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Determining the Presence of Lead in Various Brands of Commercial Hair Dyes by Atomic Absorption Spectroscopy

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Abstract

Forensic analysis of hair dyes may offer higher-level information regarding oxidative and non-oxidative dyes. Prolonged exposure to heavy metals, such as arsenic, mercury, lead, nickel, cadmium, and copper, can pose a significant health risk. It is evident that heavy metals and their by-products present in cosmetic products such as lipsticks, soaps, face creams, hair gel, and hair dyes are absorbed in the bloodstream through the skin and root of the hair, and atomic absorption spectroscopy was used to investigate 10 hair dye samples from various manufacturers in the current study. This study focuses on evaluating the level of lead contamination in hair dyes that are frequently used by Indians. The results showed that the lead concentration was higher than the WHO/FDA-set maximum allowable level. Consequently, the continuous use of hair dyes can be prevented. Chronic or dangerous impacts are possible because of health hazards linked to exposure to contaminants through the skin or other pathways.

Keywords: - Atomic Absorption Spectrophotometry; hair dyes; lead; heavy metal

1. Introduction:

The use of cosmetic products among the human population have been increased globally and become a global tradition to beautify the individual[1]. A number of items are included in the cosmetics such as facial, eyes and lips cosmetic products, hair dyes, shampoo, toothpaste, lotions, perfumes, creams, hair gel and antiperspirants etc[2]. These products are used by all groups or classes of people throughout the world. And the use of harmful heavy metals in those cosmetic products are of great concern because the presence of the heavy metals raises safety issues[3]. Among the various practices of beautification, hair dyeing is also one of the vastly popular practices nowadays in which hair are treated with different kinds of chemicals. The first synthetic dye was prepared in the laboratory in 1856 [4]. The different kind of components which are generally used in hair dyes consists of modifiers, alkalies, antioxidants, dyes, fragrances, wetting agents and a number of chemical items in small amounts which give special qualities to the hair [5]. Hair dyes are grouped into temporary, permanent, semi-permanent, demi permanent depending upon their colour resistance. The temporary dyes stays only on the cuticle while the permanent ones goes deeper into the cortex region and stays there maximum upto six washes [6].The heavy metals are present in the cosmetic products as ingredients; for example the zinc oxide is used in sun

screens, lead in hair dyes and in skin lightening creams, the various inorganic mercury compounds are used etc. The heavy metals in these cosmetic products are added deliberately as active ingredients or preservatives and found as left over impurities in the raw materials of cosmetics. For example, the mercuric chloride and lead carbonate are added in the cosmetics to peel and whiten the skin [7]. Humans are exposed to heavy metals by inhalation, ingestion, absorption or can be through other daily activities or housing activities [1,8]. Out of the twenty trace metals, ten are considered to be the most toxic to the mankind. Mainly, the five heavy metals such as arsenic, mercury, cadmium, nickel and lead are considered highly toxic to the human system which is emitted as a result of anthropogenic activities [9]. There are a number of risk factors behind the exposure to heavy metals which leads to reduced or damaged central nervous system and affecting vital organs of the body. On the other hand, the long term exposure can lead to decreased progressive physical, muscular and neurological functions which can further result into Parkinson's disease, Alzheimer's disease, multiple sclerosis and muscular dystrophy etc [10]. The uses of cosmetics in routine life have increased the concentration of heavy metals in the body which is further affecting the body organs and our body system. Cadmium is categorized as human carcinogen which mainly targets the renal system, bones, teeth etc. The reason for adding cadmium in the cosmetic products is the colour property of cadmium, so used as colour pigment. Arsenic is another toxic heavy metal which gets deposited in the nails, skin, hair and it get absorbed into the body through inhalation and ingestion. The hyper pigmentation, keratosis, dermatitis, kidney cancer, leukaemia etc are the chronic exposure results of arsenic [11,12]. The present study is mainly focused on the estimation of heavy metal lead (Pb) in the various hair dyes. Lead is an element of group -14 of the periodic table. The concentration of lead in the crust of earth is about 12.5mg/kg and in the oceans about 0.03mg/L [13]. Lead is one of the highly toxic heavy metal which is mainly responsible for affecting the enzymatic activities like synthesis of heme, affecting the development of nervous system and CVS and Renal and endocrine system [14]. The pregnant women are highly at risk because lead can penetrate through across the placenta and enters into the embryo blood circulation [4]. The various toxic elements and their compounds are soluble in water , simultaneously the sweat endorse the dermal absorption of these toxic elements or absorption further go ahead in the blood vessels and cause consequent complexities [15,16].

