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Full length article

ASSESSING THE CUMULATIVE EFFECTS OF HEAVY METAL EXPOSURE FROM COSMETIC PRODUCTS ON LOCAL CONSUMERS

Umair Habib[1], Azka Pervaiz[2], Aliza Murtaza[1], Amjad Hussain[3,], Hina Sarwar[4], Munzer Ullah[5], Muhammad Adnan Ayub[6], Naveed Ahmad[3], Maria Bashir[3]*

1. Department of Chemistry, University of Agriculture, Faisalabad 38000, Pakistan
2. Department of Biology, University of Okara, Okara-56300, Pakistan
3. Institute of Chemistry, University of Okara, Okara-56300, Pakistan
4. Department of Applied Chemistry, University of engineering and Technology Lahore, Pakistan
5. Department of Biochemistry, University of Okara, Okara-56300, Pakistan
6. Department of Chemistry, University of Sahiwal, Sahiwal-54000, Punjab, Pakistan

ABSTRACT

This study investigates the comprehensive impact of heavy metals (HMs) on individuals who use cosmetic products daily compared to non-users (controlled group), encompassing both male and female subjects. Utilizing Atomic Absorption Spectroscopy, concentrations of HMs in diverse cosmetic products were determined, with results from samples of both user and controlled groups analyzed and compared. The range of HM concentrations in blood samples was assessed, revealing varied levels across Cadmium (Cd), Mercury (Hg), Lead (Pb), Arsenic (As). Results revealed a wide range of HM concentrations, including Cd (0.4-5.1 µg/l in males, 1.8-8.1µg/l in females), Hg (60.7-85.5 µg/l in males, 78.5-99.3 µg/l in females), Pb (48.7-99.5 µg/l in males, 83.3-99.5 µg/l in females), and As. Some samples exceeded safety limits, emphasizing the need for stringent regulation and improved manufacturing practices to ensure safer cosmetic products and protect consumer health. The incorporation of survey methodologies enhances the study's depth, providing comprehensive insights into the potential health risks associated with HM exposure from cosmetic use.

KEYWORDS: Cosmetics, Heavy metals, Skin penetration, Atomic Absorption Spectroscopy, Contamination

*Corresponding author: Amjad Hussain, Department of Chemistry, University of Okara, Okara-56300, Pakistan.
Email: amjadhussain@uo.edu.pk

1. INTRODUCTION

Cosmetic is outlined as “any article meant to be rubbed, poured, sprinkled, or sprayed on, or introduce into, or applied to, the body or any half thence for cleansing, beautifying, promoting attractiveness, or sterilizing the looks, and includes any article meant to be used as an element of cosmetic”[1]. The consumption of cosmetic products is increasing in Pakistan. Various chemicals along with HMs are used in cosmetics that create serious health risks to the consumers. HMs particularly Pb, Hg, Cd, As, and Nickel (Ni), along with Aluminum (Al) which is considered a light metal, are part of different cosmetics (for example; color cosmetics, face and body care products, hair cosmetics, herbal cosmetics, etc.) [2].

HM is the collective term used for a group of metalloids or metals that have atomic densities more than 4g/dm^3 greater than water (5 times or more) [3]. These include Pb, Zinc (Zn), Cd, As, Chromium (Cr), Silver (Ag), Copper (Cu), Iron (Fe), and Hg [4]. HMs are non-biodegradable and tend to mass in living entities [5]. HMs are present everywhere due to their ubiquitous nature, so their presence is un-avoidable. Most of them are potential carcinogens and cause serious health hazards [6]. There have been reports that some cosmetic goods, such as kohl that is historically used to line the eyes in several cultures, contain high quantities of Pb, which can have negative health implications. Studies have also revealed that some eyeshadows, not just those from a particular region, may have Pb levels above the legal limit [7].

Table 1: Concentration (μg/g) of HMs in various cosmetic products. *[ND=not determined]

Product	Cd	Cr	Ni	Cu	Mn	Fe	Zn	Pb	Hg
Eye shadow	0.4-2.18	30.8-43.97	19.88-32.05	6.68-56.77	42.2-165.57	1008.5-1332.2	32.01-258.26	81.02-140.57	ND-0.075
Eye pencil	0.07-1.93	34.36-47	30.73-40.86	3.49-73.37	232.41-401.13	1254-1271.5	7.98-82.29	96.37-120.45	ND-0.0017
Powder	ND-0.22	32.51-51.98	22.99-43.81	2.4-58.88	21.5-157.43	963.49-1325	16.12-42.13	88.32-280.9	ND-0.0025
Cream	ND-0.08	29-65.27	9.63-37.94	2.36-28.54	3.51-8.12	157.71-534.78	3.62-10.002	11.54-129.26	ND
Lipstick	ND-403	27.78-110.72	9.16-74.46	1.86-21.72	8.93-32	804.1382	3.64-216.53	109.66-198.49	0.0077-0.022

In addition to being linked to the use of cosmetics, elevated concentrations of HMS are also common in a number of industries, including the commercial, residential, agricultural, medical, and technological sectors, all of which are essential for economic growth [8]. NON cosmetics user, people can still be exposed to more mercury through these routes. Heavy metal pollutants are released into the environment by industries such as chemical synthesis, electronics manufacturing, and metallurgy, which puts the local people at danger [14]. Human exposure and environmental contamination are caused by domestic sources such as lead-based paints, polluted water pipes, and kitchenware [9]. Heavy metal buildup in soil and water due to historical mining activities, the use of fertilizers and pesticides, and industrial discharge all have an impact on crops and cattle [10–12]. Heavy metals are used in medical tests and treatments, which can harm people accidently and cause them to accumulate in their body tissues [13]. Furthermore, heavy metal use has increased due to innovations in batteries, electronic gadgets, and renewable energy technologies, which caused concerns about the effects on the environment and human health [14].

