Original Research Article

CO-EXPOSURE TO LEAD AND MERCURY AMONG ARTISANAL GOLD MINERS

Abstract

Background: Illegal mining pitch and metal ores processing sites are frequently seen in many parts of Nigerian communities. Gold ore processing is widespread in communities of Zamfara State. These activities produce significant amount of dust that pollute the environment.

Aim: The study was conducted to determine the extent of exposure to lead and mercury in artisanal gold miners in Bagega and Kawaye districts and Yargalma village of Anka and Bukkuyum Local Government Areas respectively.

Method: Seventy gold ore miners were recruited from twelve different mining or processing sites of the affected villages. Serum lead determination was carried out using Atomic Absorption Spectrophotometer (AAS Perkin Elmer, 6300 model USA) and mercury was determined by cold vapor atomic absorption spectrometry (Spectra-10 variant).

Results: The blood lead and mercury levels of the exposed individuals ranged between 15 – 561.2µg/dl and 0.21 - 196µg/dl respectively. Majority (75.7%) had blood lead levels beyond 45µg/dl with average mean of 368.62±15.20 and mean blood mercury levels of 168.86±8.92 µg/dl. The blood lead and mercury levels were significantly ($p<0.05$) high in 16-30 age bracket compared to 0-15 and 31-45 age groups. Similarly, Individuals from Bagega village had significantly ($p<0.05$) high blood lead and mercury levels compared to Kawaye and Yargalma villages. The high blood lead and mercury levels recorded in this study are far above OSHA permissible limit and are therefore a call for concern.

Conclusion: The results indicate the co-exposure to ~~Pb~~ lead and ~~Hg~~ mercury in the artisanal gold miners. The individuals in age bracket 16-30 years are at high risk of synergistic adverse health

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effects of lead and mercury toxicities. The exposed individuals require urgent medical attention for proper intervention and possible total withdrawal from the work.

Key words: Gold mining, Exposure, Lead, Mercury, Synergistic effect

INTRODUCTION

Heavy metals are usually regarded as those metals with specific density greater than 5 g /cm^{-3} and adversely affect living organism and their environment [1]; [2]. These metals occur naturally in the earth's crust and their concentration varies from one environment to another [3]; [4]; [5]. The metals are released to the environment through natural and anthropogenic activities; these include weathering, erosion, mining, industrial, municipal discharge and indiscriminate use of pesticides [6]. Therefore, these metals are seen as environmental pollutants and their toxicities are becoming a serious burden afflicting humans, animals and quality of environments [7]; [8]; [9]. At very low concentration, some (Cr, Ni, Co, Cu, Se etc) play vital roles in certain biochemical reactions. Research had indicated that moderate or high exposure to these toxic metals is associated with a number of public health implications among which are: heamatological disorders, cardiovascular and- hepatotoxicities, renal and neuronal problems [10]; [11]

Illegal mining pitch and metal ores processing sites are frequently seen in many parts of Nigerian communities [12]. This must not be unconnected with high price of gold in the world market. Many people from different communities had abandoned their usual activities in search for gold. The use of rudimentary tools, unsafe and unfriendly environmental methods employed predisposed tenth of thousands people into devastating conditions. Gold ore processing is widespread in communities of Zamfara State, Nigeria [13]. The activity involved a number of stages from breaking of the ore to grinding, separating, washing, drying and to melting process [13]. These activities produce significant amount of dust that pollute the environment. The dust from these activities contains some toxic substances such as lead, arsenic, mercury, zinc, copper, cadmium etc. Gold is extracted through the use of mercury amalgamation process and hence, the latter is introduced into the environment. Therefore, during routing activities, these toxic substances are inhaled, ingested and deposited to the nearby surroundings.

Serious epidemic lead poisoning was publically declared in many gold mining communities of Zamfara State and linked to the use of rudimentary tools, unsafe and poor environmental practices [14]; [15]. In 2010, the epidemic has caused the death of over 400 children and over 4000 were affected with various degrees of neurological disabilities. Since then, lots of studies have been conducted by different Governmental, Non Governmental Organisations (NGOs) and academia, on children (most vulnerable group) to investigate blood lead levels which remain a good marker for lead poisoning. Reports had indicated that 97% of children living in those contaminated mining villages had BLLs ≥45µg/dl [16], 99.5% had 71.0µg/dl [17] and [18], reported 11.1% prevalence among children (≤6 years) having BLLs ≥45µg/dl. Elevated blood lead level is associated with vast serious health implications which gastrointestinal discomfort, CNS dysfunction, anemia, hypertension and brain damage. Therefore lead poisoning is a serious burden that requires urgent attention due to its high prevalence, morbidity and mortality.

