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ORIGINAL ARTICLE

Hepatotoxicity in Both Occupationally and Environmentally-Exposed Inhabitants of a Lead-Zinc Mining Community

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Abstract

Background: Uncontrolled and unregulated mining of heavy metals causes easy release and littering of the products in the immediate environment, predisposing the inhabitants of the mining community to organ damage by the heavy metals. This cross-sectional study was done to examine whether such a practice causes liver damage to both miners and non-miners, living in the same environment or not.
Methods: Liver function parameters – Aspartate transaminase, Alanine transaminase, Alkaline phosphatase, Total bilirubin, Total proteins, and Albumin were evaluated to determine the degree of toxicity (if any) and loss of detoxification and synthetic functions of the liver.
Results: The results showed that all the evaluated liver function parameters from the occupationally-exposed subjects were significantly higher ($p<0.05$) than those from environmentally-exposed and control subjects except albumin. Likewise, all the parameters from environmentally-exposed subjects were significantly higher ($p<0.05$) than those from control subjects except albumin.
Conclusion: The results imply that both occupationally and environmentally-exposed subjects were susceptible to hepatotoxicity by the heavy metals, though at different rates of manifestation. This calls for concerted efforts by governments at all levels to enact and promulgate laws to control mining activities, not only to increase their revenue generation but most importantly to safeguard the lives of the inhabitants of the mining communities.

Keywords: Heavy metals; Hepatotoxicity; Mining communities

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INTRODUCTION

Artisanal mining is the major mining procedure in many developing countries. This uncontrolled and unregulated procedure causes easy release of by-products of mining activities – heavy metals, into the environment. These heavy metals are known to be highly toxic to the body (Tong et al, 2000; Papanikolaou et al, 2005). Unfortunately, the paltry financial returns coming to these miners do not allow them to ponder over the possible health hazard such activities bring upon them and those living within the mining areas. Generally, many mining activities involve the extraction of heavy metals, which considerably pollute the environments given their presence in earth crust, air, water, and food, especially in mining areas (Milan et al, 2015). Incidentally, these heavy metals are known to accumulate over a long period of time and are also non-degradable (Dioka et al, 2004; Tilako et al, 2020a). This long term accumulation, non-degradability, and the fact that they can damage living things even at low concentration makes the onset of resulting disease almost asymptomatic until the full blown condition appears (Tilako et al, 2020b). Thus, the organ damage is rarely noticed on time until it becomes very difficult to recover from it.

Among the heavy metals encountered during mining include Arsenic (As), Cadmium (Cd), Chromium (Cr), Lead (Pb), and Mercury (Hg). Because of their high degree of toxicity and persistence in the environment, these metals are commonly considered as priority heavy metals that are of public health importance (Tchounwou et al, 2012; He et al, 2013). Naturally, the distribution of these heavy metals is influenced by the activities of organisms (including human), climate, topography, and time (Joseph et al, 2017). The human activities include industrial, agricultural, pharmaceutical, and domestic effluents (He et al, 2005; Tilako et al, 2019).

The liver is commonly regarded as the power house of the body where most biotransformation occurs. It is the major site of biochemical and toxicological metabolisms including

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synthesis of many important compounds like proteins, detoxification of toxic substances like drugs, excretion of compounds like bilirubin and storage of compounds like glycogen. Damage to this organ slows down metabolic processes in the body and seriously affects the individual's life processes. In both acute and chronic conditions, the cellular components of the liver, especially the enzymes are released into blood circulation. This makes the activities of these enzymes as biomarkers of hepatic damage. Thus, the analysis of the activities of these enzymes serves as diagnostic tool to assess the health condition of the liver. Also, the estimation of serum proteins offers opportunity to assess the synthetic functions of the liver, while the level of total bilirubin is an indicator of its conjugation or detoxification function. The hepatotoxicity of heavy metals, particularly lead, has been described earlier (Dioka et al, 2004; Ogbonna et al, 2019). Apart from the limited number of priority heavy metals involved in these studies, they have failed to address the faiths of those living in the mining environment, who were not involved in the mining activities – the environmentally-exposed subjects. Moreover, the earlier assessment of the ethno-medicinal herbs preparations from the context of this study suggests that there is a possibility of heavy metal toxicity of the inhabitants (Shu et al, 2019). It also implies that both occupationally and environmentally-exposed subjects can be affected by these heavy metals. Furthermore, previous studies found reasonable concentrations of these heavy metals in the soil, water, and foods from this area and its surroundings (Eze and Chukwu, 2011; Oti and Nwabue, 2013; Okogbue and Ukpai, 2013). This is further supported by the observation of inappropriate storage of the mined products in these artisanal miners' homes and littering of heaps of the mining tails everywhere in the community (Tilako et al, 2019). These cause the susceptibility of both occupationally and environmentally-exposed inhabitants to the toxic effects of the heavy metals. The effects of the heavy metals on both classes of exposed subjects have been reported in prior studies (Tilako et al, 2020a,b). We extend this study to assess the hepatotoxic effects of the heavy metals on both occupationally and environmentally-exposed subjects. This will help to sensitize and encourage governments at all levels to put appropriate legislations to enforce proper disposal/storage mechanisms for the mining products and the use of protective equipment to safeguard the lives of the inhabitants of the mining communities.

METHODS

Area of Study: The study area is Enyigba lead-zinc mining community in Abakaliki, Ebonyi State, Southeast Nigeria. It is the largest and most active mining site in Ebonyi State, Nigeria. The position, climate, activities, and staple foods of the Abakaliki mining area and its inhabitants have already been described in the literature (Tilako et al, 2020b). The Abakaliki lead-zinc is believed to be of hydrothermal origins emplaced at a temperature of about 140^{o}C (Oti and Nwabue, 2013). The region includes Abakaliki town (the state capital of Ebonyi State) and the highly mineralized rural community (Enyigba), which is about 14 km south of the metropolis. The control subjects for the study were from Ezzamgbo community, which is about 25km from the study area. The Ezzamgbo community has no history of mining activities and no known discovery of lead-zinc deposits in the community at the time of this study.

