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Determination of Heavy Metals Concentration in Hair Pomades on the Ghanaian Market Using Atomic Absorption Spectrometry Technique

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Abstract: Forty eight (48) hair pomade samples collected from female students at the University of Ghana campus were analysed for heavy metal content using atomic absorption spectrometry technique. The concentrations were compared with available data on internationally acceptable maximum limits for these elements and their possible health implications on the consumering public. Eleven (11) heavy metals were considered including Ca, Co, Cr, Cu, Fe, Mg, Mn, Ni and Zn (essential mineral nutrients) as well as Cd and Pb (toxic elements). All the samples recorded significant levels for most of the elements of interest except Cr concentrations which were below detection (<0.001 mg/kg) for each of the samples analysed. The mean and standard deviation concentrations for the elements in mg/kg are as follows: Ca (421.055±180.203), Co (16.036±5.479), Cu (3.758±2.270), Fe (209.866±67.531), Mg (19.830±24.310), Mn (9.800±2.423) and Zn (17.547±18.876), Cd (5.697±0.967), Ni (11.274±10.502) and Pb (8.269±4.864). Significantly some of the essential trace elements such as Co, Fe, Mn and Ni in the samples were quite high and exceeded reference levels in hair of healthy individuals from different countries, while the remaining elements were within the range. Also the Cd and Pb content of the samples were above the permissible limits for heavy metals in cosmetic products. There is therefore the need for immediate and regular mandatory testing of imported and local cosmetic products specifically hair pomades into the Ghanaian market by the appropriate regulatory authority to prevent the associated health risk and ensure consumer safety.

Key words: Cosmetics, concentration, health risk, limits, metals

INTRODUCTION

Exposure of Ghanaian populist to heavy metals from sources such as food, water, medicinal plants used for herbal preparations, the environment among others have been published in some studies (Anim *et al*., 2011; Annan *et al*., 2010; Boateng, 2007; Asklund and Eldvall, 2005). Little attention has been paid to heavy metals exposure from sources such as personal care products, specifically hair pomades on the Ghanaian market. Information on the exposure to metal toxins through dermal contact is very scanty or in some cases no data exist on heavy metal concentrations in personal care products (Ayenimo *et al*., 2009) in a number of places around the world.

Of the many heavy metals available in our universe only few of them are of significant health benefit to mankind. A greater number of these metals however may be toxic even in small amount (Health Concerns, 2003). Some heavy metals of nutritional value to the human body include calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), nickel (Ni) and zinc (Zn). These mineral nutrients function as part of body enzymes and also required for proper composition of body organs such as bone, blood, and the maintenance of normal cell function (Murray, 2007).

Toxic metals such as cadmium (Cd) and lead (Pb) often accumulate in the human tissues when they are not metabolized by the body for absorption and utilization (Health Concerns, 2003). The danger of these toxic metals on the human body is enhanced when there is low intake of the essential mineral nutrients in our diets. Consequently, the toxic metals compete with the essential mineral nutrients for their absorption (Wilson, 2008). However, availability of the essential mineral nutrients in the body would serve as a protection against toxic metals absorption and utilization. For instance cadmium causes kidney damage and bone degradation because it affects

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calcium metabolism (Waalkes, 1991). Zinc has been reported to cause similar signs of illness as lead, and can easily be mistakenly diagnosed as lead poisoning (Mc-Cluggage, 1991). Lead in toxic amounts in the human body inhibits oxygen and calcium transport and alters nerve transmissions in the brain. Studies show that even low concentrations of lead in the body can cause permanent damage, including reduced IQ and learning disabilities (http://www.bewholebewell.com/.../WhatYouShouldKnowAboutHeavyMetals.pdf). Research has established that lead can cross the placenta during pregnancy and has been associated with intrauterine fatal death, premature delivery and low birth weight (Papanikolaou *et al*., 2005; Al-Saleh *et al*., 2009).

Generally, humans are exposed to heavy metals by ingestion through drinking or eating, by inhalation through breathing or by absorption through the skin when they come in contact with humans during our daily activities in agricultural, pharmaceutical, industrial or residential settings among others (Ekpo *et al*., 2008). The major sources of heavy metals for non-occupationally exposed adults are from food and drink according to World Health Organization (WHO, 1995) research estimates in various countries. Also industrial activities and products that expose us to heavy metal toxins include the manufacturing of pesticides, batteries, alloys, electroplated metal parts, textile dyes, steel among others (International Occupational Safety and Health Information Centre, 1999).

