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Original Research Article

Evaluation of some heavy metal levels in blood of lead acid battery manufacturing factory workers in Nnewi, Nigeria

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ABSTRACT

Today, industrialization has been implicated in the generation of certain compounds which are potentially hazardous to human life. This is a cross sectional study designed to evaluate some heavy metal levels in blood of lead acid battery manufacturing factory workers in Nnewi, Nigeria. A total of 39 apparently healthy individuals in lead acid battery manufacturing factory aged between 19 and 56 years and 79 control individuals (comprising of 39 control individuals from Nnewi (N) and 40 control individuals from Elele (E) respectively) aged between 18 and 44 years were recruited for the study. Demographic data and body mass index (BMI) of participants were obtained using structured questionnaire and thereafter, 5ml of venous blood sample was collected from each individual for the evaluation of heavy metal levels (Pb, Ni, Cu, Zn, As and Se) using atomic absorption spectroscopy (AAS). Results showed that the factory workers had an average length of service (LOS) of 7.70±0.86 years and BMI which did not differ significantly when compared with the control groups (control N and E individuals) respectively ($p>0.05$). However, elevated levels of Ni, As and Pb and decreased levels of Cu, Zn and Se were observed in the blood of the factory workers compared with control N and E individuals respectively ($p<0.05$). Therefore, this study has shown that these individuals may be prone to heavy metal toxicity and possible depletion on some vital micronutrients which may have grave health consequences for individuals dwelling in this area.

1. Introduction

Today, industrialization has been implicated in the generation of certain compounds which are potentially hazardous to human life particularly to individuals who work in such industries. Nnewi is one of such growing industrial towns in South Eastern Nigeria and it is the second largest city in Anambra State. Some of the notable factories found in this area include lead acid battery manufacturing factories, cable manufacturing factories, metal fabricating factories and metal forging factories among others. Importantly, these factories are often found located around or within residential areas, thus exposing humans to the hazardous effects of the resultant effluents emanating from the activities carried out in these factories. Interestingly, an important and major effluent produced from these factories especially lead acid battery manufacturing factories is 'heavy metals'. Heavy metals with adverse health effects in human metabolism present obvious concerns due to their persistence in the environment and documented potential for serious health

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consequences.[1]

The term “heavy metals” assumes a variety of different meanings throughout the different branches of science. Although “heavy metals” lacks a consistent definition in medical and scientific literature, the term is commonly used to describe the group of dense metals or their related compounds, usually associated with environmental pollution.[2] Elements fitting this description include lead, mercury and cadmium. The rather broad definition of heavy metals may also be applied to toxic metalloids like arsenic, as well as nutritionally-essential trace minerals with potential toxicities at elevated intake or exposure (e.g., iron, zinc, copper).[2,3] Heavy metals are those natural components of the earth’s crust that cannot be degraded or destroyed.[4] They have relatively high density and are toxic or poisonous even at low concentration.[5] Heavy metals are among the contaminants in the environment and they may become bio-accumulative. This bio-accumulation results when there is an increase in the concentration of a chemical in a biological system over time compared with the natural concentration of the chemical in the environment.[6] Combustion processes are the most important sources of heavy metal pollution particularly power generation, smelting, incineration and the internal combustion engine.[7] Beside the natural activities, almost all human activities also have potential contribution to produce heavy metals as side effects.[8,9] Some of the important routes of exposure to these heavy metals in humans include through food, air and water. Others are through industrial products[10] and occupational exposure.[11]

Exposure to some of these environmental pollutants such as Arsenic, zinc, lead, copper, nickel, chromium, cadmium, etc, have been linked to some common health problems such as chronic fatigue, aggressiveness, anxiety, anorexia, muscular and joint pains, constipation, insomnia and high blood pressure, heart and liver damage, and skin allergy, cancer, stroke and diabetes.[12–14]

Previously, some studies have reported high levels of heavy metals such as lead (Pb), nickel (Ni), arsenic (As) etc, in soils, rivers and plants surrounding these factories in Nnewi and this may suggest a possible threat to the living population.[7,11,15] Also, threatening levels of some of such metal pollutants have been detected in meat;[16] chickens[17,18] and vegetables[19,20] around these areas. Interestingly, a number of studies have shown that these metals may bio-accumulate and exert various deleterious effects on human health by affecting different organs of the human body including the kidney, liver, pancreas, brain, testes among others.[3,21–26] In Nnewi, most of the industries and factories consume materials which contain many of these heavy metals. Since evidence abounds that effluents of these factories have been found to contain appreciable quantities of these metals either in soil, plant or running water,[11,27] there is a strong indication that individuals who work in this factory would be accumulating them in their bodies, hence this study.

2. Materials and Methods

2.1. Study design and subjects

This is a cross-sectional study designed to evaluate some heavy metal levels in blood of lead acid battery manufacturing factory workers in Nnewi, Nigeria. A total of 39 apparently healthy individuals in the exposed group (lead acid battery manufacturing factory workers) aged between 19 and 56 years were recruited for the study. The exposed group comprised workers from lead acid battery manufacturing factories who were constantly being exposed to effluents from lead acid battery manufacturing factory. The control groups were made up of two (2) sets: The first set was made up of thirty-nine (39) staff and undergraduate students of the College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus whose residential homes were at least 5-10 km from the factory sites, while the second set was made up of forty (40) staff and undergraduate students of the Faculty of Medicine, Madonna University, Elele. They were aged between 18 and 44 years. Informed consent was obtained from all individuals after being educated on the benefit of the study and completing of a structured questionnaire. Thereafter, 10ml of venous blood sample was collected from each individual for the evaluation of heavy metal levels. Blood samples for the determination of lead (5ml) were delivered into new EDTA containers, mixed and stored frozen at -4^0C until analyzed. The rest of the blood sample was delivered into lithium heparin containers, stoppered and gradually mixed to prevent clotting. The blood samples were then centrifuged for 3 minutes at 2000 rpm. The plasma were separated and put into clean dry sample containers and stored deep-frozen at -4^0C until analyzed. The plasma was used for the estimation of heavy metals (Pb, Ni, Cu, Zn, As and Se) by atomic absorption spectroscopy (AAS) according to the method of Smith et al.[28] Determination of lead in whole blood was done using the method as described by Hessel.[29]