Subjects: Subjects for the study included 89 artisanal mine workers (occupationally-exposed), 61 non-mine workers but living in the community (environmentally-exposed), and 65 subjects living about 25km away from the mining community, who have never been involved in any heavy metal mining activity prior to the study (controls), giving a total of 215 subjects. The age of the subjects ranged from 10 to 60 years old.

Laboratory Analyses: Four millimeter (4.0ml) of venous blood was collected from the ante-cubital vein of each subject into a clean and dry test tube. This was stood at room temperature and allowed to clot and retract. The blood was then spun in a centrifuge at 5000rpm for five minutes. The resulting serum was separated into a separation tube and stored frozen at -20^{o}C until needed for analysis. The analysis was done in batches of 15 to 20 samples each to reduce undue pressure on both the analyst and the equipment. COBAS c111 automated chemistry analyzer (Roche Diagnostics Ltd, Switzerland) was used to analyze liver function parameters – the serum activities of the liver enzymes (aspartate aminotransferase - AST, alanine aminotransferase- ALT, and alkaline phosphatase – ALP) and serum concentrations of total bilirubin, total protein and albumin. COBAS c111 is a closed system, and for proficient testing all reagents used were the products of the same company. The procedures and precautions for the analyses, as specified by the producers, were strictly adhered to for optimum results.

Data Analyses: All data from this study were analyzed using Statistical Package for Social Sciences (SPSS). Results were calculated with their standard deviations (SDs), while one-way ANOVA was used to calculate the differences with age. In all, statistical significance was taken at $p<0.05$.

RESULTS

Table 1 shows the mean values (±SD) of liver function parameters of the study sample. All the parameters (AST, ALT, ALP, TBil, TProt, and Alb) from occupationally-exposed individuals were significantly higher [$p<0.001$ for each, except Alb ($p<0.05$)] when compared with their mean values from the controls. Likewise, there were significant increases in the AST ($p<0.01$), ALT ($p<0.01$), ALP ($p<0.05$) and TProt ($p<0.001$) from environmentally-exposed individuals when compared with the mean values from the controls, while albumin had significantly lower mean value ($p<0.001$) than the value from the controls. Also, the mean values of these parameters from occupationally-exposed individuals were significantly higher ($p<0.05$) when compared with the mean values from environmentally-exposed individuals, except AST and ALP.

Table 2 shows the mean values (±SD) of liver function parameters across age groups of the sample. One-way ANOVA reveals statistically significant differences in mean values of alkaline phosphatase across age groups of occupationally and environmentally-exposed individuals ($F= 7.54$, $p=0.000$; $F= 9.88$, $p=0.000$ respectively), while other parameters showed no significant difference ($p>0.05$).

Table 1. Mean values (±SD) of liver function parameters of the study population

Parameters	Occup. Exposed n=89 Mean (SD)	Environ. Exposed n=61 Mean (SD)	Control n=65 Mean (SD)
AST (U/L)	39.82 (21.65)***	31.56 (40.10)**	21.80 (3.85)
ALT (U/L)	[a]29.29 (10.90)***	16.10 (11.47)**	11.31 (2.90)
ALP (U/L)	102.41 (59.58)***	86.88 (68.51)*	64.36 (8.20)
TBil (µmol/l)	[a]12.13 (6.26)***	8.73 (6.37)	7.85 (3.31)
TProt (g/l)	[a]85.44 (10.20)***	78.77 (9.14)***	71.09 (4.56)
Alb (g/l)	[a]39.77 (7.08)*	35.21 (2.88)***	37.83 (3.85)

Occup/Environ vs controls: *p<0.05, **p<0.01, ***p<0.001; Occup. vs Environ: [a]p<0.05
AST=Aspartate aminotransferase, ALT= Alanine aminotransferase, ALP= Alkaline phosphatase, TBil= Total bilirubin, TProt= Total protein, Alb= Albumin

Table 2. Mean values (±SD) of liver function parameters of the study population according to age groups.

Parameter	Group	10-20 yrs	21-30 yrs	31-40 yrs	41-50 yrs	51-60 yrs	ANOVA F(P-value)
AST	Occup	34.89(8.29)	38.53(12.27)	40.82(34.98)	57.74(36.91)	42.90(19.00)	0.91(0.47)
	Envir	30.73(16.72)	25.62(4.92)	23.84(10.82)	41.93(74.18)	26.95(13.84)	0.29(0.93)
	Contr	18.78(3.01)	21.55(4.23)	23.17(3.68)	23.51(4.10)	19.10(0.14)	1.91(0.09)
ALT	Occu	27.92(7.99)	30.29(11.38)	28.34(13.87)	36.56(6.14)	30.92(10.39)	0.88(0.50)
	Envir	23.60(26.38)	17.72(5.79)	13.63(7.30)	16.91(14.78)	14.21(8.07)	0.42(0.86)
	Contr	10.74(4.06)	10.81(2.51)	12.16(2.76)	11.82(3.00)	10.55(1.34)	1.01(0.43)
ALP	Occup	152.03(92.75)	84.18(26.46)	74.36(19.54)	99.88(36.76)	74.77(14.14)	7.54(0.000)
	Enviro	213.27(208.07)	61.80(20.01)	56.16(18.06)	59.76(22.01)	68.90(14.61)	9.88(0.000)
	Contr	63.33(7.25)	65.21(6.14)	64.61(8.11)	63.57(12.60)	74.65(4.87)	1.82(0.11)
TBil	Occu	10.79(5.45)	13.73(8.36)	11.17(4.79)	15.66(5.81)	11.55(3.96)	1.06(0.39)
	Envir	8.53(1.88)	8.30(3.46)	6.13(3.56)	9.67(5.45)	9.17(7.03)	0.93(0.48)
	Contr	7.98(4.08)	7.89(3.64)	8.04(3.14)	7.72(2.84)	6.80(1.13)	0.19(0.98)
TProt	Occu	86.09(11.27)	86.92(9.22)	83.77(11.16)	87.20(11.23)	84.12(8.77)	0.45(0.80)
	Envir	76.00(9.53)	82.75(12.81)	75.08(7.70)	78.77(8.72)	78.81(10.43)	0.95(0.47)
	Contr	71.00(3.46)	71.77(5.48)	70.47(3.64)	69.85(4.98)	66.00(1.41)	1.03(0.41)
Alb	Occu	40.09(5.77)	40.53(5.24)	37.40(9.63)	41.80(9.17)	41.62(7.67)	0.76(0.58)
	Envir	33.00(1.73)	35.00(2.16)	34.91(2.02)	36.06(2.87)	34.72(2.37)	1.44(0.22)
	Contr	37.33(3.87)	37.95(2.95)	37.05(4.32)	36.28(3.63)	38.00(7.07)	1.62(0.16)

