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Research

Impact of hair dyeing on the levels of essential and non-essential metals in human hair

***[1]Chukkol S. K., [2]Hamisu A. M., [3]Shabanda I. S., [4]Bayero A. S., [5]Mohammed K. A., [4]Danmaraya Y. A., and [4]Koki I. B.**

**[1]Department of Chemistry, Bauchi State University,Gadau, Bauchi State, Nigeria.*

[2] Department of Chemistry, University of Malaya (UM), Kuala Lumpur, Malaysia.

[3]Department of Chemistry, Kebbi State University Aliero, Kebbi State, Nigeria.

[4]Department of Chemistry, Yusuf Maitama Sule University, Kano State, Nigeria.

[5]Department of Biological Science, The martyr Shaker Al-Hashoush school, Thi-Qar Education Directorate, Iraq.

Corresponding author <*skchukkol@gmail.com*>

Abstract

Scalp hair samples were collected for the assessment of some essential and non-essential metals using atomic absorption spectroscopy (AAS). A total of 8 subjects were randomly collected comprising of 4 male non-dyed hairs and 4 female dyed hairs. In all the samples analysed, the effect of hair dyeing on essential and non-essential metals contents were evaluated. The result showed that concentrations of metals are higher in female subjects with dyed hair and differ significantly ($p<0.05$) with metal male non-dyed hair. The findings revealed that both essential and non-essential metals were introduced from the dyeing cream used. Dyeing of hair can therefore change the content of the metals in hair. Due to the growing usage of dyeing creams, it is imperative to regulate and monitor its application.

Keywords: AAS, essential, non-essential, scalp hair, dyed hair

Introduction

Hair can be described as a biological medium use in medical diagnostics, as a marker of element levels in the body (Długaszek et al. 2012). It is considered to be an attractive biological material because of the simplicity of sampling, transport and handling as well as providing information about concentrations of some trace elements that are considerably more concentrated in hair than in other biological materials which makes analysis easier (Abdulrahman et al., 2012). Trace elements can be classified into two classes namely, essential and non-essential elements (Ayse et al., 2010). The essential elements include copper (Cu), Zinc (Zn), Iron (Fe), etc (Ayse et al., 2010).These elements play a significant role in proper human development (Fakayode et al., 2013). For instance, Zn is found in the tissues of human body and is involved in cell division, it prevents cancer because it is a powerful antioxidant (Devasagayam et al., 2004). Zn deficiency may cause effects such as growth retardation in children, poor bone growth, brain disorders, poor sense of taste and smell among others. Fe is essential for the production of blood, and about 70 % of our body's Fe is found in the red blood cells known as haemoglobin which is vital for the transport of oxygen in our blood from lungs to tissues (Gupta, 2014). Fe deficiency causes anaemia, it can also cause fatigue and can affect human memory especially teens (Katsuhiko, 2017). Normal tissue functionality depends on Cu, it reduces inflammation and strengthens connectivity of tissues and it also fights against cancer cells (Shivraj et al., 2013). Cu is stored throughout the body as an enzyme, it is important and also plays a vital role in grey hair colour (Falah et al., 2017). Deficiency of Cu causes a grey hair colour and can also lead to osteoporosis, brittle bone, skeletal abnormalities and wrinkled sagging skin (Williams, 1983).

Non - essential elements such as lead (Pb), arsenic (As) and cadmium (Cd) are toxic even at lower concentrations and can cause serious health issues (Wong et al., 2006). Heavy metals such as Pb are absorbed via inhalation and food ingestion which causes kidney dysfunction and damage to the central nervous system (Duruibe et al., 2007; Koki and Jimoh, 2013). Studies revealed that dizziness and headache experienced by workers are associated with high Pb and chromium (Cr) in the scalp hair sample (Peter et al., 2012). Compounds of Pb as an element are very harmful to humans especially infants and children which can lead to death (Koki et al., 2015). It can also cause damage to the brain and the central nervous system, slowed growth, hearing problems, headache, and hyperactivity among others (Baysal and Akman, 2010).