Heavy metals can enter into human hair through a variety of sources, both endogenous and exogenous (Ryan *et al*., 1978; Moon *et al.*, 1988; Sonofonte *et al*., 2000). Endogenous source are more important than the exogenous ones for evaluating the health status of an individual as a function of physiological anomalies. The later is however very significant when studying nutritional unbalances and uptake of environmental toxicants (Evans and Jervis, 1987; Sonofonte *et al*., 2000).

The incorporation of elements into the keratin structure of hair takes place by binding to the sulfhydryl groups that are present in the follicular protein. In this regard, it should not be overlooked that detergents such as soap and shampoos, hair pomades, lotions, hair bleaches and dyes actually compete with the complexing ability of these reactive sites, thus leading to a significant leaching of elements from the shaft bulk (Sonofonte *et al*., 2000).

The scalp hair is more prone to heavy metal contamination from the environment and cosmetic treatments in most cases (Sonofonte *et al.*, 2000). Koranteng-Addo *et al*. (2010) analyzed the level of lead and zinc in human scalp hair in occupationally exposed workers in Cape Coast, Ghana and reported that the exposure level increased with the number of years an individual spent at the work place. Even though the amount of hair pomade applied daily by an individual is relatively small compared to exposures from food, water or air intake. Notwithstanding, bioaccumulation of these heavy metals can result through over time usage and hence their attended health problems.

From the information gathered on country of manufacture of the hair pomades sampled, it shows that most of the products are imported. The laxity in regulatory inspection of personal care products especially hair pomades on the Ghanaian market whether locally manufactured or imported, allows for the sale of products with harmful ingredients that would eventually jeopardize the health of consumers. Hence, there is the need to analyze the heavy metal contents of these products on the Ghanaian market periodically.

The elements Cd, Cr and Pb are all naturally occurring substances which are often present in the environment at low levels. In larger amounts, they can be dangerous. Toxicity from these heavy metals can lead to damaged or reduced mental and central nervous systems function, lower energy levels, damage to blood composition, lungs, kidneys, liver and other vital organs (Health Concerns, 2003). Long-term exposure may result in slowly progressive physical, muscular and neurological degenerative processes that mimic Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis (International Occupational Safety and Health Information Centre, 1999; Health Concerns, 2003).

This study focuses on heavy metals concentration in common hair pomades often used by Ghanaian female students at the University of Ghana, Legon campus. The concentrations of heavy metals; Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Ni, Pb and Zn in sampled hair pomades are compared to available data on internationally acceptable maximum limits for these elements and their possible health implications on the consumers.

MATERIALS AND METHODS

The study was conducted between May - October, 2010 at Nuclear Chemistry and Environmental Research Centre, Ghana atomic Energy Commission.

Sample collection: Hair pomades often used by Ghanaian female students on the university of Ghana campus, Legon were collected at random. In all 48 hair pomade samples were collected from female students in the various halls of residence depending on availability and willingness to volunteer the sample for the research. About 30-60 mg of each sample was scooped or taken from their respective container or tube, mostly in the jelly state into a virgin, pre-cleaned zipped polyethylene bag and labeled accordingly. Each of the volunteer students was interviewed to ascertain the mode of application of products. Questions include; frequency of application, whether the pomade is mixed with another product before application, any reaction on the scalp upon application among others. Also, information on country of manufacture and ingredients on the product label were noted where available. The plastic spatula used in scooping the samples was carefully cleaned using cotton soaked in acetone to prevent contamination or introducing one sample into the other, and the spatula was replaced after every ten samples. The samples were packaged and stored in a refrigerator prior to digestion and analysis.

