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Original Research Article

Evaluation of heavy metals and biomarkers of deoxyribonucleic acid damage in state employment and expenditure for result contract workers in Yenagoa

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ABSTRACT

Background: Youth unemployment and poverty in Southern Nigeria is high, thus many youths are easily recruited as dock workers and casual labourers without considering the occupational hazards associated with such jobs. This study evaluated some heavy metals and DNA damage biomarkers in state employment and expenditure for result (SEEFOR) contract workers, in Yenagoa.
Method: One hundred subjects between the age range of 20 to 55 years, comprising fifty of SEEFOR contract workers and fifty unexposed individuals as control in the study. Blood samples were collected, separated and sera used for the analyses of heavy metals and DNA damaged biomarkers using enzyme linked immunosorbent assay and atomic absorption spectrophotometry.
Results: The result showed statistically non-significant difference ($p>0.05$) values of cadmium, chromium, vanadium, nickel, arsenic and DNA damage biomarkers at the baseline compared with the control group. Cadmium, vanadium and 8-NO_2-Gua at the 6th month showed statistically significant difference ($p<0.05$). Statistically significant ($p<0.05$) increase at 12th month were equally observed in cadmium, vanadium, nickel, arsenic, and 8-NO_2-Gua compared with the control. Heavy metals cadmium, chromium, Vanadium values showed statistically significant ($p<0.005$) increase in both the 18th and 24th month. DNA damage biomarkers 8-NO_2-Gua, 4HNE, and BPDE levels also showed a significant ($p<0.005$) increase at the 18th and 24th month when compared with the control group.
Conclusions: The study suggest that the probability of occurrence of diseases related to heavy metal bioaccumulation and DNA damage originating from oxidative stress, might be higher among SEEFOR road construction workers with time.

Keywords: Heavy metals, SEEFOR, DNA damage biomarkers

INTRODUCTION

Youth unemployment in most states in Nigeria including Bayelsa is driven by demographic, educational, and economic factors. This has necessitated the recruit of many youths as casual workers in certain companies such as road construction and mining companies without considering the hazards of such jobs.[1] The SEEFOR project is designed to respond to both the short-term and medium-term needs of the participating states, and one of such needs is infrastructure; particularly the mechanical construction of minor roads where a good number of youths are hired or employed for a period of about three years. The work process involves the excavation of soil with its attendant dust generation; working with sand, gravel, chippings, cement, and asphalt which they use for paving and the eventual casting of the roads. These products contain several amounts of toxic heavy metals such as cadmium, chromium, arsenic, vanadium,

mercury, and lead, and the analysis of metals in petroleum gives a clue to catagenetic oil formation, maturation of organic matter, correlation, depositional and environmental studies.[2]

Heavy metals are generally referred to as elements with relatively high densities, atomic weights, or atomic numbers.[3] Some heavy metals are either essential nutrients (iron, cobalt, and zinc), or relatively harmless (such as ruthenium, silver, and indium), but can be toxic above tolerable levels or in certain forms. Other heavy metals, such as cadmium, chromium, arsenic, vanadium, mercury, and lead, are highly poisonous and can degrade air, water, and soil quality, subsequently causing health issues in animals, and humans, when they become accumulated.[4] In humans and animals, they can bind to and interfere with the functioning of vital cellular components and react frequently by increased generation of reactive oxygen species and interference with DNA repair processes due to oxidative DNA lesions leading to the development of cancer and premature aging.[5]

DNA is a molecule that carries genetic instructions useful for the growth, development, functioning, and reproduction of all known living organisms. It stores biological information, and is usually a double stranded molecule; the two DNA strands are termed polynucleotides since they are composed of simple monomer units called nucleotides.[6] DNA damage is an alteration in the chemical structure of DNA, such as a break in one or both strands, a base missing from the DNA backbone, or a chemically changed base as in 8-Oxo-2'-deoxyguanosine (8-OHdG).[7] More than one hundred (100) types of oxidative DNA damage have been characterized, and 8-OHdG constitutes about five per cent (5%) of the steady-state oxidative damage in DNA.[8] Swenberg et al, measured the average amount of selected steady-state endogenous DNA damage in mammalian cell which include; 8-Nitroguanine, 4-hydroxynonenal and Benzo(a)pyrene diol epoxide.[8,10]

