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Carcinogenic and Non-Carcinogenic Health Risks of Cadmium and Lead Exposure from Hair Dyes

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Abstract: Hair dye is a cosmetic product used for coloring hair, which can be temporary or permanent. It is quite trendy because they give the person a different look and possibly add hair volume, despite the fact that there are underlying toxic chemicals that can be absorbed through the scalp or inhaled as fumes. The use of toxic chemicals for producing hair dyes may result in an increase of carcinogenesis. This study aims to provide a carcinogenic and non-carcinogenic risk assessment of human exposure to lead and cadmium present in hair dye. This systematic review utilized 10 different scientific papers, 4 studies for qualitative data, and 6 studies for quantitative data. Qualitative data included the frequency of use, reasons for hair dyeing, carcinogenic awareness, and impacts on hair quality and human health. For quantitative data, level of cadmium and lead concentration in black hair dye. Findings show that people tend to dye their hair due to fashion statements and look younger, with a low level of carcinogenic awareness in hair dye ingredients. Also, adults show a higher exposure to cadmium and lead from hair dye than children. As a result of the tabulated data in hazard quotient, nothing surpasses the 1 or above limit. It shows that the black hair dye is all safe. The findings underscore the importance of increasing public awareness regarding the potential carcinogenic risks of hair dye ingredients and promoting safer practices in hair dye usage.

Keywords: *Cosmetics; Hazard; Heavy Metals; Pigments; Risk Assessment; Toxicity.*

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I. INTRODUCTION

A cosmetic product is any substance or mixture intended to be placed in contact with the external parts of the human body, with the exclusive or main objectives of cleaning, changing the look, protecting and maintaining good conditions, or eliminating body odors (Faria-Silva et al. 2022). One of the cosmetic products is hair dye. Hair dye used for coloring hair can be temporary or permanent and is classified based on its duration and the type of active ingredients involved in the dyeing process (Chisvert et al. 2018).

Hair dyes are quite trendy because they give the person a different look and possibly add volume to make hair look thicker. However, there are underlying toxic chemicals that can be absorbed through the scalp or inhaled as fumes (Staff 2024). Human skin has tiny openings that allow substances, including chemicals, to be absorbed. Skin absorption rates of caffeine have shown that hair follicles absorb at a rate 10 times higher than the outer layer of skin (Liu et al. 2011). The use of toxic chemicals as raw materials for producing hair dyes may result in the synthesis of other contaminants with potential toxicities and an increased risk of carcinogenesis (He et al. 2022). Some of the common toxic chemicals used in hair dye are P-phenylenediamine, hydrogen peroxide, ammonia, and heavy metals such as lead, cadmium, and mercury (KatakamiYuki 2022; Staff 2024). In actuality, there are no global limits for pollutants such as heavy metals in cosmetics, with the exception of 20 g/g for lead and 5 g/g for cadmium (Al-Dayel et al. 2011). While the regulatory limits for certain metals in cosmetics in Canada are 10 g/g for lead, 3 g/g for arsenic, cadmium, and mercury, and 5 g/g for antimony (Ullah et al. 2017).

Furthermore, human health risk assessment is the process to estimate the nature and probability of adverse health effects in humans who may be exposed to chemicals in contaminated environmental media, now or in the future (EPA 2025). A carcinogen is a substance, organism or agent capable of causing cancer (NHGRI 2025). As some ingredients of hair dye are toxic, there is a potential human carcinogenic risk. Potential human carcinogenic risks associated with chemical exposure which have an increased probability of developing cancer during a person's lifetime. The parameter derived from this risk assessment is the cancer

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slope factor (EC 2003). Conversely, non-carcinogenic risk is characterized by a risk ration index called hazard quotient (Jafarzadeh et al. 2022). This risk assessment evaluates the potential for non-cancer health effects from exposure to a substance. These kinds of risk assessment helps to quantify the potential development of health problems, adverse effects, and establish and/or recommend safe exposure limits.

Determining the level of concentration of lead and cadmium present in hair dye is significant for assessing exposure and health risks associated with black hair dyes. This systematic review aims to provide a carcinogenic and non carcinogenic risk assessment of human exposure to lead and cadmium present in hair dye. By thoroughly analyzing the existing literature, this review will contribute to a deeper understanding of the strengths and limitations of health risk assessment related to hair dye.

II. METHODOLOGY

This study utilized a systematic review approach following the widely accepted PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) guidelines. PRISMA was utilized to thoroughly select pertinent publications reporting on the health risk assessment of human exposure to organic chemicals and heavy metals in hair dye released between 2013 and 2025.