Sample preparation and analysis: Each of the hair pomade sampled were analyzed using the following digestion protocol for liquid oil sample: 0.2 g of the sample was weighted into labeled 100 mL polytetraflolureothylene (PTEF) Teflon bombs. Volume of 4 mL 96% concentrated sulfuric acid (H_2SO_4) and 2 mL of 40% Hydrofluoric acid (HF) were added in a fume chamber. The samples were then loaded on a microwave carousel. The vessel cap was secured tightly using an appropriate screw tool. The complete assembly was microwave irradiated for 21 min in a Milestone microwave Labstation (Ethos 900) using the following operation parameters; 250 W for 5 min, 0 W for 1 min, 250 W for 10 min, 450 W for 5 min, and 5 min allowed for venting (Milestone cook book, 1996). After digestion the Teflon bombs mounted on the microwave carousel were cooled in a water bath to reduce internal pressure and to allow volatilized material to re-solubilize. The digestate were made up to 20 ml with de-ionised water. Blanks and reference standards were treated in a similar manner. Single element standards of the elements of interest were obtained from Spectrascan, Sweden. The elements of interest were assayed using a Varian AA240FS Atomic Absorption Spectrophotometer at Nuclear Chemistry and Environmental Research Centre, Ghana atomic Energy Commission. Acetylene gas was used as the fuel with air as oxidant. A calibration curve was drawn using diluted standard solution from the stock (Spectrascan, Sweden). Quantification of the elements of interest was achieved using the calibration curve for each element.

RESULTS AND DISCUSSION

Table 1 gives a summary of the statistical analysis of the concentrations of heavy metals in forty eight (48) hair pomades sampled from female students at University of Ghana campus.

Table 1: Statistical summary of heavy metals concentration in hair pomade samples

		Element concentration (mg/kg)				
Element	n*	Mean	SD	Median	Interval	5th - 95th percentile
Ca	47	421.055	180.203	425.485	63.066-688.300	102.936-663.361
Cd	47	5.697	0.967	5.871	4.200-6.800	4.940-6.665
Co	46	16.036	5.479	3.000	10.667-25.350	11.537-24.140
Cr	nil	BDL	BDL	BDL	BDL	BDL
Cu	46	3.758	2.270	3.050	0.700-12.800	1.540-6.835
Fe	47	209.866	67.531	215.625	81.600-421.000	109.945-294.990
Mg	36	19.830	24.310	18.392	1.394-91.884	12.732-63.460
Mn	47	9.880	2.423	10.000	5.400-15.000	7.070-13.625
Ni	28	11.274	10.502	9.200	1.300-72.000	0.650-32.400
Pb	34	8.269	4.864	7.550	1.300-17.700	0.325-16.540
Zn	47	17.547	18.876	12.200	1.600-89.500	3.240-53.140

n*: Total number of samples analysed in this study is 48. However values lower than this under this column means that in such instance the element concentration in those samples are below the detection limit for the analytical technique applied. Hence, these values were not used in the statistical analysis. The abbreviation BDL means below detection limit for the element

Table 2: Reference values for elements in the hair of healthy individuals from different countries compared with levels in hair pomades for this study (mg/kg).

Element	Ghana (This study)	Italy (Sonofonte *et al.*, 2000)	England (Ward, 1988)	USA (ML, 1989)	Canada (Ryan *et al.*, 1978)	Japan (Kamakura, 1983)	New Zealand (Ward, 1986)	Bulgaria (Ward, 1987)
Ca	63.066-688.300	11–3101	150-1620	1-2220	0.7-93.1	190-3700	250-1380	170-1900
Cd	4.200-6.800	0.03-1.72	0.11-0.99	0.10-0.43		0.05-0.57	0.36-1.51	0.56-2.71
Co	10.667-25.350	0.02-3.83	0.01-0.20	0.20-0.23		0.13-0.49	0.04-0.10	0.03-0.17
Cr	Bdl	0.03-19.7	0.03-1.88	0.20-0.41		0.20-0.77	0.56-1.92	0.20-1.02
Cu	0.700-12.800	0.29-280	4.6-19.4	6.5-18.0	4-245	6.0-69.1	3.42-8.12	7.2-19.4
Fe	81.600-421.000	0.29-216	5.2-38.7	4-150		5.5-87.4	18.4-52.8	12.9-96.4
Mg	1.394-91.884	0.10-313	30.4-81.6	1-160		14-567	73-149	25-129
Mn	5.400-15.000	0.02-7.59	0.21-3.95	0.06-0.36	0.03-3.72	0.06-4.51	0.57-1.68	0.20-4.30
Ni	1.300-72.000	0.03-10.0	0.44-7.10	0.40-1.30		0.17-3.00	1.62-4.52	0.55-3.59
Pb	1.300-17.700	0.12-36.7		2.00-4.00		1.4-18.0		
Zn	1.600-89.500	24-477	142-260	120-220	108-357	72-327	158-293	144-284

The statistical analysis describes the pattern of distribution of the heavy metals in all the samples under study. Mean concentration with standard deviation (SD) of each of the eleven (11) heavy metals under consideration have been listed. The median, interval and percentile (5-95%) values of the concentration of each element have been indicated as well.