The 8-nitroguanine is a nitrated base of DNA and ribonucleic acid (RNA). It is formed by per-oxynitrite which is generated from nitric oxide and superoxide anion radicals.[11] It is known that a large amount of nitric oxide molecules and superoxide anion generated by inflammatory processes cause nitration of guanosine.[12] 4-hydroxy-2-nonenal (4-HNE) is one of the most bioactive lipid alkenals.[13] It can modulate a number of signalling processes mainly through formation of covalent adducts with nucleophilic functional groups in proteins, nucleic acids, and membrane lipids.[14] Elevated status of oxidative stress has been associated with a majority of cancer types and thus 4-HNE is believed to be a major contributing player in the mutagenic and carcinogenic effects of lipid peroxidation.[15,16] Benzo(a)pyrene diol epoxide is a pro-carcinogen, suggesting that its mechanism of carcinogenesis depends on its enzymatic metabolism to Benzo[a]pyrene BaP diol epoxide.[17] It intercalates in DNA, covalently bonding to the nucleophilic guanine bases. Benzo[a]pyrene-7,8-dihydrodiol-9,10-epoxide is the carcinogenic product of various enzymatic reactions.[18]

This present study is motivated by the increasing concern about the potential hazard of occupational exposure to heavy metals and other substances that are thought to induce DNA damage with mutagenic effect.[24] Thus, it was carried out to to evaluate some heavy metals and DNA damage biomarkers in SEEFOR contract workers in Yenagoa, Nigeria.

METHODS

Study area

The study was conducted out among SEEFOR contract workers in Yenagoa, Bayelsa State. Bayelsa state is located within latitude 4^0 15^1 North and Latitude 5^0 23^1 South. It is also within longitude 5^0 22^1 West and 6^0 45^1 East and bounded by Delta State on the North, Rivers State on the East and the Atlantic Ocean on the Western and Southern parts.

Study population

A total of one hundred subjects of age range of twenty to fifty-five years were recruited for the study. Fifty were SEEFOR contract workers, while fifty apparently healthy civil servants served as the control group. Twenty-five each of the SEEFOR contract workers and control group were males while the other half females.

Study design

We carried out a two years longitudinal study from February, 2017 to January, 2019. Blood samples were collected from the workers before the start the job (baseline). Thereafter, at the 6^{th}, 12^{th}, 18^{th}, and 24^{th} month of employment, blood samples were collected from the subjects. Subjects who consented to the study and without medical history of any known underlying ailments were included for the study. Subjects who refused consent, known tobacco smokers and those with known illness relating to the study were consequently excluded. Ethical approval was obtained from the research ethical committee of Bayelsa State ministry of health. Hereafter, the director general (DG) of the SEEFOR project in Bayelsa state was contacted and on request, a copy of the thesis proposal tendered.

Sample collection

Blood samples were collected from each of the one hundred (100) subjects. A standard clean veni-puncture technique was used to collect 10 ml of venous blood from each recruit into a plain container. The samples were centrifuged for five (5) minutes at 2,500 rpm and the supernatant sera were separated into separate for use and stored at -20^0C prior to analysis. DNA damage

biomarkers (8-nitroguanine, 4-hydroxynonenal and benzo(a)pyrene diol epoxide) were determined by enzyme linked immunosorbent assay (ELISA). Heavy metals (cadmium, chromium, arsenic, vanadium, mercury) were analyzed using atomic absorption spectrophotometry (AAS).

Analysis of biochemical parameters

Heavy metals cadmium, nickel, arsenic, chromium, and vanadium were analyzed using atomic absorption spectroscopy with appropriate wavelengths/ filters as described by Valko et al.[19] Principle: A light beam from a lamp whose cathode is made of the element being determined is passed through a flame to provide the specific wave length for that element. This specific wavelength is passed through a device such as a photomultiplier which can detect the amount of reduction of the light intensity due to absorption by the analyte. This is then directly measured using a photo-detector and the absorbance converted to concentration following Beer-Lambert's law. DNA damage biomarkers (8-nitroguanine, 4-hydroxynonenal and benzo(a)pyrene diol epoxide) were determined by ELISA.

Statistical analysis

Statistical package for social sciences (SPSS) (Version 20.0 for windows 10) was used to analyze data. The differences in the various parameters that were studied among the tests and control groups were evaluated using Kolmogorov-Simirnov Z statistics. One Way ANOVA and Duncan's Multiple range test were used to assess differences within the groups. Statistically significant values were determined at 95% confidence level.

