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A Comparative Analysis on Levels of Mercury in Human Scalp Hair of Students from Different Locations in Ghana

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Abstract: This research was carried out to assess the levels of accumulation of total mercury (Hg-T) in human scalp hair samples from selected students. Thirty seven (37) human scalp hair samples were collected from students of the Kwame Nkrumah University of Science and Technology whilst on campus and analysed for total mercury (Hg-T) concentrations by cold vapour atomic absorption spectrometry. The least concentration, 0.007±0.001 μg/g was measured in a sample from a male student. The highest concentration, 5.535±0.133 μg/g was measured in a sample from a female student.5.4% of the population had Hg-T concentrations above the WHO, 1990 limit of 2 μg/g based on fish consumption. 94.6% of the population studied however measured Hg-T concentrations below the WHO limit. In general, the concentrations measured in female students were higher compared to concentrations in male students. The mean concentration of Hg-T in female students was 1.417±0.037 μg/g compared to 0.600±0.001 μg/g for male students. The higher concentrations measured in female students may be attributed to the application of Hg containing cosmetics aside environmental exposures.

Key words: Concentration, cosmetics, exposure, limit, population, spectrometry

INTRODUCTION

Mercury (chemical symbol Hg) is a heavy metal that occurs in several forms, all of which can produce toxic effects in high enough doses. Its zero oxidation state Hg^0 exists as vapor or as liquid metal, its mercurous state Hg^+ exists as inorganic salts, and its mercuric state Hg^{2+} may form either inorganic salts or organomercury compounds; the three groups vary in effects. Toxic effects include damage to the brain, kidney, and lungs (Clifton, 2007). Mercury poisoning can also result in several diseases, including acrodynia (pink disease), Hunter-Russell syndrome, and Minamata disease (Davidson *et al*., 2004).

The consumption of fish is by far the most significant source of ingestion-related mercury exposure in humans and animals, although plants and livestock also contain mercury due to bioaccumulation of mercury from soil, water and atmosphere, and due to biomagnification by ingesting other mercury-containing organisms (U.S.EPA, 1997). Exposure to mercury can occur from breathing contaminated air (TOXFAQS, 1999); from eating foods containing mercury residues from processing, such as can occur with high-fructose corn syrup (Dufault *et al*., 2009); from exposure to mercury vapor in mercury amalgam dental restorations (Levy, 1995); and from improper use or disposal of mercury and mercury-containing objects, for example, after spills of elemental mercury or improper disposal of fluorescent lamps (Goldman and Shannon, 2001). Other important human-generated sources include gold production, non-ferrous metal production, cement production, waste disposal, human crematoria, caustic soda production, pig iron and steel production, mercury production (mostly for batteries), and biomass burning (Pacyna *et al*., 2006). Some skin whitening products contain the toxic chemical mercury (II) chloride as the active ingredient. When applied, the chemical readily absorbs through the skin into the bloodstream (Counter, 2003). Much concern is therefore, about the potential for human intoxication due to mercury in foodstuffs particularly fish.

Mercury shows no significant functions in human but its exposure hazard includes permanent neurologic and Kidney impairment (U.S.EPA, 1997). Hair specimen tests are utilized in the assessment, detection, prevention, and treatment of heavy metal burden, nutritional deficiencies, gastrointestinal function, hepatic detoxification, metabolic abnormalities, and diseases of environmental origin.

Extensive research established that scalp hair element levels are related to human systemic levels. The strength of this relationship varies for specific elements, and many

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researchers consider hair as the tissue of choice for toxic and several nutrient elements. Hair is ideal for measuring toxic metals accumulated in the body tissues over a period of time. The growing hair follicle is well supplied by the blood vessels, and blood transports essential and toxic elements present in the body. These elements are incorporated and stored in the hair proteins, which are evaluated in the test. Hair testing also gives the most accurate information about interactions between nutrients and toxic metals. Other advantages of hair testing are simple samples requirements and lower cost. Hair element analysis provides important information, which can assist the professional to support early suggestions of physiological disorders, associated with aberrations in essential and toxic element metabolism (Harkey, 1993). Scalp hair is easy to sample and its growth rate, here assumed to be 1 cm/month, changes seasonally and varies between individuals and may also be affected by the presence of Cushing's syndrome (Thomson *et al*., 2010). Because of the fast growth rate of human scalp hair, it contains a "temporal record" of element metabolism and exposure to toxic elements. While data on the hormonal regulation of human hair growth is limited, it has been shown that the scalp hair of women grows faster than men (Myers and Hamilton, 1951). This study therefore seeks to determine the levels of accumulation of total mercury (Hg-T) in human scalp hair samples from selected students on the campus of Kwame Nkrumah University of Science and Technology.