Calcium (Ca) and Mg are essential macro nutrients required for proper functioning of the human body. For instance, Ca is a constituent of bone and required for muscular contraction (Sonofonte *et al*., 2000). Whereas magnesium play a role in the transport process of sodium (Na) and potassium (K) across cellular membrane and in the functional integrity of the neuromuscular system (Sonofonte *et al*., 2000).

The mean and standard deviation concentration of Ca in the samples is 421.055±180.203 mg/kg. Figure 1 shows that Ca content represent the highest mean concentration compared to the other elements in the samples. This may be due to the fact that it is needed to compensate the skull calcium content (www.fao.org/DOCREP/004/Y2809E/ y2809eOh.htm). Too much of Ca, however, can cause the hair to feel dry, lack shine and volume. Also when Ca build-up on the scalp it causes flaking of the scalp resulting in dandruff (http://en.wikipedi.org/wiki/ Hair_care#Hair).

Table 2 shows the range of heavy metal content in hair of healthy individuals from various countries. Referring to these values for the purpose of this analysis, Ca concentration has a wide range of values with a maximum limit of 3700 mg/kg for Japan. Although this values do not reflect Ca content in cosmetic products only but from varied source contributions including those from ingestion, inhalation as well as through skin contact. Calcium content of this study is far lower than the range of values referred to in hair of healthy individuals from different countries.

Magnesium (Mg) concentration in the samples has mean and standard deviation of 19.830±24.310 mg/kg and ranges between 1.394-91.884 mg/kg. Comparing the Mg content of the samples with the levels in the hair of healthy individual from various countries, it is clear that the concentrations are lower than most of the upper limit for the various countries except for England. Hence, these Mg concentrations in the samples are essential for hair growth.

The elements (Co, Cr, Cu, Fe, Mn, Ni and Zn) are essential trace minerals with various functions in the human body. Cobalt (Co) is necessary for normal functioning and maintenance of red blood cells and all other body cells (Life Enthusiast Co-op International Inc., 2010). The presence of Cr in the body facilitates the entry of glucose into the cell (Tamari, 1987). Cu is also one of the most important blood antioxidants and prevents

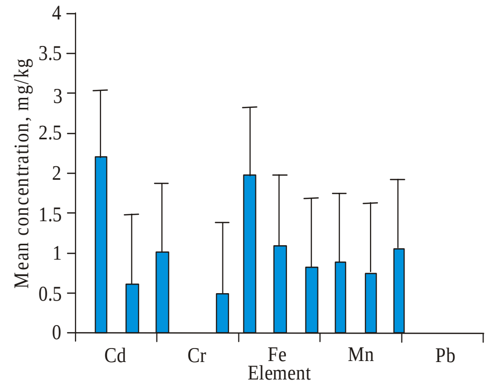

Fig. 1: Bar chart of mean concentration of elements in hair pomade samples on log10 scale with standard deviations as error bars

rancidity of polyunsaturated fatty acids and helps the cell the membranes remain healthy (Life Enthusiast Co-op International Inc., 2010). Manganese is part of various enzymes in synthesis of erythrocytes and plays a role in nervous function. Fe is essential for certain enzymes as well as for the formation of muscle and red blood cell pigments, and prevention of hair loss (Mineral Information Institute, 2011; Natural Hair Loss Prevention, 2009). The function of Ni in the human body is not quite clear, but it is known that it can inhibit or activate certain enzymes, play a role in metabolism of glucose and hormonal functions (http://www.themedifastplan. com/ feature articles/nutrientg-lossary/; http://www.food mineral. com/2011/05/functions-of-nickel.html). Whiles Zn is a constituent of enzymes and insulin, required for healthy growth of skin and hair Mineral Information Institute, 2011).

