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Concentrations of Heavy Metals in Hair of Sudanese Exploration Mining (Gold) Workers as Indicators of Environmental Pollution

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ABSTRACT
The aim of this study was to determine the concentration of Fe, Cu, Zn and Pb in scalp hair of Sudanese exploration mining (gold) workers in El-Abedea town and healthy volunteers from Khartoum, using the XRF method. The accuracy and precision of the method for the elements were evaluated through the analysis of a standard hair sample. Workers hair samples were classified corresponding to age, work duration, year of work and the area of the workplace of the participants. The results showed that the studied trace elements in both workers and control groups were positively skewed. In comparison with the control group, lower Fe, Cu, Zn and Pb were found in all studied exploration workers.

KEYWORDS: *Human hair, heavy metal, XRF, exploration mining worker, concentration, environmental pollution*

INTRODUCTION

Exploration mining workers who are digging soil from a site for finding the rare metals expose to air pollution, dust and vapors containing solid waste. All rare earth metals contain radioactive elements such as uranium and thorium, which can contaminate air, water, soil and groundwater. Metals such as arsenic, barium, copper, aluminum, lead and beryllium may be released during mining into the air or water and can be toxic to human health.

Studies have shown that soil does contain heavy metals and exposure to them can cause health problems. Heavy metals toxicity can result in damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other diseases.

Heavy metals enter the body via inhalation, ingestion, and skin absorption. If heavy metals enter and accumulate in body tissue faster than the body's detoxification pathways, a gradual build-up of these toxins will occur (1).

Exploration mining workers in El-Abedea area in northern Sudan work outside the town with little water and food sources and most of them using traditional hand tools for digging the soil and they may neither have the expertise in safety and health nor have adequate resources to provide effective control methods to reduce workers exposures to solid wastes.

X-Ray Fluorescence Spectroscopy has long been recognized as a powerful technique for the qualitative and quantitative elemental analysis of a wide range of solid and liquid samples. Compared to other competitive techniques, such as Atomic Absorption Spectroscopy (AAS) or Inductively Coupled Plasma Spectroscopy (ICPS), XRF has the advantage of being non-destructive, multi-elemental, fast and cost-effective. Furthermore, it offers a fairly uniform detection limit across a large portion of the Periodic Table and is applicable to a wide range of concentrations from 100% to a few ppm.

There is a need to provide baseline data of heavy metals exposures among metal workers in order to compare it to existing studies. This is to ensure workers were not subjected to the unacceptable level of heavy metal exposures that have been linked to harmful health effects such as cancers. As such, this study was performed with the objective to determine the exposure to heavy metals in hair samples of metalworkers in northern Sudan.

Trace elements in the body:

Trace elements (or trace metals) are minerals present in living tissues in small amounts they can greatly affect human health. They are the components of enzyme, hormones, vitamins and nucleic acid. If people do not supplement adequate trace elements like Zinc, Calcium, Iron and copper, they can be seriously troubled by various problems. Some of them are known to be nutritionally essential, others may be essential (although the evidence is only suggestive or incomplete), and the remainder is considered to be nonessential. Trace elements function primarily as catalysts in enzyme systems (2).

All trace elements are toxic if consumed at sufficiently high levels for long enough periods. The difference between toxic intakes and optimal intakes to meet physiological needs for essential trace elements is great for some elements but is much smaller for others(3).

Hence, monitoring of heavy metals from human hair has been of interest to researchers in the fields of environmental chemistry and medical science because the number of heavy metals of hair samples can reflect the nutritional state of the person or the environment where that person resides or works (4).

METHODOLOGY

Sample collection and preparation

10 hair samples from Exploration metal (gold) workers and 10 assumed environmentally healthy samples were collected. The samples were cut using stainless steel scissor and were sealed in a transparent plastic bag. Each sample was given a code number to correspond to the respondents. Simultaneously, their age, working duration and year of working experience were recorded. The hair samples were washed in acetone, three portions of water and again with acetone. Each wash lasted for 10 minutes with continuous stirring. This is the washing procedure recommended by the IAEA Advisory Group (5) the hair samples were then dried for 24 hours at room temperature and were stored in sealed labeled plastic bags. Every hair sample were put in a piece of fabric and immersed in liquid nitrogen at 77K̊, homogenized in an agate mortar with a pestle and a binder (cork dissolved in three drops of benzene) was added to the sample, carefully mixed and press into a pellet form using a pressing machine that compress to a manual pressure up to 15 tons, that is the sample preparation for XRF measurement in simple pellet press solid sample with geometrical dimensions for the X-ray absorption and transmission via homogeneous shape. Hair standard reference material sample from IAEA has been applied for measurement and result calibration (6). The standard reference sample and the hair samples collected from workers were prepared according to the procedure used for XRF measurement geometry. Samples were analyzed for elements of determination and concentration obtains relative to the data and reference certificate of the standard sample.