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In lieu of the above, tenths of hundreds of affected children were treated; villages were remediated and kept under surveillance. Educational campaigns that discourages manual gold ore processing activities, unsafe and poor environmentally practices were conducted. However, active gold ore mining activities remain on the increase in many communities of Zamfara State [13] hence; the miners might in many ways be exposed to toxic metals associated with these processes unnoticed. Therefore, the present study aimed to assess the degree of lead exposure and possible co-exposure to other toxic metals among gold ore miners in three villages of Anka local government area of Zamfara State.

Methods

Study area

The study was conducted in different gold ore processing sites of Bagega and Kawaye villages located at the coordinates (005^0 39.749′ E, 11^0 51. 858′ N and 006^0 01. 754′ E, 11^0 48. 719 N) of Anka Local Government Area and Yargalma village located at the coordinates (005^0 30.897′E, $11^0$58.108′N) of Bukkuyum Local Government Area of Zamfara State Northwestern Nigeria.

Sampling: From 16^{th} June to 23^{rd} October 2016, one hundred and fourteen blood samples (5ml each) from active artisanal gold miners of different age groups, duration of exposure and educational status were collected (Table 1). An informed consents was obtained from each participant of the study. The potential benefits and risk involved (if any) were fully explained to the study subjects. A questionnaire was designed to capture sources of exposure and level of environmental risk awareness concerning heavy metal poisoning. Information gathered included demographics (such as sex, age and geographical location), method used for gold extraction and their source of drinking water. Identified coordinates for each village were taken using Global Positioning System (GPS). Active mining activities and presence of grinding machines for ore rocks were observed in all the sites.

Serum Lead Determination

Serum lead determination was carried out using Atomic Absorption Spectrophotometer (AAS Perkin Elmer, 6300 model USA). Wet digestion was carried out on the serum samples, 1.0 ml of blood was transferred into test tube and 2.0 ml concentrated Nitric acid (HNO_3) was added slowly and heated at 130 $^{\circ}C$ until yellow fumes disappear. The test tube was allowed to cool, made to 5 ml with deionized water and stored until analyses.

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Serum Mercury Determination

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Mercury (Hg) was determined by cold vapor atomic absorption spectrometry (Spectra-10 variant). The method provides the opportunity of measuring total Hg concentration through an overnight mineralization of blood sample by potassium permanganate ($KMnO_4$) in acidic solution at 25 $^{\circ}C$. Hydroxylamine chloride solution is usually added to reduce excess oxidants and vaporized Hg is achieved by simultaneous addition of stannous (II) chloride which reacts with Hg (II) from digested sample. The vaporized Hg is then measured at the absorption wavelength of 253.7 nm.

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Data Analysis

Results were expressed as the Mean ± SEM. Differences were considered significant when $p<0.05$. Parameters were analyzed statistically by one way analysis of variance, using statistical software Instat 3 version (San Diego, USA). Pearson's correlation was carried out to investigate degree of relation between blood lead and mercury levels of the exposed subjects.

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Results

Over the four-month period, a total of 114 gold ore miners were recruited from mining and processing sites. The participants were subjected to blood lead and mercury test and 70 were eventually found with an elevated blood lead and/or mercury levels far above the CDC limit (5µg/dl). The demographics and other related indices about the study subjects were presented in Table 1. Ninety four per cent of the miners were males within the age range of 16-30 (48%) which is considered a defined age range for a working population. Majority (61.4%) had primary education and gold ore mining has been their source of livelihood for almost ten years ago. All the participants acknowledged the risk associated with the mining procedure and method employed. Wells, boreholes and streams were sources of drinking water in all the communities under study.