With the cosmetics industry's significant economic influence, this issue is especially crucial. By 2027, the global cosmetics industry is expected to have grown from $380.2 billion in 2019 to $463.5 billion, according to Allied industry Research. In Pakistan, the annual expenditure on cosmetics amounts to Rs. 101

billion, accounting for approximately 4% of total home expenses in the country. However, a concerning issue arises from the fact that a majority of cosmetic manufacturing units in Pakistan operate without proper authorization. The FDA (Food and Drug Administration) has specified permissible levels of additives in cosmetics, with As, Pb, Cd, and Hg set as 3 ppm, 20 ppm, 0.003 ppm, and 1 ppm respectively [15]. A quality inspection in 2018 reveled that only three out of fifty-nine national and international cosmetic brands contained excessive quantities ranging from 0.74 ppm to an alarming 44,292 ppm [16]. Due to the discovery that many Pakistani brands, especially beauty creams, contain dangerous chemicals like hydroquinone, mercury, or corticosteroids as main ingredients, authorities have been cracking down on them. This underscores the urgent need for tighter regulations and quality control to protect consumers from potential health risks [8]. Table 1 displays the concentration of distinct HMs in various cosmetic brands. The chemicals present in cosmetic products penetrate to the skin or other body tissues and cause skin problems or other harmful diseases. Skin rashes and inflammation of the epithelial cells can result from HMs found in applied cosmetics. The combined impact of these metals can cause serious epidermal and mucous membrane ailments. Moreover, HMs have the ability to penetrate body fluids through skin absorption. These poisons can enter essential organs through fluids in the body [17]. The permeability of the human skin varies significantly across different anatomical sites, impacting the absorption rates of cosmetic ingredients. The outermost layer of the epidermis, known as the stratum corneum, is a crucial determinant of skin permeability. The face, characterized by relatively thin and sensitive skin, facilitates enhanced absorption of cosmetic components due to a thinner stratum corneum. On the scalp, where a rich blood supply is present, topical treatments may be more effective, thanks to increased vascularity. Conversely, areas such as hands and feet, with thicker skin, exhibit lower permeability, potentially influencing the absorption rates of cosmetic products. Palms and soles, featuring thick skin layers, may further contribute to reduced absorption. Notably, regions like armpits and the perineum possess unique skin properties owing to the presence of sweat glands and hair follicles, potentially influencing the absorption characteristics of cosmetics applied to these areas. Understanding the variations in skin permeability across different sites is essential for optimizing the efficacy of cosmetic applications [18]. Sylwia Borowska and Malgorzata M. Brzóska have pioneered the route by which metals found in cosmetics can accumulate in the skin. Although elements including Hg, Pb, Cd, and Al can permeate through skin layers, entering the bloodstream and subsequently disseminating into various organs, exerting harmful effects. Meanwhile, elements like Ni, Co, and Cr tend to accumulate in the corneum layer, potentially leading to the development of allergic contact dermatitis [19, 20]. HM disclosure cause health issues including reproductive, immune, and nervous system toxicity [10].

As has been identified as a potentially hazardous substance in cosmetics, with its presence attributed to both natural processes and human activities in the environment [21]. Cosmetic products, including lipsticks and eye shadows, may incorporate As as a coloring agent or as an impurity. While the European Union has imposed a maximum limit of 3 parts per million for As in cosmetics, the FDA has not established a specific threshold. As manifests in four oxidation states, namely (III) arsenite, (V) arsenate, (-III) arsine, and (0) arsenic. Inorganic arsenite and arsenate are the prevalent forms typically found in water sources [22]. Arsenite (As (III)) exhibits higher mobility and faster adsorption kinetics compared to the more oxidized arsenate (As(V)) [23]. The chemical properties and charge of arsenite contribute to increased interactions with surfaces, affecting its adsorption dynamics. Arsenite's adsorption is influenced by redox conditions, pH, and the nature of adsorbent surfaces [24]. In contrast, arsenate demonstrates lower adsorption kinetics, and its adsorption characteristics are associated with surface complexation and precipitation reactions influenced by the presence of oxygen [25]. The redox conditions in the environment play a key role in determining the predominant oxidation state of As, impacting the adsorption kinetics. pH levels and adsorbent surfaces significantly shape As's adsorption kinetics, with arsenite dominating under reducing conditions and lower pH, while arsenate prevails under oxidizing conditions and higher pH. This understanding underscores the importance of considering oxidation states and environmental factors in managing As adsorption [26]. As exerts its impact on various organ systems, encompassing the neurological, renal, hematologic, hepatic, auditory, and cardiovascular systems. Its repercussions include diabetes, hematologic complications such as leukopenia, anemia, and eosinophilia, as well as the manifestation of cancers in the lung, brain, bladder, skin, and liver. Additionally, As exposure may lead to gastrointestinal pain and hearing loss [27]. Mandal et al. (2001) have highlighted the toxic effects resulting from inorganic As compounds are more severe than those associated with organic arsenicals [28]. Specifically, the toxicity of the trivalent arsenite is reported to exceed that of the pentavalent arsenate [29].

