HEAVY METAL COMPOSITION OF HAIR CREAM PRODUCTS, THEIR RISK QUOTIENTS AND HEALTH EFFECTS ON HUMAN MALE USERS IN LAFIA METROPOLIS, NASARAWA STATE

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ABSTRACT

Exposure to heavy metals poses significant health risks, prompting regulatory agencies to establish safety thresholds. This study investigated the concentrations of selected heavy metals (Zn, Se, Cd, Pb, Fe, As) in hair cream products from Lafia Metropolis, Nigeria, and evaluated their health implications using Risk Quotient (RQ) analysis. Standard analytical procedures were employed, with triplicate measurements yielding mean concentrations and standard deviations. Statistical significance was set at $P < 0.05$. Results revealed detectable levels of all heavy metals in the products, ordered as Zn > Se > Cd > Pb > Fe > As. Comparative analysis of human hair samples showed no significant difference ($P < 0.05$) in iron levels between grey (0.04 ± 0.01 mg/L) and undyed hair (0.06 ± 0.02 mg/L), both below the reference value (0.8 mg/L), suggesting limited iron accumulation in these hair types. Zinc levels were significantly higher in grey hair (0.48 ± 0.10 mg/L) but remained below the reference threshold (12.0 mg/L). RQ analysis identified elevated risks for Se, Cd, and As in hair creams, with values exceeding the safety threshold (RQ > 1). Arsenic in sample HDC posed the highest risk (RQ = 228.13), while cadmium in dyed female hair (0.24 ± 0.20 mg/L) slightly surpassed the reference limit (<0.1 mg/L). In male hair, Cd approached risk thresholds in dyed (RQ = 0.90) and grey hair (RQ = 0.80). Other metals (Pb, Fe, Zn) in hair samples were within safe limits. Although most hair metal concentrations were below reference values, the high RQs in hair creams indicate potential systemic exposure risks. These findings underscore the need for stricter regulatory oversight and routine monitoring of cosmetic products to safeguard consumer health.

KEYWORDS: Heavy metals, concentration, hair, Atomic absorption, spectrophotometer

INTRODUCTION

Regulatory bodies worldwide have established guidelines and permissible limits for the presence of heavy metals in cosmetics. The aim is to protect consumers from potential health risks associated with heavy metal exposure. (Verma and Vinoda, 2017). Correlations between the concentrations of some heavy metals in hair care products and scalp hair and in blood and/or urine have been reported. These reports clearly show exposure to these heavy metals, arsenic, lead and mercury, is reflected in elevated concentrations in the hair. These indicate systemic intoxication with these heavy metals is not only reflected in elevated concentrations in the hair but in the blood and urine as well (Rashed, 2023).

Exposure to heavy metals as compared to the other bio-indicators such we use cosmetic products which are chemical substances or mixtures on; the mucous membranes of the oral cavity ,hair,teeth, skin, and nails, need be keep the body in good condition by ensuring they are clean, protected, able to correct body odor, perfume the body , or change body appearance.(Bonnier *et al.*, 2020, Salvador *et al.*, 2019). A cosmetic product is defined by means of European rules as a substance or combination designed for use in touch with the external parts of the human body; depart-on products, which after their utility continue to be in touch with the skin floor, and rinse-off products, which from the skin are cleansed after a short time are two sorts of cosmetic products. (Feng, *et al*., 2020)

Hair care products have seen a significant evolution in their compositions since their inception. The complexity and diversity of ingredients serve various purposes, from the desired color's longevity to maintaining hair health and ensuring user safety. The intricate composition of hair dye products, elucidating their biochemistry and their functions has been evaluated (Bonnie *et al.*, 2020). Consequently, hair care products analysis has potential merit as a screening procedure for poisoning by their heavy metals in human hair. However, questions regarding the exogenous versus the endogenous deposition of heavy metals in the hair and uncertainties about the normal concentrations of heavy metals in the hair remain unresolved. Until these issues are resolved, hair analysis must remain as a screening tool that reflects exposure to toxic elements, and clinical signs and symptoms are needed to complete the diagnosis of heavy metal poisoning (Song *et al.,* 2017). Human hair can accumulate heavy metals and as metabolic products, it can incorporate metals into its structure during its growth process. Therefore, concentrations of heavy metals in hair can reflect the mean level in the human body, recording the world's population's exposure to heavy metals. Other trace elements deposited through sweat include Nitrogen, calcium, phosphorus, magnesium copper, manganese, and iron (Gazwi *et al.,* 2020). Heavy metals pollutants in cosmetics can also arise evidently and stay within the surroundings. As a result, human exposure to metals is inevitable, and some studies have mentioned gender variations within the toxicity of metals (Bocca,2014). They'll frequently react with organic structures by losing one or greater electrons and forming ion-cations which have affinity to the nucleophilic web of crucial macromolecules.