Table 1: Demographics and other Variables

Variables		**Percentage distribution (%)**
Sex	Males	91.4
	Female	8.6
Age	0-15 years	15.7
	16-30 years	48.6
	31-45 years	35.7
Level of Education	Primary	61.4
	Secondary	27.1
	Tertiary	2.9
	None	8.6
Occupation	Artisanal Mining	80
	Farming	20
Duration of Exposure	≤ 10 years	61.4
	>10 years	38.6

Risk Awareness		
	Campaigns	24
	Radio programs	22
	Family member	18
	Friends	20
	Family & friends	16
Source of Water		
	Well	33
	Borehole	26
	Streams	27
	Others	14

Route of exposure to lead poisoning based on the respondents' knowledge is depicted in Figure 1. Inhalation and ingestion were the two major route of exposure identified followed by inhalation/ingestion. Some respondents attributed lead poisoning to either hunger or God.

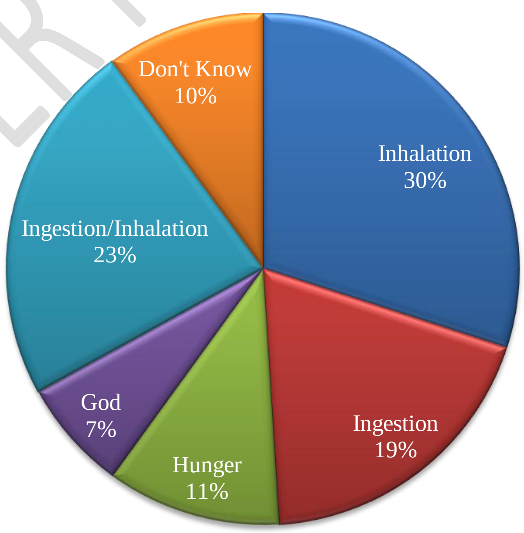

Figure 1: Route of Exposure to Lead Poisoning According to Respondent's Knowledge

The study sampled a total of 114 individuals from twelve (12) gold ore mining/processing sites of Bagega, Kawaye and Yargalma villages. Fifty five per cent of the subjects recruited in all the villages were exposed to both lead and mercury while fifteen per cent were exposed to lead only as shown in Table 2.

Table 2: Number of Individuals Sampled in Various Gold Mining Sites

Village	No. of mining/ processing sites	No. of individuals sampled	No. of Exposed to Pb and Hg	No. of Exposed to Pb
Bagega	**3**	**30**	**15 (50.0%)**	**3 (10.0%)**
Kawaye	**5**	**58**	**30 (51.7%)**	**7 (12.1%)**
Yargalma	**4**	**26**	**10 (38.5%)**	**5 (19.2%)**
Total	**12**	**114**	**55 (48.2%)**	**15 (10.4%)**

Fifty three out of seventy exposed individuals had blood lead levels far greater than 45μg/dl and none has blood lead level less than 10μg/dl (Table 3). The blood mercury levels of the exposed individuals were found to dominate within the range of 5- 45μg/dl.

Table 3: Number of exposed individuals with different blood Pb and Hg concentrations

Range	Lead	Mercury
≥ 5 and < 10 μg/dl	**0**	**33**
≥10 and < 25 μg/dl	**8**	**0**
≥25 and < 45μg/dl	**9**	**0**
≥45μg/dl and above	**53**	**22**

The blood lead and mercury levels of the exposed individuals with respect to age group were presented in Table 4. Blood lead concentration was found high in all the individual's age groups and the means differed significantly ($p<0.05$) high across the groups. The blood mercury levels were relatively low in 0-15 age group but extremely high in other age groups. The mean blood mercury levels were significantly ($p<0.05$) high across the groups.

Table 4: Blood lead and mercury levels of exposed individuals in various age groups

Age (years)	Interval conc. of Pb (µg/dl)	Mean conc. of Pb (µg/dl)	Interval conc. of Hg (µg/dl)	Mean conc. of Hg (µg/dl)
0-15	15.92 - 317.71	115.78 ± 13.06*	0.0 - 0.41	0.21 ± 0.01*
16-30	40.20 - 516.21	412.02 ± 16.13	0.1- 618.86	196.24 ± 11.09
31-45	27.40 - 487.43	368.62 ± 15.20	0.1- 673.50	168.86 ± 8.92

Values are mean ± SE. Values bearing superscripts on the same column differ significantly ($p<0.05$) when compared by Tukey-Kramer multiple comparison test.