Chromium concentrations in each of the forty eight hair pomade samples analyzed were all below the detection limit of 0.001 mg/kg. The mean and standard deviation concentrations of Co, Cu, Fe, Mn and Ni Zn measured in the samples under study were 16.036±5.479, 3.758±2.270, 209.866±67.531, 9.800±2.423, 11.274±10.502 and 17.547±18.876 mg/kg, respectively. Since there are no available internationally acceptable maximum limit for these elements in cosmetic products to refer to for this discussion, the reference values in hair was used. The reference values for Co, Cu, Fe, Mn, Ni and Zn in hair of healthy individuals were; 3.83, 280, 216, 7.59, 10.0 and 477 mg/kg (Table 2) respectively for the upper limits for Italy. Cobalt, Fe, Mn and Ni were above these reference values but Cu and Zn were below the respective maximum values. The levels recorded for Zn may be due to the fact that a reasonable amount of zinc is needed to prevent dandruff (Boilab Medical Unit, 2010). Although the level of Cu measured was below the reference value, excessive amount in the soft tissue of the body has adverse effect, the most common ones are hair

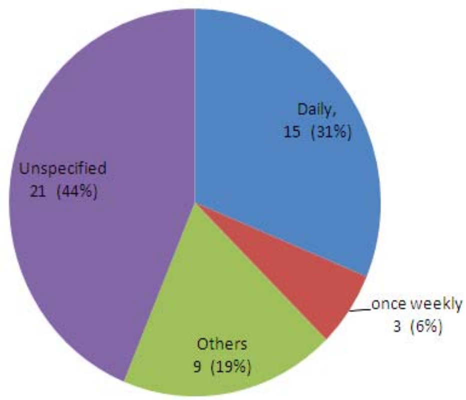

Fig. 2: A pie chart showing the frequency of application of the hair pomades by the volunteers

loss especially in women (http://drlwilson.com/articles/copper_toxicity_syndrome.htm). The concentration level measured in Co, Fe and Mn raises some concern for the content of these hair pomade products, taking into account the number of times the pomade are applied as shown in Fig.2.

About 41.7% of the samples analyzed for Ni were below the detection limit of 0.001 mg/kg. The mean concentration of Ni in the analysed samples was>10.0 mg/kg. Although this limit may be on the high side considering the sources of contribution into the human body and the hair specifically, it serves as reference value for analysis. Hence, exposes the consumers of these hair pomade products to long term health risk including symptoms of anemia, depressed oxidative ability of liver, dermatitis, high new born mortality, cancer, high incidence of heart and thyroid diseases (Life Enthusiast Co-op International Inc, 2010; Mineral Information Institute, 2011).

Cadmium and Pb are toxic elements even in small concentrations in the human body. Pb is one of the most popular heavy metals in elemental analysis, possibly due to the numerous adverse health challenges it creates in various organs of the human body. In Ghana, the requirement for Pb in cosmetic products is 1.0 ppm (1.0 mg/kg) according to the Ghana Standards Board, however there is no available permissible limit on Cd for such products. The mean and standard deviation concentrations of Cd and Pb measured in the samples were 5.697±0.967 and 8.269±4.864 mg/kg and they are within the concentration interval 4.200-6.800 mg/kg and 1.300-17.700 mg/kg respectively. Per the Ghana standards for Pb in cosmetics (in this case hair pomade) products, it implies that the Pb content of each of the samples is above this permissible limit. Considering the bioaccummulative nature of Pb and the pattern of application of the hair pomades as shown in Fig. 2, one cannot rule out the long term health complications. Lead (Pb) exposures has been linked to significant health related problems such as anemia, kidney damage, high blood pressure, infertility and reduced learning abilities (Al-Saleh *et al*., 2009). Available data on Cd in cosmetic puts the permissible limit at 3 ppm (3 mg/kg) and 5 ppm (5 mg/kg) for Canada and Germany (Health Canada, 2009) respectively. Some studies report that any amount of Cd is forbidden in all types of cosmetics due to its threat to human health because significant dermal exposure can cause irritant dermatitis (Ayenimo *et al*., 2009; Health Canada, 2009). The measured mean concentration for Cd>5 mg/kg, exposes consumers of these hair pomades to health risks. Cadmium exposure above permissible limits has been reported to cause kidney damage and metabolic anomalies caused by enzyme inhibitions (CAOBISCO, 1996).