The dermal absorption rate for lead is about 0.3% and for percutaneous is about 0-0.3% following the hair dyes preparations when applied onto the skin [17]. As, the use of beauty products across the worldwide is found as tradition from the ancient time. By keeping this in mind, a study was conducted to detect lead and cadmium as heavy metals in the lipsticks. The levels of lead and cadmium were found within the range of 0.08-5.2 µg/g and 4.08-60.20 µg/g respectively [18]. In Malaysia, the popularly sought herbal medicine, generally used the treatment of fever; pain etc. was subjected through AAS to detect the levels of lead in it. And the results shown that the eight percent of analyzed products possessed the 10.64 -20.72 ppm of lead [19]. Sindoor, another cosmetic item used by women whose long-lasting use raises health issues and lead toxicity. Various health issues, hair loss, edema, eye cancer, greying of hair, skin cancer etc. are caused by the use of synthetic dye-based sindoors. The study reported that the herbal sindoor with no side effects to replace synthetic preparations for worship and other uses [12]. The trends of tattoos among men and women have been also become popular across the worldwide in the recent years. The case studies and surveys shown that the tattooing skin raises adverse skin problems and also found that tattoo ink cause skin cancer. The study was conducted to detect the heavy metals in the tattoo ink and coloured ink used for making tattoos. The lead concentration was found highest in the black tattoo ink about 57.0978mg/ kgDW [20]. The use of heavy metals is banned or prohibited in most of foreign nations [21]. Lead and its compounds have been banned in the European laws for Cosmetics since 1976 [22]. In the temporary tattoos, oxidative hair dyes, henna, the most commonly found component is para-phenylenediamine (PPD). The use of PPD in hair dyes results in allergies and hair dye contact dermatitis [23]. As, henna is practiced to create temporary tattoos in some regions of Asia, PPD or other impurities are added as to enhance the colour of henna, but it results in various complications, causing skin allergies or dermatitis etc [24]. The use of cosmetics and skin glowing products are in demand across the world among the women of all age groups. The real composition and the additives in such products are sometime hidden or not mentioned in the constituents list by the manufacturers and importers. Due to this reason, the toxic components or impurities added to the products raise heath issues, skin complications, allergies, toxicity and other so many toxicological health risks [13]. There were many studies performed for the detection of heavy metals in the cosmetic products. The concentration of lead detected in the different samples in those different studies is listed in the table – (1). Keeping all these risk factors in mind, the present study has been designed to diagnose the lead in the various hair dyes.

Table-1. Showing the lead estimation results in different studies

S.No	Heavy metal	Instrumentation used	Samples selected	Quantity of Lead	References
1	Lead	AAS	Lipsticks	0.27 -3760 PPM	21
			Eye shadows	0.42-58.7 PPM	
2	Lead	AAS	Herbal medicine	10.64-20.72 PPM	18
3	Lead	ICP-MS	Cream products	2401.72-4379.24 ppb	24
			Shampoo	592.88-29,683.12 ppb	
			Soap	164.49-5812.78 ppb	
			Toothpaste	1856.34-6313.00 ppb	
4	Lead	Flame AAS	Fairness creams	28.85µg/g	25
5	Lead	ICP-optical emission spectrometry	Cosmetic products	DETECTED IN 82 SAMPLES OUT OF 112; 73.2% ; 7.8 ppm	6
6	Lead	AAS	Facial cosmetics	12-240 µg/g	26
7	Lead	ICP-MS	Henna bark	15.13 µg/g	27
			Walnut tree bark sample	23.16 µg/g	
8	Lead	Graphite furnace - AAS	Lip gloss	0.75 µg/g	28
			Lipstick	0.38 µg/g	
9	Lead	Flame emission spectrometer	Tattoo inks	Maximum for Black ink =57.0978 mg/kg DW	29
10	Lead	Graphite Flame - AAS	Different Hair Dyes: Liquid dyes	1.0-11.3 µg/L	30
			Dust dyes	14.0-100 µg/kg	
			Cream dyes	19.9-187 µg/kg	

