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DETECTION AND RISK OF TOXIC METALS IN COSMETICS

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ABSTRACT

Cosmetic products are a part of our daily routine for people all around the world. We use products to look good and feel good about ourselves. Cosmetic products also help people express who they are. Even though we use cosmetic products every day there is a problem. There are things like heavy metals in some cosmetic products. These heavy metals are not good for us. That is a big concern for our health. Cosmetic products are used by millions of people. That is why it is a big deal that some cosmetic products have these toxic heavy metals, in them. Cosmetic products can have things in them like lead and cadmium and arsenic and mercury and chromium. These things can get into the products by accident when the raw materials or the pigments or the preservatives that are used to make them are not clean. The way the products are made can also cause these bad things like lead and mercury and chromium to be, in them. These metals are often found in amounts but people can still get sick from them if they touch them breathe them in or swallow them by mistake. This can happen over and over again. Build up in the body causing big problems. Heavy metals can cause skin problems, like itching and rashes. Can also hurt the nerves and hormones in the body. They can even cause problems with having babies and make people more likely to get sick. Heavy metals can also cause cancer. This review looks at what researchers from around the world have found out about metals in cosmetic products like where they come from and how they can hurt people. It also looks at what the government says about metals, in these products. The thing about metals is that we really need to know how to find them and measure them. So we look at the ways to do this like atomic absorption spectroscopy or AAS for short and flame atomic absorption spectroscopy, which is also called FAAS. There are methods too such as inductively coupled plasma optical emission spectroscopy or ICP-OES and X-ray fluorescence, which is also known as XRF. These methods are really good at detecting metals because they are very sensitive and accurate. This is important for making sure cosmetics are safe to use and for following the rules that're in place to regulate these things. Heavy metals and their detection are crucial, for cosmetic safety assessment and regulatory surveillance of metals. The review emphasizes the necessity for continuous monitoring, standardized analytical protocols, stringent quality control during manufacturing, and harmonized international regulatory frameworks to effectively minimize heavy metal exposure and safeguard consumer health.

INTRODUCTION

The role of forensic chemistry detects heavy metal ions in complex samples such as biological tissues, food, water, soil, and cosmetics. Greek term “kosmeticos,” meaning “to adorn,” or “to enhanced,” generates the word “cosmetic”. Cosmetics are products that people put on their skin to keep or improve the health and look of the region without changing how the body normally works. Since ancient times, cosmetics have been used to improve one's appearance and beauty in addition to cleaning. Although their essential function hasn't altered throughout time, the manufacturing process for cosmetics has. At first, they were made with natural components in modest amounts. However, large-scale manufacture that included synthetic and petrochemical-based materials occurred as a result of industrialization. Consumer desire for natural ingredients has increased recently, leading to a return to more natural cosmetic

formulas. Consequently, a number of health and safety issues have been brought up by the extensive manufacturing of cosmetics using a variety of components. Cosmetics are often regulated these days. Cosmetics are divided into a number of categories, including cosmetics (makeup), nails, skin care, soaps, oral hygiene products and hair care products and fragrance.[1] There are more than twenty heavy metals, but lead (Pb), Cadmium (Cd), Mercury (Hg), and Arsenic (As) are four heavy metals which pose a significant threat to human health and the environment. These metals are poisonous and can cause harm even at low levels.[2] Any material or composition intended for application to the skin, lip, and external genitalia, as well as to the teeth and oral mucosa is referred to as a cosmetic product. Variety of cosmetics such as lipsticks and lip glosses for colouring the lips, foundation, concealer, powder, and rouge for colouring the face, lightening and removing flaws to create the appearance of youth and health, mascara for enhancing eyelashes, eyeliners and eye shadow for colouring the eyelids, nail polish for colouring fingernail or nails, and creams and lotion that typically cleanse the face and body, unclog pores, allow for proper perspiration, and protect the skin from acne, pimples, and blemishes. Actors utilize sophisticated cosmetics to alter their physical appearances in addition to improving their beauty.[3]