2.2. Inclusion criteria

Apparently healthy individuals aged between 19 and 56 years who are exposed to lead acid battery manufacturing factory effluents and control individual (non-exposed groups) were included in this study

2.3. Exclusion criteria

Individuals of any known kidney disease, liver disorder, alcoholics and smokers as well as those outside the age limits were excluded from the study.

2.4. *Ethical consideration*

Ethical approval for the research was obtained from Ethical Committee, Nnamdi Azikiwe University Teaching Hospital, Nnewi, Anambra State, Nigeria (NAUTH/CS/66/Vol.2/149).

2.5. *Statistical analysis*

The data were presented as mean±SEM and the mean values of the control and test group were compared by Students t-test and Pearson's bivariate correlation coefficient using Statistical package for social sciences (SPSS) (Version 16) software. A $P<0.05$ was considered as significant.

3. Results

Table 1 shows some demographic profiles of control individuals from Nnewi (control N) an industrial town and Elele (control E), a rural town and the workers of the lead acid battery manufacturing factory (V). These workers had an average length of service (LOS) of 7.70±0.86 years. The body mass index (BMI) of control N individuals (24.75±0.38) and E individuals (23.58±0.67) were not statistically different ($p>0.05$) from those of lead acid battery manufacturing factory workers (23.77±0.49).

The mean serum levels of Ni, Cu, Zn, As, Se and whole blood Pb of controls N and E individuals and factory workers are presented in Table 2. The levels of Cu, Zn, As, Se and Pb levels from control E individuals were higher and statistically different ($p<0.05$) from those of control N individuals, however, no significant difference ($p>0.05$) was observed for Ni. The regression of metal levels of control N and E subjects with BMI are presented in Figures 1 and 2, respectively. In control N, while the Ni, As and Pb levels were positively correlated, Cu, Zn and Se were negatively correlated with BMI, though non-significantly ($p>0.05$). In control E, Ni, Cu and Pb were positively correlated ($p<0.05$) with BMI, while Zn, As and Se were negatively correlated.

The Ni level of lead acid battery factory workers (3.20±0.06) were highly elevated and statistically different ($p<0.05$) when compared to control N individuals (0.04±0.00) and control E individuals (0.07±0.00). The Cu level in the lead acid battery factory (9.67±0.09) was significantly reduced ($p<0.05$) when compared with control N (16.69±0.21) and control E (19.72±0.21) individuals; Zn levels of the factory workers of 9.67±0.09 for lead acid battery were statistically reduced ($p<0.05$) when compared with the controls N (11.73±0.19) and E (17.11±0.46) individuals. While the As level in lead acid battery factory was 0.07±0.00, and it was significantly elevated ($p<0.05$) compared to both controls N and E individuals. Serum Se levels were reduced in the factory workers ($p<0.05$) when compared with the control (5.11±0.08 Vs 3.43±0.07) ($p<0.05$). However, the Pb level in the factory workers were significantly elevated ($p<0.05$) when compared with control N (0.59±0.01) and E (0.79±0.10) individuals.

The result of the classification of the metal levels of factory workers according to age groups is presented in Table 3 while Figure 3 presents the regression analyses with age. Ni, As and Pb were elevated significantly ($p<0.05$) while Cu, Zn and Se were reduced significantly ($p<0.05$) in all the age groups when compared with both controls N and E with the highest Ni, As and Pb elevation at the 41-50yrs, 51-60yrs and 31-40yrs age groups, respectively while lowest Cu, Zn and Se levels were recorded in the 41-50yrs, 51-60yrs and 31-40yrs age groups, respectively. Nickel level ($r=0.060$; $p=0.722$), As ($r=-0.002$; $p=0.991$), Zn($r=0.103$; $p=0.588$) and Pb ($r=0.181$; $p=0.276$) were positively correlated while Cu ($r=-0.016$; $p=0.925$) and Se ($r=-0.018$; $p=0.913$) were negatively correlated with age (Figure 3) though non-significantly ($p>0.05$).

Table 4 presents the effect of length of service (LOS) on heavy metal levels of lead acid battery workers according to different age groups while the regression analyses with LOS are presented in Figure 4. Ni, As and Pb were significantly elevated ($p<0.05$) while Cu, Zn and Se decreased significantly with LOS ($p<0.05$) compared with controls N and E subjects. The highest Ni and As levels were obtained in the 16yrs and above LOS age group while highest Pb level was obtained at the 6-10yrs LOS age group. Ni ($r=0.191$; $p=0.256$), (Zn: $r=0.025$; $p=0.880$), Se ($r=0.008$; $p=0.964$) and Pb ($r=0.172$; $p=0.302$) correlated positively while Cu($r=-0.185$; $p=0.266$) and As ($r=-0.045$; $p=0.787$) correlated negatively with LOS though non-significantly ($p>0.05$).