A. Data Sources

Using the PRISMA guidelines, all relevant published literature and scientific materials were scrutinized and carefully selected from multiple widely recognized search databases such as Google Scholar, Elsevier/ScienceDirect, Springer, and National Institutes of Health (NIH).

B. Literature Search

To maximize and utilize a proper and successful search strategy, the aforementioned search databases used appropriate keywords and Boolean operators such as AND or OR. Numerous sets of keywords were used and searched to obtain suitable references.

The first set of keywords used terms related to health risk assessment in hair dye, such as “health risk assessment in hair dye,” “risk assessment hair dye,” “hair dye assessment,” and “assessment in hair dye.” The second set centered around the risk assessment of heavy metals in hair dye, using terms such as “health risk assessment of heavy metals in hair dye,” “assessment of heavy metals in hair dye,” “heavy metals in hair dye risk assessment,” and “heavy metals in hair dye.” The third set focused on toxic chemicals in hair dye, employing terms like “heavy metals presence in hair dye,” “toxic chemicals presence in hair dye,” “lead and cadmium in hair dye,” and “heavy metals used in hair dye.” Fourth set is for quantitative analysis which focuses on knowledge, attitudes, and practices of society in hair dye, using terms such as “knowledge of society in hair dye,” “hair dye societal perception,” “practices in using hair dye,” and “knowledge in hair dye”.

Ensuring the accuracy of the current trends of the study, the results of the searches from online databases were limited to scientific papers and journal articles published between 2013 and 2025. During the initial literature search, all research publications found in databases were selected based on their titles, authors, publication dates, and journals to exclude duplicates. To eliminate irrelevant studies, the remaining papers underwent abstract and full-text screening for qualifying criteria.

C. Inclusion and Exclusion

All relevant articles included in this review were categorized based on the following criteria: (1) studies that addressed the level of cadmium and lead concentration present in hair dye; (2) studies that indicated the black hair dye color; (3) studies that evaluated the dermal, ingest, and inhaled route of exposure of hair dye; (4) studies that stated the frequency of use and reasons in hair dyeing; (5) studies that included the carcinogenic awareness and impacts of hair dye in hair quality and human health; (6) studies conducted and published between 2013 and 2025; (7) original studies published as research articles or review articles; (8) original articles with full-text; and (9) published in the English language or have an English translation.

Studies were excluded if they (1) heavy metal and other chemicals concentration only; (2) not included black hair dye; (3) present only one desired data of heavy metals; (4) were case series, case reports, systematic reviews, or narrative reviews; (5) lacked corresponding outcome parameters or research data or (6) do not have available full-text; or (7) no English translation.

D. Search Results

A total of 40 studies were initially drawn out by using combinations of search terms from search databases such as Google Scholar, Elsevier/ScienceDirect, Springer, and the National Institutes of Health (NIH). These online databases’ search results were limited to research and review articles written in English and published between 2013 and 2025, which filtered 7 studies from the initial results. Thus, only 33 research publications remained and were subjected to final screening based on the inclusion criteria. A total of 10 research and review articles were finally included in the qualitative and quantitative analysis after further screening and evaluating the eligibility of the research and review articles based on the contents of titles, abstracts, and availability of the full research materials. The PRISMA flow diagram (see Fig. 1) illustrates the steps of study selection and findings.