1.1 Heavy metals

There are over twenty known heavy metals, but four in particular- Lead (Pb), Cadmium (Cd), mercury (Hg), and arsenic (As) are extremely dangerous because of their high toxicity and capacity to negative impact the environment and the human health.[4] Notably, some metals can have major negative consequences even at trace amount .usually found in the d- block and p- block of the periodic table, heavy metals are distinguished by their metallic properties and propensity to form different salts. Although the criterion may range slightly throughout scientific sources, many definitions also link heavy metals to heavying a high atomic mass. Lead, cadmium, nickel, mercury, and arsenic are a few examples of these metals.[5] Using cosmetics like face powder, lipstick, and eye shadow on a daily or frequent basis can lead to the build-up of certain of these heavy metals in human system.[6] The presence of heavy metals in both living and non-living ecosystems is a major source of worry. In biological systems, these metals can interfere with or replace important trace elements that are necessary for health. This interference might result in metabolic imbalances and faulty biological processes. Importantly, the harmful consequences of heavy metal accumulation are not restricted to humans and mammals; similar toxic effects, including increased morbidity and death, have been observed in insects, other animal species, and even plants.[7]

Table 1.1 Heavy metal commonly found in cosmetics.

Metals	Main sources in cosmetics	Health effects
Lead (Pb)	Lipsticks, eyeliners	Neurotoxicity, anemia
Cadmium (Cd)	Color pigments	Kidney damage, cancer
Chromium (Cr)	Eye shadows, foundation	Skin allergies, lung cancer
Arsenic (As)	Whitening creams	Skin and internal organs toxicity
Mercury (Hg)	Skin lighteners	Brain, kidney, immune system damage

2. Common heavy metals found in cosmetics and their consequences

- **Lead: lead (Pb)** is one of the most extensively studied **toxic heavy metals,** primarily due to its harmful impact on human health. Unlike other elements that may be intentionally used for their beneficial properties, lead is typically regarded as a contaminant**.** When it enters the body and accumulates in vital organs**,** lead exhibits neurotoxic, nephrotoxic, and hepatotoxic effects—damaging the nervous system, kidneys, and liver, respectively. Its toxicity is especially concerning because it can cause both acute and chronic health issues, even at low exposure levels may also have adverse effects on the reproductive system.[8-9] Lead can also affect fatal development through its passage via the placenta.[10] Consumers who use eye cosmetics had three times the level of lead in their blood compared to non-consumers.[11] Numerous researches have looked into the presence of lead in cosmetic products, with lipsticks being among the most thoroughly studied. In fact, more than fifteen researches have focused solely on cosmetics product category. Notably, just one study found no lead (Pb) in lipstick samples, showing the extensive contamination risks connected with this cosmetic item.[12] Lead also present in lip gloss.[31] Three more investigations found insignificant Pb level in lipsticks as the lower limit.[14] Most investigations found Pb levels within the FDA's permitted limit of 20 ppm.[15] Some research investigated whether there were any differences between high- and low- priced lipsticks (0.06 ppm).[12]

- **Cadmium:** Cadmium is a metal used in cosmetics for its colourful salts, which range from deep yellow to orange.[6] Toxicities in humans have been linked to its absorption by topical cosmetics despite the low (0.5%) concentration.[18] Due to its potential to cause oxidative stress, it also contributes to skin aging. The primary issue with Cd is its propensity to build up in human tissues before gradually escaping

into the bloodstream. It typically attaches itself to the keratin, though. It primarily impacts the skeletal, reproductive, and metabolic systems and Renal and respiratory systems.[19] It has been linked to renal damage, lung cancer, diabetes, osteoporosis.[20] Several authorities have outlawed cadmium, another element that is still present in some cosmetics, according to multiple researchers. One study indicating that lipsticks don't contain Cd was carried out by.[21] Levels below 0.002 ppm and levels up to 60.20 ppm were recorded in a number of different investigations. However, only two investigations revealed elevated levels of Cd over 5 ppm.[14] Lipstick use may be connected to systemic toxicity because it can be consumed. A study found a difference between lipsticks and lip gloss that cost high (0.34 ± 0.20 ppm) and those that cost less (0.89 ± 0.58 ppm). It was reported that mascaras had a decreased Cd concentration (0.034 ppm).[22]