MATERIALS AND METHODS

This research work was carried out between August 2009 and April 2010 in the Chemistry Department of the Kwame Nkrumah University of Science and Technology.

Sample collection: Human scalp hair samples were collected from thirty seven (37) students of the Kwame Nkrumah University of science and Technology (KNUST), Kumasi, Ghana whilst they were on campus. Nineteen of the students reside in Accra while eighteen reside in Kumasi. Accra is the capital city of Ghana and is characterized by cement, paints, steel, textiles and paper manufacturing industries. Kumasi is the capital city of the Ashanti region of Ghana and is characterized by mainly mining activities and timber processing. Hair samples were collected from the donors at one month intervals for three months. Each hair sample weighed between 0.25 to 0.40 g. Samples collected were each stored in clean plastic polyethene bags and taken to the KNUST Chemistry Instrumentation Laboratory.

Sample preparation and analysis: Samples were washed with acetone, three times with distilled water and washed again with acetone. Each sample was oven dried at 60ºC. Samples were uniformly cut to very smaller length and 0.2 g of the homogenized hair samples were weighed into 50 mL volumetric digestion flask followed by addition of 1 mL H_2O, 2 mL HNO_3-$HClO_3$ (1:1) and 5 mL H_2SO_4 in turns. The mixture was heated at a temperature of 200±5ºC for 30 min. The sample solutions were then cooled and diluted to 50 mL with double distilled water. A blank and standard solutions using 25, 50 and 100 μL of 1 μg/mL standard Hg solution were subjected to the same treatment as the samples.

Sample analysis: Automatic Mercury Analyzer Model HG-5000 was used to analyze total mercury in all the digested human hair scalp samples. It employs the batch mercury cold vapour generation system. The analyzer consists of an air circulation pump, a reaction vessel, $SnCl_2$. $2H_2O$ dispenser, an acidic gas trap and a four-way stop-cock with tygon tubes to which is attached a ball valve. Response are recorded and displayed on an electronic data processor (computer). Samples, blanks and reference standards were analyzed in triplicate.

RESULTS AND DISCUSSION

Table 1 shows the mean concentrations for triplicate measurements of Hg-T in the human scalp hair samples by the use of Cold Vapour Atomic Spectrometry Technique (HG-5000 Automatic Mercury Analyzer). A statistical summary of the results obtained is also presented in Table 2. The studied population exhibited scalp hair mercury concentrations below the 2 μg/g set by WHO, 1990 based on fish consumption except in two samples; H17 and H21 with mean Hg-T concentrations of 2.215±0.100 and 5.535±0.133 μg/g, respectively.

The results shows the concentrations of Hg-T in human scalp hair samples collected from 37 students within the ages of 18 and 27 years with no known history of occupational exposure to mercury. The concentration of total mercury in the samples analyzed ranged from 0.007 to 5.535 μg/g with a mean value of 0.717±0.045 μg/g. The highest concentration, 5.535± 0.133 μg/g which exceeded the WHO limit was measured for a 23 year old female student resident in Kumasi whiles the least concentration 0.007±0.001 μg/g was measured for a 25 year old student resident in Accra. It is clear from the results that age does not have any correlation with the measured concentrations of Hg-T in the samples. Interestingly, there is a trend with gender. Even though only 6 female samples were analysed, the mean concentration of Hg-T for females, 1.417±0.037 μg/g is marginally greater than the mean concentration, 0.600±0.001 μg/g measured for 31 male human scalp hair samples (Table 2). The relatively high concentration of Hg-T measured in female scalp samples compared to male samples may be due to application of Hg containing cosmetics by females. Table 3 presents a statistical

