in those collecting solid wastes and those recycling metal scrap (2). The individuals might have some frequency in the rate they are in contact with dangerous elements in the open space. With next to zero regulatory control, and near absence of personal protective equipment during these activities, they potentially put themselves and the environment at an immediate risk (3). In furtherance, some researches had indicated that behavioral and sociodemographic attributes such as age, gender, duration of employment, educational status, and lifestyle preferences, might be important variables that could enhance the way the human make-up accumulate hazardous metals (3). Most handlers lacking relevant education and biosafety enlightenment might be more at liberty falling victim to occupational hazards linked to heavy metals (5).

When these heavy metals are ingested, there is the likelihood that they might result in damage to hematological makeup of the system (6). Long-term exposure to these agents have been connected with alterations in hematological indices as well as abnormalities in erythrocytic counts, concentrations of hemoglobin, level of thrombocytes, and leucocyte count (6, 7). These hematological alterations serve as clinical indicators of immune response activation, systemic inflammation, and physiological stress (7). High levels of lead and cadmium can result in oxidative stress, which damages cellular membranes and impairs leukocyte and erythrocyte function (4, 6).

There is a need to fully examine the intersecting effects of mixed-metal exposure in the scrap metal industry. This study aimed to evaluate blood heavy metal levels and hematological indices among occupational metal scrap workers compared to non-exposed controls in Benin City, Nigeria.

MATERIALS AND METHODS

Study Area and Design

A human observational cross-sectional study was conducted in the Iya-Ero area in Benin City, South-South Nigeria from February 2022 to May 2022. The study compared occupational exposure among metal scrap workers to non-exposed controls. A standardized questionnaire collected information on age, length of exposure, and other pertinent factors.

Sample Size and Population

The sample size was calculated using the cross-sectional single population proportion formula described by Araoye (8): $N = Z^2Pq/d^2$. Where *N* is the minimum required sample size, *Z* is the 95% confidence level standard normal deviate (1.96), *P* is the estimated clinical prevalence of advanced exposure complications (0.02), *q* is 1 - P (0.98), and *d* is the allowable margin of error (0.05). Replacing these variables gives a numeric value of approximately 30 exposed subjects.

The two percent baseline of prevalence indicates the functional, sub-clinical state of the active cohorts, equilibrating onset xenobiotic accumulation versus the absence of overt, terrible hematological crises. This current work mirrors indigenous Nigerian heavy metal-exposure pilot models, such as Onwuama et al. (9). They found heavy metal variations with the aid of focused cohort of 18 active occupationally exposed workers. To accommodate for the participant attrition initiated by exclusion screening (for examples elimination of tobacco, alcohol, or chronic pharmaceutical medication users) and the difficult-to-access outlook of this unregulated informal workforce led to the adjustment of this final cohort. A purposive approach in sampling technique was adopted in selecting these groups, hence the enrolment of targeted pilot samples of fifty male (50) participants—comprising of thirty (30) occupationally exposed scrap workers and 20 age-matched, non-exposed controls.

Inclusion and Exclusion Criteria

Inclusion criteria for the group participants exposed requires male employees in constant contact with metal recycling activities for a minimum of twenty four months. The control subjects were apparently healthy males with no record of work or leisure-related predisposition to dangerous to heavy metals (10). To limit confounding indications, subjects that continuously drink alcohol, indulged in tobacco usage, long-term medications, or possesses record of chronic illness or cancer were removed from a preliminary screening process.

Laboratory Methods

In accordance to standard protocols (10), five mL of venous blood was collected from the antecubital vein with the aid of sterile venoject needles and vacuutainer tubes. Full blood count was analysed using automated hematology analyzer (Sysmex KX-21N). Lead (Pb), chromium (Cr), cadmium (Cd), and manganese (Mn) levels (measured in µg/dL) were determined with the aid of atomic absorption spectrophotometry following acid digestion of the specimens. Standard calibration curves and laboratory quality control procedures, including the usage of sample blanks, were followed to ensure detection limit accuracy (10).

Statistical Analysis

The data obtained from the research were analyzed using GraphPad Prism version 6.0. Normality levels were done prior to analysis. Continuous variables were expressed as mean ± standard deviation (SD) and 95% confidence intervals were evaluated. The independent Student's t-test was used to compare the means of hematological variables and heavy metal levels between the exposed and control groups. Pearson's correlation was used to determine the relationships between different trace metals. Statistical significance was considered at $p < 0.05$.