Pb is a very hazardous metal that has been classified as a priority pollution because of its negative impacts on human health. Severe effects from Pb exposure might include anemia, kidney failure, damage to the central nervous system, brain damage, abnormal behavior, and problems with hearing and thinking [30, 31]. Pb exposure has also been associated to lower fertility in both women [32] and men [33]. Adults only absorb 11% of the Pb that enters their systems, compared to children who may absorb 30–75% [34]. It is estimated that the epidermis absorbs only 1% of Pb. Although Pb may penetrate the placenta and potentially reach the brain of the newborn, causing fetal demise, pregnant women are particularly concerned. An abortion has also been associated with it [35]. The World Health Organization (WHO) and the US Environmental Protection Agency (USEPA) have set maximum permitted levels of Pb in water for consumption at 0.01 and 0.015 μg/g, correspondingly [36]. Based on elevated Pb concentrations in their blood, Sun et al. (2002) have shown that Pb absorption by the skin occurs from various types of this metal (lead stearate, lead oxide, lead powder, and lead sulphate) administered to the dorsal side of the hand and the back of Pb-battery workers [37].

Cadmium is one of the most dangerous metal in the environment. It can be found in meals, beverages, and in the air. The liver carries the majority of the cadmium ions in the body, and most other tissues absorb them. One of the most serious risks in life is the accumulation of pb. Renal dysfunction, osteotoxicities, and anemia Chronic human contact with Cd has been associated to renal failure, hepatic malfunction, and cancer in several bodily organs [38]. The study conducted by Afridi H. I. et al. (2022) revealed a considerable increase in the amount of Cadmium in biological samples, such as blood and scalp hair, of female dermatitis sufferers compared to referent participants ($P<0.001$) [39].

Hg is hazardous and flammable HM. It is a lustrous, silver-white liquid that forms both organic and inorganic compounds when amalgamated with other components. It vaporizes quickly and is the only metal that exist in a liquid state at room temperature [40]. Additionally, there are three different types of Hg compounds: the metallic element (Hg^0); inorganic salts (mercuric (Hg^{2+}) and mercurous salts, Hg_2^{2+}); and more hazardous organic molecules (phenyl, ethyl, and methylmercury, MeHg). Hg comes in various forms, each with a unique bioavailability and toxicity [41]. Elemental Hg, in its metallic form, is relatively inert, and its adsorption kinetics vary based on environmental conditions and interacting surfaces, notably studied in Hg vapor adsorption in air and soil interfaces [42]. In contrast, more reactive divalent Hg participates actively in adsorption, with kinetics influenced by pH, temperature, and competing ions, extensively researched in aquatic environments [43]. Mercurous species, less common but relevant in specific chemical contexts, lack the same level of scrutiny in adsorption kinetics as other oxidation states, emphasizing the need for further exploration to enrich our understanding of Hg behavior in diverse chemical settings [44]. It is typical for inorganic Hg to oxidize to Hg^{2+} and subsequently produce $MeHg^+$, which is a more poisonous form. In food chains, organomurcury methylmurcury is readily bioaccumulated and biomagnified. For Hg in cosmetics, the EU has established a maximum of 1 ppm (1 µg/g). The FDA only permitted the use of Hg compounds as preservatives in cosmetics for the eye area, and only in completed products at levels no higher than 65 parts per million (ppm). Hg compounds are not permitted in any other cosmetic items, unless they are present in trace amounts of less than 1 ppm [45]. According to H.H. Abbas et al. (2020), there are only two common signs of Hg exposure: uneven movement of the eyes and imbalanced stiffness & ataxia. Significant quantities of Hg are found in cosmetics and at elevated alert levels in the scalp hair of users [46]. The extended consumption of products containing Hg leads to nephritic syndrome [47]. In literature, various studies have been reported for HMs in numerous cosmetic products from many regions (Table 2) [48].

The primary objective of this study is to comprehensively assess the cumulative effect of HM exposure in different blood samples of cosmetic users and controlled group (males and females). By employing AAS, the main objective is to quantitatively determine the concentrations of HMs in blood samples, thereby evaluating potential health risks associated with their usage. Here, we seek to raise awareness among consumers, cosmetic industry and regulators regarding the significance of monitoring HM content in cosmetics to ensure safety. The results of this study aim to shed light on the prevalence of HMs in the cosmetic and beauty products and their latent health implications. Furthermore, regulatory authorities could utilize this data to implement strict rules and safety standards for the formulations of cosmetic.

Table 2: Comparison of HM concentrations (μg/g) in various cosmetic products from different countries, along with similar findings reported in existing literature.

Product	Region	Pb	Cd	Cu	Co	Fe	Cr	Ni	Zn
Lipsticks	Japan, China, Pakistan	2.58-11.33	0.2-0.430	0.026-6.036	0.3-0.872	258-1164	ND-0.77	0.696-1.610	0.696-1.610
Shampoo	Pakistan, Damam, Dubai	1.782-3.322	0.058-0.203	0.071-2.387	0.183-0.373	27.97-154.2	ND	0.095-0.386	0.496-1500
Eye liner	-	66.4-213.6 (120.5)	0.3-1.8 (1.0)	-	-	78.0-325.2 (169.2)	33.5-43.1 (37.6)	78.0-325.2 (8.43)	72.0-128.5
Eye shade	Saudi Arabia	4.41-11.9	ND-0.266	14.4-37.3	1.28-31.3	1000-3760	5.89-7000	6.01-46.8	38.6-2000
Maskara	Saudi Arabia	ND-2.18	0.002-0.035	ND-1.04	1.73-20.4	1000-9500	1.44-17.1	5-3.14	ND-63.1
Hair pomades	Ghana	1.30-17.70	4.20-6.800	0.70-12.80	10.66-25.35	81.60-421.0	ND	1.300-72.00	1.60-89.5
Cream	Pakistan, Dubai, India	1.741-3.708	0.041-0.058	2.058-65.34	0.233-0.225	1846-2469	ND	0.258-0.308	0.646-32.83

2. MATERIALS AND METHODS

2.1 Material

Analytical grade nitric acid (HNO_3, 65%) and hydrogen peroxide (H_2O_2, 30%) were procured from E. Merck. Standard solutions of Cd, Hg, Pb, and As were purchased from Fisher Scientific. Ni salt was provided by E. Merck to prepare Ni standard solution. Deionized water was used in the experiment.

