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Elevated Cadmium Levels in Blood of the Urban Population in Enugu State Nigeria

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Abstract: Two hundred and forty blood samples were collected from children, women and men in urban area of Enugu State. The samples were analyzed for cadmium by AAS after wet digestion. The results of the analysis in ppm show the range and %detectable values as (0.007-0.293)85.42 %. The concentrations were very high as most exceeded the W.H.O. maximum permissible limit. The sample population was classified according to different age groups, sex, occupationally and non occupationally exposed, pregnant women/nursing mothers and other women and also as those exposed/or not exposed to some probably risk factors to be associated with the heavy metals. Adolescents had the highest mean concentration. Males showed lower concentration, while pregnant women/nursing mothers had higher mean concentration than the other women. The results obtained indicated no significant difference between the responses for any of the factors indicating that the concentrations of cadmium are not affected by these factors.

Key words: Cadmium · Blood · Wet digestion · Environmental pollution · AAS · Nigeria

INTRODUCTION

Environmental exposure to heavy metals is a continuing source of mortality and morbidity throughout the world. The critical issues however are that adequate preparations have not been made towards the protection of the environment. In Nigeria, the growing rate of industrialization is gradually leading to contamination and deterioration of the environment [1]. Some reported works established the fact that there is heavy metal (including cadmium) pollution in Nigeria. For example, cadmium concentrations of some of the samples of ground water in a typical rural settlement in Southwest Nigeria, with concentration range of 0.24-0.36 mg/L exceeded the World Health Organization recommended thresholds of 0.003 ppm for potable water [2]. High concentrations of cadmium and other toxic metals have been determined in airborne cement dust around Sagamu, South-western Nigeria showing elevated concentrations of cadmium (0.004-0.026 gm^{-3}) [3]. Also, in the determination of cadmium in soil samples of Warri and environs, the concentrations were 7.605-24.194 ppm which was higher than the acceptable levels of 2 ppm for polluted soils [4].

Cadmium is extremely poisonous and toxic to humans. Greater health risks of cadmium poisoning results directly in lung damage, reduction in sperm count, toxic action of high body burden on the kidney (renal tubular damage) and possibly the skeleton [5-7]. Toxicity associated with acute respiratory exposures may include pulmonary edema (accumulation of fluid in the lungs) where ingested cadmium may result in nausea, vomiting and abdominal pain [8]. Environmental discharge of cadmium due to the use of petroleum products, combustion of fossil fuels (petroleum and coal) and municipal refuge contribute to airborne cadmium pollution [9] and possibly introduce high concentrations of this potential reproductive toxicant into the environment. This may be particularly true for Nigeria where refuse are burnt without any control. In addition, humans may be unwittingly exposed to cadmium via contaminated food or paper [10] cosmetics and herbal folk remedies [11]. All these factors put Nigerian population at high risk of cadmium toxicity [12]. The levels of cadmium in blood can be taken as representative of dose/ exposure [13]. Therefore, the aim of this investigation is to determine the concentrations of cadmium in human whole blood samples obtained from men, pregnant women, nursing mothers, other women and children in Enugu State and also to identify possible risk factors for cadmium toxicity among the Nigerian population.

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MATERIALS AND METHODS

To get the approval to work on human part, an Ethical Clearance Certificate was obtained from the University of Nigeria Teaching Hospital Health Research Ethics Committee, Ituku Ozalla, after undergoing an interview and submitting a detailed proposal of the research work. Informed consent was obtained from the sample population. All were made to complete a questionnaire concerning their environmental exposure as a means of obtaining information on likely environmental impact on the blood heavy metals levels

Collection of Samples: 3 mL of blood were collected directly from the select population made up of children, women (pregnant, nursing mothers, others) and men from Bishop Shanahan Hospital and Good Shepherd Hospital (in Nsukka) and St Rapheal's Clinics, University Teaching Hospital (UNTH) Ituku Ozalla, Uzommiri study centre, Lantana catering school and Ezindu professional centre (in Enugu) by vein puncture by a qualified nurse under contamination controlled conditions using pyrogen free sterile disposable syringes. The blood samples were put into 5 mL capacity EDTA plastic bottles containing K_3EDTA as anticoagulant. The samples were mixed carefully by shaking. All the samples were stored in the refrigerator to prevent deterioration before the analysis [14].

Quality Assurance Procedures: Validation of the digestion method of analysis used and certification of the instrument as good enough for the analysis was done by carrying out recovery experiment and precision analysis respectively.