RESULTS

Table 1 shows no statistically significant difference ($p>0.05$) of cadmium (0.0144±0.0024), chromium (0.0049±0.0012), vanadium (0.0472±0.0083), 8-nitroguanine (27.99±189), BPDE (29.67±2.83), and arsenic (0.0314±0.0098) at baseline of study population when compared with the control group. Except nickel and 4-hydroxynonenal which showed significant differences ($p=0.042$ and $p=0.039$) respectively, compared with the control group. Table 2 shows that at the 6th month, cadmium, vanadium, nickel and 8-NO_2-Gua showed statistically significant differences ($p<0.05$) compared with the control. Table 3 showed that at 12th month of exposure, cadmium (0.0180±0.0014), vanadium (0.1227±0.1926), nickel (22.58±6.67), arsenic (0.0320±0.0013), 8-NO_2-Gua (30.50±2.19) and BPDE (31.29±2.52) showed statistically significant differences ($p<0.05$) compared with the control group. Table 4 revealed that SEEFOR contract workers at the 18th month showed statistically significant differences ($p<0.005$) in Cd, Cr, Ni, V, Ars, 8-NO_2-Gua, 4HNE, and BPDE levels at the 18th month compared with the control. Table 5 revealed that all studied parameters showed statistically significant differences ($p<0.05$) when compared with the control at the 24th month. Table 6 shows that highest mean values were observed for Cd, V, Ni, Ars, 8-NO_2-Gua, 4HNE and BPDE in 24th month. Results showed progressive statistically significant differences ($p<0.05$) in all measured heavy metals and DNA damage biomarkers when compared with baseline values throughout duration of study. Table 7 revealed arsenic showed statistically significant difference ($p=0.041$) for gender comparison of heavy metals and DNA damage biomarkers among the SEEFOR contract workers

Table 1: Mean±SD values of heavy metals and DNA damage biomarkers SEEFOR contract workers at baseline, (n=100).

Study population	Cd (ppm)	Cr (ppm)	V (ppm)	Ni (ppm)	As (ppm)	8-NO_2-Gua (ng/ml)	4HNE (µg/ml)	BPDE (ng/ml)
Control, (n=50)	0.0144± 0.0012	0.0049± 0.0010	0.0472± 0.0053	21.85± 3.52	0.0314± 0.0038	27.99± 0.89	29.43± 2.76	29.67± 2.05
SEEFOR workers, (n=50)	0.0144± 0.0024	0.0049± 0.0012	0.0472± 0.0083	21.85± 4.50	0.0314± 0.0098	27.99± 1.89	29.43± 3.56	29.67± 2.83
P value	0.887	0.969	0.896	0.042*	0.080	0.711	0.039*	0.883

*Mean difference is significant at the 0.05 level.

Table 2: Mean±SD values of heavy metals and DNA damage biomarkers in the study population at the 6th months, (n=100).

Study population	Cd (ppm)	Cr (ppm)	V (ppm)	Ni (ppm)	As (ppm)	8-NO_2-Gua (ng/ml)	4HNE (µg/ml)	BPDE (ng/ml)
Control, (n=50)	0.0143± 0.0019	0.0050± 0.009	0.0473± 0.0079	23.37± 3.65	0.0305± 0.0079	27.82± 1.27	30.69± 2.79	30.64± 2.56
SEEFOR workers, (n=50)	0.0162± 0.0014	0.0048± 0.0012	0.0850± 0.0962	22.21± 5.33	0.0317± 0.0051	29.25± 1.97	30.56± 3.12	30.48± 2.64
P value	0.030*	0.299	0.029*	0.031*	0.301	0.000*	0.202	0.699

*Mean difference is significant at the 0.05 level.

Table 3: Mean±SD values of heavy metals and DNA damage biomarkers in the study population at the 12th months, (n=100).

Study population	Cd (ppm)	Cr (ppm)	V (ppm)	Ni (ppm)	As (ppm)	8-NO_2-Gua (ng/ml)	4HNE (µg/ml)	BPDE (ng/ml)
Control, (n=50)	0.0142± 0.0025	0.0051± 0.0014	0.0475± 0.0076	24.89± 4.84	0.0296± 0.0063	27.64± 1.80	31.94± 3.96	31.60± 4.13
SEEFOR workers, (n=50)	0.0180± 0.0014	0.0047± 0.0011	0.1227± 0.1926	22.58± 6.67	0.0320± 0.0013	30.50± 2.19	31.69± 2.74	31.29± 2.52
P value	0.000*	0.224	0.009*	0.019*	0.011*	0.000*	0.059	0.044

*Mean difference is significant at the 0.05 level.

