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Determination of the levels of some heavy metals in industrial workers

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Abstract

Background: Heavy metals are the major sources of globally distributed pollutants in our environment and account for substantial portion of many disorders in the body. This study investigated the levels of some heavy metals; mercury (Hg), lead (Pb), cadmium (Cd) and arsenic (As) as well as assessed the kidney and liver function tests in industrial workers who have been occupationally exposed.

Method: Six millimeters of blood specimen were collected into non-anticoagulant bottles from a total number of 111 participants (industrial workers and control subjects). The participants were grouped into Groups 1, 2, 3 and control. The heavy metals (Hg, Pd, As and Cd) were analyzed using atomic absorption spectrophotometer. Serum urea, creatinine, alkaline phosphatase, aspartate amino transferase, alanine amino transferase, conjugated bilirubin and total bilirubin were determined using spectrophotometric methods.

Results: The results showed significant increases ($p<0.05$) in the levels of the heavy metals in the industrial workers compared with that of control. The mean levels of Pb in Groups 1,2, and 3 were 15.81 ±6.00, 17.53 ±5.20, 19.40± 4.40 respectively compared with the control (4.20± 2.40). These levels of Pb are higher than the levels set by the Agency for Toxic Substance and Disease Registry and Center for Disease Control (10 µg/dl).

Conclusion: It was concluded that chronic exposure to these heavy metals may predispose the industrial workers to serious adverse health effects.

Keywords: *Heavy metals, lead, mercury, arsenic, cadmium*

Résumé

Contexte: Les métaux lourds sont les principales sources de polluants distribués mondialement dans notre environnement et représentent une partie substantielle de nombreux troubles dans le corps. Cette étude a étudié les niveaux de certains métaux lourds; Le mercure (Hg), le plomb (Pb), le cadmium (Cd) et l'arsenic (As) ainsi que l'évaluation des tests de la fonction rénale et hépatique chez les travailleurs industriels qui ont été exposés au travail.

Méthode: Six millimètres d'échantillons de sang ont été recueillis dans des bouteilles non anticoagulantes d'un nombre total de 111 participants (travailleurs industriels et sujets témoins). Les participants ont été regroupés en groupe 1, 2, 3 et contrôle. Les métaux lourds (Hg, Pd, As et Cd) ont été analysés en utilisant un spectrophotomètre à absorption atomique. L'urée sérique, la créatinine, la phosphatase alcaline, l'aspartate amino-transférase, l'alanine amino-transférase, la bilirubine conjuguée et la bilirubine totale ont été déterminées à l'aide des méthodes spectrophotométries.

Résultats: Les résultats ont montré des augmentations significatives ($p <0,05$) dans les niveaux des métaux lourds chez les travailleurs industriels par rapport à ceux du contrôle. Les niveaux moyens de Pb dans les groupes 1,2 et 3 étaient 15,81 ± 6,00, 17,53 ± 5,20, 19,40 ± 4,40 respectivement par rapport au témoin (4,20 ± 2,40). Ces niveaux de Pb sont supérieurs aux niveaux fixés par l'Agence pour les Substances Toxiques et le Registre des Maladies et le Centre de Contrôle des Maladies (10 µg/dl).

Conclusion: On a conclu que l'exposition chronique à ces métaux lourds pourrait prédisposer les travailleurs industriels à des effets néfastes graves sur la santé.