Essential and non-essential elements can be found in cosmetics as additives or as impurities due to contamination during the production process (Ahmed et al., 2017; Almeida et al., 2019; Bounmysay and Ruengsitagoon, 2019), and remains a practice in contemporary industrial settings. Hair dye is one of the commonly used cosmetic product and is applied directly on the scalp which exposed the user to some harmful elemental components of the dye, via absorption through body organs, especially through skin pores (Nohynek et al., 2010). Prior to 1960, it was believed that presence of these metals in cosmetics such as hair dye that are applied on the surface of the body has no effect on internal organs (Orisakwe and Otaraku, 2013). But it was later discovered that these metals can penetrate the skin and accumulate in the body tissue causing toxicity to the body (Al-Saleh and Al-Doush, 1997). Hair dyeing is more common and frequent among women compared to men, resulting in higher exposure to toxic metals in a lifetime (Ulter et al., 2014), hence gender was chosen as a factor for assessing metal levels in human hair (Liang et al., 2017).

Hair samples are cheap and relatively fast to analyse in the laboratory using AAS, which can easily detect and quantify non-essential and essential minerals in hair samples (Ivan and Enzo, 2011). Human hair was selected as one of the important monitoring materials of biological pollution by the global environmental monitoring system (GEMS) of the United Nations environmental programme. Moreover, hair is used in forensic investigations in the absence of body fluids like blood, urine and tissues after the death of a person as such it is left as a piece of evidence for years (Pascal, 2004). It is an important material used in the determination of both organic and inorganic substance to study nutritional or occupational sources on the body (Rahman et al, 2000). Therefore, analysis of essential and non-essential metals (Cu, Zn, Cd, and Pb) in human scalp hair serves as an assessment for environmental pollution which can be used to study the levels of the metals and exposure of the individuals. Hence, in this study, we evaluate the level of exposure to Cu, Zn, Cd, and Pb among 8 subjects comprising of dyed and non-dyed hair groups.

Materials and methods

Sample collection: Hair samples were collected randomly from 8 subjects (4 female dyed hairs and 4 male non-dyed hairs) from Kuala Lumpur city, Malaysia. Comparison is made between male and female due to women's fashionable character of hair colouring/dyeing which stands at more than 75% higher than men. Scalp hair samples were obtained by normal cutting with the aid of hair clippers and sealed immediately in clean plastic bags after collection to avoid any external contamination. The samples were then transported to analytical chemistry laboratory, University of Malaya for analysis.

Quality control: All chemicals were of analytically grade and are used without further purification. Nitric acid (65 %), solutions of 1000 PPM of Copper nitrate ($Cu(NO_3)_2$), Zinc nitrate ($Zn(NO_3)_2$), Cadmium nitrate ($Cd(NO_3)_2$) and Lead nitrate ($Pb(NO_3)_2$) were obtained from Darmstadt, Germany. Laboratory vessel used where soaked in 10 % (v/v) HNO_3 for an hour and rinsed with deionised water and oven-dried.

Sample pre-treatment: About 3 mm length of each hair samples were cut using a stainless steel scissors and mix to ensure homogeneity. Each Sample was then put into 250 mL beaker and was washed with acetone to remove all organic substances and followed by washing with deionised water to remove all the soluble impurities. Each washed hair samples was dried at a temperature of 110 ^{o}C in oven for over an hour and allowed to cool in desiccator before digestion.

Sample digestion: 1 g of each sample was weighed with the aid of electronic weighing balance and each sample was placed into a 100 mL beaker (i.e. each sample was prepared in duplicate). 10 mL of concentrated nitric acid was added into each beaker. The beakers were covered with a watch glass and each beaker containing the samples was allowed to pre-digest at room temperature for duration of 15 minutes. The mixture was heated gently until each hair sample dissolves and gives a transparent clear solution. The beakers containing the sample solutions were further heated to boiling for 15 minutes and allowed to cool. The container walls and watch glass were washed with deionised water. Each sample solution was filtered into 25 mL volumetric flask and a stepwise dilution was performed using 2 % nitric acid.

Instrumentation: Flame atomic absorption spectrometry (A Analyst 400 PerkinElmer, Singapore) was used to determine Pb, Cd, Cu and Zn at wavelengths 217, 228.8, 324.7 and 213.9 nm respectively at slit widths of 0.7 nm.