The effect of gender on the metal levels of the factory workers is presented in Table 5. There was no significant difference ($p>0.05$) between the Ni, Cu, Zn, As, Se and Pb levels of male and female workers of the factory. Ni levels of all the male factory workers were significantly elevated ($p<0.05$) compared with the controls N and E male individuals with a similar trend in the female gender. The Cu levels of male workers of lead acid battery, was significantly reduced ($p<0.05$) compared with their respective controls N and E male individuals. Zinc levels of all the male factory workers were significantly reduced ($p<0.05$) compared with male controls N and E individuals and with the same trend observed in the female workers. Arsenic levels in male and female factory workers were significantly elevated ($p<0.05$) compared to their respective control individuals. Selenium levels of male and female factory workers of were reduced significantly ($p<0.05$) compared with their respective male and female control N and E individuals. There were significantly elevated ($p<0.05$) blood Pb levels in male factory workers compared with the male control N and E individuals. The same trend was observed between the Pb levels of all female factory workers and their respective

Table 1: Demographic profile of lead acid battery manufacturing factory workers

Variables	Age (years)	LOS (years)	Weight (kg)	Height (m)	BMI (kg/m^2)
Control N (n=39)	23.28±1.04^{ab}		74.82±1.04^{c}	1.74±0.01^{b}	24.75±0.38^{b}
Control E (n=40)	21.68±0.33^{a}		66.10±10.91^{b}	1.68±0.01^{a}	23.58±0.67^{b}
V (n=38)	31.38±1.32^{c}	7.70±0.86	66.26±1.57^{b}	1.67±0.01^{a}	23.77±0.49^{b}

*Values are in mean (±SEM); within the column, means with different superscripts are statistically significant ($p<0.05$).
Key: **N**: Control individuals from Nnewi, **E**: Control individuals from Elele, **V**: Workers from lead acid battery factory, **BMI**: Body mass index, **LOS**: Length of service

Table 2: Heavy metal levels of lead acid battery manufacturing factory workers

Variables	Ni (μmol/L)	Cu (μmol/L)	Zn (μmol/L)	As (μmol/L)	Se (μmol/L)	Pb (μmol/L)
Control N (n=39)	0.04±0.00^{a}	16.69±0.21^{c}	11.73±0.19^{d}	0.01±0.00^{a}	5.11±0.08^{c}	0.59±0.07^{a}
Control E (n=40)	0.07±0.00^{a}	19.72±0.21^{d}	17.11±0.46^{e}	0.02±0.00^{a}	6.66±0.08^{d}	0.79±0.10^{b}
V (n=38)	3.20±0.06^{c}	11.30±0.07^{b}	9.67±0.09^{c}	0.07±0.00^{d}	3.43±0.07^{b}	1.12±0.09^{e}

*Values are in mean ±SEM; within the column, means with different superscripts are statistically significant ($p<0.05$).
Key: **N**: Control subjects from Nnewi, **E**: Control subjects from Elele, **V**: Workers from lead acid battery manufacturing factory

Table 3: Effect of age on heavy metal levels of lead acid battery manufacturing factory workers

Age group	Ni (μmol/L)	Cu (μmol/L)	Zn (μmol/L)	As (μmol/L)	Se (μmol/L)	Pb (μmol/L)
N (n=39)	0.04±0.00^{a}	16.72±0.21^{b}	11.71±0.19^{a}	0.01±0.00^{a}	5.13±0.08^{b}	0.59±0.01^{a}
18-30yrs (n=25)	3.17±0.77^{c}	11.32±0.09^{a}	9.59±0.10^{a}	0.07±0.00^{b}	3.48±0.09^{a}	1.10±0.02^{c}
31-40yrs (n=7)	3.34±0.92^{cd}	11.38±0.14^{a}	9.58±0.23^{a}	0.07±0.00^{b}	3.34±0.16^{a}	1.16±0.03^{c}
41-50yrs (n=4)	3.43±0.17^{d}	11.10±0.13^{a}	10.30±0.26^{a}	0.07±0.00^{b}	3.35±0.22^{a}	1.15±0.07^{c}
51 60yrs (n=2)	2.85±0.09^{b}	11.43±0.30^{a}	9.46±0.27^{a}	0.07±0.00^{b}	3.58±0.32^{a}	1.11±0.06^{c}

Values are in mean (±SEM); within column, means with different superscripts are statistically significant ($p<0.05$)
Key: **N**: Control individuals from Nnewi

Table 4: Effect of LOS on metal levels of lead acid battery manufacturing factory workers

LOS group	Ni (μmol/L)	Cu (μmol/L)	Zn (μmol/L)	As (μmol/L)	Se (μmol/L)	Pb (μmol/L)
N (n=39)	0.04±0.00^{a}	16.69±0.21^{b}	11.73±0.19^{b}	0.01±0.00^{a}	5.11±0.08^{b}	0.59±0.01^{a}
0-5yrs (n=12)	3.11±0.13^{b}	11.43±0.16^{a}	9.77±0.18^{a}	0.08±0.00^{c}	3.39±0.11^{b}	1.06±0.02^{b}
6-10yrs (n=17)	3.26±0.08^{b}	11.29±0.09^{a}	9.53±0.14^{a}	0.06±0.00^{b}	3.47±0.10^{a}	1.16±0.02^{c}
11-15yrs (n=4)	3.20±0.15^{b}	11.30±0.07^{a}	10.04±0.42^{a}	0.07±0.02^{v}	3.03±0.29^{a}	1.12±0.03^{bc}
Above 16yrs (n=5)	3.31±0.15^{b}	11.17±0.18^{a}	9.53±0.14^{a}	0.08±0.00^{c}	3.56±0.19^{b}	1.11±0.05^{bc}

Values are in mean (±SEM); within column, means with different superscripts are statistically significant ($p<0.05$)
Key : N: Control subjects from Nnewi, **LOS**: Length of service

Table 5: Effect of gender on metal levels of lead acid battery manufacturing factory workers