Mots-clés: *Métaux lourds, plomb, mercure, arsenic, cadmium*

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Introduction

Heavy metals are the major category of globally distributed pollutants in our environment and they cause serious health effects such as reduced growth rate and development, cancer, organ damage, nervous system damage etc. Heavy metal poisoning could result from drinking contaminated water; for instance water from lead pipes [1]. Possible exposures to these metals have resulted in health problems [2]. However, for the maximum protection of human health, the Centre for Disease Control and Agency for toxic Substance and Disease Registry have set a reference value for the exposure to these metals. Lead ≤ 10µg/dl, mercury ≤0.[illegible] µg/dl, cadmium ≤ 0.5µg/dl and arsenic ≤ 0.01µg/dl [3,4]. Thus, exposure to these heavy metals above the reference value is liable for causing serious health effects. Lead has been shown to interfere with DNA transcription, enzymes, neurons, and heme synthesis [5,6]. Lead may also be harmful to the developing immune system, causing production of excessive inflammatory proteins which is a risk factor for asthma development in children [7]. Mercury is capable of inducing a wide range of clinical presentations such as fatigue, anxiety, depression, odd paresthesias, weight loss, memory loss, and difficulty in concentrating and these are the symptoms of low-grade chronic mercury exposure. Mercury also exist in various forms (mercurous and mercuric) and they have the ability to deposit in most parts of the human body [8,9]. Acute poisoning with mercuric salts (typically $HgCl_2$) generally targets the gastrointestinal tract and the kidneys. Extensive precipitation of enterocyte proteins occurs, with abdominal pain, vomiting, and bloody diarrhea with potential necrosis of the gut mucosa. This may produce death either from peritonitis or from septic or hypovolemic shock [8]. It was reported that chronic low level mercury exposure in workers from a mercury recycling plants was associated with visual disturbances but not neuropsychological changes [10]. Arsenic exposure comes with immediate symptoms like abdominal pains, vomiting and diarrhea. It also affects the skin severely leading to skin pigmentation, lesion, hand patches on the palms and soles of the feet and different types of cancer result on further exposure [11-13]. Cadmium can affect several organs when they are exposed to increased or accumulated quantities. Cadmium affects the kidney primarily because the kidney tubules receive much of the toxic effects although it has toxic effects on other parts of the kidney [14-16]. Cadmium can also induce bone damage as well as affect the placenta, liver, lungs and the reproductive system causing infertility [17-21]. Therefore, the study aimed at investigating the levels of some heavy metals: lead, mercury, cadmium and arsenic as well as the kidney and liver function tests in industrial workers who have been occupationally exposed.

Materials and methods

Participants

The design of the study was approved by the Ethical committee of the Faculty of Health Sciences and Technology, College of Health Sciences, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria and informed consent was received from all participants before the commencement of the work. A total of 131 participants comprising 81 industrial workers from three different companies and 30 control participants were investigated. The industrial workers were grouped into three groups (Groups 1, 2 and 3) according to their industries. Group 1 consist of 40 participants working in a leading automobile oil producing industry and they are involved in the production of engine oils used by cars of different types, big trucks, motorbikes, and generator of different sizes. The workers in group 2 (31 participants) were involved in producing vegetable oil and soap. Group 3 (30 participants) comprise those who were involved with the recycling of lead from lead products, lead damaged batteries, processing and crushing of battery plastic containers. The recycled lead is used to produce battery locally while some are exported abroad while the crushed plastic battery containers are transported and sold to plastic producing industries. The control participants (30) were apparently healthy subjects who have not been occupationally exposed to heavy metals. Six millimeters of blood specimen were collected from the participants into plain non-anticoagulant bottles after they gave their consents. The serum was separated into another clean container before analysis.

Determination of heavy metals

Serum levels of the metals (Hg, Pd, As and Cd) were determined with flame atomic absorption spectrophotometer (AAS) using a direct method [22]. The method is based on the principle that atoms of the element when aspirated into AAS vaporized and absorbed light of the same wavelength as that emitted by the element when in the excited state.

Estimation of Alkaline phosphatase (ALP)

ALP at an alkaline pH hydrolyses di-sodium phenylphosphate to form phenol. The phenol formed reacts with 4-aminoantipyrine in the presence of potassium ferricyanide as an oxidising agent, to form a red colour complex. The intensity of the colour formed is directly proportional to the activity of ALP present in the sample [23].