CONCLUSION

The result of the analyses indicate that the concentrations of the essential elements which comprises of Ca, Cu, Mg and Zn are generally within reasonable levels necessary for the hair as well as the body relative to the reference values (Table 2). However, some of the essential trace elements such as Co, Fe, Mn and Ni were quite high and exceeded reference levels in hair of healthy individuals from different countries. Chromium content of the samples were significantly low (<0.001 mg/kg). However, significant concentrations above the permissible limits for the toxic elements Cd and Pb were measured in most of the hair pomade samples. These call for immediate and regular mandatory testing of imported and local cosmetic products, specifically hair pomades to ensure consumer safety.

Nonetheless, one should not overlook the fact that both essential and toxic elements accumulate in the body with time due to the frequency of their usage. If these elements are not eliminated at the rate at which they bioaccummulate they pose serious health risk to their consumers.

The lack of appropriate permissible limits for most of these elements for Ghana, regular inspection and laboratory analysis of the elemental content of such products on the market exposes the population to avoidable health risks. Whereas, in the US, FDA lay the responsibility on the cosmetic manufacturers to ensure the safety of their products and ingredients before introducing them to the market. As part of the manufacturing and import inspections, and follow-up to complaints of adverse reaction from cosmetic and related products, samples are examined and analyzed regularly for compliance to safety regulations (US FDA, 2005).

It is therefore important to expand the scope of the this study to cover wider consuming public, additional toxic elements of significant interest to health as well as conduct extensive population exposure risk assessment study of the hair and other cosmetic products on the Ghanaian market.

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REFERENCES

Al-Saleh, I., S. Al-Enazi and N. Shinwari, 2009. Assessment of lead in cosmetic products. Regulatory Toxicol. Pharmacol., 54: 105-113.

Anim, A.K., E.K. Ahialey, G.O. Duodu, M. Ackah and N.O. Bentil, 2011. Accumulation profile of heavy metals in fish samples from Nsawam, along the Densu River, Ghana. Res. J. Environ. Earth Sci., 3(1): 56-60, ISSN: 2041-0492, Maxwell Scientific Organization.

Annan, K., A.I. Kojo, A. Cindy, A. Samuel and B.M. Tunkumgnen, 2010. Profile of heavy metals insome medicinal plants from Ghana commonly used as components of herbal formulations. Phcog Res., 2: 41-44.

Asklund, R. and B. Eldvall, 2005. Contamination of Water Resources in Tarkwa mining area of Ghana. Department of Engineering Geology, Lund University, KFS AB, Lund, Sweden.

Ayenimo, J.G., A.M. Yusuf and A.S. Adekunle, 2009. Heavy Metal Exposure from personal care products. Bull. Environ. Contam. Toxicol., 84(1): 8-14.

Boateng, O.D., 2007. The quality assessment of some herbal preparations produced in Ghana. M.Sc. Thesis, Submitted to Department of Chemistry, Kwame Nkrumah University of Science and Technology, Kumasi.

Boilab Medical Unit, 2010. Hair Mineral Analysis. Nutritional and Environmental Medicine, London, England. Reterived from: www.biolab.co.uk.

CAOBISCO, 1996. Heavy Matal. Retrieved from: www.caobisco.com/doc-uploads/nutritional-factsheets/metals.pdf.

Ekpo, K.E., I.O. Asia, K.O. Amayo and D.A. Jegede, 2008, Determination of lead, cadmium and mercury in surrounding water and organs of some species of fish from Ikpoba River in Benin City, Nigeria. Int. J. Phy. Sc., 3(11): 289-292.

Evans, G.J. and R.E.J. Jervis, 1987. Hair as a boi-indicator: limitions, complications in the interpretation of results. Radiational. Nucl. Chem. Art., 110: 613-625.

Health Concerns, 2003. Heavy Metal Toxicity. Life Extension Foundation. Reterived from: http://www.lef.org/, http://www.bewholebewell.com/.../What You Should Know About Heavy Metals.pdf. http://www.themedifastplan.com/feature-articles/nutrientglossary/. http://www.foodmineral.com/2011/05/functions-of-nickel.html.