Factories	Gender	Ni (μmol/L)	Cu (μmol/L)	Zn (μmol/L)	As (μmol/L)	Se (μmol/L)	Pb (μmol/L)
N	M (n=29)	0.37±0.02^{a}	16.90±0.24^{d}	11.85±0.23^{d}	0.01±0.00^{a}	4.05±0.01^{c}	0.59±0.01^{a}
	F (n=10)	0.38±0.03^{a}	16.50±0.48^{d}	11.06±0.30^{d}	0.01±0.00^{a}	4.07±0.12^{c}	0.59±0.03^{a}
E	M (n=18)	0.08±0.01^{a}	20.99±0.35^{f}	16.29±0.39^{e}	0.02±0.00^{ab}	6.53±0.13^{d}	0.85±0.02^{c}
	F (n=22)	0.05±0.00^{a}	18.66±0.36^{e}	17.79±0.76^{f}	0.02±0.00^{b}	6.76±0.10^{d}	0.74±0.02^{b}
V	M (n=27)	3.17±0.07^{c}	11.31±0.08^{c}	9.76±0.12^{c}	0.07±0.00^{d}	3.43±0.09^{b}	1.12±0.02^{d}
	F (n=11)	3.30±0.12^{c}	11.26±0.14^{c}	9.43±0.09^{c}	0.07±0.00^{d}	3.43±0.11^{b}	1.09±0.03^{d}

Values are in mean (±SEM); within column, means with different superscripts are statistically significant ($p<0.05$)
Key: **N**: Control individuals from Nnewi, **E:** Control individuals from Elele, **V**: Workers from lead acid battery manufacturing factory, **M**: Male, **F**: Female

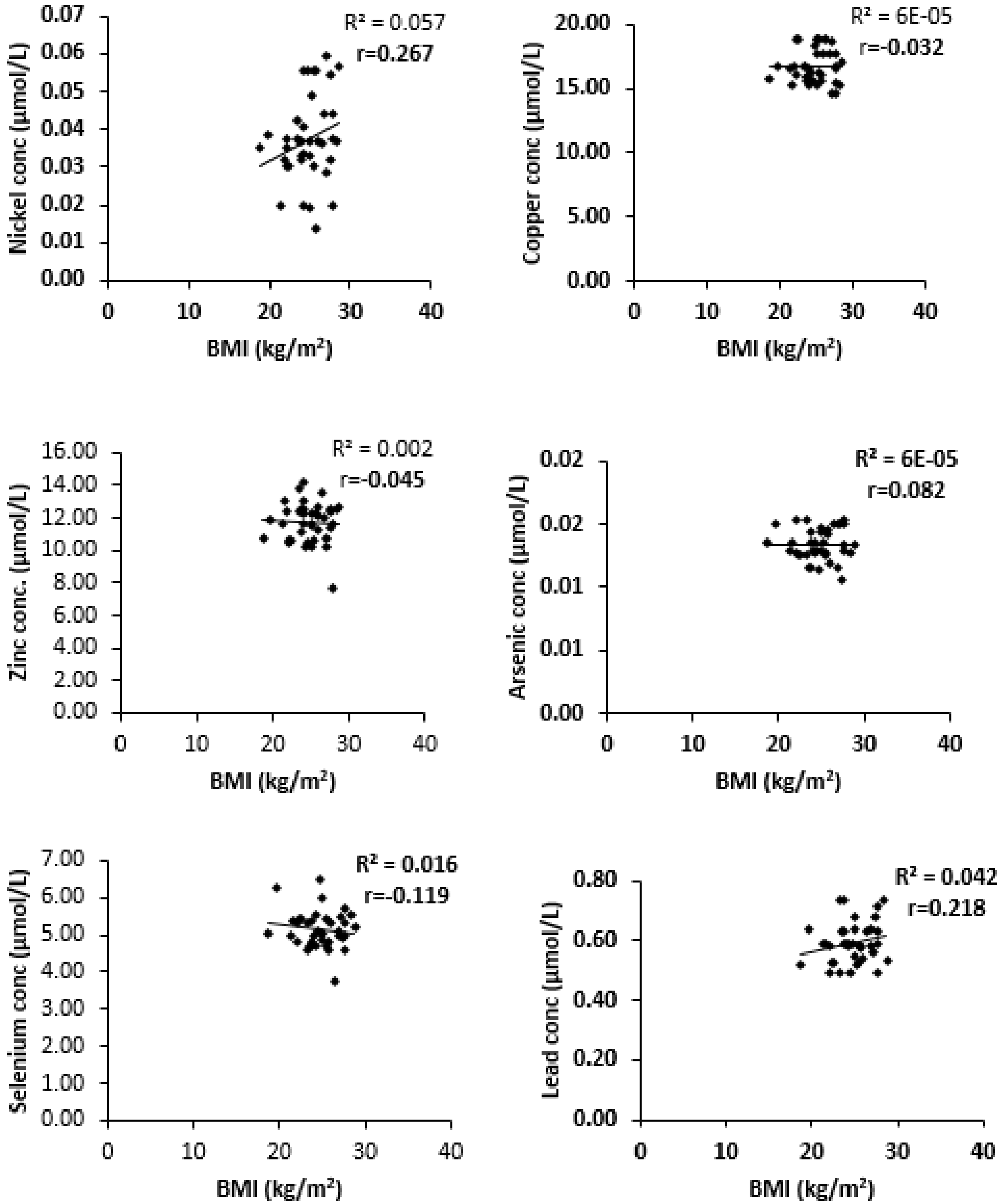

Fig. 1: Regression of metal levels of control individuals with BMI (Nnewi)