Table 3 shows liver function parameters of the subjects according to gender. The mean values of all the parameters (AST, ALT, ALP, Total bilirubin and Total protein) from the occupationally-exposed males were significantly higher ($p<0.001$ for each) when compared with the mean values from the corresponding male controls, except Albumin ($p>0.05$). Likewise, the mean values of these parameters, including Albumin, from the occupationally-exposed females were significantly higher ($p<0.001$; $p<0.001$; $p<0.01$; $p<0.01$; $p<0.001$ and $p<0.05$ respectively) when compared with the mean values from the corresponding female controls. In the environmentally-exposed, the mean values of ALT, ALP, and Total protein from males were significantly higher ($p<0.01$; $p<0.01$ and $p<0.001$ respectively) when compared with their mean values from the male controls, albumin had significantly lower ($p<0.05$) value than the controls while AST and Total bilirubin showed no significant differences ($p>0.05$). In the female environmentally-exposed subjects, AST, ALT and Total protein were significantly higher ($p<0.05$; $p<0.05$ and $p<0.001$ respectively) than the values from their corresponding controls, the mean albumin value was significantly lower ($p<0.01$), while ALP and Total bilirubin showed no significant differences ($p>0.05$).

Figure 1 shows the correlation between blood levels of lead and liver function parameters of the study sample. There were significant positive correlations between blood levels of

lead and each of the parameters – AST (r = 0.193, p<0.01), ALT (r = 0.474, p<0.001), ALP (r = 0.261, p<0.001), total bilirubin (r = 0.270, p<0.001), total protein (r = 0.507, p<0.001), except albumin (r = 0.108, p>0.05).

Table 3. Mean values (±SD) of liver function parameters of the study population according to gender

Parameter	Occupation-Exposed n=89		Environment-Exposed n=61		Control n= 65	
	Male n= 50	Female n= 39	Male n= 23	Female n=38	Male n=35	Female n=30
AST	44.53(27.47)[c]	33.48(6.59)[c]	44.33(63.35)	23.84(9.06)[a]	23.58(3.37)	20.15(3.61)
ALT	31.56(12.99)[c]	26.21(6.46)[c]	19.59(14.67)[b]	14.32(8.69)[a]	12.36(2.39)	10.48(2.99)
ALP	120.02(69.89)[c]	79.58(31.86)[b]	105.77(63.11)[b]	75.01(68.98	65.02(7.53)	63.57(9.14)
TBil	13.18(7.02)[b]	10.62(4.85)[b]	11.45(8.57)	7.23(3.86)	8.82(3.17)	7.05(3.24)
TProt	83.80(10.17)[c]	87.42(10.06)[c]	78.25(9.84)[c]	79.47(8.94)[c]	71.28(3.68)	70.93(5.49)
Alb	38.84(7.31)	40.86(6.71)[a]	35.29(3.93)[a]	35.42(2.53)[b]	37.84(3.85)	37.74(4.02)