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Please, add OSHA permissible level for each metal.

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Among the villages analyzed, miners working in Bagega mining/processing sites had the highest blood lead and mercury levels and was statistically significant ($p<0.05$) compared to Kawaye and Yargalma (Figure 2). Miners in Yargalma village had the lowest blood lead and mercury levels, though far beyond CDC limit. Relationship between age and metals concentration in their blood is depicted in Figure 3 and 4. Positive correlation was observed between age and blood lead and mercury levels with R^2 values of 0.0462 and 0.0497 respectively.

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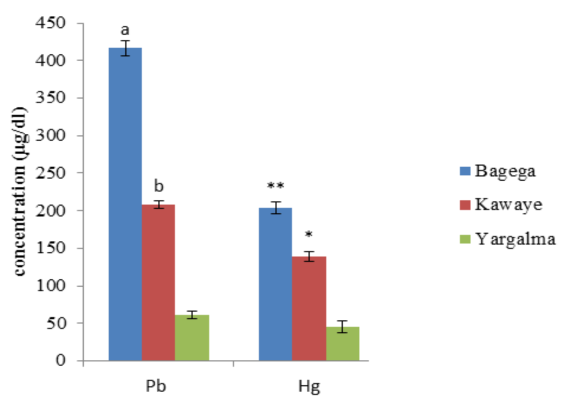

Figure 2: Mean Blood Lead and mercury levels of artisanal gold miners in Different Villages of Zamfara State Nigeria

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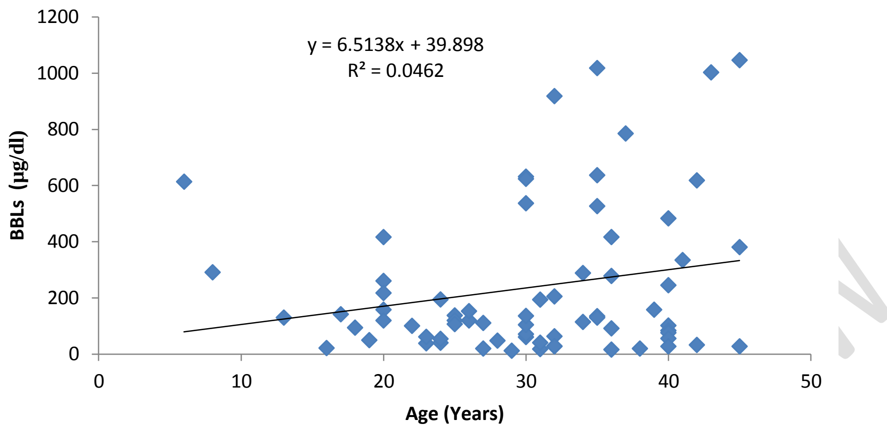

Figure 3: Correlation between Age and Blood Lead Concentration

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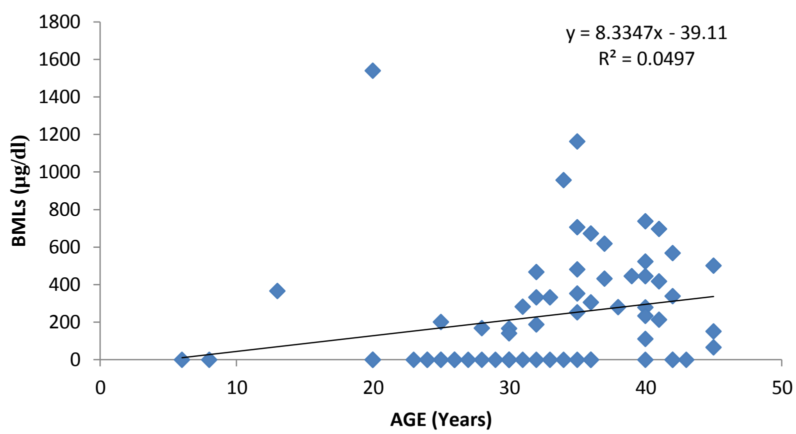