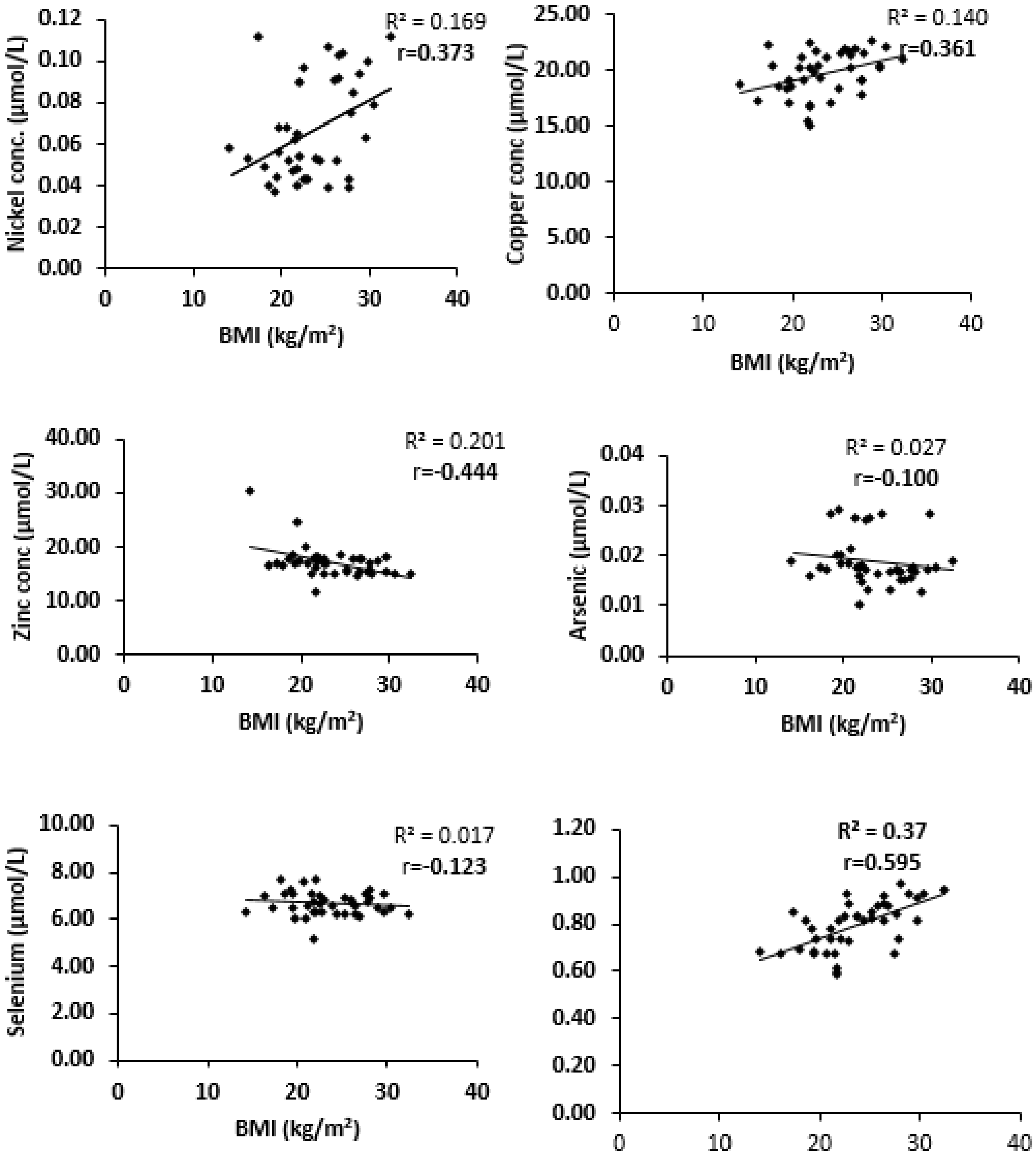

Fig. 2: Regression of metal levels of control individuals with BMI (Elele)