2. Methodology: -

2.1 ***Collection of samples***

10 hair dye samples were collected from the local Indian market (Kharar, Punjab). They were divided in two categories branded and non-branded samples. Developers and dyes were mixed in different ratios to prepare a hair dye. In category-I all hair dye samples were creamy whereas, in category-II 12 samples were in powder form. The creamy samples were prepared using the developers present with the respected hair dyes and the powder sample was prepared using water as mentioned in the instructions.

Sample preparation

Sample preparation for heavy metal determination was done at room temperature. Sample extraction was done using nitric acid (HNO_3). For powder samples 10mg of sample was taken and mixed with 10 ml of HNO_3. For both creamy and powdered samples equal ratio (10:10) ml of dye and HNO3 was mixed. The sample was allowed to stand for 15 minutes and then, heated on the heating mantle at boiling point of nitric acid until all the acid evaporated i.e. until all the brown fumes disappeared [31]. Measured quantity of sample + HNO_3 → Extracted sample

After that 20 ml of deionised water was added to the sample and it was heated gently again until the volume is 10ml. The suspension was cooled down and filtered through the whatman filter paper, washing the filter paper and beaker with deionised water until a volume of about 25 ml is obtained. Thus, the samples were taken for AAS analysis in the borosilicate vials.

Analysis of the sample

The standard of lead were analysed in different ppm (5, 10, 15) by AAS. The prepared hair dye samples were analysed for lead and compared with the standard. The AAS used was model 240 FS AA equipped with hollow cathode lamp, acetylene air flame resonance line wavelength 217.0 nm.

Thus, the 10 hair dye samples were analysed in AAS (model- 240 FS AA).

Results and discussion

Heavy metals toxicity has been exemplified as the problem of environment pollution and hazardous health impact, it is necessary to know about the all possible sources. In this context, we have tested different hair dye products for the presence of lead. Total 30 branded and non-branded samples of hair dye were taken for the study.

According to the results obtained using atomic absorption spectrophotometer it has been observed that the lead is present in both branded and non-branded hair dyes. FDA has banned the use of lead in hair dyes as it had been proved that lead acetate which been used as a colouring agent in hair dyes, is a neurotoxin and has various adverse effects on human body as well as the environment.

Table-2. Lead concentrations (ppm) in hair dye samples

Sample(n=30)	Lead(in ppm) Mean ± S.D
Category -1(non-branded) n=15	**2.33± 0.20**
Category-2(branded) n=15	**2.56±0.32**

Table 3. Showing standard values of the heavy metal i.e. lead

Standard	Concentration (ppm)	Absorbance	%RSD
1	5.00	0.0416	1.1
2	10.00	0.829	0.4
3	15.00	0.1249	0.7

Table 4. Showing absorbance values of the hair dye samples obtain by AAS

HEAVY METAL(LEAD)	Concentration (ppm)	Absorbance	% RSD
SAMPLE 1	**2.06**	**0.0172**	**3.0**
SAMPLE 2	**2.57**	**0.0213**	**3.2**
SAMPLE 3	**2.26**	**0.0188**	**2.4**
SAMPLE 4	**2.52**	**0.0210**	**0.4**
SAMPLE 5	**2.31**	**0.0192**	**3.0**
SAMPLE 6	**2.18**	**0.0181**	**3.7**
SAMPLE 7	**2.45**	**0.0204**	**2.0**
SAMPLE 8	**2.98**	**0.0247**	**3.4**
SAMPLE 9	**2.40**	**0.0199**	**0.8**
SAMPLE 10	**2.80**	**0.0232**	**1.2**