2.2 Blood Sample Collection

Blood samples were drawn from a broad set of volunteers, ranging in age from 18 to 60. These volunteers were chosen to provide a representative and through cross section of the population of the Lahore (Figure 1) by being picked from a variety of occupational fields cross several working areas. A total of 60 blood samples were collected, including both persons who regularly use cosmetics and those who do not. This Participant sample was carefully balanced to include both men and women, encompassing a broad spectrum of demographic characteristics. By taking a rigorous and purposeful approach to sample collection, the study is able to gain a comprehensive picture of the effects HMs on both cosmetic and non-cosmetic usage across genders in Lahore (Table 3). Each sample was marked and kept in-accordance to its category. Samples were preserved in EDTA and stored in the refrigerator using vials.

Figure 1: Sample collection areas in Lahore for study on HM exposure.

2.3 Sample Preparation

1ml of blood of each sample (preserved in EDTA) taken in various beakers. Digestion was carried out by the addition of 1-2 ml concentrated nitric acid (65%). Then, concentrated HNO_3 was added to the previous resultant followed by the addition of H_2O_2 (30%) to the dried product then concentrated HNO_3 was added again. In each step, the sample was heated, dried and cooled. Digested samples were diluted by addition of double deionized water. Filtration was conducted and then sample was preserved in plastic bottles for estimation. Each bottle was tagged according to its category and was stored in a cool and dry place. The blanks were used to trace sources of artificially introduced contamination. Blank was prepared by mixing 1ml blood sample in 1-2 ml water followed by the addition of 2ml H_2O_2 and 1-2ml HNO_3. In each step, the sample was heated on a hot plate (180℃) till drying and then cooled to room temperature. The, AAS (Agilent Technologies 200 series AA) performed analysis of Hg, As, Pb (217.0 nm), and Cd (228.8 nm). Standard metal solutions were utilized to calibrate the AAS device before analysis. The operational circumstances and instrument settings were carried out in accordance with the manufacturer's instructions.

Table 3: Description of sample collection in different areas of Lahore for study on HM exposure.

Sample	Criteria (age)	No. of samples	Gender distribution	Areas of Lahore
Controlled group	18-60 years	20	Male (10) Females (10)	Iqbal Town, Shahdara, Johar Town, Model Town, DHA
Cosmetic users	18-60 years	40	Male (20) Females (20)	Iqbal Town, Shahdara, Johar Town, Model Town, DHA

2.4 Standard Solution Preparation

Standard solution has known concentration. Fisher scientific calibrated standard solution of metals such as Pb, Cd, Cr, Hg, Cu and Co with 1000ppm concentration were available in the laboratory but the standard solution of Ni was prepared by using the analytical grade MERCK salts by using the following formula.

$$C_1V_1=C_2V_2 \quad (1)$$

2.5 Estimation

To determine the concentration of selected HMs in given samples, sample solution, blank solution and standard solution were tested with AAS and curves were obtained for all metals in these solutions.

2.6 Survey Methodology

The survey was conducted to assess the impact of HM exposure from cosmetic products on local consumers. Participants were recruited through various channels, including social media platforms, community groups, and local advertisements. Individuals aged 18 years and above were eligible to participate in the survey.

The survey instrument was designed to collect information on demographic characteristics, cosmetic product usage patterns, and experiences of adverse health effects potentially associated with HM exposure. The questionnaire consisted of closed-ended questions to facilitate quantitative analysis of responses.

Data collection took place over a period of time, during which participants were invited to complete the survey either online or through paper-based forms distributed at local community centers. Participants were assured of anonymity and confidentiality, and informed consent was obtained before participation.

A total of 100 respondents completed the survey, providing valuable insights into the prevalence of cosmetic product usage, demographic distribution, and reported health effects associated with HM exposure.

3. RESULTS AND DISCUSSION

Concentrations of HMs were determined using curves obtained through AAS. The concentrations of As, Pb, Cd, and Hg in blood samples of both males and females were compared. In cosmetic users, male blood samples exhibited lower concentrations of HMs compared to females. Similarly, in the controlled group who do not use cosmetics, the trend of lower HM concentrations in males compared to females was observed.