Estimation of Aspartate (AST) and Alanine (ALT) amini transferases

Amino group is enzymatically transferred by AST / ALT present in the sample from L-aspartate/ alanine to the carbon atom of 2-oxoglutarate yielding oxaloacetate / pyruvate and L-glutamate. AST/ ALT activity is measured by the concentration of oxaloacetate/ pyruvate hydrozone formed from the reaction with 2,4- dinitrophenyl hydrazine [24].

Determination of conjugated and total bilirubin
Bilirubin in the sample reacts with diazotized sulphanilic acid to form the purple colour azobilirubin (direct bilirubin). In the presence of methanol, the same reaction is used to measure total bilirubin. The intensity of the colour produced is directly proportional to bilirubin concentration [25].

Determination of serum urea
Urea reacts with diacetyl monoxime at high temperature in an acid medium at high temperature in the presence of cadmium ions and thiosemicarbazide. The absorbance of the red colour produced is measured in a spectrophotometer and it is directly proportional to the concentration of urea in the sample [26].

Determination of serum creatinine
Creatinine reacts with picric acid in alkaline medium. The absorbance of the yellow-red colour produced is measured spectrophotometrically [27].

Statistical analysis
The Mean and Standard Deviation (SD) were calculated for each parameter using Statistical Package for Social Sciences (SPSS version 17.0). Differences in the means for each parameter between the two groups were compared using analysis of variance (ANOVA).

Results
The mean serum levels of the heavy metals in the workers from the industries as well as Control participants are presented in Table 1. Mercury in groups 1 and 2 were significantly higher ($p<0.05$) compared to group 3 and control. Table 2 shows the

Table 1: The levels of Lead, Mercury, Cadmium and Arsenic in the Industrial workers and control participants

Parameters	Group 1 Mean ± SD N=40	Group 2 Mean ± SD N=31	Group3 Mean ± SD N=30	Control Mean ± SD N=30	F-value	P-value
Lead (μg/dl)	15.81 ± 6.00	17.53 ± 5.20	19.40 ± 4.40	4.20 ± 2.40	23.342	0.000*
Mercury(μg/dl)	0.73 ± 0.03	0.75 ± 0.03	0.24 ± 0.20	0.04 ± 0.01	20.430	0.000*
Cadmium (μg/dl)	0.10 ± 0.02	0.10 ± 0.04	0.20 ± 0.20	0.05 ± 0.05	6.255	0.001*
Arsenic (μg/dl)	0.06 ± 0.02	0.05 ± 0.01	0.14 ± 0.12	0.03 ± 0.01	17.807	0.000*

*= *Significant at $p<0.05$*

Table 2: Kidney and Liver function tests in the industrial workers and control subjects

Parameters	Group 1 40	Group 2 31	Group 3 30	Control 30	F value	P value
Serum urea (mmol/L)	4.63 ±1.25	6.35±1.33	4.30 ±1.01	4.44±1.32	19.847	0.000*
Serum creatinine (μmol/L)	72.50±20.18	116.32±44.52	85.23±22.85	91.50±29.23	13.155	0.000*
Serum alkaline phosphatase (IU/L)	68.93±13.17	72.90± 14.10	71.35±13.72	70.20±16.26	0.495	0.687
Serum aspartate amino transferase (IU/L)	8.65 ±2.34	9.07 ±2.10	8.13±2.06	8.92 ±2.00	1.357	0.259
Serum alanine amino transferase (IU/L)	9.08±4.52	8.84±2.53	7.23 ± 2.62	7.01 ±2.10	3.992	0.009*
Serum conjugated bilirubin (μmol/L)	2.59 ± 0.14	3.53 ±4.09	2.63 ± 0.18	2.55±1.19	1.798	0.150
Serum total bilirubin (μmol/L)	11.60 ±0.57	11.71 ±0.68	11.33 ±0.65	10.02 ± 1.84	18.460	0.000*

*= *Significant at $p<0.05$*

kidney and liver function tests in the industrial workers. There were significant differences in the levels of serum urea, creatinine, alanine amino transeferase and total bilirubin in the industrial workers compared with control.