Table 4: Mean±SD values of heavy metals and DNA damage biomarkers in the study population at the 18th months, (n=100).

Study population	Cd (ppm)	Cr (ppm)	V (ppm)	Ni (ppm)	As (ppm)	8-NO_2-Gua (ng/ml)	4HNE (µg/ml)	BPDE (ng/ml)
Control, (n=50)	0.0146± 0.0015	0.0067± 0.0009	0.0495± 0.0078	24.52± 4.20	0.0322± 0.0055	27.43± 1.55	30.42± 2.10	30.43± 2.61
SEEFOR workers, (n=50)	0.0205± 0.0030	0.0136± 0.0013	0.0534± 0.0036	26.02± 4.63	0.0344± 0.0100	32.67± 2.19	34.30± 2.89	33.67± 2.42
P value	0.000*	0.000*	0.002*	0.097	0.096	0.000*	0.000*	0.000*

*Mean difference is significant at the 0.05 level.

Table 5: Mean±SD values of heavy metals and DNA damage biomarkers in the SEEFOR contract workers at the 24th months, , (n=100).

Study population	Cd (ppm)	Cr (ppm)	V (ppm)	Ni (ppm)	As (ppm)	8-NO_2-Gua (ng/ml)	4HNE (µg/ml)	BPDE (ng/ml)
Control, (n=50)	0.0156± 0.0021	0.0082± 0.0012	0.0516± 0.0082	24.15± 6.34	0.0349± 0.0052	27.22± 1.74	28.89± 1.74	29.26± 2.63
SEEFOR workers, (n=50)	0.0224± 0.0031	0.0155± 0.0014	0.0565± 0.0025	28.46 ± 4.63	0.0378± 0.0110	35.79± 3.15	36.19± 3.01	35.74± 2.35
P value	0.000*	0.001*	0.007*	0.000*	0.001*	0.000*	0.000*	0.001*

*Mean difference is significant at the 0.05 level.

Table 6: Mean±SD values of heavy metals and DNA damage biomarkers in SEEFOR contract workers with respect to duration of exposure.

Duration of exposure	Cd (ppm)	Cr (ppm)	V (ppm)	Ni (ppm)	As (ppm)	8-NO_2-Gua (ng/ml)	4HNE (µg/ml)	BPDE (ng/ml)
At baseline	0.01443± 0.0025	0.0049± 0.0012	0.0472± 0.0083	21.85± 4.50	0.0314± 0.0098	27.99± 1.89	29.43± 3.55	29.67± 2.83
At 6 months	0.0162± 0.0014	0.0048± 0.0011	0.0850± 0.0962	22.22± 5.33	0.0317± 0.0052	29.25± 1.97	30.56± 3.12	30.48± 2.64
At 12 months	0.0181± 0.0015	0.0047± 0.0011	0.1227± 0.1926	22.58± 6.67	0.0320± 0.0013	30.50± 2.19	31.69± 2.74	31.29± 2.51
At 18 months	0.0205± 0.0030	0.0136± 0.0012	0.0534± 0.0036	26.02± 4.63	0.0344± 0.0100	32.67± 2.19	34.30± 2.86	33.65± 2.43
At 24 months	0.0224± 0.0031	0.0155± 0.0014	0.0565± 0.0025	28.50± 4.63	0.0378± 0.0110	35.79± 3.15	36.19± 3.01	35.74± 2.35
P value	0.001*	0.020*	0.033*	0.000*	0.010*	0.000*	0.001*	0.002*

*Mean difference is significant at the 0.05 level.

Table 7: Mean±SD of heavy metals and DNA damage biomarkers concentrations in SEEFOR contract workers with respect to gender.

Variables	Male, (n =28)	Female, (n=22)	P value
Cd (ppm)	0.0181±0.0038	0.0185±0.0036	0.921
Ni (ppm)	24.62±5.71	24.65±4.43	0.778
As (ppm)	0.0354±0.0113	0.0314±0.0026	0.041*
8-NO_2-Gua (ng/ml)	31.24±3.78	31.23±3.36	0.645
4HNE (µg/ml)	32.77±4.64	32.08±2.95	0.165
BPDE (ng/ml)	32.08±3.03	32.26±3.74	0.670

*Mean difference is significant at the 0.05 level.