- **Arsenic:** Arsenic is a common metalloid and a significant environmental pollutant. Despite being redox inactive, it targets sulfhydryl groups on proteins, which can deplete glutathione.[23] This amino acid-based antioxidant protects cellular components from radicals and heavy metals. Long-term dermal contact with as can induce.[23] Although it can cause hyperpigmentation and keratosis locally, it can also contribute to cancer and vascular problems on a systemic level. Contamination of cosmetic items extends beyond permissible limits. It is commonly found in cosmetic items sold on the underground market.[14] The FDA set a restriction of 3ppm for As in lead acetate, a colorant that may contain this metalloid, similar to the limit for Hg.[24] This permissible maximum limit falls below the general limits specified by Health Canada for all cosmetics.[25] Arsenic and its salts are prohibited in cosmetic products in the EU.[26] Several investigations show that as is not a significant pollutant, with levels rarely exceeding 3 ppm. Most research report a level of up to 0.34 ppm in lipsticks[26,28] However one study found a maximum. 6.931 ppm of as.[14] One study higher levels were reported for body lotions (1.543 ppm).[29] As levels in mascaras do not exceed 3.704, 2.071, or 1.656 ppm [28]. Shampoos, conditioners, and color for hair contain low as concentrations (<0.71 ppm). A study found that cleansers and sunblock contain no more than 0.010 ppm of as.[27] Some skin-lightening lotions exceed the 3 ppm threshold, which raises concerns. As is likely present as a contaminant alongside other heavy metals employed in this process. Despite these findings, as is a rare ingredient in cosmetics.[30] The presence of this substance may cause problems, especially in long-term legal products and illegal cosmetics on the underground market. These may cause an issue. Pb can be absorbed through both mucosal and gastrointestinal tract routes. In certain investigations, the level of Pb in toothpaste is quite low (0.036 ppm).[33] However, in other investigations, the greatest amount was 12.04 ppm and 18.092 parts per million.[34] Lead is a pollutant found in varying amounts in cosmetic preparations. Several agencies have recognized Pb as a dangerous metal by setting up Limits to its presence in cosmetics.

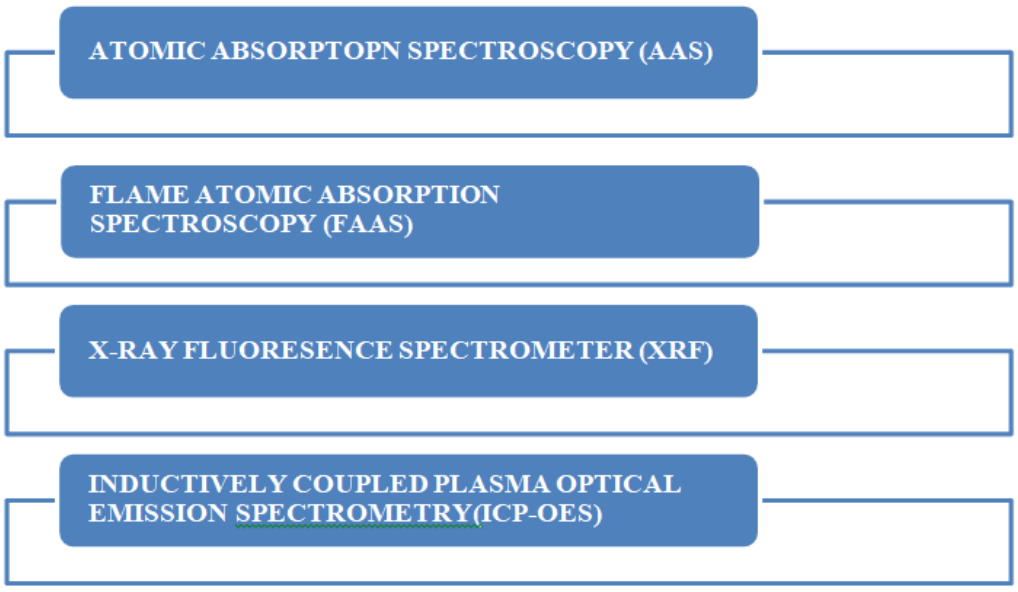
Table 1.1 Heavy metal commonly found in cosmetics.