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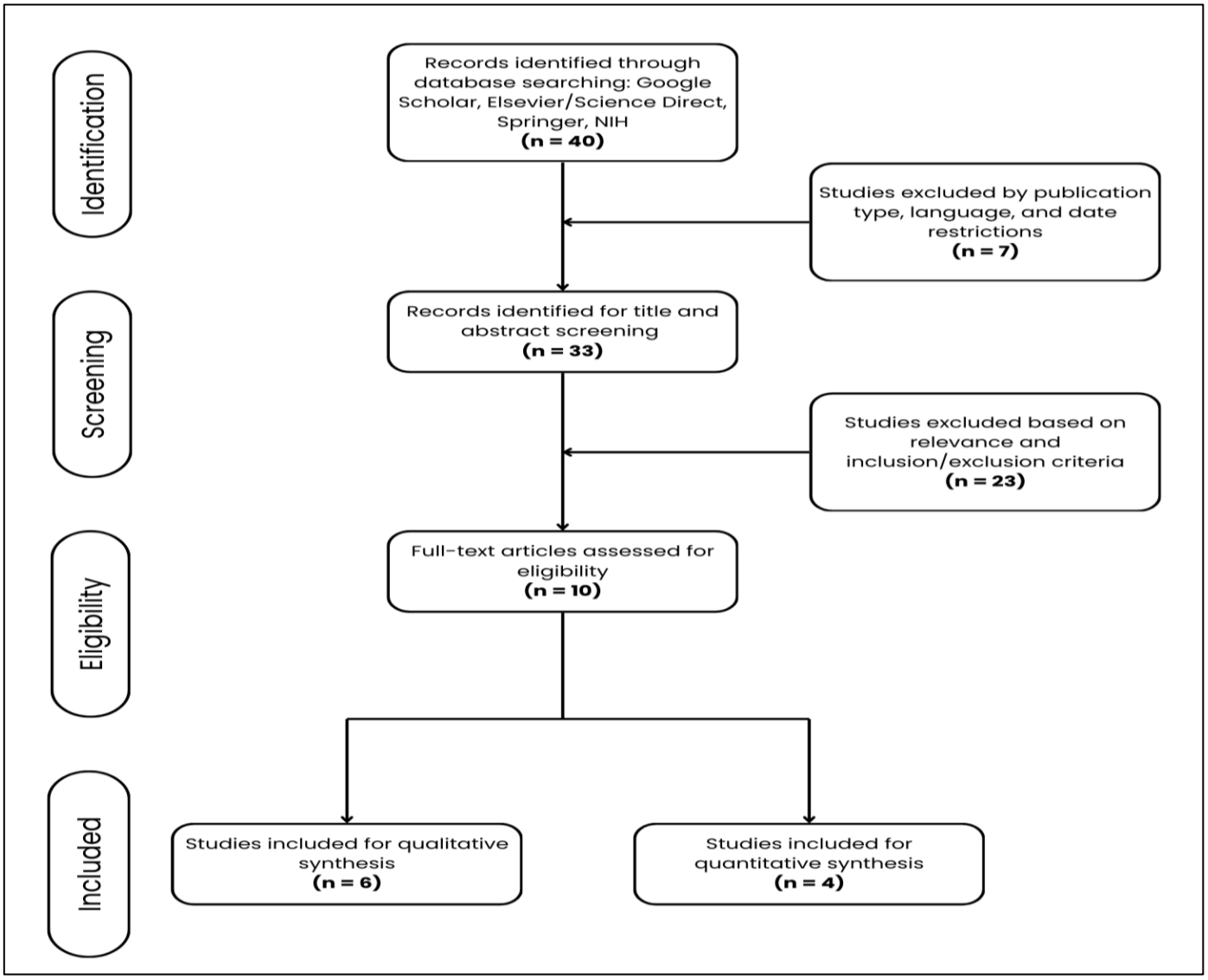

Fig 1: Flow Diagram of the Selection of Studies using the PRISMA Guidelines

E. Data Extraction

In this paper, 10 studies were selected from 40 articles based on the established eligibility criteria. The systematic review encompassed various studies and literature conducted around the world. The gathered literature was subjected to evaluation, and relevant data specific to the review objectives were recorded in Google Docs. The data and information extracted from 10 studies include cadmium and lead found in hair dye and the health risk assessment in accordance with the data shown in the studies.

F. Statistical Analysis

After sorting and analyzing the qualitative characteristics of selected studies, the literature is further evaluated for eligibility for quantitative and qualitative analysis. Different related literature and articles that indicate the level of concentration of cadmium and lead present in hair dye were included to determine the health risk assessment in the dermal and inhaled routes of exposure to hair dye. In order to determine the health risk assessment, the data gathered will be calculated using the formulas (See Table 1).

According to Meletic et al. (2023), health risk assessment is based on the calculated non-carcinogenic and carcinogenic risks. Average daily dose (ADD) is the first step in the assessment of carcinogenic risk and non-carcinogenic risk. It is the daily intake and taking into account all three pathways of exposure, specifically ingestion, inhalation, and dermal contact. The term average daily dose (ADD) is used for the non-carcinogenic, while the same formulas with the term lifetime average daily dose (LADD) are used for the carcinogenic risk. In addition, carcinogenic risk (CR) is presented through the total carcinogenic risk (TCR), which refers to the overall estimation of cancer development from exposure to multiple carcinogenic substances across different exposure pathways.

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Table 1: Equations Used for the Calculations in this Review

Parameter	Formula
Dermal ADD	$\frac{C\ x\ SA\ x\ AF\ x\ ABS\ x\ EF\ x\ ED}{BW\ x\ AT} x\ CF$
Ingestion ADD	$\frac{C\ x\ IgR\ x\ EF\ x\ ED}{BW\ x\ AT}\ x\ CF$
Inhalation ADD	$\frac{C\ x\ InhR\ x\ EF\ x\ ED}{PEF\ x\ BW\ x\ AT}$
Hazard Quotient	$ADD_{dermal} + ADD_{ingestion} + ADD_{inhalation}$
Specific HQ*	$\frac{ADD}{RfD}$
Hazard Index	$\Sigma\ HQ$
Carcinogenic Risk	$CR_{dermal} + CR_{ingestion} + CR_{inhalation}$
Specific CR**	$ADD\ x\ CSF$
Total CR	$\Sigma\ CR$

Sources: Alam et al. 2019; USEPA 1989; Miguel et al. 2007

*Dermal ADD is divided by the RfD for dermal absorption; apply with ingestion and inhalation.
**Dermal ADD is multiplied by the CSF for dermal absorption; apply with ingestion and inhalation.