Occup/Environ vs controls: [a]p<0.05, [b]p<0.01, [c]p<0.001

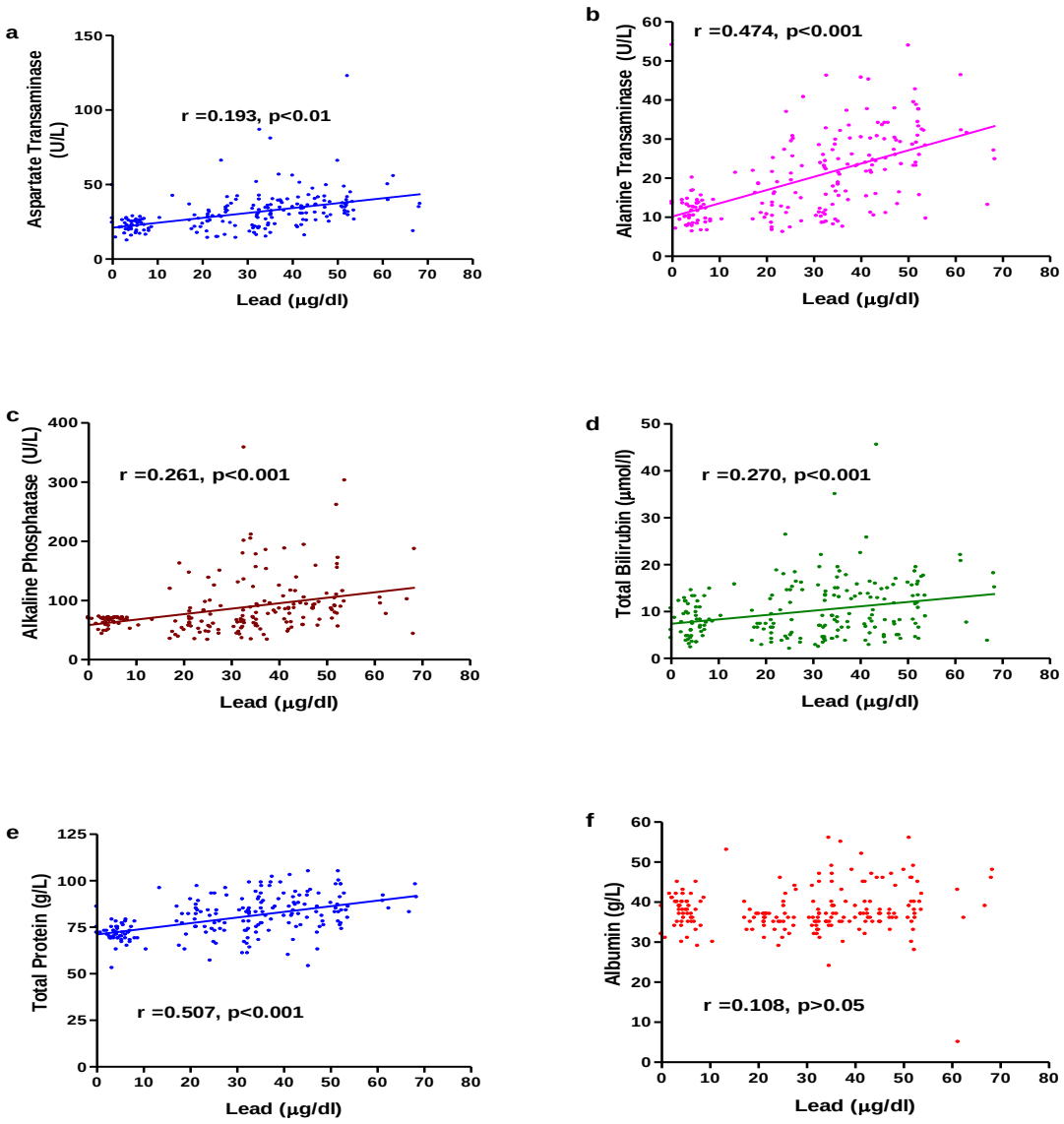

Figure 1. Correlation between blood lead levels and liver function parameters of the study population.

Figure 2 shows the correlation between blood levels of arsenic and liver function parameters of the study population. The result showed that there were significant positive correlations between blood levels of arsenic and the parameters - AST (r = 0.214, p<0.01), ALT (r = 0.396, p<0.001), ALP (r = 0.162, p<0.05), Total bilirubin (r = 0.174, p<0.05), total protein (r = 0.310, p<0.001), but not with albumin (r = 0.026, p>0.05).

Figure 3 represents a correlation between blood levels of mercury and liver function parameters of the study population. There were no significant correlations between mercury and AST (r = 0.119, p>0.05), ALP (r = 0.037, p>0.05), Total bilirubin (r = 0.129, p>0.05) and Albumin (r = 0.039, p>0.05), except ALT (r = 0.236, p<0.001) and Total protein (r = 0.151, p<0.05) which showed significant positive correlation.

Figure 4 presents a correlation between blood levels of cadmium and liver function parameters of the study population. There were significant positive correlations between blood levels of cadmium and ALT (r = 0.222, p<0.05) and Total protein (r = 0.166, p<0.05) and showed no significant correlation with AST (r = 0.127, p>0.05), ALP (r = 0.111, p>0.05), Total bilirubin (r = 0.071, p>0.05) and Albumin (r = 0.099, p>0.05).

Figure 5 presents a correlation between blood levels of chromium and liver function parameters of the study