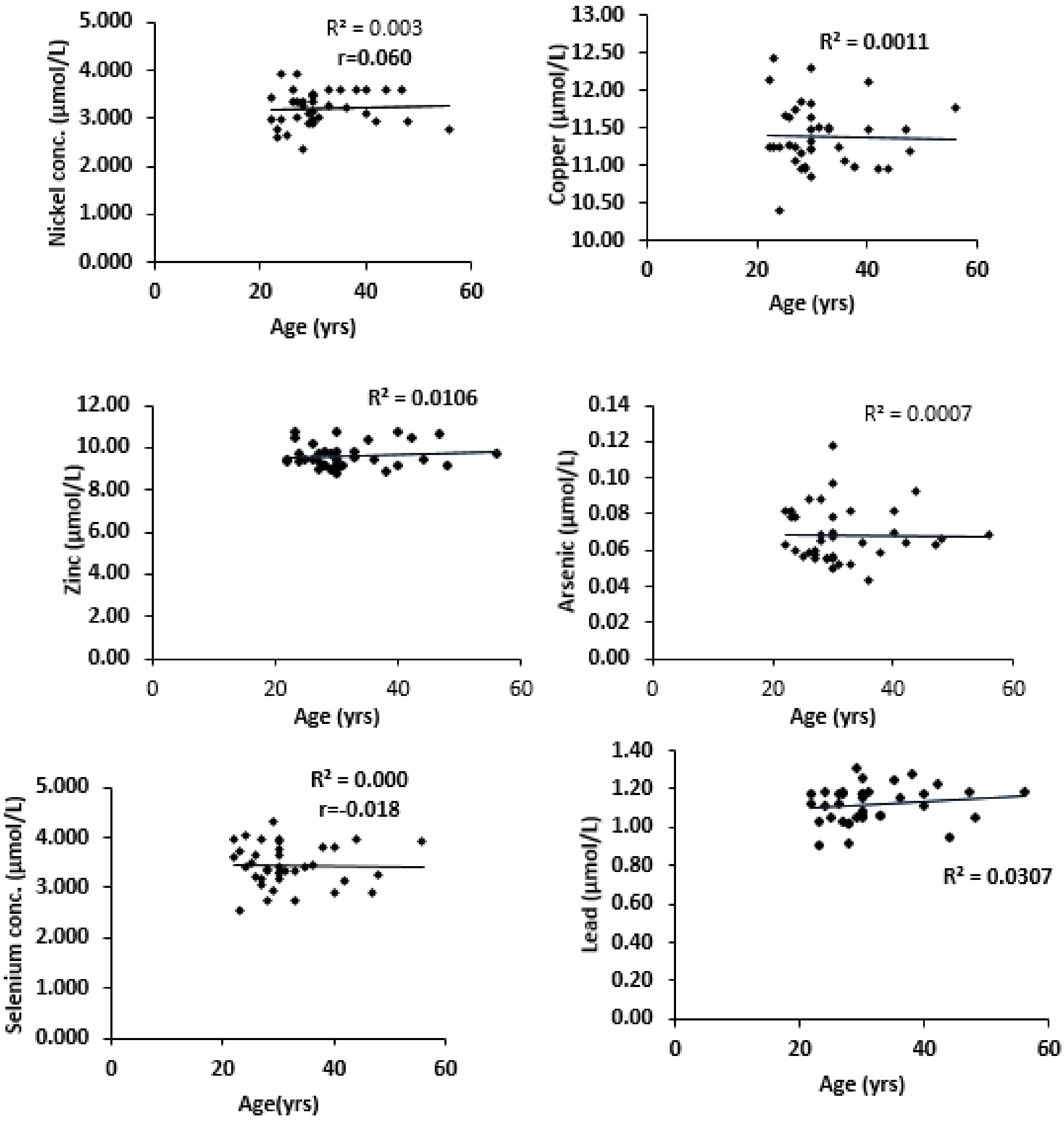

Fig. 3: Regression of metal levels of lead acid battery manufacturing factory workers with age

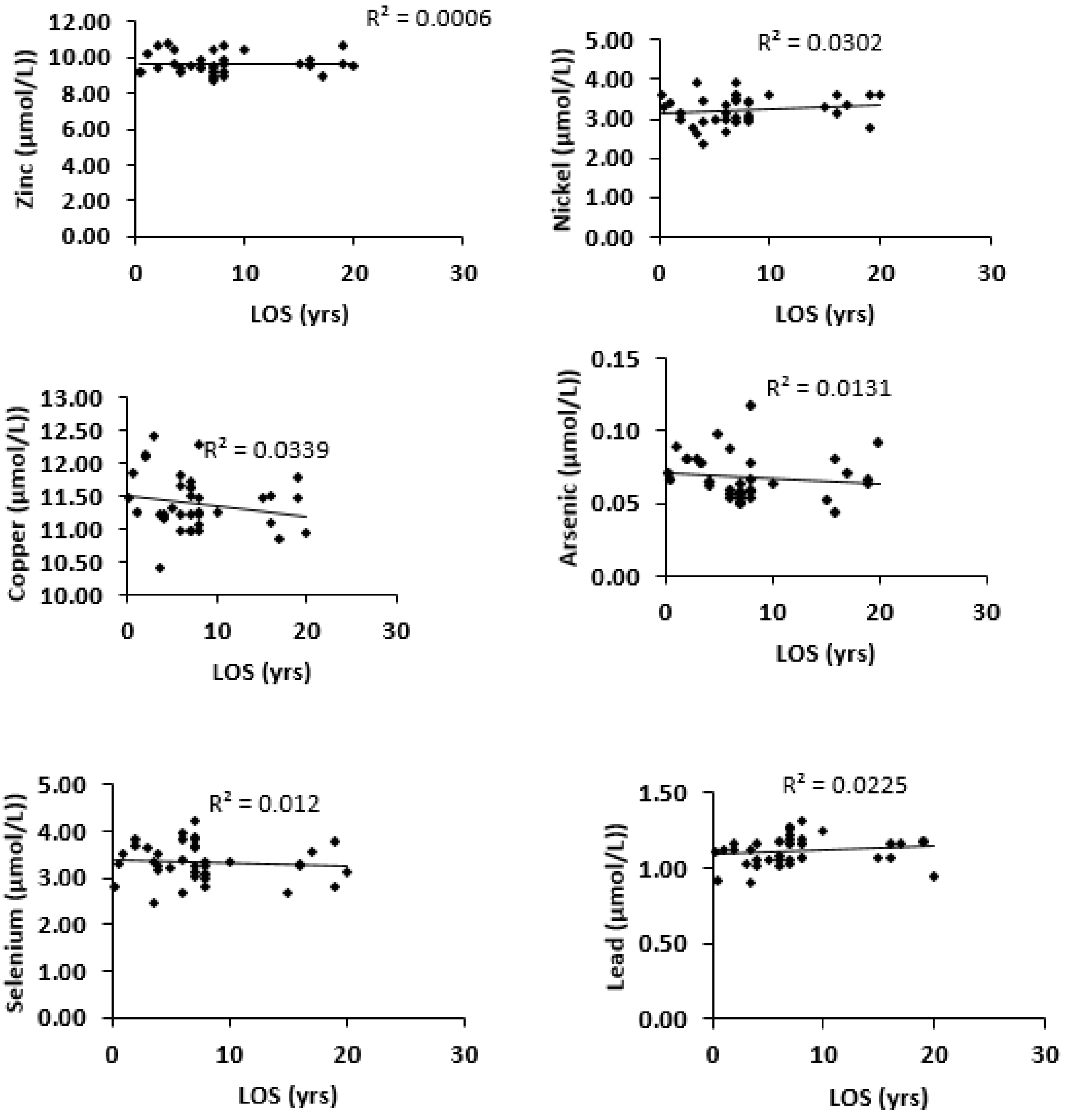

Fig. 4: Regression of metal levels of lead acid battery manufacturing workers with LOS

female controls N and E individuals.