S.NO	Pb	Cd	As
Lipstick	<DL-252.4 (21,22,24,31)	ND-60.20 (14,21,22,24,31)	0.01–6.931 (14,13,28)
Body lotion	<DL to 47.5 (28)	ND (28)	ND-0.007 (29)
Face cream	ND-1.9 (27)	ND-0.37 (27)	ND-0.171 (27)
Mascaras	ND-12.51 (14,15,32)	ND-0.03 (14)	0.050–1.656 (14)

Table 2.2 Techniques used to detect heavy metals detection.

Study	Year	Country	Sample type	Lead (Pb)	Cadmium (Cd)	Arsenic (As)	Detection method
Chauhan et al.	2010	India	Soap, shampoo, face cream	Present in soaps	detected	Not detected	AAS
Liu et al.	2013	USA	Lipstick, lip gloss	0.3-7.19 ppm	Not detected	Not detected	ICP-OES
Al-Saleh et al.	2009	Saudi Arabia	Lipstick, eye shadows	0.43-13.65 ppm	0.02-0.52 ppm	Not detected	AAS
Shabir et al.	2017	Pakistan	Kajal, lipstick, face powder	0.5-9.2 ppm	0.05-1.8 ppm	0.01-0.5 ppm	FAAS
Sain et al.	2021	Indian	Foundation, compact, eye shadow	1.8-6.2 ppm	0.1-0.7 ppm	Not detected	ICP-OES
Saah et al.	2024	West Africa	lipsticks	detected	detected	Not detected	XRF

3. Detection and analysis of heavy metals by different analytical techniques



- **ATOMIC ABSORPTION SPECTROSCOPY (AAS)**

Atomic absorption is one of the most commonly used spectroscopy method for small amount metal analysis used by **Sainio et al. (2000).** It work on the Principle of uses the absorption of light by free atoms in the gaseous state to calculate the concentration of metals. Application is commonly used for detection metals like lead (Pb), Chromium (Cr), and Cadmium (Cd) **Sainio et. al (2000)** used AAS to determine the presence of Pb and Cr in lipsticks and other cosmetics products**.**

Chauhan et al. (2010) studied determination of lead and Cadmium in cosmetics products. Five cosmetics products

(soap, face cream, shampoo, shaving cream, and talcum powder) of three different brands (coded as A, B, C) were collected from local market of Gwalior, India. Total 15 sample analysed by using Atomic Absorption Spectrophotometer (AAS). Lead found in all cosmetics soap brand B. Face power had the lowest lead content. While lead and cadmium levels were within permissible limits, continuous use of contaminated cosmetics could lead to measured heavy metals collects in the body. There is need to control and display heavy metals contain in consumer cosmetics products.

- **FLAME ATOMIC ABSORPTION SPECTROSCOPY (FAAS)**

Flame atomic absorption is commonly used method to analysis quantify the concentration of heavy metals in sample. **Faruruwa et al. (2014)**, **lwegbue et al. (2016)**. It is based on the absorption of light by free atoms in the gaseous state, which are commonly generated in a flame. **Faruruwa et al. (2014)** analysed 40 facial cosmetic samples from superstores and open markets in Kaduna, Nigeria, using **Flame Atomic Absorption Spectroscopy (FAAS)**. They found **cadmium in 85%** of the products, and **lead exceeded safe limits in 18 samples** (0.20–31.70 mg/kg). Products from open markets generally had higher metal content than those from superstores, except for foundation. The study concluded that **both expensive and low-cost cosmetics may contain harmful heavy metals**, posing health risks with prolonged use.