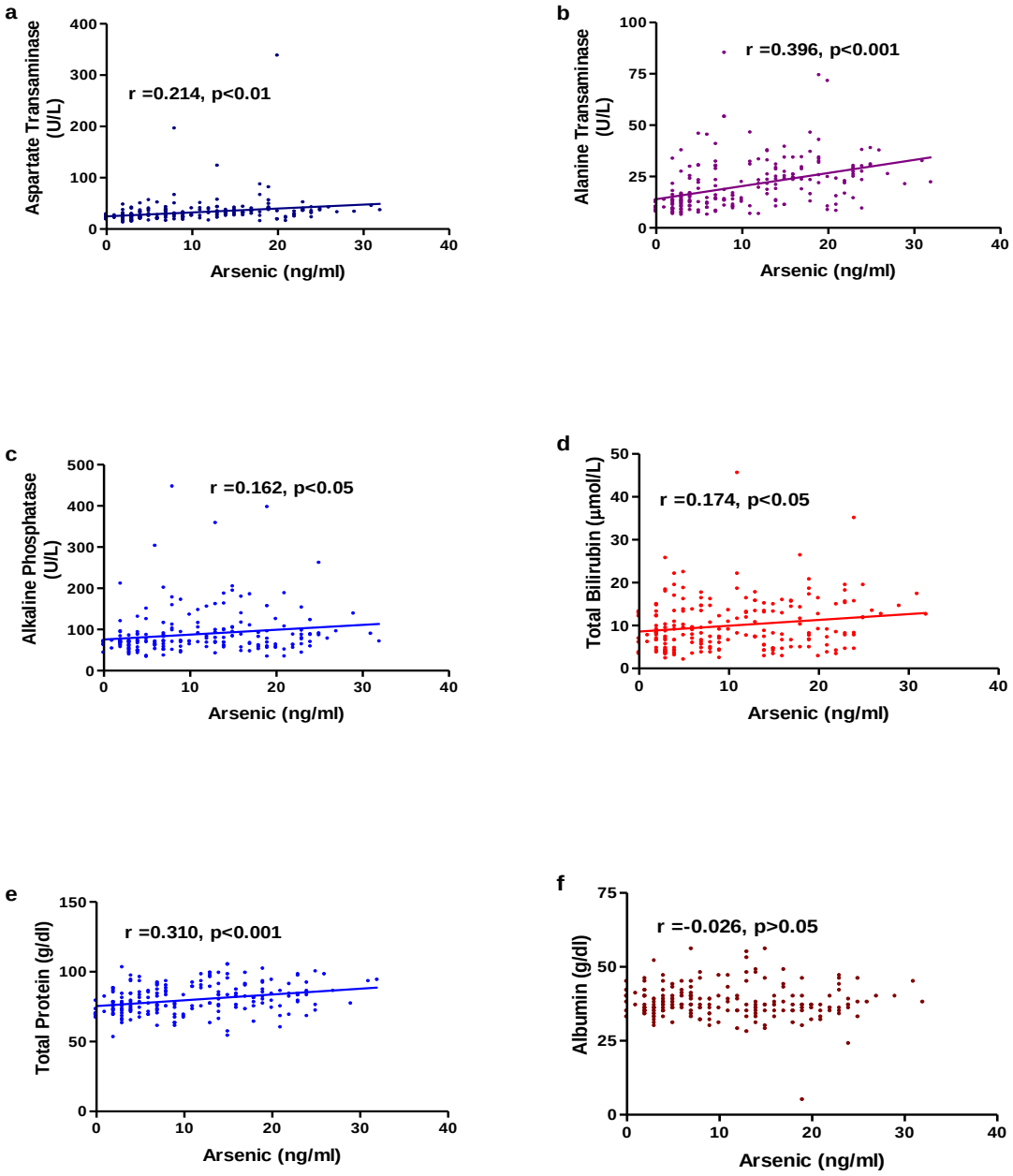

Figure 2. Correlation between blood levels of arsenic and liver function parameters of the study population.

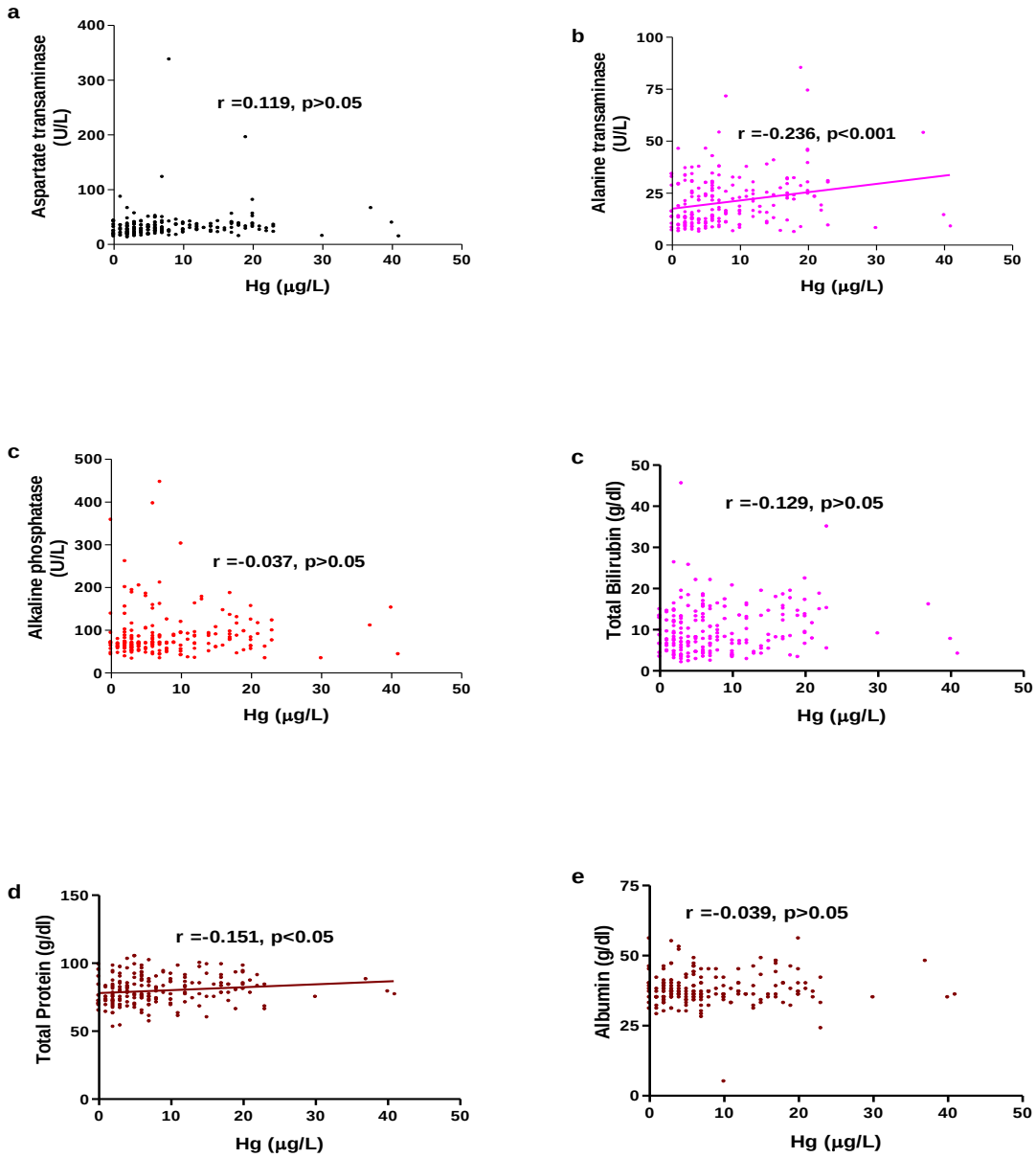

Figure 3. Correlation between blood levels of mercury and liver function parameters of the study population.

population. There were significant positive correlations between blood levels of chromium and ALT (r = 0.252, p<0.001) and Total protein (r = 0.156, p<0.05) but showed no significant correlation with AST (r = 0.109, p>0.05), ALP (r = 0.030, p>0.05), total bilirubin (r = 0.053, p>0.05) and Albumin (r = 0.084, p>0.05).