Sample analysis by (XRF) Canberra 35 plus (MCA) system

The analysis was carried out in the X-ray laboratory at Khartoum university, college of physics science, Sudan, The experiment was run using radioactive Cd109 source X-ray fluorescence spectrometer to utilize the elemental analysis in hairs samples. The XRF had silicon-lithium (Si-Li) diode detector with an energy resolution of 180 eV at Ek (5.8 KeV) of manganese (Mn) linked to a Canberra 35 plus (MCA) system that connected to the computer to obtain acquiring data. A quantitative approach was employed for elements concentration in hairs using a calibration comparative approach to the certified standard sample (7).

RESULTS AND DISCUSSION

We determined the concentration of heavy metals in human hair samples from exploration mining workers in Al-abide in northern Sudan and control group. The precision and accuracy of the (XRF) Canberra 35 plus was tested by analyzing standard hair IAEA-085 (8), and found that it has a good agreement as shown in table (1). The data have been presented by arithmetic mean (MEAN) and standard deviation (SD). We detected 16 heavy metals in hair samples, out of those five elements; Fe, Cu, Zn and Pb to be presented in this paper. This is due to the factor that these named elements have quantified data for all samples, i.e. not below the limit of detection (LDL).

Tables (2) and (3) show raw data for the control group and workers group respectively, which list individual concentration for detected elements Fe, Cu, Zn and Pb, together with their Mean, Range ± SD and Mean control/Mean exploration in the table (4). There is no correlation for the elements contained in the hair as a function of sampling data. The standard deviations of the measurement for most of the elements are at an acceptable level, indicating the precision of the method. In the worker group, the maximum concentration value is 374 ppm for Fe. The hair of the exploration mining (gold) workers group shows a range of 89.9 – 9.49 ppm Fe, 1.74 – 1.26 ppm Cu, 13.5 – 7.4 ppm Zn and 1.74 – 0.71 ppm Pb while that of the control group has a range of 374 – 11.3 ppm Fe, 16.8 – 5.28 ppm Cu , 197 – 6.21 ppm Zn and 5.61 – 0.908 ppm Pb. The impact of age and work period on element concentrations was investigated. We did not find any correlation of concentrations of heavy metals influence of age and working periods. Fe and Zn elements show a high standard deviation. This might be as a result of dust contamination because the exogenously deposited elements were not removed completely during washing of the hair. Comparison of the MEAN of each element in the two groups was performed as shown in Figure 1. The SD for each element within each group is high because of the variation in the hair element content among individuals. The mean concentrations are: Fe (362 ± 119.89) ppm, Cu (11.25 ±4.84) ppm, Zn (190.79 ± 84.69), Pb (4.702 ±1.93) ppm for exploration workers group and Fe (80.44 ± 25.977) ppm, Cu (0.48 ± 0.162) ppm, Cu (0.48 ± 0.162) ppm, Zn (6.1 ± 2.066) ppm, Pb (1.03 ± 0.324) ppm, for control group, respectively. Mean concentrations in the control group are found to be significantly higher compared to the exploration workers suggests the exposure of hair to the environmental pollutants, the possible uptake from exposure of exploration worker during working, less intake of food, the potential for lower grade of heavy metals from drinking contaminated water or eating fish from contaminated water bodies which leads to decrease in metal concentration (external contamination).

Table1. Analytical data obtained in this work compared to the value for the elements in standard hair.

Element	Analytical value, ppm	Certified value, ppm
Mn	15.9	8.4 – 9.2
Fe	73.8	71.0 – 87.8
Cu	15.5	15.7 – 17.8
Zn	150	156 – 170
Hg	21.2	22.4 – 24.0
Se	0.929	0.96 – 1.17

Table 2. Heavy metals Fe, Cu, Zn and Pb measured in control group.