Numerous acute and chronic toxic consequences of heavy metals have an effect on specific frame organs. Gastrointestinal and kidney disorder, fearful organ disorders, pores and skin lesions, vascular harm, immune device disorder, beginning defects, and most cancers are examples of the complications of heavy metals toxic results. Simultaneous exposure to two or greater metals may also have cumulative results (Cobbina *et al*., 2015; ; Costa 2019; Fernandes *et al*., 2020; Gazwi *et al.,* 2020). This research work: Analysis of heavy metals concentrations in selected human hair cream products was done. It is aimed at investigating the concentrations of heavy metals: Arsenic, Cadmium, Iron, lead, Zinc, and Selenium present in selected human hair cream products, so as to advice users on the effects of the heavy metals was done. Comparison used are with the reference ranges of selected heavy metals in human hair (mg/l): arsenic (0.008-0.8), Cadmium/Chromium, (0.1), Iron (0.6-15), Lead (0.6), Zinc (12.0), Selenium (0.8) (Mickeley *et al*., 1998).

MATERIALS AND METHODS

Location of Study: This study was carried out at Lafia, Nasarawa State Nigeria. Lafia is a town in central Nigeria (Figure 1). It is the capital city of Nasarawa State and has a population of 330,712 inhabitants according to the 2006 census results. Latitude: 8° 29' 38.04" N and Longitude: 8° 30' 55.15" E. The mean monthly maximum and minimum temperatures ranges from 35.06°C and 20.16°C, respectively while the mean monthly relative humidity is 74%. Annual rainfall is about 168.90mm in the Guinea Savanna zone of North Central Nigeria (NIMET, 2008).

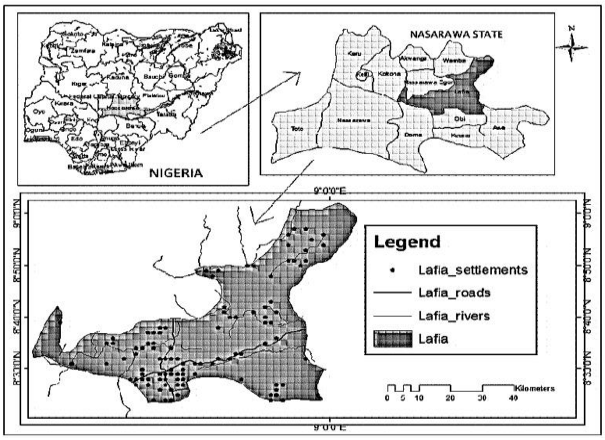

Fig 1: Lafia study area map adapted from Lafia- Nasarawa State

Experimental samples, collection and design: The hair cream products samples used in this study were bought from the Modern Market in Lafia. Five different selected products were purchased. The Hair samples were collected from the Hair Barbing Saloon in Lafia metropolis. The hair samples include both undyed hair, dyed hair and grey hair. The laboratory facilities used was from the Analytical Laboratory of Federal University Lafia, Nasarawa state. The sample brands were coded (SMC = Sample 1, SAMD = Sample 2, HMC=Sample 3, HM = Sample 4, HDC = Sample 5) for the selected hair Cream.

Sample Preparations: Each samples 1.0 gram was weighed, 2ml of concentrated Nitric acid (HNO_3) was added to each sample to acidify it and the samples in their respective labeled containers (corked), were kept in a refrigerator (4°C) until needed for analysis (Sultana *et al.*, 2019)The digestion used for the analysis was done by di-acid method in which a unit volume of each sample, 1ml, was collected after mixing the sample very well, and treated with a mixture of concentrated Nitric acid and per-chloric acid in a heating tube. The mixture was heated under a fume cupboard for 2 hours (150-200°C). The tube allowed to cool and its content was mixed with distilled water and made up of 50ml in a volumetric flask. It was filtered through a Whatman No 42-filter paper. The filtrate (extract) was used for heavy metal analysis by atomic absorption spectrophotometry (AAS) (Abata *et al*., 2019).