On the other hand, non-carcinogenic risk is presented through the hazard index, which allows the hazard quotient (HQ) and hazard index (HI) to be used for the purpose. Hazard quotient (HQ) is the ratio of exposure to an appropriate reference dose, while the hazard index (HI) is the sum of the HQs of the chemicals in a mixture (Goumenou and Tsatsakis 2019). For the purpose of calculating hazard quotient and hazard index in health risk assessment, the average daily dose calculation factors are detailedly presented in Table 2.

Table 2: Factors Used for the Calculation of Average Daily Dose

Parameter	Denoted by	Unit	Value	
			Children	***Adult***
[a] Concentration of heavy metal	C	mg/kg	-	-
[a] Exposure frequency	EF	day/year	350	350
[a] Exposure duration	ED	year	6	24
[a] Body weight	BW	kg	15	70
[a] Average time	AT	day	2190	8760
[b] Scalp skin surface area	SA	cm^2	450	650
[a] Adherence factor	AF	$mg/cm^2/day$	0.2	0.07
[a] Dermal absorption factor	ABS	-	0.001	0.001
[a] Ingestion rate	IngR	mg/day	200	100
[a] Inhalation rate	InhR	m^3/day	7.6	20
[a] Particulate emission factor	PEF	m^3/kg	1.36×10^9	1.36×10^9
[a] Conversion factor	CF	kg/mg	1×10^{-6}	1×10^{-6}

[a] Miletic et al. (2023)
[b] Gao et al. (2018)

According to the U.S. Environmental Protection Agency (2025), exposure frequency (EF) refers to the frequency with which the exposure occurs and might be provided in days per year or events per day. Meanwhile, exposure duration (ED) is the amount of time that an individual or population is exposed to the contaminant being evaluated and is typically provided in years.

One of the exposure factors is ingestion rate (IngR). Ingestion rate (IngR) is the amount of food, water, or soil/dust containing the contaminant that an individual ingests during a specific period of time (EPA 2025). The ingestion rate for children is always higher than for adults because children are more in contact with the soil or sediment (Miletic et al. 2023). For example, children often engage in activities that involve direct contact with soil and sediments, such as playing in sandboxes, digging in dirt, and putting fingers in their mouths after touching the ground. Another is the inhalation rate (InhR), it represents the volume of air inhaled over a specified timeframe (EPA 2025). The particulate emission factor (PEF) is used only in the inhalation formula and represents the number of particulates. In addition, scalp skin surface area (SA) represents the surface area of the skin in the scalp that comes into contact with the contaminated water, soil/sediment, or other contaminated substances. The adherence factor (AF) is used as a number of heavy metals that adhere to the skin, and its figures in the formula for dermal contact.

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While the dermal absorption factor (ABS) refers to the fraction of chemical that is absorbed through skin after dermal contact. It is the factor that only figures in the formula for dermal contact. Lastly, a conversion factor (CF) is used to standardize the units in the formulas. All the aforementioned factors are from a single reference to avoid further complication in calculating the carcinogenic and non-carcinogenic risk.

Table 3: Reference Dose for Dermal, Ingestion and Inhalation Routes Of Cd And Pb (Mg/Kg-Day)

Heavy Metal	RfD_{dermal}	$RfD_{Ingestion}$	$RfD_{Inhalation}$
Cadmium	0.00001 [a,d]	0.001 [a,b,c,d]	0.001 [a,b]
Lead	0.00052 [a,b,c,d]	0.0035 [a,c]	0.00352 [a,b,c,d]

[a] Zheng et al. (2015)
[b] Narshimha (2020); US EPA (1989)
[c] ClinMed International Library
[d] Ngole-Jerne & Fantke (2017); US EPA (2010)

Table 4: Cancer Slope Factors for Dermal, Ingestion And Inhalation Routes of Cd And Pb (Kg-Day/Mg)

Heavy Metal	CSF_{dermal}	$CSF_{Ingestion}$	$CSF_{Inhalation}$
Cadmium	6.1 [c]	6.1 [c]	6.3 [a,b,e]
Lead	0.042 [d]	0.0085 [c,d]	0.042 [a,b,c]

[a]Johnbull et al. (2019); US EPA (2009), US EPA - IRIS (2010)
[b]Aguillera et al. (2021); US EPA (2009)
[c]Miletic et al. (2023); US EPA (2001), Yi et al. (2017)
[d]Raksha Shetty et al. (2024); ATSDR

Furthermore, the heavy metals focused in this study are cadmium and lead. Reference dose (RfD) is an estimate of a daily exposure level for dermal, ingestion, and inhalation routes of cadmium and lead to humans (See Table 3). Concerning the reference dose values, a lower RfD value indicates a greater negative impact on humans.