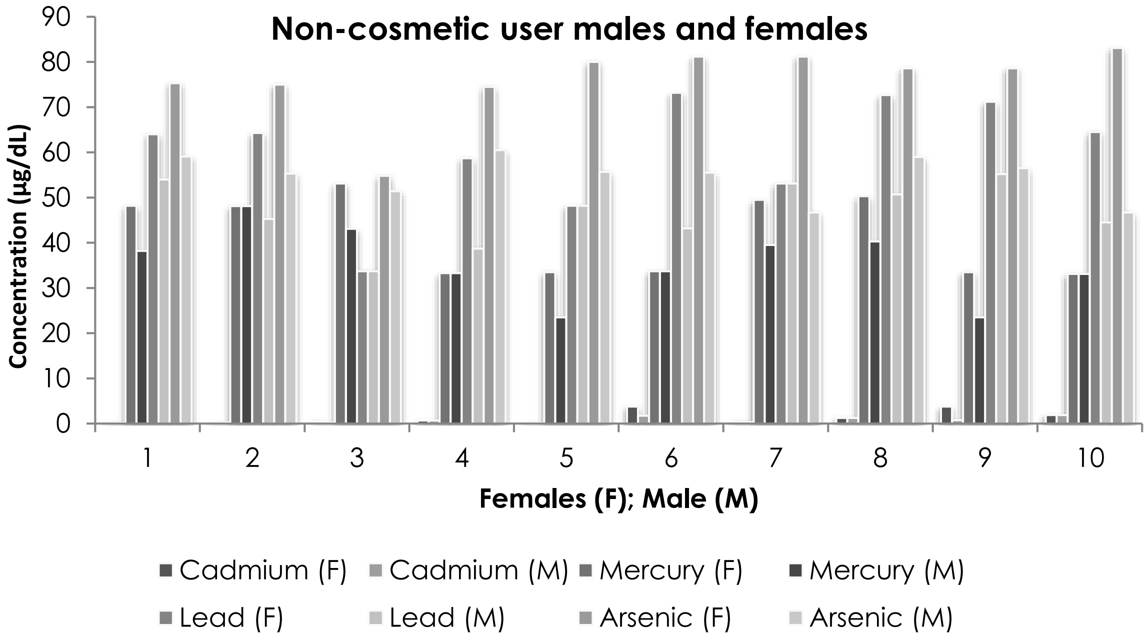

Figure 2: Graphical representation of controlled group males and females.

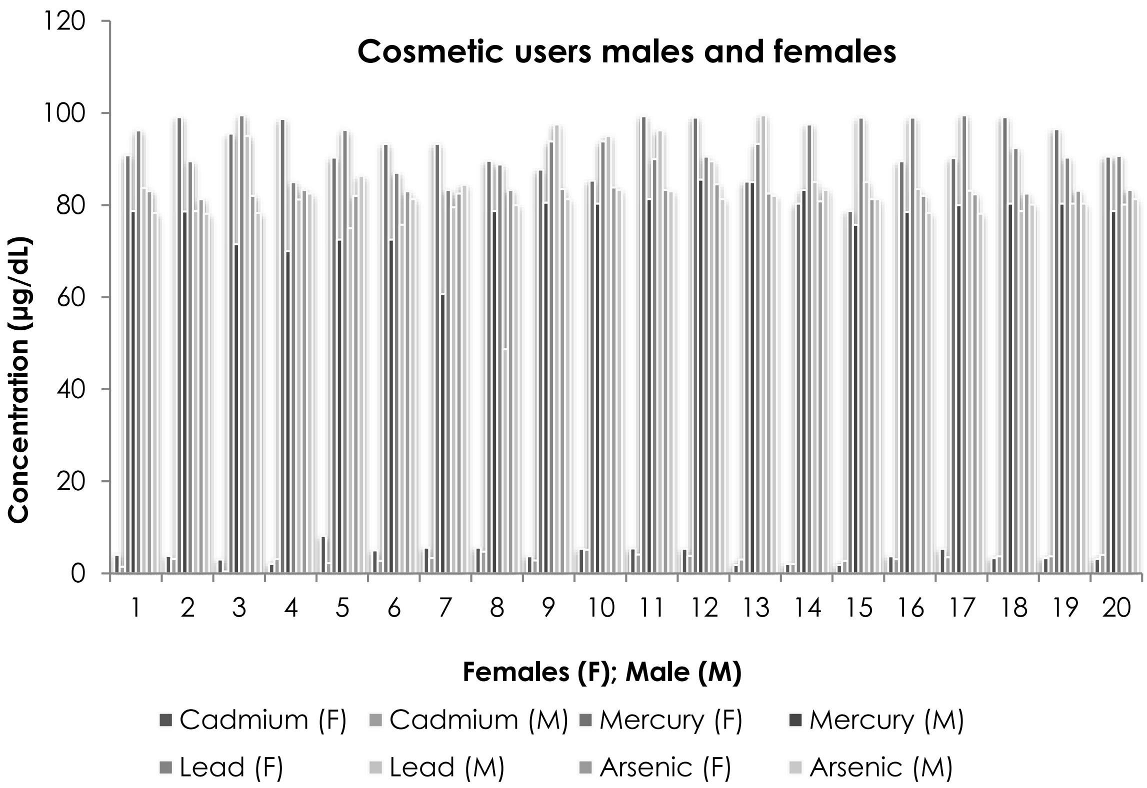

Figure 3: Graphical representation of cosmetic user males and females.

The maximum and minimum limit of these metals in blood samples was not regular. A random range of Cd, As, Hg, and Pb are shown in figures (Figure 2 and Figure 3) of non-cosmetic and cosmetic users respectively.

3.1 Study of controlled group (Males and Females)

The concentration of Cd is higher in females as compared to males. The maximum concentration of Cd in males is 0.15-1.88 µg/l and in females 0.25-3.75 µg/l. The concentration of Hg in males is between 23.5-48.1 µg/l and in females 33.1-53.1 µg/l. The minimum values of Pb in both are the same 33.7 µg/l and there is a huge difference in the maximum values, 55.2 µg/l in males and 73.2 µg/l in females. The level of As in the blood samples of males is lower than females as usual. In the male blood samples range of As is 46.7-60.5 µg/l and 54.8-83.1 µg/l in female blood samples.

Table 4: Statistical analysis of the concentration of HMs in blood samples of controlled group.

Parameter	Cd(F)	Cd(M)	Hg(F)	Hg(M)	Pb(F)	Pb(M)	As(F)	As(M)
Maximum	3.75	1.88	53.1	48.1	73.2	55.2	83.1	60.5
Minimum	0.25	0.15	33.1	23.5	33.7	33.7	54..8	46.7
Mean	1.28	0.74	41.63	35.63	60.36	46.66	76.23	54.64
Variance	1.97	0.44	76.76	62.72	154.96	48.53	65.18	23.95
S. D	1.40	0.66	8.76	7.92	12.45	6.97	8.07	4.89

Mean, Median, Maximum, and Minimum values of HMs in controlled group were calculated by statistical formulas. Results after calculation are listed in Table 4. The study has shown that HMs are increasing in exposed working people.