Figure 4: Correlation between Age and Blood Mercury Concentration

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Discussion

Occupational exposure to heavy metals is a serious threat to the worker, worker's family and the general public. Dust generated from mining and processing sites can be taken home on clothes, shoes; skin and hair become ingested by the worker and his/her entire family members. This has been responsible for the outbreak of lead poisoning that led to the death of several hundreds of children and leaving thousands requiring medical attention. The present study was a unique finding in exploring the degree of miners' exposure to the toxic metals in the affected areas. Seventy gold ore miners were recruited from twelve different mining/processing sites of the affected villages. The demographic data indicated that 94% of the miners were males within the age bracket of 16-30 years (Table 1). This is a typical age range required for working population set by fair labour standard act. The information gathered from the questionnaire administered showed that majority of the participants had primary education and were informed about the detrimental effects of exposure to toxic metals like lead and mercury. Indeed, the study observed that the miners were mainly exposed to the metals through ingestion and inhalation of the dust generated due to poor mining procedures and rudimentary tools used.

Blood analysis revealed that all the participants were exposed to lead significantly above 10µg/dl and majority (75.7%) had blood lead levels greater than 45µg/dl. This study recorded high blood lead levels in the artisanal miners compared to all the documented blood lead values among children in the area. Getso *et al.* [18] reported 11.1% in children, 31.0% [17] and 35% in construction workers [19]. Though, our finding reveals significantly lower values than 59.6µg/dl as reported by Orisakwe *et al.* [20] in paint factory workers Recast the highlighted sentence. Similarly, 43.1µg/dl and 42.0µg/dl were reported by Azami *et al*. [2] in Iranian workers and Dioka *et al*. [21] in artisans in the mechanic village Nnewi in Nigeria respectively. A joint committee by United Nation Environmental Protection and United nation Children's Fund (UNEP-UNICEF) documented that individuals with blood lead levels exceeding 45µg/dl should be given medical emergency within 48 hour [22].

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High blood lead levels recorded in the present study could be as result of the participation of the exposed individuals in all the mining processes, especially grinding that generate lots of lead dust. Fifty five percent had co-exposure to metal mercury and 40% had blood mercury levels greater than 45µg/dl. This is another toxic metal known to inflict serious public health problem. The study observed that the miners come in contact with mercury at the melting stage which is the final step of the gold extraction process.

Categorically, individuals in the 16-30 age group had high mean values (412.02±16.13 and 196.24±11.09) for both blood lead and mercury levels respectively. The blood lead and mercury levels were elevated significantly ($p<0.05$) as compared to other age groups. Thus, it is quite reasonable that there was high exposure in this group as they are the most active and stay at work for more than 12 hours/day/week in all the mining activities. Previous studies observed intense use of old rudimentary mining techniques in Bagega mining and processing sites. The main processing site was about 4 hectares capacity with more than 200 sluicing ponds [17]; [23]. Several crushing and grinding machines were busy and mining activities were fully conducted, and the atmospheric environment was highly dusty. The dust in the atmosphere are deposited in agricultural products and open water reservoir. People directly inhale the contaminated dust and consumes on contaminated agricultural products and water. The mean blood lead and mercury levels of exposed individuals from all the three villages in the study areas were beyond the occupational workers' level (≤40µg/dl) set by Occupational Safety and Health Administration [24]. Recently, research documents reported adverse effect to occupational adult workers even at concentration of less than 10µg/dl.

Individual miners working in Bagega mining and processing sites had the highest blood lead and mercury levels and was statistically significant ($p<0.05$) compared to Kawaye and Yargalma. Thus, the high blood lead and mercury observed could be attributed to the intensive mining activities, poor and unfriendly techniques employed by the miners.

Relationship between age and miners blood lead and mercury levels showed positive correlation with R^2 values of 0.0462 and 0.0492 obtained respectively. Thus, the relationship was not significant ($p>0.05$).

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Limitations

The information provided by the study does not fully describe the magnitude of blood lead and mercury among the teeming miners. This is due to refusals of some miners to provide blood for the research for personal reasons. Secondly, miners outside the identified mining and processing sites were not tested. The data obtained could represent an underestimate of the actual number of miners in the study area.

Notwithstanding, the data obtained in this study provide useful information on blood lead and mercury levels among miners in the areas.

Conclusion

The present study indicates that there is co-exposure to the two toxic metals in the artisanal gold miners, and the individuals in age bracket 16-30 years are at high risk of synergistic adverse health effects of lead and mercury toxicities. This points to the fact that the situation requires urgent attention.

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