On the other hand, the cancer slope factors (CSF) is the counterpart of RfD and used in carcinogenic risk calculations, which serve as a metric for quantifying the excess cancer risk resulting from exposure to substances, are presented in Table 4 for both cadmium and lead, with specific reference to dermal, ingestion, and inhalation pathways.

III. RESULTS AND DISCUSSION

A. Cadmium and Lead Content in Black Hair Dyes

This review conducted a risk assessment for the heavy metals cadmium and lead found in black hair dye. Cadmium, in particular, is used as a pigment in cosmetics, allowing for warm colors (red, orange, yellow) to be created (Saleh et al. 2020; Chauhan et al 2010). It has been primarily used in the production of lipsticks and face powders (Attard and Attard 2022). Although it is not the primary pigment used in hair dyes, products can become contaminated with cadmium during the manufacturing process, as raw materials may leave traces of metals in the final product. On the other hand, lead can contaminate cosmetics when companies use herbal or plant materials that may have prior contamination of heavy metals from soil or water. Additionally, mineral-based colorants and mica powder used in cosmetics may also contain traces of lead. Both of these heavy metals can cause adverse effects, starting with vomiting, diarrhea, and irritation, but can lead to more severe conditions with prolonged exposure, such as neurotoxicity, carcinogenicity, and organ damage (Saah et al. 2024).

B. Qualitative Results

This section explores societal perceptions of hair dye use. Utilizing the Knowledge, Attitudes, and Practices (KAP) model, it investigates societal trends, public awareness of carcinogenic in hair dye, and health effects such as impacts on hair quality and human health.

➢ *Results of the Studies*

The qualitative data and results extracted from four selected scientific papers are detailed in Table 5. Among the four studies, the 3rd study solely focuses on female participants in their cross-section analysis regarding their knowledge, attitudes, and practices in hair dye. The younger age of the study participants found in the 1st study and the oldest participants found in the 2nd study, with 16 years old and 76 years old, respectively. Regarding their frequency of usage in hair dye, there is a selection to choose their frequency and it shows the number of participants and its percentage.

To determine their attitude towards hair dye, the researchers asked the study participants the reasons for dyeing their hair. Based on these studies, some of the participants do not disclose their reasons and some have multiple reasons for hair dyeing. Moreover, the researchers included in their cross section studies regarding the carcinogenic awareness of the participants whether they are aware of the cancerous substances present in hair dye or not.

- *Knowledge, Attitudes, and Practices (KAP) Model*

The Knowledge, Attitudes, and Practices (KAP) model is a foundational tool in public health research that offers a systematic approach to understanding health behaviors, empowering researchers to design impactful interventions and assess their success (Zarei et al. 2024). This survey is a quantitative method that provides access to quantitative and qualitative information, however, it is based on self-reported statements, not objective measurements (FAO n.d.; SPRING

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n.d.). As a result, the responses may be varied by the judgment, cooperation, and memory of the participants in answering the questionnaires provided by the surveyors.

In these studies, the study participants are randomly selected and voluntarily answer the questionnaires about hair dye. Based on the number of participants in four studies, females were dominantly volunteered themselves and more likely to use hair dye. The ages of participants range between 16 to 74 years old, 17 to 76 years old, more than or less than 20 years old, and 20 to 60 years old. According to Emma Hayes (2019), it is not advisable to use on children under 16 years old any hair dye products based on manufacturers. Hair dyes contain chemicals that in rare cases can cause severe, even life-threatening, allergic reactions; for instance, a case study of a school girl who dyed her hair had a severe allergic reaction to her home dye kit which she felt burning, itching, and severely swollen eyes (BBC 2017).