DISCUSSION

The results of this study revealed that the occupationally-exposed subjects have significantly increased the values of liver function parameters when compared with the environmentally-exposed and control subjects. These findings are in agreement with previous studies conducted in this domain (Wachukwu *et al.,* 2001; Shalan *et al.,* 2005; Khan *et al.,* 2008; Chukwu and Evelyn, 2016) focusing on the effects of lead and other heavy metals on the functions of the liver. The changes include indicators of hepatocellular damage – the liver enzymes, detoxification and conjugation functions – total bilirubin and synthetic functions – serum proteins. The activities of liver enzymes are indicators of the integrity of the liver (Chukwu and Evelyn, 2016). Increased activities are usually associated with hepatocellular damage, hence the values obtained from this study imply that the miners are susceptible to liver damage – hepatotoxicity. Particularly, increased activities of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) in blood had been used as indicators of altered permeability of plasma membrane, high liver microsomal membrane fluidity, free radical generation, alteration in the liver tissue histogram, cellular damage and altered metabolism during lead toxicity

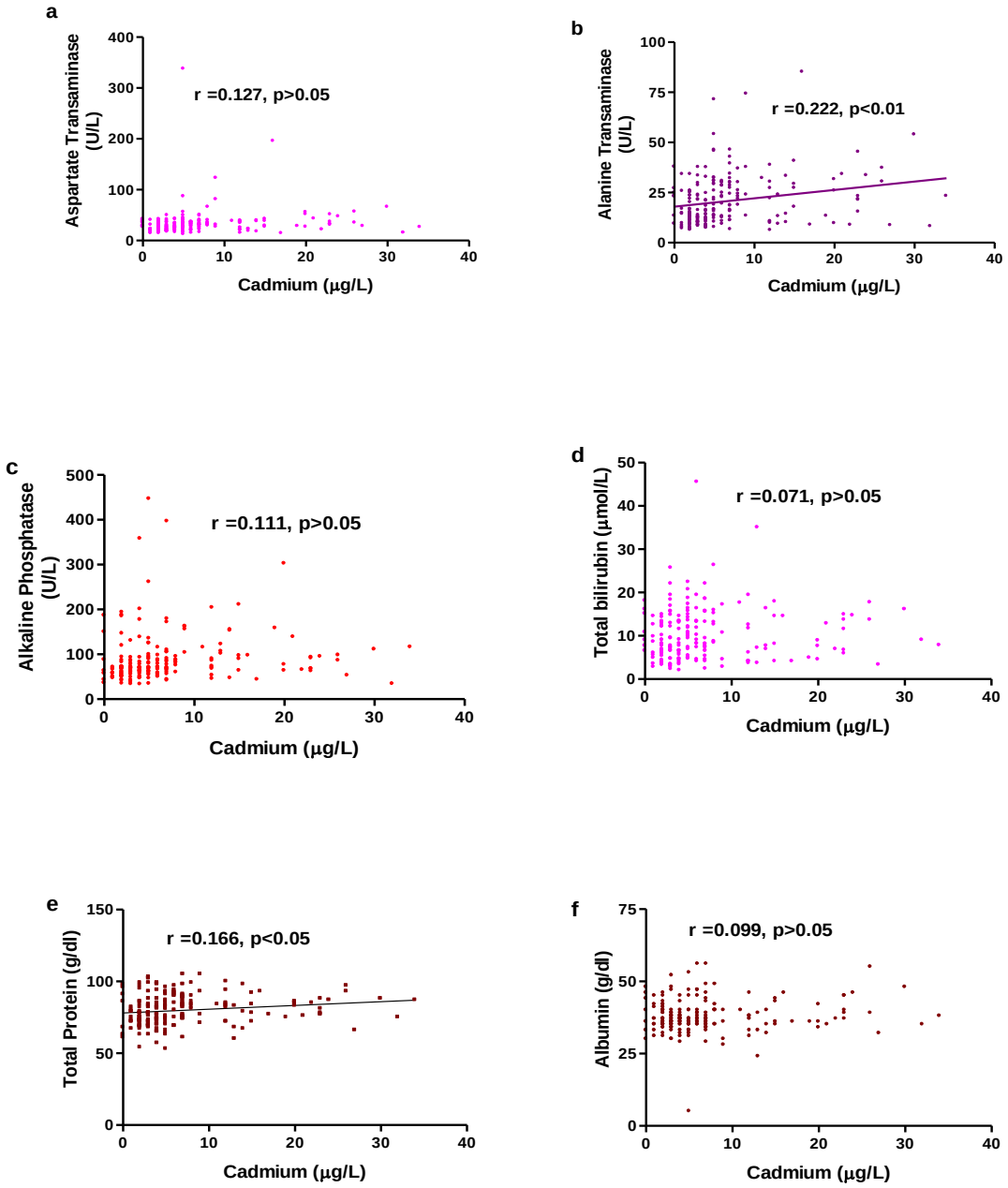

Figure 4. Correlation between blood levels of cadmium and liver function parameters of the study population.

(Upasani and Balaraman, 2001; Seddik *et al.,* 2010). Though, increased activity of alkaline phosphatase is an indicator of obstructive liver disease, in addition to other disease conditions, it also indicates an increased permeability, damage and/or necrosis of liver cells. Hence, in this case, damage or necrosis of the liver cells occur by the heavy metals. The elevation in serum total bilirubin level is probably an indication of the failure of the conjugation functions of the liver. Bilirubin is conjugated with glucuronide in the smooth endoplasmic reticulum of the liver, but under pathological condition, the conjugation function will derail, leading to increased unconjugated bilirubin. The failure of conjugation function may be due to the peroxidation of membrane lipids of the smooth endoplasmic reticulum (Nabil *et al.,* 2012). Moreover, lead, and probably other priority heavy metals, is known to induce hemolysis by increasing the fragility of the red cell membrane and reducing the survival time of the erythrocytes. Therefore, priority heavy metals can cause increased serum total bilirubin in exposed subjects by two mechanisms – peroxidation of the membrane lipids and induction of hemolysis. The results of this study also showed that total protein is significantly increased in occupationally-exposed subjects when compared with both environmentally-exposed and control subjects. However, the albumin levels were in reverse direction, level in occupationally-exposed was