DISCUSSION

The overall results of this study have presented evidence of bioaccumulation of some heavy metals as well as DNA damage biomarkers in SEEFOR contract workers when compared with the controls. The differences in the concentrations of the assayed parameters in the study population was correspondingly found to be statistically significant ($p<0.05$). The concentrations of the assayed parameters pointed to the health hazard of prolonged occupational exposure of road construction workers as recruited in the study, and correlated with the duration of exposure. The result showed statistically non-significant difference ($p>0.05$) in comparison of the control values of blood heavy metals and DNA damage biomarkers concentration at baseline against the study group. Data gathered indicate that there was a progressive and significant increase in heavy metals and DNA damage biomarkers from the 6th to the 24th month in SEEFOR, though with noticeable dissimilarities. These findings are also in consonance with various reports Enterline and Marsh, and Nordberg et al on occupational induced increase in heavy metal blood concentrations.[20,21]

The study also indicated progressive significant increase ($p<0.05$) in DNA damage biomarkers in the occupational study group with prolonged duration. This progressive significant increase in DNA damage biomarker could imply that the increase heavy metals exposure resulted in a possible DNA damage. Das et al had earlier implicated nickel as a potential immunomodulatory and immunotoxic agent aside from its action as an allergen in humans. An increase in the incidence of chromosomal abnormalities but with no chromosome distortion was reported among nickel refinery workers, which was found to be similar with another report on workers exposed to manganese, nickel, and iron.[22,23]

Works by Bloomfield and Blum, conspicuously give credence to this present study whose findings included a notable increase in chromium concentration with duration of exposure; and was statistically significant ($p<0.05$) on comparison with the baseline and inter analysis between the 6th and 24th months. The rise in heavy metals also was accompanied by corresponding rise in DNA damage biomarkers.[24]

It was also observed that there were no significant differences in the DNA damage biomarkers up until the 12th month. This could be attributed to various biological homeostatic mechanisms such as antioxidant system, cellular enzymatic system, and hepatic microsomal activities. Superoxide dismutase converts superoxide anion to hydrogen peroxide which in turn is metabolized by catalase or glutathione peroxidase to water and molecular oxygen. These interactions between these systems possibly delayed the eventually observed significant difference.

The observed higher serum levels of 8-nitroguanine, 4-hydroxynonenal, and benzo(a)pyrene diol epoxide in the SEEFOR contract workers when compared with the control group may have been induced by the heavy metals emitted. This is in agreement with the work done by Ifenkwe et al where they published those metals influenced the concentrations of the oxidative stress biomarkers.[25] This suggests that cadmium, chromium, nickel, and arsenic are potent oxidative factors eliciting measurable concentrations of 8-NO_2-Gua, 4HNE, and BPDE. The results of cadmium in this study validates the work of Achparaki et al which says that exposure to cadmium has the proclivity to causing a variety of pathological alterations in several organs and tissues as well as induce diabetic complications, hypertension, and osteoporosis.[26] This may be due to its ability to deplete cells' major anti-oxidants and enzymes causing an increase in the generation of reactive oxygen species.

The study also revealed that Arsenic showed a statistically significant difference ($p=0.041$) for gender comparison of heavy metals, and DNA damage biomarkers among the SEEFOR contract workers. This is in consonance with a few works postulating that arsenosis is common among males (53.7%) in comparison to females (46.3%) indicating that females are more susceptible to the toxic effects of chronic arsenic exposure yet controverting the report of the international agency for research on cancer-IARC in 2004, which says males are more susceptible than females to develop skin lesions when exposed to arsenic which in an inorganic form is a potent human carcinogen. Though the mean arsenic value in males was higher than in females in this present study, the exact mechanism by which this occurred is yet to be clearly understood.

Limitation

The study was conducted in a small study population. Hence, large population study is needed to establish the exact concentration of these parameters in SEEFOR contract workers.

CONCLUSION

The study revealed significant increase in chromium, cadmium, nickel, vanadium, arsenic, and the studied DNA damage biomarkers in SEEFOR contract workers recruited in the study. This confirms that occupational exposure of SEEFOR contract workers predisposed to increase in heavy metals bioaccumulation and the observed significant increase in DNA damage biomarkers possibly originating from oxidative stress, and capable of causing diseases associated with oxidative damage in them.

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