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IMPACT OF OCCUPATIONAL EXPOSURE TO LEAD ON LIVER AND KIDNEY FUNCTION INDICES OF ARTISANAL GOLD MINERS IN ZAMFARA STATE, NIGERIA

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ABSTRACT

Background: The worldwide heavy metal contamination has been attributed to growing industrial, persistent mining activities and poor environmental laws especially in developing countries. Lead in particular, remains a significant threat to the environment and public health. The present study was designed to evaluate the impact of occupational exposure to lead on liver and kidney function parameters of artisanal gold miners in Zamfara State, Nigeria. **Methodology:** A total of sixty (60) artisanal gold miners who were apparently healthy were recruited in the study. Thirty (30) individuals who were not in any way exposed to lead were used as control subjects. The BLLs were assayed using Microwave Plasma Atomic Emission Spectroscopy (MP- AES-Agilent 4210 USA). The biochemical indices for liver and kidney function were determined by standard methods. **Results:** The mean BLLs of the miners were higher than the recommended level (38.30±2.40µg/dL). The serum activity of alanine aminotransferase (ALT), aspartate aminotransferase (AST) and alkaline phosphatase (ALP) in miners increase significantly ($p<0.05$) compared to control subjects. The findings also indicated significant ($p<0.05$) increase in the serum levels of total protein and albumin in exposed miners compared to controls ($p<0.05$). However, there were no significant ($p>0.05$) changes in the serum levels of total and direct bilirubin, urea, creatinine and electrolytes of miners compared to controls. **Conclusion:** It is therefore, the study demonstrated that occupational exposure to lead is a potential risk for elevated BLLs, liver and kidney dysfunction.

KEYWORDS: Occupational Exposure, Miners, Blood Lead Levels, Liver Function.

1.0 INTRODUCTION

Mining activities are substantially contributing to the world growing economy. Tenth of thousands tons of metal ores are extracted annually for utilization in industries. However, these mining operations are considered most harmful occupations associated with many health implications not only to miners but to the entire ecosystem.[1,2] The emission of heavy metals by mining activities pollutes air, water and soil, hence, inflicting adverse health effects on humans, animals and environment.[3, 4]

Lead poisoning is described as an elevated blood lead levels (BLLs) (considered greater than 5µg/dl set by US CDC) have been observed in both occupational workers and general population. Lead poisoning has become an issue of public health importance worldwide due to grave health implications.[5,6] Moreover, in developing countries like Nigeria, the menace continued to worsen by confounding factors like negligence from relevant authorities, less awareness, persistent illegal mining activities and poor environmentally friendly practices. Occupational exposure to lead has been observed in some parts of Nigeria but less recognized even among medical practitioners.[2,7]

Inhalation of polluted air and dermal contact via dust are the main route of absorption of inorganic lead in occupational settings while oral absorption remained common to general population. Once ingested, it get absorbed into blood stream, distributed and accumulated in various organs of the body especially liver, kidney, male gonads and bones.[8,9]

Chronic exposure to lead has been linked to liver, kidney, hematological and reproductive dysfunction. Moreover, evidence has indicated that lead toxicity and its complications may even occur at lower levels and hence there is no defined safe threshold for lead.

Wealth evidence demonstrated that most lead is stored largely in the liver and kidney. Therefore, chronic lead poisoning can result in pathological changes in these vital organs. Animal models have revealed significant association between hepatotoxicity and blood lead levels.[10] Moreover, studies have shown that electrolyte (ions of body fluids) imbalance could serve as a biomarker of environmental pollution and useful in identifying target organs of toxicity. Lots of studies have been conducted on evaluating the effects of heavy metals on electrolytes in animals and hence, electrolyte imbalance has been implicated in cardiac arrhythmias.[11]

Lead like other heavy metals exert its deleterious effect mostly via generation of reactive oxygen species (ROS) such as $O^{\cdot}_2$, H_2O_2 and $^{\cdot}O_2$ thereby causing oxidative cellular and tissue damage to the liver and a decrease in the number and volume of renal glomeruli.[10,12] Hepatocellular damage is well examined by some clinical markers such as Alanine aminotransferase (ALT), Aspartate aminotransferase (AST) and Alkaline phosphatase (ALP). Serum activity of these enzymes is mostly considered a reflection of the physiological state of the liver.[13]

The association between metal toxicity and liver and kidney functions parameters has been reported in literature with contradictions. Therefore, the study attempts to evaluate the influence of environmental lead exposure on liver and kidney functions parameter in artisan gold miners of Zamfara State Nigeria.