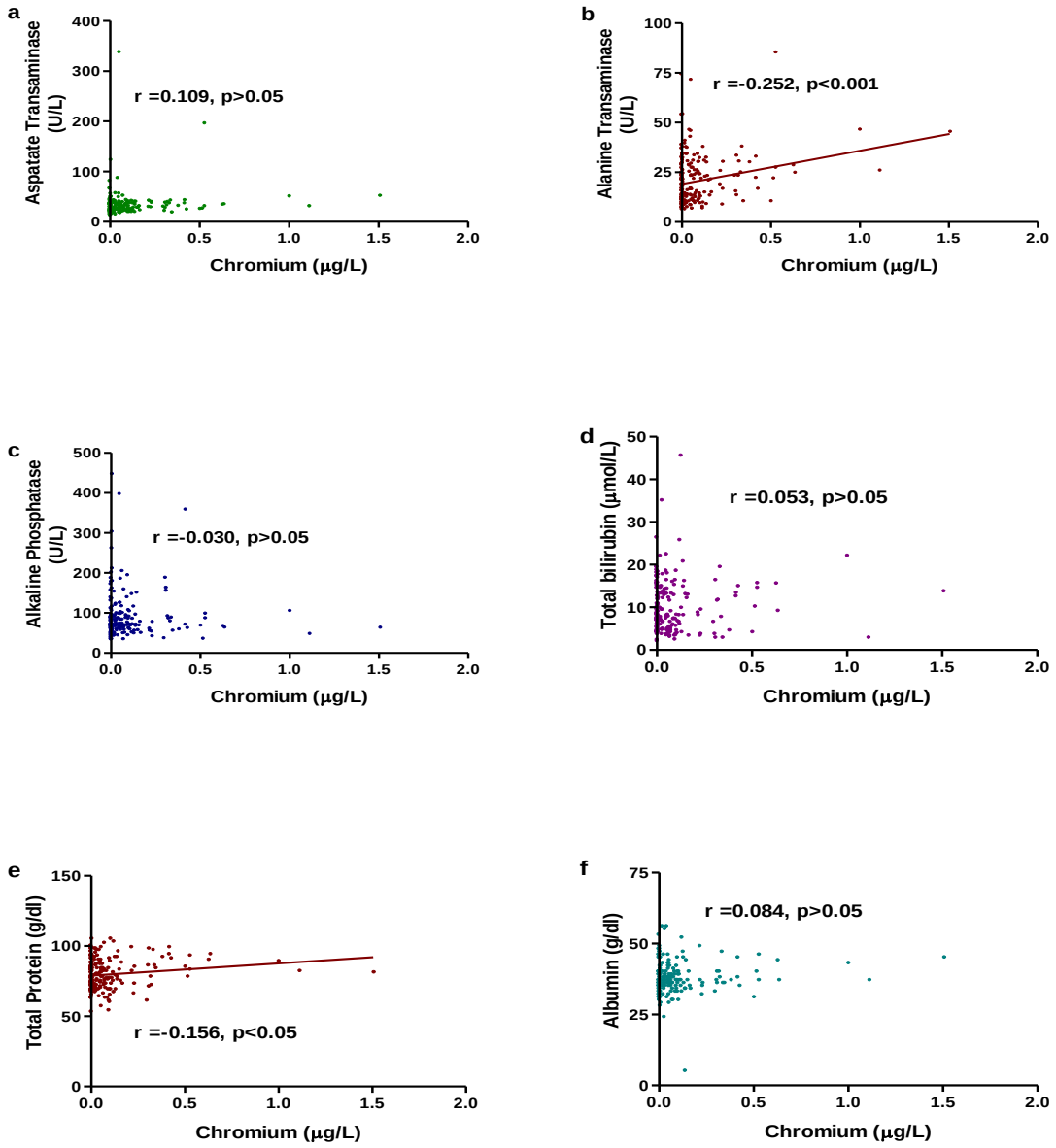

Figure 5. Correlation between blood levels of chromium and liver function parameters of the study population.

significantly lower than that from environmentally-exposed or control subjects. Albumin is exclusively produced by the hepatocytes – the liver cells (Dana, 2021); therefore, lower value in occupationally-exposed subjects is a further indication of reduced functional capacity of the liver. The increase in the value of the total protein in occupationally-exposed subjects even with lower albumin level may be connected to a possible increase in globulin level. Firstly, injury to the hepatocytes caused by heavy metals can activate nuclear regulatory factors leading to the absorption of inflammatory cytokines like IL-8 and IL-6 (Ogbodo et al, 2013), as well as other immune factors. Also up-regulation of liver function, in response to the actions of heavy metal, can cause increased production of immunoglobulin G (Lei et al, 2014). Therefore, though the actions of the heavy metals on the liver may slow down the production of α- and β-globulins, the need for immune response to the prevailing condition will activate full functions of lymphocytes and plasma cells in lymphoid tissue to produce more γ-globulins. The increase in these immunoglobulin and other regulatory factors can cause increase in total protein.

The mechanism of heavy metals-induced liver injury is thought to be via increased oxidative stress and also reduction in activity of cytochrome P^{450} (CYP450) – a major part of drug metabolism (Won-Joon *et al.,* 2013). Vaziri *et al.* (2003) demonstrated that lead is associated with mild up-regulation of superoxide-generating enzymes, while other studies (Brzoska and Jakoniuk, 2001; Farmand *et al.* 2005; Ogbodo et al, 2013) found that lead and other priority heavy metals induce reactive oxygen species, which deplete antioxidants and destabilize cell membranes by attacking the fatty acids of the cell membrane. Furthermore, previous studies (Tilako et

al, 2020b) showed negative correlation between the serum concentrations of priority heavy metals and antioxidant micronutrients – substances that abate oxidative stress. These studies therefore point to the same conclusion – that heavy metals induce hepatotoxicity by increasing oxidative stress. Hence, it has previously been posited that heavy metal-induced liver disease can be prevented from becoming irreversible by removal of heavy metal exposure if detected at an early stage (Cotrim *et al.,* 1999).