RESULTS

The socio-demographic from the work were displayed in table 1. All subjects in both the exposed (N = 30) and control (N = 20) groups were male. The age distribution between the groups did not differ significantly ($p > 0.05$). All exposed subjects did mot acquire any kind of formal education and did not use personal protective device while executing their duty. Some of the occupationally-exposed subjects (44.00%) had 4 to 7 years' experience on the job.

Table 2 presents the comparison of parameters from hematological analysis. The leukocyte estimation was higher significantly in the occupationally-exposed group ($6.90\pm1.70 \times 10^3/\mu L$) compared to the control ($4.93\pm1.60 \times 10^3/\mu L$) ($p < 0.01$). The percentage of lymphocytic counts was lower significantly in the occupationally-exposed group (42.80±8.59%) when related to the control (45.90±7.50%) ($p < 0.01$). Additionally, the red cell distribution width (RDW) was reduced significantly in the occupationally-exposed subjects (41.66±5.10%) compared to the control subjects

(44.66±5.16%) ($p < 0.04$) while other parameters analysed showed no significant difference ($p > 0.05$).

Table 1: Socio-Demographic Characteristics of Participants.

Variable	Exposed (N = 30)	Control (N = 20)
Age (years)		
18-22	11 (36.7%)	10 (50.0%)
23-28	4 (13.3%)	6 (30.0%)
29-33	2 (6.7%)	4 (20.0%)
34-38	6 (20.0%)	0 (0.0%)
39 and above	2 (6.7%)	0 (0.0%)
Educational Level		
Formal	0 (0.0%)	20 (100.0%)
Informal	30 (100.0%)	0 (0.0%)
Years of Exposure		
1-3	11 (36.7%)	N/A
4-7	13 (43.3%)	N/A
8-11	5 (16.7%)	N/A
12-15	1 (3.3%)	N/A
Protective Device Use		
Yes	0 (0.0%)	N/A
No	30 (100.0%)	N/A

Note: All participants (100%) were male. Statistical comparison for sex is not applicable. N/A = Not applicable.

Table 2: Mean Comparison of Hematological Parameters of Exposed and Control Subjects.

Parameter	Exposed (N=30)	Control (N=20)	p-Value
White Blood Cell ($10^3/\mu L$)	6.90 ± 1.70	4.93 ± 1.60	0.01*
Lymphocytes (%)	42.80 ± 8.59	45.90 ± 7.50	0.01*
Monocytes (%)	9.90 ± 7.62	8.00 ± 2.95	>0.05
Neutrophil (%)	40.90 ± 11.27	42.00 ± 9.00	>0.05
Eosinophil (%)	4.60 ± 0.78	3.50 ± 0.70	>0.05
Basophil (%)	1.80 ± 0.49	0.60 ± 0.50	>0.05
Red Blood Cell ($10^6/\mu L$)	5.60 ± 0.50	6.00 ± 0.70	>0.05
Hemoglobin (g/dL)	14.17 ± 1.15	13.90 ± 1.80	>0.05
Hematocrit (%)	42.50 ± 3.30	41.70 ± 5.04	>0.05
MCV (μm^3)	75.89 ± 8.97	69.50 ± 11.68	>0.05
MCH (pg)	25.30 ± 3.06	23.17 ± 4.04	>0.05
MCHC (g/dL)	33.34 ± 3.75	33.33 ± 5.91	>0.05
RDW (%)	41.66 ± 5.10	44.66 ± 5.16	0.04*
Platelet ($10^3/\mu L$)	217.20 ± 116.70	213.00 ± 50.30	>0.05

*Footnote: Data expressed as Mean ± Standard Deviation (SD). Statistical evaluation utilizing independent t-tests. * indicates statistical significance at p < 0.05. MCV: Mean corpuscular volume, MCH: Mean corpuscular hemoglobin, MCHC: Mean corpuscular hemoglobin concentration, RDW: Red cell distribution width.*

Table 3 showed that the level of Lead (Pb) were significantly raised in the occupationally-exposed group (3.00±0.90 µg/dL) compared non-exposed (0.65±0.15 µg/dL) ($p < 0.01$). Also, chromium (Cr) was elevated significantly in the exposed subjects (1.61±0.40 µg/dL) relative to the control (0.60±0.13 µg/dL) ($p < 0.01$). The amount of Cadmium (Cd) was raised significantly non-exposed group (5.80±1.40 µg/dL) compared to the control group (0.30±0.07 µg/dL) ($p < 0.01$) while Manganese (Mn) was reduced significantly in the occupationally-exposed subjects (0.80±0.20 µg/dL) compared to the control group (2.20±0.52 µg/dL) ($p < 0.01$).