2.0 MATERIALS AND METHODS

2.1 Study Area and Subjects

The study was conducted in Mayanchi, Kadauri and Daki Takwas located at the coordinates (N $12^0$21´.127´ E00616. 075, N12034´. 515´ E6633^{0}0. 749´ and N$12^0$09´. 553´ E006^{0}00. 004´ respectively) of Maru and Anka Local Government Areas of Zamfara State where mining activities have been in the area persistently for decades. A total of sixty (60) apparently healthy miners (all males and age range 15 -45 years) who must have spent at least five years on the job were recruited for the study. The control comprised thirty (30) apparently healthy individuals that were matched for age, sex and with no history of exposure to heavy metals, to any substance or medication known to influence the variables of the study were purposively selected for the study. All the subjects were duly informed about the purpose, benefits and potential health risk of exposure to heavy metals. The consent was obtained from the study population and the food and dietary intake of all the subjects were normal. Demographics and occupational data were obtained through questionnaire.

2.2 Sample Collection

A blood sample (10 mL) was collected by venipuncture under aseptic condition; five milliliters (5mL) were transferred into heparinized tubes from each participant and centrifuged at 5000 rpm for five minutes. The serum obtained was used for the assay of liver and kidney function parameters. Blood lead, cadmium, chromium, copper, zinc and aluminum were determined by Microwave Plasma Atomic Emission Spectroscopy (MP-AES-Agilent 4210 USA).

Serum total protein levels were determined using Biuret method, albumin using the dye-binding method (BCG) and total and direct bilirubin by the Evelyn and Malloy's method all described by.[14] The determination of serum alkaline phosphatase (ALP) activity was done by modified King and Armstrong method described by.[15] The activities of Aspartate transaminase (AST) and alanine transaminase (ALT) were measured using commercial kit and according to manufacturer's instruction (Randox laboratories Ltd) described by.[16]

2.3 Statistical Analysis

Results were expressed as the Mean ± standard error of mean (SEM). Data for test subject and control were analyzed by Students t-test. Parameters were analyzed statistically by one way analysis of variance, using statistical software Instat 3 version (San Diego, USA) and Tukey Kramer multiple comparison tests was used to establish the significance of the observed difference among various groups. Differences were considered significant when $p<0.05$. Pearson's correlation was carried out to investigate degree of relationship between blood lead, cadmium, chromium, copper, zinc and aluminum levels of the exposed subjects.

3.0 RESULTS

The demographics and duration of exposure of the study populations is presented in Table 1. The mean age of study population was 22.77±6.95 and 58.3% of the exposed miners were within the age range of 16 – 30years. Majority (80%) had been on the job for more than five (5) years and 83.3% had formal education. Forty percent (40) were smokers. The study sampled a total of sixty (60) individuals miners from twelve (10) gold ore mining sites of Mayanchi, Kadauri and Daki Takwas villages (Table 2).

The miners mean blood lead level was 38.30±2.40µg/dL, cadmium 0.41±0.02µg/dL, chromium 2.05±0.13µg/dL, copper 76.46±3.91µg/dL, zinc 35.34±1.23µg/dL and aluminum 21.28±3.58µg/dL (Figure 1). Among the occupationally exposed groups, miners within the 31-45 age bracket had the highest blood lead concentration and significant ($p<0.05$) variation was observed across the age groups. Significantly ($p<0.05$) high blood aluminum concentration was observed in 16-30 age group compared to other groups. However, no significant ($p>0.05$) change was observed in blood cadmium, chromium and zinc levels of all the age groups.

Table 3 showed that the serum activity of liver enzymes (ALT, ALT and ALP) in miners were significantly ($p<0.05$) high compared to control. However, the serum activity of these enzymes were not significantly ($p>0.05$)

change among the miners' age groups. The serum concentration of total protein, albumin, total and direct bilirubin in miners were significantly ($p<0.05$) altered compared to control. No significant ($p>0.05$) changed was observed in total protein, albumin, total and direct bilirubin in miners age groups (Table 4).

Correlation between liver enzymes function parameters and blood heavy metals concentration is presented in Table 5. Significantly ($p<0.05$) high positive association between blood cadmium level and serum activity of ALT was observed in the exposed miners. Similarly, significantly ($p<0.05$) high positive association between blood zinc level and serum direct bilirubin concentration was observed. Significant ($p<0.05$) negative association was observed between blood copper concentration and serum activity of ALT in the exposed miners.