Furthermore, the analysis conducted on the age of the subjects revealed gradual but non-significant increase in the levels of the liver function parameters as age increased except alkaline phosphatase, which showed significant decrease in levels across age groups. Though, there is a dearth of information on the age-related changes in these parameters from occupationally and environmentally-exposed subjects, the adverse effects associated with these heavy metals exposure may be dependent on mining duration. Since these heavy metals are known to accumulate over a long period of time and are also non-degradable (Dioka et al, 2004; Tilako et al, 2020a), adults who have spent more time in the mining activities will be more prone to liver damage. The decrease in the activity of alkaline phosphatase across age groups may be related to age-dependent physiological variations in alkaline phosphatase levels. Younger children are known to have higher alkaline phosphatase levels due to increased bone turn over as they grow (Serap *et al.,* 2011). It may also be related to the decrease in zinc levels in exposed subjects. Zinc, a micronutrient antioxidant that functions as a catalytic and structural component of zinc-containing enzymes (Dioka *et al.,* 2004), is known to decrease significantly in subjects exposed to priority heavy metals (Tilako et al, 2020b).

This study also showed that changes in serum liver function parameters are more pronounced in males than the females in both occupationally-exposed and environmentally-exposed subjects with the hepatic enzymes and total bilirubin, the main indicators of hepatotoxicity, while total protein and albumin levels were lower in males than in females. While higher hepatotoxicity in males may be related to frequency of work (men go out for manual jobs more frequently than women), the cause for the differences in total proteins and albumin may not be well understood. However, it may have to do with more frequent exposure that leads to increased oxidative stress, reduced liver function and low excretion of hormones that regulate protein biosynthesis (Nabil *et al.,* 2012).

This study also revealed positive correlation between priority heavy metals and biomarkers of hepatotoxicity, though this correlation varied with individual metals. For instance, while the more aggressive/toxic metals – lead and arsenic, correlated with all the parameters except albumin, others correlated with only alanine aminotransferase and total protein. While this finding agrees with the results of Lee *et al.* (2006) and Lynda *et al.* (2011), it disagrees with those of Chukwu and Evelyn (2016), who did not find any significant correlation between blood lead level and liver function parameters. The disagreement among these studies may be due to differences in frequency and duration of exposure of the subjects, and the heavy metals contents of the soil and food in the different study areas. The positive correlation seen in this study is not only an indication of hepatocellular toxicity by these priority heavy metals but also an indication that these metals have different degree of toxicity.

This study also demonstrated that even environmentally-exposed subjects have significantly higher liver function parameters than the control subjects. The implication is that not only occupationally-exposed subjects are prone to hepatotoxicity but also environmentally-exposed. Though the changes in these parameters are more pronounced in the miners, it will only take longer periods for the non-miners living in the community to start developing and experiencing liver pathology. This has previously been reported in nephrotoxicity of the heavy metals (Tilako et al, 2020a). With these findings, and the fact that heaps of mining tails were seen littering these communities (Tilako et al, 2019), both miners and their family members are dangerously predisposed to developing both kidney and liver pathologies if nothing is done to arrest the situation. It has also been demonstrated that even ethno-medicinal preparations from these mining areas contain substantial amounts of the heavy metals (Shu et al, 2019). Unfortunately too, priority heavy metals have been found to be endocrine disruptors (Iavicoli et al, 2009). For instance, lead exposure was found to decrease spermatogenesis in rat (Shubina and Dudenkova, 2016), cadmium and lead were found to cause endocrine disruption in fish (Paschoalini et al, 2019) and mercury exposure has been reported to cause hormonal problems in both men and women, interfering with the production and action of hormones, causing polycystic ovarian disorder, ovulation impairment and therefore infertility (Nicholson, 2021). Almost all heavy metals are serious toxicants as carcinogens (Kim et al, 2015), though the mechanisms of their actions are not yet well elucidated because they are sophisticated and complex in nature (Chen et al, 2019). If all these are true, then the genetic make-ups of the inhabitants of the mining communities (especially those born and bred there) are in danger, possibly experiencing fertility problems and may be DNA mutations. Most mining activities in the country are in the hands of artisanal miners uncontrolled and unregulated. This practice does not only cause loss of revenue to the government, but most importantly endanger the lives of the inhabitants of these mining communities. It is therefore very necessary that governments at all levels come together to enact and promulgate laws to control mining activities, not only to curb illegal mining and increase revenue generation but also to safeguard the future of their people.

LIMITATION

Despite efforts made in explaining the importance of the study, many miners, especially the teenagers among them, refused to participate in the study. Miners older than 60 years were also encountered, but they all refused to participate. This reduced the number of participants, who previously agreed to take part in the study. Another limiting factor was lack of sponsorship, which made the authors to bear the high

cost of the materials used in the study.

CONCLUSION

This study found that priority heavy metals extracted from the research context of the study caused significant elevation of liver function parameters, implying that they can cause liver pathology, affecting all the functions of the liver. It also demonstrated that both miners and non-miners are susceptible to this condition. The uncontrolled and unregulated mining activities, with the littering of the products of mining around the households of the miners, are seen as the major cause of susceptibility of non-miners to the effects of the heavy metals. This calls for rigorous efforts by governments at all levels to enact and promulgate laws to control mining activities to increase their revenue generation and most importantly safeguard the lives of the inhabitants of the mining communities.

Conflict of Interest: The authors declare that there is no conflict of interest in this work.

Ethical Clearance: Approval for the study was sought and obtained from the Health Research Ethics Committee of the College of Medicine, University of Nigeria Teaching Hospital, Ituku-Ozalla, Enugu, Nigeria. Further ethical clearance was obtained from the State Ministry of Health, Abakaliki, Ebonyi State, Nigeria while the subjects gave their informed consents after thorough explanation of the importance and procedures for the study.

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