- **X-RAY FLUORESENCE SPECTROMETER (XRF)**

X-ray fluorescence in a non- destructive analytical technique used to determine the elemental composition of material, especially for detection heavy metals in solid, powders, or even liquids**. Saah et al. (2024)** analysed 12 lipstick samples sold in Ghana using **X-ray fluorescence (XRF)** to detect heavy metals including **chromium (Cr), manganese (Mn), nickel (Ni), copper (Cu), cadmium (Cd), and lead (Pb)**. The results revealed **elevated levels of these metals**, which may pose **serious health risks**, such as **skin irritation, allergic reactions, neurotoxicity, and potential organ damage**.

- **INDUCTIVE COUPLE PLASMA OPTICAL EMISSION SPECTROMETERY (ICP-OES)**

ICP-OES is a powerful multi-element analytical technique used to detect and quantify trace elements, including heavy metals, in a wide range of sample type like cosmetics, water, soil, and biological sample**. Liu et at. (2013)** investigated on seven lip cosmetic brands, ranging price from $5.59 to $24, a total of 32 individual samples including 8 lipsticks and 24 lip glosses were analysed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). The samples were tested for heavy metals like Mn, Ti and, Al with highest concentration of Ti and Al. 75% of samples included Pb, and 47% of them had Pb levels higher than the FDA-recommended 10 maximum level of 0.1 ppm standard. The greatest Cr (9.72ppm) and Rayat-Bahra University, Mohali the highest level of Cd, Mn, and Pb were found in products.

4. RESULT

This preliminary investigation on metal content in lip cosmetics raises significant public health issues. However, the FDA does not currently regulate metals found in cosmetic goods.

Metal concentrations in lip cosmetics have been documented by investigations in both the United States and other countries.[3-35] The continued presence of heavy metals in cosmetic products such as lip gloss, lipstick, mascara, and foundation raises serious concerns about consumer health and safety. Although heavy metals are not purposefully included, they can enter cosmetic formulas as contaminants via raw materials, pigments, packaging, and manufacturing processes.[35,36] Metals such as lead (Pb), cadmium (Cd), arsenic (As), mercury (Hg), and chromium (Cr) have been found in cosmetics, with levels frequently exceeding the limits set by regulatory agencies such as the US Food and Drug Administration (FDA) and Health Canada.[38] Lip cosmetics, particularly lip gloss and lipstick, have gained a lot of attention because they might be consumed during application and usage.[41] Several investigations found detectable levels of lead in lipsticks, with some exceeding the FDA's suggested limit of 10 ppm.[42] Mascara and foundation, which are frequently used near sensitive areas such as the eyes and face, may offer hazards, particularly when metals such as chromium or nickel, recognized allergens and sensitizers, are present [(43)].Given the health dangers, there is an urgent need for tougher restrictions, regular monitoring, and better production procedures. Long-term cosmetic use should also be made more public, especially for items that come into contact with mucosal membranes, such as lipsticks and eyeshadows. To reduce contamination, manufacturers must follow clean manufacturing methods and get raw materials from approved vendors.

CONCLUSION

The presence of heavy metals in cosmetic items such as lip gloss, lipsticks, mascara, and foundation has raised concerns about their potential toxicological effects, which includes carcinogenesis, neurotoxicity, reproductive harm, and organ damage. While heavy metals such as (Pb), cadmium (Cd) may be unintentionally introduced during the manufacturing process though raw material, their buildup over time offers considerable health dangers. Several analytical techniques, including Flame atomic absorption spectroscopy (FAAS), inductively couple plasma optical emission spectroscopy (ICP-OES), atomic absorption spectroscopy (AAS), and X- ray fluorescence (XRF), has been used trace quantities of these metals in cosmetic

with great accuracy and sensitivity. The review literature reveals that, while some product fall below the acceptable level defined by regulatory authorities such as the FDA, others exceed safety thresholds, particularly in uncontrolled or local markets.

Therefore, stringer quality control, consumer awareness is imperative to ensure product safety and reduce public health risk.

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