Results and discussion

The statistical analysis including mean and standard deviations of Cu, Zn, Pb and Cd concentrations in the dyed and non-dyed hair samples were calculated using MS Excel 2010, and presented in table 1. The results shows a wide variation in the metal concentrations with mean Cu concentrations ranging from 5.6 – 45.4 µg/g. The highest Cu concentration was recorded in female dyed hair while male non-dyed hair records the lowest Cu concentrations (Fig 1). High Cu concentrations in some of the female dyed hair in comparison to the male non-dyed hair may be linked to the presence of Cu in hair dyeing cream (Wei et al., 2008). It is believed that dyeing of human hair can introduce heavy metals into hair, but the levels are different for different element, and depends on the period or duration of the exposure (Massadeh et al., 2011). Cu is an important element to human life as it helps in cellular metabolism but at elevated concentrations could be harmful to humans. Diseases such as stomach and intestinal irritation, anaemia, adrenal hyperactivity and insufficiency, allergies, hair loss, strokes, and hypertension are associated with exposure to high concentration of Cu. Long term exposure to Cu may culminate to kidney and liver damage (Abdulrahman et al., 2012).

Table I: Heavy metal concentrations in hair samples analysed (µg/g).

Sample ID	Cu	Zn	Pb	Cd
FDH_1	11.9 ± 0.30	156.0 ± 3.40	11.7 ± 1.50	1.3 ± 0.60
FDH_2	9.4 ± 0.00	145.3 ± 0.00	4.1 ± 0.00	0.9 ± 0.00
FDH_3	45.4 ± 9.20	234.5 ± 40.60	7.3 ± 0.80	1.4 ± 0.60
FDH_4	41.2 ± 0.20	142.4 ± 0.70	6.9 ± 0.90	1.3 ± 0.40
MNH_1	15.5 ± 0.80	151.7 ± 8.80	4.2 ± 0.10	0.8 ± 0.01
MNH_2	11.0 ± 0.10	105.5 ± 2.00	6.7 ± 1.50	1.0 ± 0.30
MNH_3	5.8 ± 0.03	130.2 ± 1.00	4.3 ± 0.00	0.7 ± 0.07
MNH_4	5.6 ± 0.20	107.3 ± 6.10	4.4 ± 0.20	0.7 ± 0.0

FDH = Female dyed hair, MNH = Male non-dyed hair

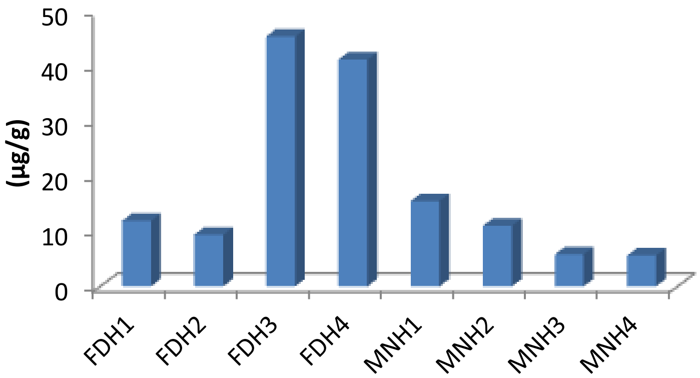

Fig 1: Levels of Cu concentrations in hair samples

From fig 2, the highest concentration of Zn was also recorded in female dyed hair, the concentrations were in the range of 105.5 – 234.5 µg/g. Low Zn concentrations were observed in most of the male non-dyed hair. Inconsistencies in dyeing and differences in brand of the dyeing cream could lead to the variations in metal levels in the dyed hair (Wei et al., 2008). Zn is an important trace mineral that humans need to stay healthy (Chasapis et al., 2012). Zn is found in body cells throughout the body, and it is needed for the defensive body immune system to work properly. It plays a significant role in cell division, cell growth, wound healing and breakdown of carbohydrates. It is also needed for senses of smell and taste. During pregnancy, infancy and childhood the body needs Zn to grow and develop properly, and it also facilitates the action of insulin. Zn deficiency is characterized by growth retardation, loss of appetite and impaired immune function. In more severe cases Zn deficiency causes hair loss, diarrhoea, impotence, delayed sexual maturation, impotence, hypogonadism in male's eye and skin lesions. Weight loss, delayed healing of wounds, taste abnormalities and mineral lethargy may also occur.