3.1.1 Factors Contributing to Elevated Heavy Metal Concentrations in Non-Users

Although the primary objective of our investigation was to evaluate HM concentrations in cosmetics users, the finding that non-users had elevated HM levels emphasizes the significance of taking other potential sources of exposure into account. Regardless of the usage of cosmetics, a number of variables could be responsible for the reported HM amounts in non-users:

3.1.1.1 Environmental Contamination

HM contamination of air, soil, and water can occur widely as a result of environmental pollution, which includes vehicle exhaust, industrial emissions, and agricultural runoff [49, 50]. Individuals living in urban or industrial regions may be exposed to higher levels of HM by breathing in contaminated air or consuming contaminated food and water [51].

3.1.1.2 Dietary Habits

Regardless of the usage of cosmetics, dietary intake is a substantial pathway for HM exposure in the general population. Foods that bio-accumulate HM in the food chain include cereals, shellfish, and green vegetables [52, 53]. These foods can increase an individual's consumption of HM. The amount of HM in food consumed can also be influenced by the way it is processed and cooked [54].

3.1.1.3 Occupational Exposures

Occupational activities involving direct contact with heavy metal-containing materials or processes, such as mining, metalworking, and construction, can result in elevated HM levels in non-users [55]. Workers in these industries may inadvertently carry HM residues into their homes, affecting household members through secondary exposure pathways [56, 57].

3.1.1.4 Geographical Location

Variations in commercial activities, soil type, and proximity to sources of pollution can all contribute to regional disparities in HM exposure levels. Risks associated with heavy metal exposure may be higher for non-users living in regions with past, present, or future mining operations or industrial activity [58]. The propagation of airborne heavy metal pollution can also be influenced by meteorological conditions, elevation, and dominant wind patterns [59, 60].

3.1.1.5 Consumer Products and Household Items

Cookware, electronics, cosmetics, kids' toys, and other consumer goods might expose users to heavy metals [55–56]. Non-users may encounter HM-containing items in everyday life, which contributes to the total body burden of HM.

3.1.2 Interplay of Multiple Factors

It's critical to understand that HM contamination in non-users is frequently multivariate and the consequence of numerous environmental, nutritional, occupational, and social variables interacting. Furthermore, the impact of heavy metal exposure on physical health might be modified by individual vulnerability, inheritance, and metabolic variations [61].

3.1.3 Implications for Public Health

A comprehensive approach is required to reduce the dangers of HM exposure beyond the regulations governing cosmetics, as evidenced by the finding of higher HM levels in non-users. Environmental contamination, dietary safety precautions, improved occupational hygiene standards, and increased consumer knowledge of HM-containing items are all important areas for public health interventions. Health care providers, government agencies, business partners, and community organizations must work together to protect the public's health from the harmful impacts of heavy metal exposure.

3.3 Study of Cosmetic Users (Males and Females)

Although the level was not too elevated in the blood samples however toxicity effects are alarming. Analysis of four notable metals exhibits the increasing trend neither regular nor similar to each other. Pb metal concentration is higher than Hg and their amount is comparatively higher than As while the level of Cd is very low. All metals result show that elevation is above the stated safe amount. Graphically, a comparison was also performed between blood samples of non-cosmetic and cosmetic users and HMs amounts were not the same. Exposed persons are at risk of toxicity. Moreover, these samples showed elevated values than general. Furthermore, it should be recognized that good health and protection measures are required. The range of the concentration of Cd in blood samples ranged from 0.4-5.1 µg/l in males and from 1.8-8.1 µg/l in females. These values are comparatively lower than those reported by M.G. Parizi et al., [62]. Sin and Tsang reported Hg levels in blood samples ranging from 0 to 82 µg/l, whereas in our study, the lowest and highest values for Hg among blood samples were found to be 60.7-85.5 µg/l in males and 78.5-99.3 µg/l in females. These findings suggest that the Hg levels observed in our study are notably higher across both genders compared to the range reported by Sin and Tsang [63]. Pb levels in blood samples were significantly lower, ranging from 48.7 to 99.5 µg/l in males and 83.3 to 99.5 µg/l in females, compared to the findings of M.G. Parizi et al., [62] who reported Pb levels of 76.98 ± 106.29 µg/l. Results predict the lowest and highest concentrations of As in all blood samples were 78.1-86.3 µg/l and 80.8-84.5 µg/l in males and females respectively. Results after calculation are listed in Table 5.

Table 5: Statistical analysis of concentrations of HMs in blood samples of cosmetic users.

Parameter	Cd(F)	Cd(M)	Hg(F)	Hg(M)	Pb(F)	Pb(M)	As(F)	As(M)
Maximum	8.1	5.1	99.3	85.5	99.5	99.5	84.5	86.3
Minimum	1.8	0.4	78.75	60.7	83.3	48.7	80.8	78.1
Mean	4.05	3.12	91.59	77.63	92.77	83.55	82.67	81.14
Variance	2.66	1.18	35.29	31.05	21.52	123.78	0.85	5.19
S. D	1.63	1.08	5.94	5.57	4.64	11.125	0.92	2.28

The present research was performed for the assessment of the concentration of HMs within the blood of normal humans that don't use cosmetic products on daily basis and the people that use these products daily. Variations in the concentration of HMs are surely proven in the above tables and figures.

The concentration of Cd is low in those females who use cosmetic products in a very minute quantity in their daily routine and they do not face any toxic and poisonous effects as the other women who use cosmetic products repeatedly and are facing many toxic effects. Cd is observed as non-poisonous metal in these products and the above figure 3 shows the minute quantity of this metal.