Health Canada, 2009. Draft Guidelines for Heavy Metalsin Cosmetics. Retrieved from: http://www.hc-sc.gc.ca/cpsspc/legislation/consultation/_cosmet/metal-metaux-eng.php.

International Occupational Safety and Health Information Centre, 1999. Prevention Today, 5(3): 1-12.

Kamakura, M.A., 1983. Study of the characteristics of trace elements in the hair of Japanese-Reference values, the trace elements patterns for determining normal levels. Jpn. J. Hyg., 28: 823-838.

Koranteng-Addo, J.E., E. Owusu-Ansah, L.K. Boamponsem, J.K. Koka and R.O. Agjei, 2010. Analyses of lead and zinc levels in human scalp hair in occupationally exposed workers in Cape Coast, Ghana. J. Chem. Pharm. Res., 2(5): 384-391.

Life Enthusiast Co-op International Inc., 2010. Symptoms of Mineral Deficiencies. Carson City, NV 89701United States. Reterived from: http://www.life-enthusiast.com/index/Products/Minerals/Symptoms-of-Mineral-Deficiencies.

Mc-Cluggage, D., 1991. Heavy Metal Poisoning, NCS Magazine, Published by the Bird Hospital, CO, USA. Reterivedfrom:(www.cockaties.org/articles/diseases/metals.html).

Milestone cook book, 1996. Digestion report code 240. Milestone Application lab.Mineral Lab. USA, 1989. Supplied data.

Mineral Information Institute, 2011. The Role of Elements in Life Processes. Adam Aircraft Circle Englewood, CO 80112 USA.

Moon, J., A.J. Davinson, T.J. Smith and S. Fadl, 1988. Correlation clusters in the accumulation of metals in human scalp hair: Effects of age, community of residence, abundances of metals in air, water supplies. Sci. Tot. Environm., 72: 87-112.

Murray, M., 2007. Value of Hair Mineral Analysis. Reterived from:http://www.thenhf.com/old/articles-466.htm. (Accessed on: February 25, 2011).

Natural Hair Loss Prevention, 2009. Retrieved from: http://www.keepingyourhair.com/natural-hair-loss-prevention/hair-loss-and-nutrition#more-90. (Accessed on: May 03, 2011).

Papanikolaou, N.C., E.G. Hatzidaki, S. Belivanis, G.N. Tzanakakis and A.M. Tsatsakis, 2005. Lead toxicity update. A brief review. Med. Sci. Monit., 11: RA329-RA336.

Ryan, D.E., J. Holzbecher and D.C. Stuart, 1978. Trace elements in scalp-hair of persons with multiple sclerosis, of normal individuals. Clin. Chem., 24: 1996-2000.

Sonofonte, O., N. Violante and S. Caroli, 2000. Assess of reference valves for element in human hair of urban schoolboys. J. Trace Elements Med. Bio., 14: 6-13.

Tamari, G.M., 1987. Metabolic role of minerals analytical and clinical considerations. Original published Med. Organica, 16: 36-40.

US FDA, United States Food and Drug Authorities Guidance for Industry. Center for Food Safety and Applied Nutrition (CFSAN), 2005. FDA Authority over Cosmetics. Retrieved from: http://www.cfsan.fda.gov/dms/cos-206.html.

Waalkes, M.P., 1991. Cadmium and human health. Health Environ. Digest., 5(4):1-3.

Ward, N.I. and C. Cambell, 1986. Increased bromide levels in serum, hair during lithium treatment. J. Affective Dis., 11: 161-164.

Ward, N.I., N.M. Spyrou and A.A. Damyanova, 1987. Study of hair element content from an urban population using NAA assessment of environmental status. J. Radioanal. NucI Chem.,116:125- 135.

Ward, N.I., Personal Communication, 1988, cited in Sonofonte, O., N. Violante and S. Caroli, 2000. Assess of reference valves for element in human hair of urban schoolboys. J. Trace Elements Med. Bio., 14: 613.

WHO, World Health Organization, 1995. Environmental Health Criteria 165: Inorganic Lead, Geneva: International Programme on Chemical Safety. World Health Organization, Geneva.

Wilson, L., 2008. The Dangers of Toxic Metals. Retrieved from: http://www.dreddyclinic.com/dangers-of-toxic-metals.htm.