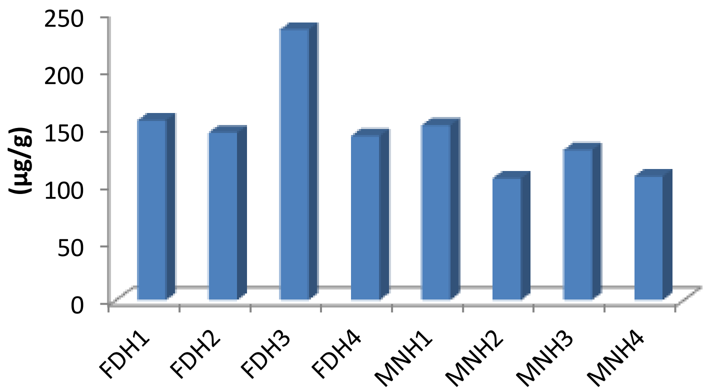

Fig 2: Levels of Zn concentrations in hair samples

The concentrations of Pb in the analysed hair samples were between 4.1 – 11.7 µg/g, and fig 3 revealed that highest Pb concentration was recorded in female dyed hair samples except for FDH2. The low concentration of Pb in FDH2 could be due to low exposure to the dyeing substances. Presence of high concentrations of Pb in the female dyed hair indicates that dyeing introduces Pb in the hair. Strumylaite et al., 2004 reported significant concentrations of Pb in the dyed hair samples. The levels of Pb in the analysed hair samples for the entire subjects studied were much lower than values reported in Poland and China (Michalak et al., 2014; Zheng et al., 2011). Exposure to high levels of Pb can culminate to severe brain damage, kidneys and ultimately leads to death. Long term exposure can result in back pain problems, constipation, convulsion, diabetes, depression, headache, migraine, thyroid imbalance, abdominal pain, arthritis, attention deficit, anaemia etc (Abdulrahman et al, 2012).

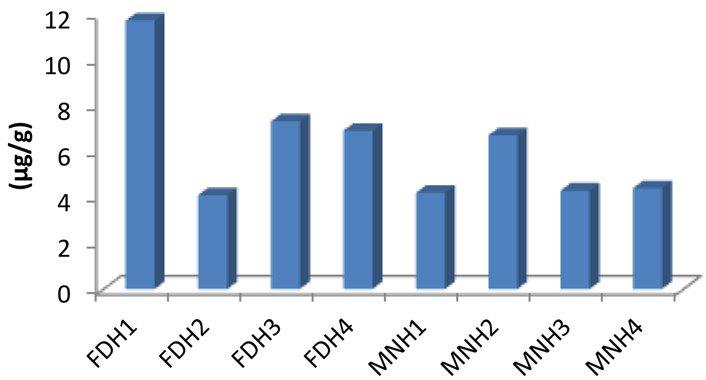

Fig 3: Levels of Pb concentrations in hair samples

The levels of Cd in the hair samples analysed varies from 0.7 – 1.4 µg/g. The highest concentrations of Cd were observed in female dyed hair as shown in Fig 4, while the lowest concentrations were recorded in male non-dyed hair. The differences between the concentrations of Cd in the female dyed and male non-dyed hair could be traced to the dyes applied (Prakash et al., 1988). The levels of Cd in hair samples were lower than values reported in Poland (Trojanowski et al., 2010). Cd is known to be a very toxic metal to humans, and long term exposure to Cd could lead to several diseases such as fragile bones, arthritis, cardiovascular disease, lung damage and kidney disease (Abdulrahman et al, 2012).

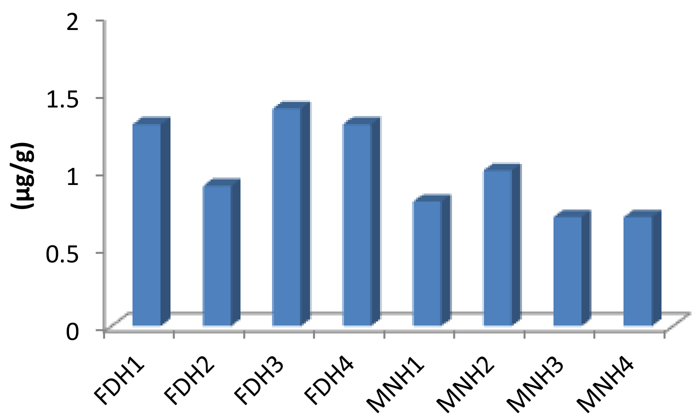

Fig 4: Levels of Cd concentrations in hair samples

Conclusion

The present work provides the background concentrations of selected heavy metals in dyed and non-dyed hair samples comprising of female dyed hair and male non-dyed hair. In all the samples analysed, the impact of heavy metal levels on hair dyeing were evaluated. The results indicate that significant levels of heavy metals in the female dyed hair could be attributed to the dyeing of hair, and frequent exposure may reach toxic levels by adsorption through human skin. Thus appropriate action needs to be taken to monitor and regulate dyeing of human hair for the health and safety of the citizens.

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