4. Discussion

This study determined the levels of some heavy metals (Ni, Cu, Zn, As, Se and Pb) in the blood of workers of lead acid battery manufacturing factory (V), in Nnewi, a fast growing industrial city, South East of Nigeria. The workers in these factory like their control counterparts, are living in an environment that has been found to have very high levels of such metals in soil, plants and rivers especially Pb due to environmental contamination caused by urbanization and development.[7,15] The air in the work environment usually contains a number of pollutants, which when inhaled and absorbed by the body, pose a potential risk for workers' health.[30,31] Contamination of the environment includes that arising from agricultural activities, gaseous deposits from the air, waste water, sewage and industrial effluents and these industrial effluents may contain contaminants such as metallic ions that pose a threat to the natural ecosystem.[32] There have been so far no reference values of heavy metals in population of Anambra State, Nigeria. This is possibly the first time an assessment of the level of these metals is being conducted in the blood of workers of the factory in question in Nnewi despite long term use of these metals and their related materials. However, some related reports had earlier emerged that assessed Ni, Cd and Pb levels in paint workers in nearby Nkpor, Anambra State,[32] Pb in artisans occupationally exposed to it in the mechanic village in Nnewi, Nigeria[33] and levels of lead from flaking paint chips from buildings in South Eastern, Nigeria.[34] The impact of factory effluents on factory workers has been established to lead to high levels of heavy metals in the blood of workers.[30] This work showed that of all the six heavy metals studied Ni, As and Pb were significantly elevated ($p<0.05$) in the factory workers while Cu, Zn and Se were reduced significantly ($p<0.05$) when compared with their control individuals. Surprisingly, the former group of heavy metals is generally toxic even at very low levels while those in the later group are required by the body, however, the latter group can be toxic when accumulated above the acceptable levels.[35]

The results of this work indicated a more than tenfold elevation in Ni level in the blood of workers of the factory studied when compared with the control. Ni is a metal used in making acid batteries, coins and jewelry.[36] It is not surprising therefore that its levels in the blood of factory workers in Nnewi will be very high as evidenced by the results obtained from this study. These results are supported by the report of El-Shafei[38] who showed that 25 nickel-plating workers overwhelmingly suffered from compromised liver function due to high Ni level obtained in their blood. The mean value of blood nickel obtained in this study was higher than those of other countries which could be attributed to reported prevalent environmental pollution in Nigeria. For instance, Llobet et al.reported that blood nickel concentration range of adults in Spain was 0.0008-0.0881 ppm.[37] The mean value from this study was comparable with 0.25 ppm obtained from men in Nkpor and Nnewi in Anambra State by Orisakwe et al.[32] The implication of this is that following the levels of nickel in this study, lead acid battery factory workers in Nnewi are more likely to suffer graded toxic effects of Ni such as hand eczema and high risk of respiratory cancer.[36] Reports of blood nickel in occupationally exposed workers are scarce in Nigeria and Nnewi in particular, however, related report by Orisakwe et al.[32] on the liver and kidney function tests among paint industry workers in Nkpor Nigeria, showed that Pb, Cd and Ni levels were significantly higher in the exposed workers than the unexposed individuals. Also, some other similar studies in this area have documented elevated levels of lead in the blood of cable and metal forging factory workers.[38,39]

However, Cu level decreased significantly ($p<0.05$) in the factory workers under study when compared with the control individuals. This result differs from the earlier report of high copper level in the scalp hair of a group of workers in a copper smelter[40] and Solutto et al.[41] who investigated copper exposure in the sera of a group of 68 industrial welders.[42] Copper metal is a very important component of many enzymes especially those involved in redox cycling, mitochondrial respiration and iron absorption,[43] however, low level of Cu observed in this work suggest that the workers may be exposed to adult-onset progressive neuropathy[44] and development of severe blood disorders that may lead to myelodysplastic syndrome[45] and alteration of some cellular constituents involved in anti-oxidant activities such as iron, selenium and glutathione metabolism.[46]

Zn levels in the factory workers were significantly decreased when compared with the control individuals in Nnewi. Zn is an important mineral element involved in a lot of metabolic activities of the body. Interestingly, the low level of zinc was not below the acceptable plasma zinc level of 9.2-20μmol/L. The low levels of this metal obtained in this work may have resulted from an inadequate intake or absorption of the metal by these individuals. The decreased Zn levels obtained in this work is similar to that by Dioka et al. on a group of artisan in Nnewi[33]and type 2 diabetic patients resident in Abakaliki by Nwosu and Nwosu.[47] Lead appears to produce relative Zn deficiency.[48] This is because as dietary zinc increases, lead absorption and its subsequent toxicity decrease.[49] Zinc influences both tissue accumulation of lead and susceptibility to lead toxicity.[50] It is probable therefore that decreases in zinc as reported in this work may enhance the toxicity of lead. The deficiency of zinc in these factory workers portend a great danger as the deficiency will compromise a lot of the important roles that zinc plays in human beings.

According to the report of the American Dermatitis Society,[51] arsenic was voted Allergen of the Year, 2008. It is regarded as one of the most toxic substances known as a rat poison, and as a fungicide.[4] The levels of this element obtained in this study were very high in the blood of the entire factory workers studied. This is a very worrisome issue bearing in mind that arsenic exposure can cause death[52] and induce oxidative injury.[53] The arsenic levels obtained in this work are above the 1μg/L (0.01μmol/L) recommended as permissible level in blood of adults[54] and an earlier report by ATSDR[55] suggested that arsenic levels may be high in certain areas as a result of weathering and anthropogenic activities including metal mining and smelting (mainly men), wood preservation (mainly men) and electronic industries using gallium and indium arsenide (mainly women).