Table 5: Knowledge, Attitudes, And Practices (Kap) and Carcinogenic Awareness In Hair Dye

N	Age Range	Frequency of use				Reason				Carcinogenic Awareness			Study
	years	n	%	Description		n	%	Description		n	%	Description	
250	16–74	56	22.4	Annually		149	59.6	To look younger		30	24	Yes	Gupta (2018)
Male: 141 Female: 109		74	29.6	2–6 per year		51	20.4	For fashion statement		152	60.8	No	
		48	12.0	>6 per year		27	10.8	From a recommendation		63	25.2	Don't know	
						23	9.2	Others					
333	17–76	197	59.2	Annually		119	30.59	To get rid of gray hair		9	29.72	Yes	Sharee f et al. (2024)
Male: 105 Female: 228		87	26.1	2–5 per year		73	18.76	For fashion statement		207	62.16	No	
		49	14.7	>5 per year		67	17.22	To boost self-confidence		27	8.10	Don't know	
						47	12.08	To have a new look					
						44	11.31	To look more beautiful					
						39	10.02	To look younger					
319	≤ 20 n = 216	57	17.86	Monthly		279	87.5	For fashion statement		79	24.8	Yes	Sayed et al. (2024)
Female: 319		78	24.45	Bimonthly		22	7.0	From a recommendation		240	75.2	No	
		13	4.06	Annually		13	4.0	To get rid of gray hair					
	> 20 n = 44	132	41.4	Not once		6	2.0	To look younger					
98	20–60	57	58.16	>12 per year		75	76.53	To look younger		53	54.08	Yes	Joshi et al. (2021)
Male: 24 Female: 74		23	23.47	Monthly		55	56.1	For fashion statement		45	45.92	No	
		15	15.3	Bimonthly		21	21.4	To get rid of gray hair					
		3	3.06	Weekly		2	2.04	Not specified					

Furthermore, the usage frequency of the study participants varies such as once a year, less than 12 per year, monthly hair dyeing, or not even once. These studies show that many of the study participants were annually and monthly using hair dye. It is recommended to hair dye again at least four to six weeks after hair dyeing to keep hair healthy (Petite 2024). Along with that, the study participants questioned the reason for using hair dye. One of the top answers involved the desire to get rid of gray hair with 153 total participants and to look younger with 269 overall participants (see Table 5). Collective data also revealed that many participants have an inclination for a younger look achieved by the concealment of the gray and white hairs, possibly due to their genetic problems and age. Fashion statement was established as the top answer for the reason of hair dye usage with 403 respondents among all study participants. Coloring hair with different hues is a kind of fashion trend in different places worldwide and boosts one's confidence.

- *Carcinogenic Awareness*

A carcinogen is a substance, organism, or agent capable of causing cancer (NHGRI 2025). In 2018, the Food and Drug Administration (FDA) banned lead acetate-containing hair dye due to prolonged exposure to lead can result in brain damage, nerve damage, and neurological disorders, among other problems. The Centers for Disease Control and Prevention (CDC) also labeled lead acetate as a likely carcinogen (Holland 2017; Akers 2023). Dark hair dye colors, such as black and brown, contain more chemicals that might be carcinogenic than light colors (Akers 2023).

- *Human Health*

Hair dye products contain many ingredients that may irritate the scalp and cause allergic reactions such as itching, swollen eyelids, burning sensation on the scalp, face, or neck, red rashes, and so on (Whelan 2023). Studies did not indicate the severity of the allergic reactions of the study participants. The common reaction to the application of hair dye is itchiness and the manifestation of rashes. In the first study, side effects are listed but no statistical data indicated the number of participants that experienced these effects. Most of the hair dye boxes have an instruction to test the allergic reaction before applying the product to hair. However, many people do not read the instructions which makes the risk increase.

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Throughout the four selected studies, the majority of the study participants were not aware that hair dye can cause cancer because of the carcinogenic compounds in the ingredients (see Table 5). Out of 1000 total participants, 734 participants were not aware that hair dye can cause cancer. Only a few participants are aware of carcinogenic substances in hair dye. The lack of societal knowledge that people are exposed to carcinogens by using hair dye raises utmost concern.

➢ *Impact of Hair Dye*

The results of the study (see Table 6), specifically concerning health effects related to hair dyeing, are summarized in Table 6. In four selected studies, some study participants do not report the side effects or adverse effects of the hair dye. In the first study, no statistical data showed the adverse effect but it only listed the effect. Nevertheless, study participants who reported the effect, some of them do not show the side effect but simply nothing happens to them in dyeing hair.