3.4 Methodological Approach to Assessing HM Exposure Effects in Local Consumers

To comprehensively evaluate the impact of HMs on local consumers, our research employs a multifaceted approach encompassing various survey methodologies. Firstly, a Health Effects Assessment is conducted to ascertain if consumers are experiencing any adverse effects linked to HM exposure, including skin irritation, allergies, or systemic health issues. Secondly, an Exposure Pathways Analysis is undertaken to investigate the routes through which consumers come into contact with HMs from cosmetic products, such as dermal absorption or ingestion, while also assessing the relative contributions of each pathway to overall exposure. Finally, a Risk Assessment is performed utilizing exposure data and toxicological information to gauge the potential health risks posed by detected HM levels, comparing them against established safety thresholds or guidelines. This comprehensive methodology aims to provide a nuanced understanding of HM exposure's impact on local consumers, thereby contributing to informed decision-making regarding the safety and regulation of cosmetic products.

3.4.1 Demographic Characteristics of Participants

The survey results revealed a diverse range of cosmetic product usage among respondents, with a significant portion reporting daily use (41%), followed by occasional (23%) and rare (19%) usage. Weekly usage was comparatively lower at 6%, while 11% of respondents indicated that they never use cosmetic products. Gender distribution among participants showed a higher representation of females (77%) compared to males (23%).

In terms of age demographics, the respondents spanned a wide range, with the majority falling between 18 and 26 years old. Specifically, 18 and 19-year-olds each accounted for 7% and 11% of the sample, respectively. The age groups of 20 to 24 years constituted a sizable portion, ranging from 10% to 13%. Beyond this range, respondents aged 25 to 45 years collectively represented 22% of the sample, with smaller percentages distributed across different age brackets.

3.4.2 Health Effects Assessment

The study conducted a comprehensive survey to assess the health effects experienced by individuals exposed to HMs through cosmetic products.

Table 6: Health Effects Assessment from Public Exposure to HMs in Cosmetic Products.

Health Effects	Frequency	Percentage
Skin Irritation	43	43%
Allergic Reactions	11	11%
Eye Irritation	22	22%
Respiratory Issues	9	9%
Systemic Issues	14	14%
No effects	19	19%

The data indicates that skin irritation was the most commonly reported health effect among respondents, followed by eye irritation and systemic health issues. A noteworthy observation is that a significant portion of respondents (19%) reported no adverse effect.

Villanacci et al. highlight the various adverse health effects experienced by individuals exposed to mercurous chloride in the beauty cream, including neurological symptoms, insomnia, irritability, fatigue, weight loss, constipation, loss of taste, paresthesiae, migraine headaches, memory loss, and night blindness. Penicillamine and chelation therapy were initiated as treatment for mercurous chloride and Hg-related compound exposures [64].

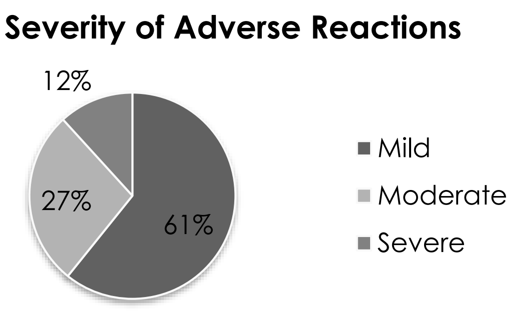

Figure 4: Adverse reaction by the use of HM containing cometic.

The severity of these adverse reactions varied (Figure 4), with the majority categorized as mild, although a notable proportion reported moderate and severe reactions.

Additionally, the survey assessed whether individuals sought medical attention for these adverse reactions (Figure 5) providing insights into the proactive measures taken by consumers in response to their symptoms.

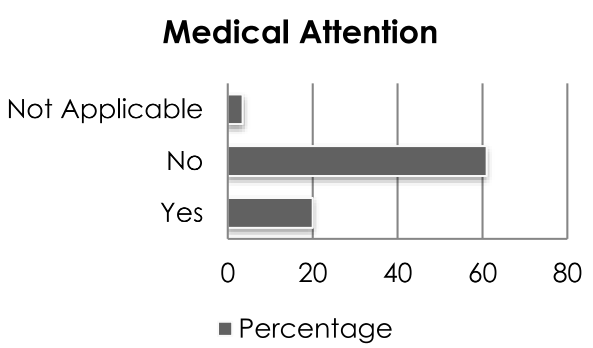

Figure 5: Medical attention of public regarding health issues by the use of cosmetics.

These findings highlight the diverse range of health impacts associated with HM exposure from cosmetic products.

3.4.3 Exposure Pathways Assessment

A significant majority (69%) reported direct application of cosmetics on the skin, particularly on areas like the face and lips. Additionally, 10% mentioned applying products near mucous membranes such as the eyes and mouth, R. Sahu (2014) noted that cosmetic products are often applied the skin, lips, eyes, eyelashes, and mucosa [65]. while 15% reported using spray-on cosmetics and 6% preferred dabbing techniques (Figure 6).

Interestingly, only 13% admitted to using cosmetic products on broken or irritated skin, with the majority (83%) avoiding such practices and a small portion (4%) mark it as not applicable. Furthermore, the survey explored accidental ingestion of cosmetic products, with 31% of respondents admitting to this occurrence. However, a majority (54%) reported no such incidents, while 15% remained uncertain about accidental ingestion. These findings (Figure 7) underscore the importance of understanding exposure pathways and safe usage practices to mitigate potential health risks associated with cosmetic product use.