Methods (Principles) On Hair Analysis: Heavy metals readily form complex with organic constituent; therefore, it is necessary to destroy them by digestion with strong acid. Digestion destroys the organic matter, removes interfering ions and bring metallic compounds in suspension to solution (Graga, 1989).100 ml of well mixed sample was transferred into a beaker of beaker.5.0 ml of conc.$HN0_3$ acid was added to it. The beaker was placed in hot plate and evaporated to near dryness making sure that the sample did not boil. The beaker containing the residue was cooled and another 5.0 m of concentration $HN0_3$ was added with water glass and return to the hot plate and mixed until gentle refluxing occurs. Heating continued with addition of concentration$HN0_3$until necessary digestion is completed as signalled by a light-coloured residue. Finally2.0 ml conc$HN0_3$ was added and the beaker warmed slightly to dissolve the residue.

Data Analysis: Statistical products and service solution (IBM-SPSS), version 20.0 was used. One –way analysis of variance (ANOVA) was employed for the analysis. Descriptive statistics was used to separate the means and standard deviations, while Duncan multiple Test Range was used to compare the means. Level of significance was accepted at $p<0.05$. Determination of the effects is based on the reference values as established by statistical regulatory bodies.

Calculation: E mg/L = 1000/V x X/1000 x Vf/Va x D E = the element being determined. V = volume of hair dye sample extract analysed X = concentration from standard curve displayed Vf = Total volume of extract Va = volume of extract aspirated D = Dilution factor where applicable.

Risk Quotient (RQ) Assessment of Heavy Metals in Hair Dye Products and Hair Samples

To evaluate the potential health risks associated with the use of commercial hair cream products, a Risk Quotient (RQ) analysis was conducted based on the concentration of six heavy metals—lead (Pb), selenium (Se), arsenic (As), zinc (Zn), cadmium (Cd), and iron (Fe)—detected in five different hair cream samples and human hair samples. The

RQ was calculated as the ratio of the mean concentration of each metal to its corresponding oral reference dose (RfD), recommended by international agencies such as the United States Environmental Protection Agency (USEPA, 2023) and the World Health Organisation (WHO, 2021).

RESULTS

The concentrations of selected heavy metals in hair cream products and human hair samples (undyed, dyed, and grey) are presented in Table 1. The data represent mean concentrations (mg/L) ± standard deviation obtained from triplicate analyses using Atomic Absorption Spectrophotometry (AAS) for the elements lead (Pb), selenium (Se), arsenic (As), zinc (Zn), cadmium (Cd), and iron (Fe). The analysed hair cream products include five samples: SMC (Sample 1), SAMD (Sample 2), HMC (Sample 3), HM (Sample 4), and HDC (Sample 5).

Statistical analysis revealed significant differences ($P < 0.05$) in heavy metal concentrations among the various samples. Among the metals analysed, zinc exhibited the highest concentration overall, with the highest value in SAMD (8.855 ± 0.016 mg/L) and the lowest in HMC (4.534 ± 0.024 mg/L). Selenium concentrations were highest in HDC (7.205 ± 0.369 mg/L) and lowest in SAMD (0.188 ± 0.055 mg/L). Cadmium levels were most elevated in SMC (2.053 ± 0.045 mg/L) and least in HMC (0.836 ± 0.039 mg/L). Lead concentrations peaked in HMC (1.851 ± 0.026 mg/L), with the lowest recorded in SAMD (0.338 ± 0.018 mg/L). Iron was highest in HDC (0.644 ± 0.030 mg/L) and lowest in SAMD (0.242 ± 0.014 mg/L). Arsenic was most abundant in HMC (0.158 ± 0.054 mg/L) and least in HDC (0.027 ± 0.020 mg/L). Overall, the decreasing order of heavy metal concentrations in the hair cream products was: Zn > Se > Cd > Pb > Fe > As.

Table 1: Heavy metal concentration of Pb, Se, As, Zn, Cr and Fe (mg/L) from selected hair cream products.