Table 6: Reported Health Effects Of The Study Participants

N	Health Effects			Study
	n	%	Description	
36	No statistical data		Itching	Gupta (2018)
			Erythema	
			Swelling	
52	16	30.76	Itching	Shareef et al. (2024)
	14	26.92	Rashes over the face/forehead	
	10	19.23	Headache	
	6	11.53	Frizzy hair	
	6	11.53	Hairfall	
249	129	40.5	Hair loss	Sayed et al. (2024)
	69	21.6	Dry hair	
	51	16	Dandruff	
242	149	46.8	Itching	
	26	8.1	Red rashes	
	26	8.1	Puffy face	
	14	4.5	Eye infection	
	9	2.7	Bruising	
	9	2.7	Increased heart rate	
	9	2.7	Tiredness	
67	31	46.94	Dry hair	Joshi et al. (2021)
	20	30.62	Hair loss	
	15	22.45	Hair thinning	
	11	17.35	Dandruff	
	10	15.31	Hair discoloration	
	9	14.29	Texture change	
	6	9.19	Hair splitting	
	21	31.63	No side effects	

- *Hair Quality*

One of the effects of frequent hair dyeing is hair damage because hair dyes contain hair chemicals, such as ammonia and hydrogen peroxide, which strip the natural oil from hair and over time weaken the hair shaft which allows it to become brittle, dry and prone to breakage (TOI 2025). In four selected studies, some participants do not report the side effects of hair dye to themselves. Table 6 concludes that hair loss and dry hair were the most reported side effects among a total of 404 study participants with 155 and 100 individuals, respectively. It shows that hair dyes can weaken and damage hair, which makes the hair look unhealthy.

C. Quantitative Results

The focus of this study is on cadmium and lead as target contaminants, as they appear to be more uniform among the selected studies. Some of the other studies have complicated data, such as uncertain values with a plus or minus (±) sign before the number, leaving the concentration value unclear.

➢ *Mean Concentration*

Six studies conducted by other researchers were chosen to investigate the mean concentrations of cadmium and lead in hair dyes. The authors used these results to calculate the average daily dosage and assess the potential hazards and carcinogenic risks associated with these heavy metals.

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Table 7: The Mean Concentrations of Cadmium and Lead Found In Black Hair Dyes

Study	n	Mean Concentration (ppm)	
		Cd	*Pb*
Albugami et al. (2024)	4	0.001	0.162
Khalili et al. (2018)	8	0.000483	0.1699
Amhimmid et al. (2022)	1	0.25	5.85
Iwegbue et al. (2016)	3	bdl	1.83
Hussein (2013)	2	0.0145	0.685
Ozbek & Akman (2016)	2	0.00725	0.345

The hair dye samples analyzed contained cadmium concentrations ranging from below the detection limit to 0.25 ppm, while the lead concentrations ranged from 0.162 to 5.85 ppm. Table 7 presents the concentration values and corresponding sample sizes for each study. The highest lead content analyzed by Amhimmid et al. (2022) was found to be 5.85 parts per million, while the cadmium levels in the hair dye samples from Iwegbue et al. (2016) were below the detection limit.

➢ *Average Daily Dose*

The average daily doses of cadmium exposure through dermal absorption ranged from 2.78 x 10^{-11} to 1.44 x 10^{-3} mg/kg-day for children and 3.01 x 10^{-33} to 1.56 x 10^{-10} mg/kg-day for adults. Tables 8 and 9 summarize the research on average daily doses (ADD) for lead (Pb) and cadmium (Cd) from black hair dye. The analysis was based on a critical review of the ADD values reported for Cd and Pb in each study, taking into account the sample size, age group, and study citation.

Table 8: The Average Daily Dose Of Cd For All Exposure Routes Found In Black Hair Dye

n	Cadmium						Study
	ADD_{dermal} *(mg/kg-day)*		$ADD_{ingestion}$ *(mg/kg-day)*		$ADD_{inhalation}$ *(mg/kg-day)*		
	Child	*Adult*	*Child*	*Adult*	*Child*	*Adult*	
4	5.775 x 10^{-11}	6.23 x 10^{-13}	1.28 x 10^{-8}	3.63 x 10^{-6}	3.57 x 10^{-13}	5.79 x 10^{-11}	Albugami et al. (2024)
8	2.78 x 10^{-11}	3.01 x 10^{-13}	6.18 x 10^{-9}	6.62 x 10^{-10}	1.73 x 10^{-13}	9.73 x 10^{-14}	Khalili et al. (2018)
1	1.44 x 10^{-8}	1.56 x 10^{-10}	3.20 x 10^{-6}	3.42 x 10^{-7}	8.93 x 10^{-11}	5.04 x 10^{-11}	Amhimmid et al. (2022)
3	bdl	bdl	bdl	bdl	bdl	bdl	Iwegbue et al. (2016)
2	8.34. x 10^{-10}	9.04 x 10^{-12}	1.85 x 10^{-7}	1.99 x 10^{-8}	5.18 x 10^{-12}	2.92 x 10^{-12}	Hussein (2013)
2	4.17 x 10^{-9}	4.52 x 10^{-11}	9.27 x 10^{-8}	9.93 x 10^{-8}	2.59 x 10^{-11}	1.46 x 10^{-11}	Ozbek & Akman (2016)