Table 3: Mean Comparison of Blood Heavy Metals of Exposed and Control Subjects.

Parameter (µg/dL)	Exposed (N=30)	Control (N=20)	p-Value
Lead	3.00 ± 0.90	0.65 ± 0.15	0.01*
Chromium	1.61 ± 0.40	0.60 ± 0.13	0.01*
Cadmium	5.80 ± 1.40	0.30 ± 0.07	<0.01*
Manganese	0.80 ± 0.20	2.20 ± 0.52	0.01*

*Footnote: Data expressed as Mean ± SD. Evaluated via independent t-test. * indicates statistical significance at p < 0.05.*

In the group that was occupationally-exposed, a significantly negative correlation was seen between Chromium and Cadmium ($r = -0.470$, $p < 0.05$). In the control group, a significantly positive correlation was observed between Cadmium and Manganese ($r = 0.490$, $p < 0.05$).

Table 4: Correlation between Trace Metals in Exposed and Control Subjects.

	Lead	Chromium	Cadmium	Manganese
Exposed Group				
Lead	1	-0.150	0.170	0.270
Chromium	-0.140	1	-0.470*	-0.260
Cadmium	0.170	-0.470*	1	-0.290
Manganese	0.270	-0.260	-0.290	1
Control Group				
Lead	1	-0.025	0.070	0.150
Chromium	-0.025	1	-0.165	0.210
Cadmium	0.060	-0.165	1	0.490*
Manganese	0.110	0.210	0.490*	1

*Footnote: Pearson's correlation coefficient (r). * indicates statistical significance at p < 0.05.*

DISCUSSION

A significant predisposition seen in this informal section with somewhat free existential outlook is highlighted by the observation that all occupationally-exposed metal recyclers were not having institutionally tutored education and were not at liberty to use personal protective equipment. Metal Scrap workers in these sector are persistently exposed to dangerous impacts without adequate protective attributes. This aftermath might result to elevated inhalation and dermal absorption of dangerous substances (2). The raised level of metal loads in the system observed in this study might be linked to this tenable socio-demographic factors.

The reduced medical prevalence of significant challenges seen in hematology in this research aligns with similar indigenous occupationally-related pilot surveys seen the Nigerian metal-recycling industry. Onwuama et al. (9) studied a cohort of 18 metal forging factory personnel. Their study observed that irrespective of linked systemic predisposition, significant deviation in heavy metal balances in blood circulation, the subjects under review remained clinically functional and relatively free of likely medical incidences. This gives credence to the fact that small-scale, cross-sectional pilot studies covering active workers normally show onset in early phase, sub-clinical stages of xenobiotic accumulation of these substances rather than widespread medical morbidity.

Physiologically, the arrangement of the body of humans is quite unique with respect to the notion that it has an inherent capability in the production of raised amount of leukocytes. These leukocytes provide pathological defense to withstand likely inflammation in the tissues and organs (2). A fundamental physiological indicator observable in this work was the substantial rise in the leukocyte counts in the occupational-exposed workers when compared to controls. Simultaneously, a significant reduction was observed in the amount of lymphocytes documented. Previous literature documented that long timeline occupational-exposure might lead to the alteration of the immune cell responses (5). The absence of significant difference in the amount of hemoglobin concentration red blood cell count indicated that the parameters did not show observable differences during the timeline of the exposure (4 to 7 years) (6).

The raised bioaccumulation of lead and chromium in the exposed occupationally indicated that the hazards might be linked to the locations where these assignments are executed (4). On the other hand, the significant lowering in the amount of manganese in occupationally-exposed subjects might be relatively linked to biological interaction. In this scenario, biological toxicity from heavy metals directly compete with essential trace elements for cellular transport processes (5).

The significantly raised amount of cadmium in blood in the occupationally exposed group have relationship with similar unregulated occupationally exposed cohorts. Generally, the recycling locations well established generating dangerous dust from heavy metal and far-reaching fumes. This act might lead to marked systemic bioaccumulation over a long timeline (3, 5). As revealed in some related study populations, occupational-exposure in these sectors results in hazardous concentration of cadmium and lead (4, 6). High concentration of cadmium in the biological system are known to be dangerous to daily physiological existence. These agents are known to generate severe oxidative stress, destroy cellular membranes, and negatively hinders leukocyte and erythrocyte functions (4, 6). The significant biological accumulation of cadmium observed in this study might be linked directly to the effects of their socio-demographic profile. The total absence of health and safety as well as the resultant absence of personal protective gears promoted the persistent, unregulated inhaling and ingestion of cadmium-laden particulate matter during recycling exercises (5).