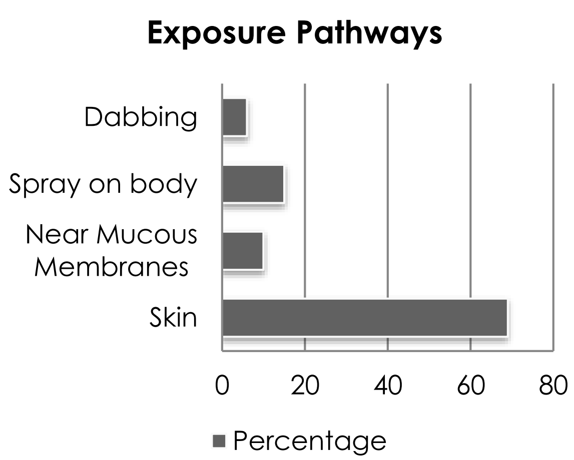

Figure 6: Exposure Pathways to Cosmetic Products.

3.4.4 Risk Assessment

The survey investigated participants' awareness and attitudes regarding HM presence in cosmetic products, as well as their safety assessment practices and concerns about potential health risks. Results indicated that 42% of respondents were aware of regulatory standards for HMs in cosmetics, while 43% were not, and 15% remained unsure (Figure 7).

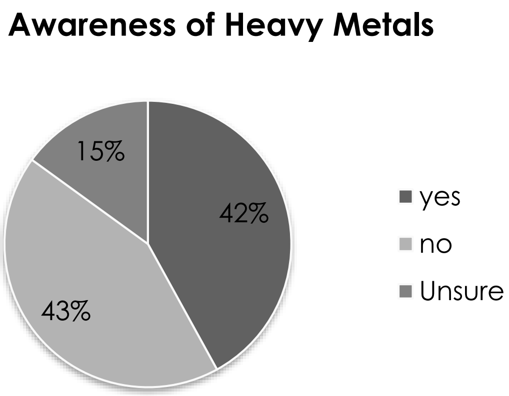

Figure 7: Awareness and attitudes of public regarding HM presence in cosmetic products.

When evaluating the safety of cosmetic products, diverse strategies were observed: 40% checked product labels for ingredient information, 21% researched online for reviews and safety data, 25% trusted brand reputation, and 10% sought advice from healthcare professionals. Interestingly, a small proportion (1%) consulted beauty parlor beauticians, and 3% admitted to never checking for safety measures. Concerning health risks associated with HMs, 16% expressed no concern, 51% were somewhat concerned, and 33% were very concerned.

To mitigate the risks associated with cosmetics, conducting thorough research into the credibility and reputation of brands within the cosmetics industry is essential. This process involves scrutinizing official websites, customer reviews, and news articles to gain comprehensive insights. By verifying claimed certifications, such as B Corp Certified, EWG Verified, Leaping Bunny, and USDA Organic, is critical through the respective certification organizations' websites. Quality control measures are paramount to ensure product safety and consistency, necessitating stringent procedures for testing raw materials and final products. Similarly, rigorous ingredient screening is imperative for compliance with regulatory standards, with adherence to Good Manufacturing Practices ensuring hygiene and sanitation. Modern systems for traceability and documentation are vital for accountability throughout the manufacturing process. Prioritizing environmental sustainability and embracing continuous improvement initiatives further enhance product integrity, while regulatory compliance ensures adherence to industry regulations. Expert consultation from beauty professionals, dermatologists, and environmental organizations adds valuable insights into the authenticity of brand claims.

While providing insights into cosmetics-related heavy metal exposure, our study faces limitations including potential confounding variables such as environmental, dietary, and occupational factors. Isolating the consequences of cosmetics use is difficult due to the complexity of exposure pathways and the absence of thorough assessment. Furthermore, the cross-sectional nature of the study, and selection bias make causal inference difficult. Establishing causation and comprehending the long-term health implications require experimental or longitudinal designs.

CONCLUSION

The study aimed to investigate the presence of HMs, including Cd, As, Pb, and

Hg, in the blood samples of cosmetic consumers compared to controlled group, with a focus on potential health risks. Through analysis using AAS, it was observed that Cd and As levels did not pose immediate threats to human health. However, concerning concentrations of Pb and Hg were detected, indicating potential toxicity upon repeated exposure. This underscores the importance of evaluating cosmetic brands for adherence to standard HM concentrations to mitigate health risks. The presence of HMs in non-users highlights the multifactorial nature of HM exposure. Factors such as environmental contamination, dietary habits, occupational exposures, and geographical location contribute to HM contamination in non-users. To address these concerns comprehensively, regulatory oversight must be fortified to ensure adherence to safety standards, including regular monitoring and strict enforcement. Prioritizing ingredient transparency empowers consumers to make informed decisions, while stringent quality control measures are crucial for minimizing HM contamination during manufacturing. Education campaigns play a pivotal role in raising awareness about risks and safe practices, facilitating the reporting of adverse reactions. Furthermore, sustained research and development efforts are crucial for exploring alternative ingredients and manufacturing methods, fostering innovation and collaboration across sectors to safeguard public health effectively. Thus, a multifaceted approach integrating regulatory, industry, and public engagement efforts is essential for mitigating the health risks associated with HM exposure from cosmetic products.

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Data availability: Not applicable

Code availability: Not applicable.

Authors' contributions:

"**Umair Habib:** Methodology, Original draft preparation, Investigation, Formal analysis, Visualization, **Azka Pervaiz:** Writing- Reviewing and Editing, **Aliza Murtaza:** Original draft preparation, **Amjad Hussain**: Supervision, Conceptualization, **Hina Sarwar:** Methodology, project administration, Writing- Reviewing and Editing, **Munzer Ullah**: Visualization, **Muhammad Adnan Ayub**: Software, Validation. **Naveed Ahmad:** Data curation, Writing- Reviewing and Editing, Writing- Reviewing and Editing, **Maria Bashir:** Software, Writing- Reviewing and Editing.

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