Recovery Experiment: Three samples of blood were used. Each sample was taken in two portions of 2 mL into two conical flasks. 1mL of prepared 10 ppm cadmium standard solution was added to spike one set of portions (i.e three conical flasks) of the blood samples. The other set was left unspiked. Perchloric acid and nitric acid were added into all the conical flasks in the ratio 1:3 as follows: 2 mL perchloric acid and 6 mL nitric acid. The conical flasks were covered with evaporating dishes and the mixtures digested at low temperature using a thermostated Bitinett hot plate until clear solutions were obtained. At the end of the digestion, they were all made up to 20 mL and the concentrations of cadmium determined using atomic absorption spectrophotometer. The recovery was then calculated as follows:

$$\%\text{Recovery} = \frac{x - y}{z} \times 100$$

x is concentration (ppm) of cadmium determined in the spiked samples.
y is the concentration (ppm) of cadmium determined in the unspiked samples.
z is the concentration (ppm) of cadmium added to the spiked samples.

Precision Analysis: 1 mL of prepared 10 ppm cadmium standard solution was pipetted into a 20 mL standard flask and made up to mark, to give 0.5 ppm cadmium. This was analysed 5 times for cadmium. The results obtained were subjected to statistical analysis using the formula below:

$$\frac{S}{X} \times \frac{100}{0}$$

S is standard deviation
X is mean

Sample Preparation: Each sample (3 mL) was transferred into 100 mL conical flask. The EDTA bottle was rinsed with little nitric acid and transferred into the 100 mL conical flask. Perchloric acid and nitric acid were added in the ratio 1:3 as follows: 2 mL perchloric acid and 6 mL nitric acid. The conical flask was covered with an evaporating dish and the mixture digested at low temperature using a thermostated bitinett hot plate until a clear solution was obtained. The digest was made up to 20 mL with deionized water in a 20 mL standard flask [14]. The sample solutions were then analysed for cadmium using a GBC atomic absorption spectrophotometer, model no A6600 AVANTA PM.

RESULTS AND DISCUSSION

Results of the recovery analysis were in the range 88.39-106.11 % which shows good recovery, signifying good accuracy. The precision which is the repeatability or reproducibility of individual measurements expressed as relative standard deviation or coefficient of variation of the instrument shown was 1.538 % which is below 10 % signifying high precision [15]. For most instrumental

methods, coefficient of variation is in the order of 10 % [16]. Cadmium was detected in 205(85.42 %) samples while in 35(14.58 %) of the samples, it was below the detection limit of 0.0004 ppm. The concentration range was from 0.007-0.293 ppm. Cadmium was in very high concentrations in some of the blood samples and was not detectable in some others. This can probably be attributed to various factors including in general, the type of food eaten by individual donors, as there is an inverse relationship between concentration of heavy metals in the body and a healthy diet. Human diet studies have indicated that the bioavailability of heavy metals such as lead, cadmium, nickel, manganese and chromium are dependent on food constituents (dietary protein, fibre, phytate, ascorbic acid and vitamin-B metabolites) and essential elements such as iron, zinc, calcium, magnesium and phosphorus [17&18]. Comparing the concentrations obtained from this study with the WHO, 1996 guideline value for cadmium in blood, all the detectable samples had concentrations higher than the permissible levels stipulated i.e 0.0003-0.0012 ppm [5]. Thus there is a clear indication of high concentrations of the heavy metal in the general population in Nigeria, especially the South-east.

From the various studies carried out on the environment which are also been reported in this study, environmental pollution seems to be prevalent in Nigeria. High concentrations of the heavy metal have been determined in the analysis of water, for example, some sachet water analysed in Eastern Nigeria were found to contain cadmium exceeding the maximum contaminant level [19] High concentrations of cadmium have been determined in the analysis of food. The cadmium content of 78 different Nigerian foods of various classes were higher than the levels obtained in similar foods in some developed countries [20], while Fakayode and Olu-Owolabi, [21] reported that concentrations of cadmium, 0.07 mg/kg in chicken eggs in Ibadan were comparatively greater than levels found in other countries. High concentrations of cadmium have also been determined in the analysis of soil e.g Igwilo *et al*., [22] reported the concentrations of cadmium (0.07-3.45 ppm) in soil samples near Anam River in Otuocha, Anambra State, which he considered to be high, Several studies that have established higher concentrations of the heavy metal in Nigeria as compared with many countries. For example, Moriyama *et al*., [23] reported a comparatively higher concentration of cadmium in Nigerian foods in the analysis of cadmium in different kinds of foods from Greece, Japan, China, other European countries and Nigeria. However, even with the established higher concentrations of cadmium in Nigeria than in other countries, little effort is being made in addressing cadmium exposure in the domestic environment [24]. This shows that the Nigerian population is at risk of the adverse health effects that may result from cadmium toxicity.