Selenium levels in the factory workers obtained in this work were significantly decreased ($p<0.05$) when compared with the control. According to an analysis of NHANES data from 2003-2004, the mean serum selenium concentration in the U.S. adults aged 40 years or older is 13.67μg/dL (1.73μmol/L).[56] This value is quite below the values obtained in the lead acid battery factory and the control. Selenium levels vary somewhat by region because of the amount of selenium in soil and in local foods consumed[57] and Caucasians have higher Se levels than African Americans.[58,59] The decreased selenium levels as obtained in this study may pre-dispose these workers to selenium-deficiency related diseases such as male infertility and Kashin-Beck disease, a type of osteoarthritis that occurs in certain low-selenium areas of China, Tibet and Siberia.[60–62]

Lead (Pb) stands out as the most ubiquitous metal in the Nigerian environment, caused by combined effects of automobile emissions,[63] industrial effluents,[27] paint flakes,[34] refuse dumps[64] and electronic wastes.[65] The levels of lead (Pb) obtained in the blood of factory workers in this work were significantly elevated ($p<0.05$) relative to that of the control individuals. This work agrees with the report of similar studies that blood Pb was significantly higher in the exposed workers than the control[66,67] and agrees further with the view that blood lead level is influenced by the occupational practices and roughly parallels the duration of occupational exposure.[68] This finding confirms the notion that occupational exposure increases blood lead level in exposed individuals. The significant statistical finding of elevated blood lead values in this study is consistent with the various reports of similar workers.[33] High blood levels had been noted to cause neurobehavioural and intelligence deficits and can lead to lyses of red blood cells as it inhibits the Na^+-K^+-ATPase pump attached to erythrocyte membrane.[69] The result of this work is a serious source of concern. Several reported works indicated that lead is a toxin with no apparent threshold below which it is harmless. Elevated blood lead level in adults can damage the cardiovascular system (CVS), central nervous system CNS), reproductive, hematological and renal systems of work-related individuals and the individuals in the present study are not exempted.

In adults, blood lead levels have been reported to steadily increase with increasing age while in adults of all ages; men have higher blood lead levels than women.[70] Heavy metals bio-accumulate as a particular chemical element remains in an individual over time.[71] This work assessed the effect of age on the metal levels of the factory workers within some age groups: 18-30; 31-40; 41-50 and 51-60 years. Importantly, Ni, As and Pb were significantly elevated while Cu, Zn and Se were significantly reduced in some age groups, but none of them was significantly correlated with age which indicates that significant age effect could not be established in the levels of the metals in the present study. The reason for this result may be due to the fact that very few factory workers were involved in this study. Secondly, the durations of service in these factories were very low.

Furthermore, the duration of exposure of workers in a particular environment affects the level of heavy metals in the blood of the workers.[68] In this work, attempt was made to determine the effect of LOS on heavy metal levels in the workers under study. There was no significant correlation between any of the heavy metals and LOS in this study. This result does not agree with that of Ukaejiofo et al. who reported a significant increase in blood Pb level in lead handlers in Enugu State, Nigeria with a decrease with duration greater than 10 years[72] and further with Adela et al. who reported a steady increase in the proportion of garage workers in Jimma Town, Ethiopia with higher blood lead levels with increase in service years.[68] A possible explanation for the present result may be that periodic heavy metal determinations are not useful indicators of heavy metal exposure.[73]

Interestingly, there is increasing evidence that health effects of toxic metals differ in prevalence or are manifested differently in men and women.[74] This work evaluated the effect of gender in the levels of these heavy metals in the factory workers. Although the result showed that the levels of the metals in this study were not statistically different ($p>0.05$) between the males and females individuals, there was elevated Pb levels in the males factory workers than the male control individuals. This result agrees with that of Becker et al.[75] and WHO that men have higher blood lead than women probably because of exposure but also due to blood hematocrit as Pb is bound to erythrocytes.[76] In a work reported by Orisakwe et al. a significant serum nickel in male was obtained when compared with female counterparts; however, no significant difference was obtained for blood lead and levels of the male and female groups when compared.[32] In the present work, although gender difference could not be established, the Ni, As and Pb levels of males were significantly elevated in the factory males and females than their female control counterparts establishing the fact the factory environment has an influence on the metal levels in blood and this position was supported by the work of Ibeto and Okoye.[77] The same trend was observed for Cu, Zn and Se which were significantly reduced ($p<0.05$) in the factory males and females than their female gender. Gender differences in exposure to toxic metals have been reported and there is increasing evidence that health effects of certain toxic metals are also manifested differently in males and females, due to differences in kinetics, mode of action or susceptibility.[74] Metabolism of heavy metals such as Ni has shown markedly higher prevalence of nickel-induced allergy and hand eczema in women compared with men while men have higher blood Pb levels than women. Arsenic-related skin effects such as skin cancer have been observed in men than women.[78,79] Arsenic-related suppression of spermatogenesis in experimental animals have been observed[80] probably by affecting pituitary gonadotrophins and inhibiting androgen production. Although high arsenic levels were observed in most of male workers than the female, the results of this present study did not show any gender difference in the levels of arsenic obtained in the blood of the factory workers.

5. Conclusion

In conclusion, this study showed elevated levels of Ni, As and Pb and decreased levels of Cu, Zn and Se in the blood of lead acid battery manufacturing factory workers when compared with the control individuals which implies that individuals in this factory are at a great risk of these heavy metal toxicity as well as suffering the effect of depletion of some the essential micro-minerals and this trend is quite worrisome and demands urgent attention.

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None.

7. Conflict of Interest

None.

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