In work areas with combined metal exposures, the interactions of different groups of metal are normally dynamic. The significant negative correlation seen between chromium and cadmium in the occupationally-exposed subjects quantitatively points to a likely antagonistic relationship. It has been proposed that raised bioaccumulation of a specific metal could bring down the chances of picking up another type. This mechanism is not unconnected with competition for transport pathways and intracellular binding proteins (5).

Limitations

The limited number of subjects (sample size used in this work significantly reduces the statistical power and limits the generalizability of the findings. The unwillingness of the field working to readily enlist in the study due to busy schedules and the emphatic fear that their blood might be used for ritualistic purposes by the field researches drastically hindered our sampling effort. Irrespective of the fervent explanation of the group leaders in location dialect, enormous numbers still declined enlistment.

Conclusion

Occupationally exposed metal recyclers in the subjects under investigation showed significantly increased blood lead and chromium levels, accompanied by significant alteration in leukocyte counts. These findings indicated likely inflammatory responses linked to occupational exposure.

DECLARATIONS

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This study did not receive any specific funding from public, commercial, or non-profit agencies.

Conflict of Interest
The authors declare no conflict of interest.

Author Contributions
E.B.O. conceptualized the study, performed laboratory analysis, and drafted the manuscript. A.I.A. assisted with data collection, statistical analysis, and manuscript revision. All authors read and approved the final manuscript.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical Approval

The ethical approval for the studies was obtained from the Health Planning, Research and Statistics Unit of the Edo State Ministry of Health in Benin City, Nigeria, (Reference No.: HA-737/30). Written informed consent was received from each subjects and the goal of the research was explicitly was explained to them in both Pidgin English and conventional English.

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REFERENCES

1. Chaudhary MD, Chaudhary RD, Sale K, Chaudhary C, Manek P, Parmar N, et al. Occupational exposure to heavy metals: A review of health outcomes and safety interventions. Bioinformation. 2026;22(1):547–552. doi:10.6026/973206300220547
2. Rasool U, Thomson P. Level of trace metals and associated impact on biochemical, hematological, and genotoxic effects in occupationally exposed waste-collecting workers. Biomed J Sci Tech Res. 2024;58(2):50170–50183. doi:10.26717/BJSTR.2024.58.009132
3. Wen L, Zhou L, Zhu X, Mei Y. Epidemiological profile and determinants of whole blood heavy metal levels in occupationally exposed populations: a cross-sectional study in Hunan Province, China. Front Public Health. 2025;13:1635236. doi:10.3389/fpubh.2025.1635236
4. Fahim YA, Hasani IW, El-Khawaga AM, Abdelhakim HK, Sharaf NE, Lasheen NN. Occupational Exposure to Heavy Metal Dust and Its Hazardous Effects on Non-ferrous Foundry Workers' Health. J Chem Health Risks. 2024;14(3):473–488. doi:10.22034/jchr.2024.19124.473
5. Narayanan M. Heavy metal exposure among industrial workers: mechanisms of toxicity, biomonitoring strategies, and public health risk assessment. Discov Public Health. 2026;23(1):146. doi:10.1007/s44250-026-00146-w
6. Parvez SM, Huda MM, Rahman M, Jahan F, Fujimura M, Hasan SS, et al. Hematological, cardiovascular and oxidative DNA damage markers associated with heavy metal exposure in electronic waste (e-waste) workers of Bangladesh. Toxicology. 2024;509:153978. doi:10.1016/j.tox.2024.153978
7. Hassan K, Khan MK, David M, Jahan S, Afsar T, Husain FM, et al. Detection of reproductive and hematobiochemical biomarkers to evaluate the impact of heavy metal exposure on brick kiln workers. Sci Rep. 2025;15(1):4617. doi:10.1038/s41598-025-04617-w
8. Araoye MO. Research Methodology with Statistics for Health and Social Sciences. Ilorin: Nathadex Publishers; 2003. p. 115–121.
9. Onwuama OS, Dioka CE, Meludu SC, Onwuama CC, Ogbodo EC, Nwosu NJ. Assessment of heavy metal levels in blood of metal forging factory workers in Nnewi, Anambra State, Nigeria. J Pharm Biol Sci. 2024;7(1):12–19. doi:10.18231/j.jpbs.2024.012
10. Odozi EB, Ayeni EE. Effect of aqueous leaf extract of Moringa oleifera on some complete blood count and some oxidative stress markers of stress-induced Albino Wistar rats. Afr J Lab Haematol Transfus Sci. 2024;3(2):107–113. doi:10.4314/ajlhts.v3i2.6

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