No	Age	Concentration (ppm)			
		Fe	Cu	Zn	Pb
1	14	71.1	16.3	185	5.26
2	14	16.8	5.65	8.92	1.76
3	23	374	15.9	186	5.61
4	28	52.0	7.96	77.8	0.908
5	30	145	14.4	197	5.13
6	30	36.6	6.63	6.88	1.61
7	30	11.3	5.28	6.21	2.99
8	30	58.5	13.5	78.9	5.52
9	45	267	16.8	175	5.22
10	63	60.4	6.80	6.68	1.81

Table3. Heavy metals Fe, Cu, Zn and Pb measured in exploration metal (gold) workers group.

No	Age	Exposure duration (year)	Concentration (ppm)			
			Fe	Cu	Zn	Pb
1	17	0.3	49.5	1.48	13.1	1.31
2	18	0.6	25.3	1.46	7.40	1.47
3	20	0.2	9.46	1.26	9.57	0.974
4	20	2	12.0	1.51	9.44	0.71
5	25	7	9.82	1.30	9.31	1.15
6	27	0.3	14.6	1.74	8.52	1.37
7	29	3	11.8	1.57	10.3	1.47
8	35	4	13.8	1.72	13.5	1.47
9	40	1	89.9	1.49	11.8	1.74
10	42	11	10.4	1.67	12.5	0.842

Table4. Comparison of element concentration in hair samples between the control group and exploration workers.

Element	Mean concentration ppm	Range ± SD	Mean control/Mean exploration
Fe Control Exploration	109.27 24.66	362.7 ± 119.89 80 ± 25.977	4.43
Cu Control Exploration	10.92 1.52	1.25 ± 4.84 0.48 ± 0.162	7.186
Zn Control Exploration	92.839 10.544	190.79 ± 84.69 6.1 ± 2.066	0.114
Pb Control Exploration	3.5818 1.251	4.702 ± 1.93 1.03 ± 0.324	0.349

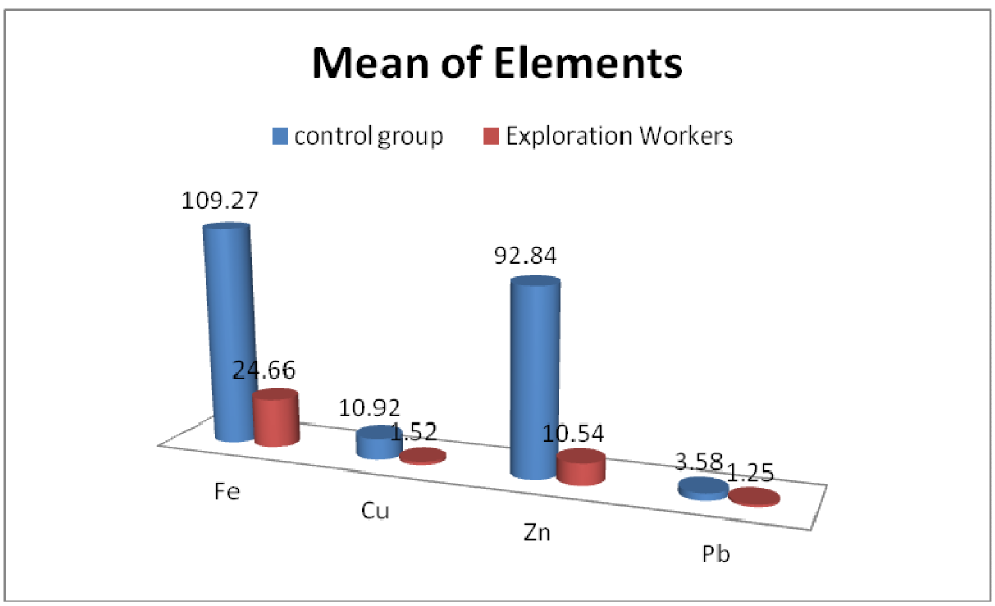

Figure1. Comparison Chart of Control group and exploration (gold) workers for Mean Element Concentration.

Conclusion

We reported five heavy metals Fe, Cu, Zn and Pb in human hair samples, The mean concentrations for these elements determined to be higher in the control group samples in comparing to the exploration workers group.

It is concluded that Since the exploration mining area far from the town and because of the traditional mining tools they use the worker are working hard and suffering water and food leakage beside the pollutant environment which lead the workers to illnesses as they will intake lower grade of metal concentrations, and necessary preventive measures need to be taken so as to protect the workers from the hazards of element leakage in their workplace.

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