SAMPLE	Pb	Se	As	Zn	Cd	Fe
SMC	0.462±0.014	2.053±0.045	0.044±0.040	7.242±0.026	2.053±0.045	0.357±0.017
SAMD	0.338±0.018[b]	0.188±0.055	0.061±0.001	8.855±0.016[a]	1.855±0.039	0.242±0.014[a]
HMC	1.851±0.026[a]	1.422±0.053	0.158±0.054[a]	4.534±0.024[b]	0.836±0.039[b]	0.422±0.024
HM	0.581±0.011	0.805±0.159[b]	0.082±0.091	5.823±0.023	1.258±0.042	0.369±0.018
HDC	0.555±0.024	7.205±0.369[a]	0.027±0.020[b]	6.271±0.017	1.825±0.051	0.644±0.030[a]

Values show means of triplicate analysis ± standard deviation. Figures in the column are significantly different (*P < 0.05*). (SMC = Sample 1, SAMD = Sample 2, HMC=Sample 3,HM = Sample 4, HDC = Sample 5)
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Table 2 presents the mean concentrations of selected heavy metals (Zn, Cd, Fe, Se, and Pb) in undyed, dyed, and grey male hair samples. Zinc (Zn) was found to be highest in grey hair (0.48 ± 0.10 mg/L), followed by dyed hair (0.28 ± 0.09 mg/L), and lowest in undyed hair (0.23 ± 0.01 mg/L). Cadmium (Cd) exhibited the highest concentration in dyed hair (0.09 ± 0.01 mg/L), with a slightly lower value in grey hair (0.08 ± 0.05 mg/L), and was not detected in undyed hair. Iron (Fe) was most abundant in undyed hair (0.06 ± 0.02 mg/L) and least in grey hair (0.04 ± 0.01 mg/L), with no detectable levels in dyed hair. Selenium (Se) showed the highest concentration in grey hair (0.06 ± 0.02 mg/L), moderate levels in dyed hair (0.04 ± 0.03 mg/L), and was absent in undyed hair. Lead (Pb) was detected only in grey hair (0.03 ± 0.02 mg/L), while it was not detected in undyed and dyed hair.

Table 2: Mean Concentration (mg/L) of heavy metals in undyed, dyed and undyed Hair Male

Element	Ref. Value	Mean Concentration (mg/L)		
		Undyed	Dyed	Grey
As	0.008-0.8	0.00	0.00	0.00
Cd	0.1	0.00	0.09±0.01	0.08±0.05
Fe	0.6-15	0.06 ± 0.02	0.00	0.04±0.01
Pb	0.6	0.00	0.00	0.03±0.02
Zn	12.0	0.23±0.01	0.28±0.09	0.48±0.10
Se	0.8	0.00	0.04±0.03	0.06±0.02

Generally, the data suggest that grey hair accumulates higher levels of Zn, Se, and Pb compared to dyed and undyed hair, whereas dyed hair showed elevated levels of Cd. Iron concentration was highest in undyed hair. These variations may reflect differences in hair pigmentation, chemical exposure from hair treatments, and environmental factors.

Values show means of triplicate analysis ± standard deviation. Figures in the column are significantly different mean concentration of heavy metals in undyed, dyed and undyed Hair for Males ($P<0.05$).

Risk Quotients

Table 3 presents the estimated risk quotients (RQs) of heavy metals detected in selected hair cream products based on reference threshold values. Notably, selenium (Se), cadmium (Cd), and arsenic (As) displayed RQs well above 1.0 in most samples, indicating potential health risks.

Table 3: Estimated Risk Quotients of Heavy Metals in Hair Cream Products

Sample	Pb	Se	As	Zn	Cd	Fe
SMC	0.770	2.566	5.500	0.604	20.530	0.024
SAMD	0.563	0.235	7.625	0.738	18.550	0.016
HMC	3.085	1.778	19.750	0.378	8.360	0.028
HM	0.968	1.006	10.250	0.600	0.270	0.388
HDC	0.925	1.573	228.125	0.031	6.440	0.043

The highest RQ for arsenic was observed in HDC (228.13), which substantially exceeded safety thresholds. Lead (Pb) and iron (Fe) remained below or near safety limits across all samples, while zinc (Zn) exhibited the lowest RQs, suggesting lower toxicological concern. Overall, the data highlights the need for regulatory oversight due to the potential dermal and systemic exposure risks from prolonged use of these products.