The comparison of kidney function parameters between exposed miners and control is indicated in Table 6. The kidney function parameters were compared between the exposed miners and apparently healthy control. A non-significant ($p>0.05$) increase in serum urea, creatinine and electrolyte concentrations in miners was observed compared to control.

Table1. Demographics.

Variables		Percentage (%)
Sex	Male	100
	Female	0
Age	5-15	20
	16-30	58.3
	31-45	21.7
Duration of Exposure	≤5	20
	>5	80
Level of Education	Primary	21.7
	Secondary	48.3
	Tertiary	13.3
	None	16.7
Smoking	Smokers	40
	Nonsmokers	60

Table 2: Number of Study Subjects Sampled in Various Mining Sites.

Village	No. of mining sites	No.of subjects sampled	Percentage (%)
Mayanchi	5	30	50
Kadauri	2	12	20
Daki Takwas	3	18	30

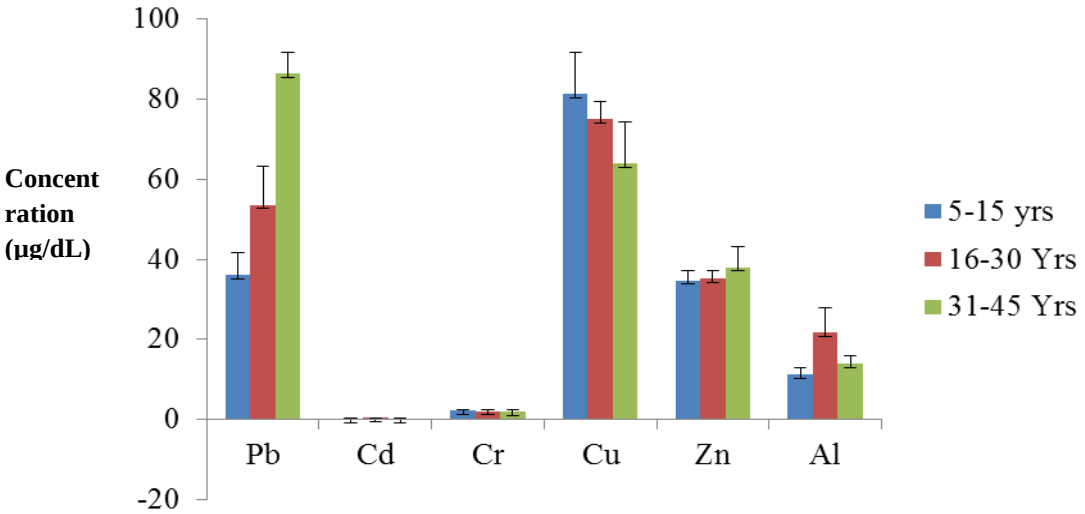

Figure 1: Mean Blood Pb, Cd, Cr, Cu, Zn, and Al Concentrations of Miners in Age Groups.

Table 3: Liver Function Parameters in Miners and Control.

Study subjects	TP (g/dl)	Alb(g/dl)	TB (µmol/L)	DB (µmol/L)	AST(U/L)	ALT(U/L)	ALP(U/L)
Miners	5.64±0.17[a]	1.84±0.14[a]	2.46±0.37[a]	0.64±0.13[a]	58.75±1.65[a]	40.37±2.73[a]	138.76±2.69[a]
Control	8.09±0.27[b]	5.23±0.05[b]	1.40±0.14[b]	0.37±0.01[b]	22.73±3.54[b]	15.76±0.81[b]	68.07±0.95[b]

Values are in mean ± SEM; within the column, mean with different superscript letters are statistically significant ($p<0.05$). Key: **TP**: Total Protein; **Alb**: Albumin; **TB**: Total Bilirubin; **DB**: Direct bilirubin; **AST**: Aspartate aminotransferase; **ALT:** Alanine aminotransferase; **ALP**: Alkaline phosphatase.

Table 4. Effect of Age on Liver Function Parameters in Miners.