Table 1: Concentrations (ppm) of Cadmium in blood of different age groups of urban population in Enugu State, Nigeria

Age groups		*Concentration*
=12	Mean	0.088 ± 0.056
	Range	0.01 - 0.23
	N	42
13-25	Mean	0.093 ± 0.049
	Range	0.01 - 0.29
	N	66
>25	Mean	0.090 ± 0.055
	Range	0.01 - 0.28
	N	97
Significance (ANOVA)		0.865 NS

NS means Not significant

As shown in Tables 1 and 2 cadmium was detected in 42(70 %) children with a concentration range of 0.011-0.231 ppm and an average of 0.088 ppm. It was detected in 48(80 %) pregnant women and nursing mothers with a concentration range of 0.008-0.280 ppm and an average of 0.099 ppm. It was detected in 65(98.48 %) men with a concentration range of 0.007-0.210 ppm and an average of 0.093 ppm and it was also detected in 50(92.59 %) of the other women (excluding the pregnant women and nursing mothers) with a concentration range 0.013-0.293 ppm and an average of 0.080 ppm. The females had a higher mean concentration than the males even though there was no significant difference (P>0.05) between the two groups. Pregnant women and nursing mothers had higher mean cadmium concentration than the "other women" with no significant difference between the two groups (P>0.05). Men followed the pregnant women/nursing mothers in cadmium burden in blood and this may be attributed to the fact that greater number of men than women have smoking habit. Cigarette smoking contributes to the risk of developing heart and renal disease and is probably the most important source of cadmium exposure since tobacco plant contains a lot of cadmium [25]. Cigarette smoke contains particles and gases generated by the combustion of its various components at high

Table 2: Concentrations (ppm) of cadmium in blood of different categories of the urban population in Enugu State Nigeria

Categories		Yes	No	Sig 2 tailed
Pregnant women/Nursing mothers	Mean	0.099 ± 0.064	0.080 ± 0.046	0.102 NS
	Range	0.01 - 0.28	0.01 - 0.29	
	N	48	50	
Occupationally exposed	Mean	0.091 ± 0.053	0.090 ± 0.054	0.984 NS
	Range	0.01 - 0.29	0.01 - 0.23	
	N	94	111	
		Male	Female	
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Sex	Mean	0.090 ± 0.049	0.091 ± 0.057	0.885 NS
	Range	0.01 - 0.23	0.01 - 0.29	
	N	91	114	

NS means Not significant

temperature. More than 4000 compounds have been identified in environmental tobacco smoke. The cigarette smoke can be inhaled directly by the smoker and non-smokers in cigarette contaminated environment through passive smoking. The average cadmium content of cigarettes available in Nigeria is 1.28 µg per cigarette and a person who smokes 20 cigarettes per day is estimated to increase his daily cadmium retention by approximately 1µg/day (0.53 – 1.65 µg/day) [26]. With respect to the different age groups shown in Table 1, 13-25 years old had the highest mean concentration of cadmium than the other age groups even though there was no significant difference between the groups (P>0.05). These are young adolescents; they constitute a little studied group that differs from adults and children. Adolescents grow rapidly and have higher energy and nutrient requirements compared to adults. A higher energy intake may expose them to more heavy elements, both toxic and essential ones, via diet [27]. Moreover, it is among this group that the greatest number of cigarette smokers may be found. Humans may be unwittingly exposed to heavy metals via herbal folk drugs which are usually more common in the rural areas particularly among women [11]. The levels obtained in this study are higher than those obtained in other countries, e.g the mean cadmium concentration in blood of pregnant women in Bangladesh was 0.0012 ppm [28] while the range for adult men and women in Spain was 0.002-0.0324 ppm [29]. Also adults in New York were reported to have mean blood cadmium concentration of 0.00077 ppm [30]. The values however compared well with some blood cadmium concentrations obtained from other parts of the country, such as mean of 0.06 ppm obtained by Arinola *et al*., [31] in the blood plasma of male adults in Ibadan and mean of 0.09 ppm for adult men in Nkpor Nnewi in Anambra State Southeast Nigeria [32], but higher mean cadmium concentration (0.76 ppm) was obtained in the blood of men in Akure, Ondo State in the Southwest region [33].