Discussion

Heavy metals are potentially dangerous to health and prolonged exposure can cause damage to the organs of the body. Many industrial workers are not aware of the risk associated with this occupational exposure. Previous workers have shown increased levels of heavy metals in mechanical industries and vehicle construction industries which use metals like chromium, lead zinc, copper, manganese and nickel [28]. The finding of high levels of lead in the industrial workers could be attributed to the raw material (Pb) that is commonly used. One of the industries is involved in the recycling and production of pure lead and lead batteries. This industry recycles lead from used and damaged motor batteries. Some of this recycled Pb is also exported abroad while some are used locally for the production of motor batteries.

Consequently, these workers may get exposed to lead either through ingestion (hand-to-mouth or contaminated food), inhalation through the lungs or through the skin. The relative high values of lead observed in the industrial workers could also be attributed to toxic waste chemicals, drinking and bathing from the borehole water inside the industries [1]. This water is run through lead pipes to prevent rusting because this water is mainly used for the cooling of their machines and other purposes. This finding is in line with previous report [29] which showed increases in the level of lead in the subjects investigated. The high level of mercury observed in this study is in line with the findings of increased mercury in industrial workers [10]. This could have been encountered during the course of working with some electrical-equipments and in some chemicals [30]. Human toxicity has been shown to vary with the forms of mercury, the dose and the rate of exposure. The target organ for inhaled mercury vapor is primarily the brain. Mercurous and mercuric salts chiefly damage the gut lining and kidney while methyl mercury is widely distributed throughout the body [31].

Occupational exposure to cadmium and chromium has been reported in different workers such as electroplating, steel making, leather tanning, photography, dyeing and chemical manufacture operations [28]. The high level of cadmium found in the industrial workers can possibly be attributed to the introduction of cadmium in the environment through sewage sludge, fertilizer and ground water leading to the contamination of vegetables and food crops. This is because a larger number of the workers live around the industries and have farm lands where they cultivate crops. The consumption of the contaminated farm products may possibly lead to cadmium exposure [32]. Furthermore, the significant level of arsenic in the workers could possibly be due to effluent from industrial waste, petrochemicals and fuel which are common source of arsenic. These workers may get exposed to Arsenic during lead smelting because arsenic is a content of smelted lead [33].

The result from the study also show that out of the four tested heavy metals (Pb, Hg, Cd and As) in the various groups; lead has the greatest concentration in the industrial workers when compared with the reference values [3,4]. This is in line with the report which stated that among the heavy metals, those having the most serious health implications are arsenic, lead, cadmium, and mercury [34]. Lead has been recognized for centuries as a cumulative general metabolic poison [35]. It is a neurotoxin and it is responsible for neurological signs such as pains, muscle weakness, mental problems and symptoms associated with abdominal pains, nausea, vomiting diarrhea [7]. Although Mercury, Cadmium and Arsenic pose major health problems as earlier mentioned, the levels observed in this study were minimal in the individual workers as to cause serious health problems.

The serum urea and creatinine levels showed significant increases in Group 2 when the levels in the industrial workers were compared with the control. The result is in line with a previous report which showed that exposure to heavy metals can cause vascular or renal damage [36]. Long term exposure to heavy metals have been linked to various complications such as renal dysfunction, joints and reproductive systems, cardiovascular system and acute and chronic damage to the central nervous system (CNS) and peripheral nervous system (PNS) [37,38]. Among the liver function tests, alanine amino transeferase showed significant increase in Groups 1 and 2 when the industrial workers were compared with the control. Total bilirubin also showed significant increase in the industrial workers compared with the control. This implies that there may be liver involvement especially during a long term exposure and at higher concentration [39,40].

Conclusion

The result of this study showed that the heavy metals were significantly increased in the industrial workers compared with the control. Chronic exposure to these heavy metals may predispose the industrial workers to serious adverse health effects.

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