Age Range	TP (g/dl)	Alb(g/dl)	TB (µmol/L)	DB (µmol/L)	AST(U/L)	ALT(U/L)	ALP(U/L)
5-15	6.40±0.39[a]	1.78±0.03[a]	1.15±0.18[a]	0.64±0.13[a]	67.12±7.32[a]	36.46±7.44[a]	134.96±3.86[a]
16-30	5.41±0.13[a]	1.96±0.12[a]	2.43±.063[ab]	0.56±0.04[a]	58.66±1.67[a]	41.46±3.27[a]	139.87±3.53[a]
31-45	5.08±0.10[a]	1.78±0.07[a]	3.80±0.71[a]	0.50±0.08[a]	54.20±3.25[a]	46.4±2.07[a]	142.78±5.43[a]
Control	8.09±0.27[b]	5.23±0.13[b]	1.40±0.14[c]	0.37±0.01[b]	22.73±3.54[b]	15.76±0.81[b]	68.07±0.95[b]

Values are in mean ± SEM; within column, means with different superscript letter alphabets are statistically significant ($p<0.05$). Key: **TP**: Total Protein; **Alb**: Albumin; **TB**: Total Bilirubin; **DB**: Direct bilirubin; **AST**: Aspartate aminotransferase; **ALT:** Alanine aminotransferase; **ALP**: Alkaline phosphatase.

Table 5. Correlation between Liver Function Parameters and Blood Heavy Metals Levels.

Parameter		Pb	Cd	Cr	Cu	Zn	Al
TP	R	0.05547	-0.1335	-0.0528	-.01346	-0.09317	-0.03072
	p-Value	0.7373	0.4178	0.7494	0.4138	0.5727	0.8527
Alb	R	-0.01300	0.21900	0.03082	-0.13740	-0.03838	0.00080
	p-Value	0.4365	0.1804	0.8522	0.4041	0.8166	0.9614
TB	R	-0.03647	0.02958	-0.04513	0.05362	0.63675	0.00405
	p-Value	0.8255	0.8581	0.7850	0.7456	0.8242	0.9805
DB	R	0.03803	-0.2152	-0.10720	-0.09622	0.34050	-0.00980
	p-Value	0.7257	0.1883	0.5159	0.5601	0.0390[a]	0.9528
AST	R	0.00055	0.04033	-0.21990	0.00853	-0.16290	0.07210
	p-Value	0.9973	0.8074	0.1786	0.9589	0.3218	0.6627
ALT	R	0.06560	0.38770	0.08940	-0.49390	0.12180	0.11310
	p-Value	0.6916	0.0147[a]	0.5883	0.0014[b]	0.4367	0.4930
ALP	R	-0.06954	-0.21700	0.12910	0.04892	-0.18400	-0.03358
	p-Value	0.6740	0.1837	0.4333	0.7674	0.2621	0.8392

[a] Correlation coefficient positive and significant: $p< 0.05$

[b] Correlation coefficient negative and significant: $p< 0.001$). Key: **TP**: Total Protein; **Alb**: Albumin; **TB**: Total Bilirubin; **DB**: Direct bilirubin; **AST**: Aspartate aminotransferase; **ALT:** Alanine aminotransferase; **ALP**: Alkaline phosphatase.

Table 6: Comparison of Kidney Function Parameters between Miners and Control.

Parameter	Miners			Control			
	Mean	SD	Median[IQR]	Mean	SD	Median[IQR]	p-Value
Ur(mg/dl)	5.47	1.26	5.20 [2.9-7.9]	3.01	0.79	3.10 [2.1-5.8]	0.2006
Cr(mg/dl)	0.96	0.30	0.90 [0.5-1.7]	0.62	0.15	0.60 [0.3-0.9]	0.8951
Na^+(mMol/L)	106.85	22.73	105.00 [61.0-186.0]	90.22	9.89	92.00 [61.0-104.0]	0.6760
K^+(mMol/L)	4.86	0.60	5.00 [3.2-6.1]	4.56	0.96	4.50 [3.6-9.0]	0.5993
Cl^- (mMol/L)	75.23	17.73	74.00 [37.0-111.0]	67.12	14.30	66.00 [37.0-96.0]	0.1898

Ur: Urea, **Cr**: Creatinine, **SD**: Standard deviation

4.0 DISCUSSION

Mining of gold ore involves a number of processes that includes the extraction, crushing, grinding, washing and amalgamation with mercury to obtained fairly gold concentrate. These processes caused the emission of heavy metals-containing dust into the environment. The dust is inhaled and deposited onto water bodies and agricultural lands. Occupational exposure to heavy metals has become a serious threat to public health

worldwide.[6] Heavy metals are known to cause numerous health implications. Therefore, the exposed miners stand a high risk of having liver, kidney and other degenerative diseases.[12] The present study evaluated the liver and kidney function parameters among gold ore miners in two Local Government Areas of Zamfara State, Nigeria.