Table 1: Mean Concentrations of Hg-T in human scalp hair samples

Sample code	Age (years)	Gender	Residence	Concentration, µg/g
H1	25	M	Accra	0.165±0.001
H2	25	M	Accra	0.069±0.012
H3	25	M	Accra	0.007±0.001
H4	25	M	Accra	0.016±0.010
H5	25	M	Accra	0.970±0.022
H6	22	M	Accra	0.591±0.031
H7	22	M	Accra	0.175±0.001
H8	22	M	Accra	0.328±0.020
H9	22	M	Accra	1.182±0.101
H10	18	M	Accra	0.091±0.011
H11	18	M	Accra	0.534±0.102
H12	24	M	Accra	0.260±0.100
H13	26	M	Accra	0.676±0.201
H14	25	M	Accra	0.214±0.001
H15	19	M	Accra	1.915±0.031
H16	25	M	Accra	0.755±0.002
H17	25	M	Accra	2.215±0.100
H18	25	M	Accra	0.014±0.001
H19	25	M	Accra	0.291±0.022
H20	22	M	Kumasi	0.017±0.012
H21	23	F	Kumasi	5.535±0.133
H22	23	M	Kumasi	0.428±0.002
H23	22	M	Kumasi	0.432±0.010
H24	20	M	Kumasi	0.387±0.002
H25	21	F	Kumasi	0.009±0.001
H26	22	M	Kumasi	0.183±0.015
H27	23	M	Kumasi	1.495±0.031
H28	23	M	Kumasi	0.717±0.015
H29	23	M	Kumasi	0.943±0.006
H30	21	F	Kumasi	0.549±0.020
H31	18	F	Kumasi	0.715±0.022
H32	19	M	Kumasi	0.721±0.001
H33	26	M	Kumasi	0.599±0.021
H34	21	F	Kumasi	0.647±0.025
H35	23	M	Kumasi	0.917±0.012
H36	23	M	Kumasi	0.879±0.014
H37	24	F	Kumasi	0.906±0.002

Table 2: Statistical summary of donors

Description	N	Range	Mean, µg/g	SD
Female	6	0.647-5.535	1.417±0.037	2.143
Male	31	0.007-2.215	0.600±0.001	0.545
Total	37	0.007-5.535	0.717±0.045	0.961

Table 3: Statistics of donors based on residence

Residence	N	Range	Mean, µg/g	SD
Accra	19	0.007-2.215	0.551±0.055	0.632
Kumasi	18	0.009-5.535	0.893±0.029	1.213

summary of the measured concentrations of Hg-T in the samples based on place of residence when students are not on campus.

The concentrations measured in 19 human hair scalp samples form students resident in Accra ranged between 0.007-2.215 µg/g with a mean concentration of 0.551±0.055 µg/g. The concentrations from the 18 donors resident in Kumasi however ranged from 0.009-5.535 µg/g with a mean of 0.893 ±0.029 µg/g. The higher concentrations of Hg-T in human scalp hair from donors in Kumasi compared to donors in Accra may be due to differences in environmental background exposures aside the consumption of fish and the use of cosmetics. The levels of Hg in the air in Kumasi may be higher due to the numerous gold mining activities in the area. The geometric mean total hair mercury among pregnant women was reported to be 0.21 µg/g and did not differ from hair Hg levels of nonpregnant women (GM = 0.20 µg/g) by the US National Health and Nutrition Examination Survey (McDowell *et al*., 2004). Another study of high fish consumption in more than 100 persons shows mercury levels of 50 µg/g in areas of methylmercury contamination in Japan. Many factors are responsible for the variations in Hg levels in hair. Some of these factors include; colour of hair, the length of hair, and the species of fish the person consumes, the quantity

of fish consumption, the geographical location, the age and weight of the individual etc. The spectacular high value of 5.535 μg/g may not be solely due to high fish intake but also due to external exposures.

CONCLUSION

Hair Hg analysis in national samples provide a useful biomarker for long-term Hg exposure in humans. The results of this study indicate that all the hair samples obtained from the individuals and analyzed for total mercury had a 100 % incidence of Hg-T. The results of the study show that, 94.6% of the population had mercury concentrations below 2 μg/g as recommended by WHO, 1990 whilst 5.4% exceeded the limit. The relatively low concentration of total mercury in the hair samples may be due to less exposure from anthropogenic and other sources. However, the exceptionally high concentration of 5.535 μg/g measured in a female human scalp hair gives concern for further monitoring of Hg-T particularly in females. The levels of Hg-T in cosmetics on the Ghanaian market also need to be investigated periodically

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