Some donors may be occupationally exposed such as those working in filling stations (pump attendants, administrators, sales men), mechanics, painters (car) and petty traders on roadsides while the non-occupationally exposed may include housewives, security men, bankers, students, lecturers, doctors and caterers. The people making up the occupationally exposed were selected because of the fact that cadmium is associated with fossil fuels spillage or combustion as a means of exposure and the filling stations are places of constant direct contact with high concentration of the fossil fuels [34,9], painting cars can also bring one in constant contact with fossil fuels. The non occupationally exposed are those considered to be minimally exposed to these heavy metals as a result of their occupational status. Several studies have reported higher concentrations of the heavy metal in those considered to be occupationally exposed than in the non-occupationally exposed individuals [32] but some studies have also reported that non occupationally exposed have higher concentrations of the heavy metal than the occupationally exposed [31]. The cadmium blood burdens of the two groups (Table 2) showed that those believed to be occupationally exposed had higher mean concentration of the heavy metal than those considered to be non-occupationally exposed. However, there was a no significant difference (P>0.05) between the two groups. This shows the widespread impact of cadmium in the environment reaching the general population as is made clear from already reported works done in Nigeria on food and the environment. It could also be due to the dietary status of the occupationally exposed. If they really take balanced diet as they indicated in their questionnaire,

Table 3: Concentrations (ppm) of cadmium of the categories from the questionnaires

Factor		Yes	No	Sig 2 tailed
Not eating balanced diet	Mean	0.097 ± 0.066	0.090 ± 0.053	0.877 NS
	Range	0.04 - 0.17	0.01 - 0.29	
	N	3	202	
Eating lots of fish	Mean	0.096 ± 0.045	0.090 ± 0.054	0.563 NS
	Range	0.03 - 0.18	0.01 - 0.29	
	N	19	186	
Taking herbal medicine	Mean	0.098 ± 0.058	0.089 ± 0.0525	0.403 NS
	Range	0.02 - 0.28	0.01 - 0.29	
	N	33	172	
Smoking cigarette	Mean	0.103 ± 0.042	0.090 ± 0.054	0.314 NS
	Range	0.05 - 0.18	0.01 - 0.29	
	N	12	193	
Using bleaching cream	Mean	0.067 ± 0.054	0.092 ± 0.053	0.146 NS
	Range	0.01 - 0.19	0.01 - 0.29	
	N	12	193	
Handling pesticides	Mean	0.094 ± 0.047	0.089 ± 0.055	0.594 NS
	Range	0.01 - 0.29	0.01 - 0.28	
	N	48	157	
Lived in a house under renovation	Mean	0.093 ± 0.042	0.090 ± 0.056	0.703 NS
	Range	0.02 - 0.20	0.01 - 0.29	
	N	36	169	
Handled broken fluorescent	Mean	0.101 ± 0.055	0.088 ± 0.053	0.201 NS
	Range	0.01 - 0.28	0.01 - 0.29	
	N	37	168	
Living with occupationally exposed	Mean	0.087 ± 0.043	0.091 ± 0.055	0.690 NS
	Range	0.02 - 0.18	0.01 - 0.29	
	N	31	174	

NS means Not significant

then that might have caused the insignificant difference between the two groups. T-tests were used to compare the responses (yes or no) for each of the factors stated in the questionnaires and the results are shown in Table 3. The results obtained indicated no significant difference ($P>0.05$) between the responses for any of the factors with respect to mean concentrations of cadmium. The non-significant differences indicate that the effect of these factors on blood cadmium levels is not likely to be as important as food and the environment.

CONCLUSIONS

It is clear that the blood of most Nigerians contain high levels of cadmium. The data obtained from this study provides some information about the cadmium burdens of the part of the Nigerian population living in the Southeast, especially in Enugu and Nsukka in Enugu State. The data can be considered as reference showing the ranges of cadmium concentrations in the blood of the various age groups and in males and females in the area of study. With the review of cadmium content of air, water, soil, plants and food especially fish in Nigeria, the high values obtained in this study can be attributed mostly to the impact of environmental pollution.

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