The study observed that majority of the miners was young adults within the age range of 16 – 30years which is considered a defined age range for a working population. The results of this study revealed that the miners had mean blood lead level (BLL) far greater than the Biological exposure index (BEI) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) (20µg/dl).[17] This indicates that the miners were significantly exposed to lead and its deleterious effects.[18] The elevated blood lead levels could be attributed to inhaled dust and on clothes, shoes; skin and hair which become ingested by the miners due to poor control measures and non-use of personal protective equipment.[19]

The activity of serum AST, ALT and ALP was significantly ($p<0.05$) increase in gold ore miners compared to control subjects. Heavy metals such as lead, chromium and aluminum induce oxidative stress via generation of reactive oxygen species (ROS). This will invariably cause membrane lipid peroxidation and alter membrane integrity and fatty acid composition with consequent increase in malondialdehyde (MDA) level in the liver.[20] Liver cell injury is accompanied by the release of enzymes (AST and ALT) from damaged hepatocytes.[6] Lead accumulates in soft tissue such as liver and cause peroxidative damage to liver cell membranes and with eventual increase in activity of serum AST and ALT.[19] ALP catalyzes the hydrolysis of various phosphomonoesters at an alkaline pH. The enzyme is usually found in the walls of biliary ducts. Therefore, an increase activity in serum may indicate hepatobiliary or hepatocellular injuries. Liver dysfunction may impact on transport function of biliary ducts which may result to increase activity of serum ALP.[21] Therefore, serum activity of these enzymes is considered as a reflection of the morphological and functional state of the liver. These findings corroborates with the work of[22] who reported increased activity of serum AST, ALT and ALP in occupationally exposed mechanics and panel beaters in Benin City Nigeria. Similarly,[10] reported significant ($p<0.05$) increase in hepatic enzymes of lead exposed workers in the South Khorasan Province, Iran.

The study also observed positive correlation between blood lead levels and the hepatic enzymes though not significant ($p>0.05$). This brings the possibility that the miners may develop long-term liver injury upon persistent exposure to lead.[10] Reported similar association in lead exposed workers in the South Khorasan Province, Iran.

A significant ($p<0.05$) decrease in serum total protein and albumin was observed in exposed miners compared to control subjects. The assessment of serum total protein and albumin is very crucial, simple and cheap way of determining the synthetic functionality of the liver.[23] Increase in blood lead levels, was found to decrease the synthesis of protein and albumin.[21,24] Animal studies demonstrated that chronic exposure to lead inhibits globulin synthesis in bone marrow, hence, serum protein and albumin levels are useful parameters for assessment of liver injury due to occupational exposure.[25] Our findings corroborates with that of[19] who conducted an occupational cohort study in the lead mine complex in Iran from 2018 to 2020. However, the finding is in contrast to the results reported by.[6, 22]

Total and direct bilirubin levels were found to increase significantly ($p<0.05$) in exposed miners compared to control subjects, though within the normal range. This may indicated that the ability of the liver to conjugate bilirubin is still intact. Non-significant ($p>0.05$) positive correlation between blood lead levels and total and direct bilirubin was observed in the exposed miners compared to control.

The findings of this study indicate that there was no significant ($p>0.05$) increase in serum urea, creatinine and electrolyte concentration in the exposed miners compared to control. However, studies had shown that there is strong relationship between exposure to heavy metals and kidney dysfunction.[26] Chronic exposure to lead has been reported to induce renal disease. The renal effects of lead are due to its deposition in the renal proximal tubules.[27] Exposure to low levels of lead can cause renal interstitial fibrosis due to consequential accumulation of ROS and increase prevalence of chronic kidney disease (CKD).[10]

Non-significant ($p>0.05$) increase in serum electrolytes was observed in the miners compared to control. Elevation in serum electrolyte may not be important to human because can induce hypernatremia and hyperkalemia.[11,28] observed significant increase in plasma electrolyte in Common Carp (*Caprinus carpio*) after short tern exposure to sublethel concentration of lead. Exposure to heavy metals has been reported to induce significant imbalance in plasma electrolyte in mice.

5.0 CONCLUSION

Elevated blood lead levels were recorded in the miners which is far above the CDC threshold value (5µg/dl) and therefore it could lead to many health implication associated with lead exposure. The study revealed increase serum activity of hepatic enzymes (AST, ALT and ALP), serum total and direct bilirubin, urea, creatinine and alteration in electrolytes. Decrease in serum total protein and albumin was observed among the miners. The study therefore, reveal that mining activities Zamfara State, Nigeria are associated with the risk of

exposure to lead toxicity, liver dysfunction and alterations of in markers of kidney injury.

Declaration of Competing Interest

The authors declared no known competing interests or personal relationships that could have appeared to influence the work reported in this paper.

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