Table 4 displays the calculated risk quotients of heavy metals in hair samples of male subjects, categorised by hair treatment types. The results show that all measured metals, except cadmium (Cd), remained well below the risk threshold (RQ < 1.0). Cd showed elevated risk in dyed (RQ = 0.90) and grey (RQ = 0.80) hair samples, approaching the safety limit. Other elements, including lead (Pb), selenium (Se), and zinc (Zn), exhibited minimal risk, while arsenic (As) was undetected in all samples. These findings suggest that although most metals do not pose immediate concern, Cd exposure through hair treatment products may require further investigation

Table 4: Estimated Risk Quotients of Heavy Metals in Hair Samples of Male Subjects

Hair Type	Pb	Se	As	Zn	Cd	Fe
Undyed	0.000	0.000	0.0	0.019	0.0	0.004
Dyed	0.000	0.050	0.0	0.023	0.900	0.000
Grey	0.050	0.075	0.0	0.040	0.800	0.003

DISCUSSION

The result is presented in decreasing order of Zn> Se> Cd>Pb>Fe> As . The difference could be due to the differences in the cosmetic formulation by the different manufacturers. From the result, it was observed that Zn had a significant (P<0.05) concentration of heavy metals across the period of the variation table, showing ranges in the concentration of the different heavy metals in the same samples.

Across the variation table, in the same sample for SMC Zn has a higher concentration of 7.242±0.26 (mg/L) and As has the lowest with 0.044±0.040 (mg/L) concentration. In the sample SAMD, Zn has a higher concentration of 8.855 ±0.016 mg/L and As has a lower concentration of 0.061±0.001 mg/L. In sample HMC, Zn has a higher concentration of 4.534 ±0.024 mg/L and As has a lower concentration of 0.158±0.054 mg/L. In sample HM, Zn has a higher concentration of 5.823 ± 0.023 mg/L, whereas As is lower with the concentration of 0.082 ± 0.091 mg/L. In sample HDC, Se has a higher concentration of 7.205 ± 0.365 mg/L, whereas As is lower with the concentration of 0.027 ± 0.020 mg/L.

The result of this study is in line with the works of Apostoli *et al.* (2020) who reported that heavy metals are a class of non-biodegradable pollutants that can enter human bodies through different routes such as food, hair and tend to accumulate in the body. Through bioaccumulation of these heavy metals from different exogenous and endogenous sources from food/water can initiate disruption of cellular events, including growth, proliferation, differentiation, damage, the repairing process and apoptosis. (Borges *et al.*, 2022).

Hair analysis for the male group, shows no significant difference(P<0.05) in the grey hair concentration of Iron, (0.04±0.01 mg/L) with undyed hair (0.06±0.02mg/L), the higher value blows the reference value of (0.6-15mg/L) which indicates that the hair type is not for iron accumulation (P<0.05). The mean concentration of Zn (p<0.05) significantly increased in undyed hair (0.23±0.01mg/L) dyed hair (0.28±0.09 mg/L), and grey hair (0.48±0.10 mg/L),the higher value below the reference value of (12.0mg/L).

Cadmium Cd has a higher concentration (0.09±0.01mg/L) in Dyed hair and lower in grey hair (0.08±0.05mg/L), the higher value is below the reference range of (0.1mg/L). A report also observed that Cadmium which is sometimes found in hair products, is toxic (Sosted *et al.*,2013). When at a higher concentration combined with other exogenous and endogenous sources could elevate the concentration of Cd which can cause a lot of diseases through bioaccumulation in human body (Sosted *et al.*, 2013; Patel *et al.*,2021). This ranges from dermal, renal, neurological and GI diseases to the development of several cancers including lungs, larynx, bladder, kidneys, testicles, bone and typhoid. (Philip *et al.*, 2018).

Cadmium is often been used in cosmetics for its coloured salts ranging from deep yellow to orange (Beiner *et al.*, 2015). In contrast to low GI absorption, Cd is more efficiently taken from the lungs through industrial dirt.(Pi *et al.*,2015). Acute or persistent inhalation of Cd in industrial regions might cause renal tubular dysfunction and lung injuries (Li *et al.*, 2019; Lech and Sadlik,2017). Cd blood concentration in people who smoke is sort of twice higher than that of nonsmokers. (Dogan *et al.*,2023), discovered Cd blood level of 0.4 against 1.3µg/L for nonsmokers vs. smokers in person populace. This appears to be associated with the character of tobacco vegetation to build up particularly high Cd concentrations in tissues mainly within the leaves (Proshad *et al.*, 2020). Cd absorption in human body is reduced by Zn, Ca and Se. Also, cigarette smoking significantly in Cd intake. Elevated Cd hair concentration could be caused by exogenous contamination which may come from permanent solutions, dyes, cares, bleach and some hair sprays. (Rahman, *et al.*,2016).