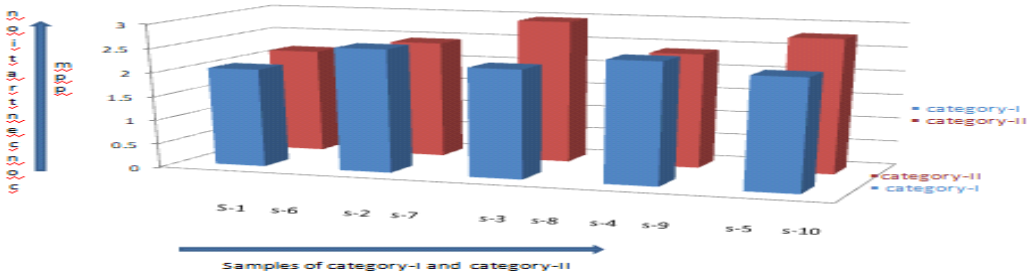

Figure-1 Represents the concentration of lead present in category- I (non branded) category –II (branded)

According to the information presented in Figure I, the hair dye market comprises two categories: non-branded and branded. Lead, a heavy metal, was identified in all hair dye samples analyzed. As indicated in Table 1, the concentration of lead in all 10 samples exceeded the permissible limit of 0.6 ppm, with an average of 2.33 and 2.56 for the branded and non-branded hair dyes, respectively. The lead content in branded hair dyes ranged from 2.18 to 2.80, whereas the lead content in non-branded hair dyes ranged from 2.06 2.52. The absorbance values for Category-1 range from 0.017 to

0.0213, whereas those for Category II ranged from 0.0181 to 0.0247, as indicated in table-3 when compared to the standards at different concentrations (ppm) shown in table-2. Consequently, it can be inferred that Category II hair dyes contained more Pb than Category I hair dyes. Furthermore, branded products generally contain higher amounts of heavy metals than non-branded or local products do. This is because lead is used to achieve a darker hair color and maintain it for an extended period. Also, the permissible limit of lead to be present in the hair dyes is 0.5 ppm to 0.6 ppm [2] and according to the results obtained the amount of lead present is more than this permissible limit. Several cases and studies have reported hair dye poisoning and other cosmetic toxicities [2]. In all the samples analyzed using AAS, higher amounts of lead were detected, although the use of heavy metals as coloring agents in higher amounts is forbidden by the FDA. The United States Food and Drug Administration (FDA) has determined that lead acetate, a common ingredient in hair dyes, no longer complies with safety regulations because of its potential to cause a range of adverse health effects. The decision of the FDA to phase out lead acetate from hair dyes is a crucial step in safeguarding the public from continued exposure to lead, a toxic substance known to pose significant health risks. Consequently, it is imperative that alternative color additives are employed to ensure the safety of consumers and prevent the onset of various health-related issues associated with lead exposure.

4. Conclusion

The current study encompasses an analysis of the lead concentration in hair dyes that are available in the market, including both branded and non-branded samples. It is clear that lead is one of the most harmful toxic metals found in hair dyes and poses significant health risks. According to the findings obtained through AAS, the presence of lead in hair dyes exceeds the permissible limit. It is noteworthy that branded hair dyes contain higher levels of lead than non-branded products. Prolonged use of products contaminated with heavy metals may result in the gradual release of these metals into the human body, leading to severe health consequences. It is essential to eliminate these elements from the body at the same rate at which they accumulate, as they pose a significant risk to consumers' health. These heavy metals may damage the nervous and reproductive systems and can even cause cancer or death. Therefore, it is important to be aware of the presence of heavy metals in hair dyes so that they can be used accordingly. According to the FDA, the use of lead acetate as a color additive should be banned, and lead acetate must be replaced with other color additives, as lead is a neurotoxin.

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Conflict of Interest: None to declare.

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