The analysis revealed that lead (Pb) levels were highest in grey hair samples from the male participants (0.03±0.02 mg/L), with a comparable elevated value of 0.07±0.03 mg/L also recorded in the same group. Despite this increase, the concentrations remained below the standard reference limit of 0.6 mg/L. Lead is classified as a highly toxic element, even at trace levels, due to its ability to interfere with vital physiological functions and cause damage to multiple organ systems (Lee *et al.*, 2016). Pb remains one of the most routinely assessed heavy metals in environmental and toxicological studies because of its established health risks. Although essential trace elements like iron (Fe), zinc (Zn), chromium (Cr), and arsenic (As) play crucial roles in biological processes, they become harmful when their concentrations surpass physiologically acceptable thresholds. Conversely, non-essential metals such as cadmium (Cd), mercury (Hg), and lead (Pb), which lack any known biological function, are toxic even at minimal exposure levels (Cobbina *et al.*, 2016). In this study, concentrations of As, Cd, and Pb remained within permissible safety margins ($P < 0.05$), suggesting the tested products are unlikely to pose immediate health threats.

Notable variations in metal concentrations were observed across different male hair types—undyed, dyed, and grey—likely influenced by environmental exposure, dietary intake, personal care product use, lifestyle habits, and physiological attributes like age and hair type. For As, Cd, and Se, levels were either undetectable or minimal, potentially reflecting occupational or environmental factors affecting the study population.

The elevated risk quotient (RQ) values identified for lead, cadmium, selenium, and arsenic in commercial hair creams support findings from earlier investigations showing significant contamination of cosmetic products with hazardous metals. Okonkwo *et al*. (2022), for example, documented high cadmium and lead levels in hair dyes from South Africa, often exceeding international health guidelines and posing substantial toxicological risks. Similarly, Al-Saleh and Al-Enazi (2020) detected alarming concentrations of arsenic and selenium in hair products available in Saudi Arabia, attributing these findings to substandard raw materials and poor-quality control. These heavy metals can permeate the skin barrier with regular use, potentially leading to bioaccumulation and chronic exposure effects (Chen *et al*., 2023). The detection of metals in dyed hair samples in this study confirms this route of exposure. Thus, these results align with increasing global concerns about unregulated toxic substances in cosmetic products and underscore the urgency for improved safety oversight.

CONCLUSION

This study has demonstrated the presence of elevated concentrations of hazardous heavy metals, most notably cadmium, arsenic, selenium, and lead, in several commercial hair cream products. Risk Quotient (RQ) values calculated for these elements exceeded the safety threshold ($RQ > 1$), indicating a considerable potential for adverse health effects from chronic exposure. Cadmium and arsenic, in particular, recorded the most alarming RQ values, suggesting both non-carcinogenic and carcinogenic risks associated with routine product use. Furthermore, the presence of these elements in dyed hair samples supports the likelihood of dermal penetration and systemic accumulation over time. In contrast, metals such as zinc and iron were found within safe concentration limits and are therefore considered to pose minimal toxicological concern.

RECOMMENDATIONS

To safeguard public health, there is a pressing need for regulatory agencies to enforce strict quality control measures in the formulation of cosmetic products. Manufacturers must adhere to established international safety guidelines, such as those from the World Health Organisation (WHO) and the United States Environmental Protection Agency (USEPA), particularly regarding raw material sourcing and production standards. Future research should explore the variation in heavy metal accumulation across different hair types—undyed, dyed, and grey—as well as across genders and occupational groups. Such stratified studies will provide deeper insights into demographic and lifestyle factors influencing metal exposure.
Hair analysis should be incorporated as a non-invasive biomonitoring tool in environmental and public health studies to evaluate long-term exposure to toxic metals. This approach is particularly suitable for tracking chronic exposure and internal bioaccumulation trends.
Further studies should employ molecular tools, including DNA sequencing of hair follicles, to investigate the genetic basis of hair damage or loss linked to heavy metal exposure. These investigations may help elucidate the molecular mechanisms of toxicity and identify susceptible individuals.

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