Notably, the study by Amhimmid et al. (2022) reports significantly higher ADD values for Cd in both children and adults compared to other studies. On the other hand, according to Iwegbue et al. (2016), both adult and pediatric Cd levels were below the detection limit. The lowest ADD values for Cd in both adults and children were reported by Khalili et al. (2018). Similarly, for lead (Pb) dermal absorption, the results show a range of ADD values, though less dramatic than for Cd. The highest ADD values for Pb in both adults and children were reported by Hussein (2013), while the lowest ADD values were reported by Albugami et al. (2024).

The studies differ in sample size, which may have an impact on the reliability of the ADD estimates and the representativeness of the data. In terms of cadmium (Cd) ingestion, the results show a significant variation in exposure estimates, with ADD values ranging from 1.28 x 10^{-8} to 9.27 x 10^{-8} mg/kg-day for children and 3.63 x 10^{-6} to 9.93 x 10^{-8} mg/kg-day for adults.

Table 9: The Average Daily Dose of Pb for All Exposure Routes Found in Black Hair Dye

n	Lead						Study
	ADD_{dermal} *(mg/kg-day)*		$ADD_{ingestion}$ *(mg/kg-day)*		$ADD_{inhalation}$ *(mg/kg-day)*		
	Child	*Adult*	*Child*	*Adult*	*Child*	*Adult*	
4	9.32 x 10^{-9}	1.01 x 10^{-10}	2.07 x 10^{-6}	2.22 x 10^{-7}	5.79 x 10^{-11}	3.26 x 10^{-11}	Albugami et al. (2024)
8	9.78 x 10^{-9}	1.06 x 10^{-10}	2.17 x 10^{-6}	2.33 x 10^{-7}	6.07 x 10^{-11}	3.42 x 10^{-11}	Khalili et al. (2018)
1	3.37 x 10^{-7}	3.65 x 10^{-9}	7.48 x 10^{-5}	8.01 x 10^{-6}	2.09 x 10^{-9}	1.18 x 10^{-9}	Amhimmid et al. (2022)
3	1.05 x 10^{-7}	1.14 x 10^{-9}	2.34 x 10^{-5}	2.51 x 10^{-6}	6.54 x 10^{-10}	3.69 x 10^{-10}	Iwegbue et al. (2016)
2	3.94 x 10^{-8}	4.27 x 10^{-10}	8.76 x 10^{-6}	9.38 x 10^{-7}	2.45 x 10^{-10}	1.38 x 10^{-10}	Hussein (2013)
2	1.98 x 10^{-8}	2.15 x 10^{-10}	4.41 x 10^{-6}	4.73 x 10^{-7}	1.23 x 10^{-10}	6.95 x 10^{-11}	Ozbek & Akman (2016)

The highest ADD values for Cd in children were reported by Albugami et al. (2024) and Ozbek & Akman (2016), while adults with Cd had the highest ADD value, according to Albugami et al. (2024). On the other hand, according to Khalili et al. (2018), adults and children with Cd had the lowest ADD values. Similarly, a range of ADD values in lead ingestion demonstrated to be not as significant as for cadmium. The two studies that report the highest ADD values for Pb in both adults and children are Albugami et al. (2024) and Khalili et al. (2018), while the lowest ADD value for Pb in adults was reported by Hussein (2013). The results for cadmium (Cd) inhalation show a range of ADD values,

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suggesting that exposure estimates vary. The highest ADD values for Cd in both adults and children were reported by Amhimmid et al. (2022), while the lowest ADD values were reported by Khalili et al. (2018). Notably, Cd levels in adults and children were found to be below the detection limit (bdl) by Iwegbue et al. (2016).

Likewise, for lead (Pb) inhalation, the results show a range of ADD values, indicating variability in exposure estimates. The highest ADD values for Pb in both adults and children were reported by Amhimmid et al. (2022), while the lowest ADD values were reported by Khalili et al. (2018). Again, Cd levels in both adults and children were found to be below the detection limit (bdl) by Iwegbue et al. (2016).

➢ *Hazard Quotient and Hazard Index*

Moving on to the hazard quotient (HQ) and hazard index (HI), the results show a range of values for both cadmium (Cd) and lead (Pb). These parameters are significant in identifying the non-carcinogenic risks of heavy metals present in a substance. Human exposure to trace quantities of toxic elements present in hair dyes can cause notable health effects, as discussed in the previous section on qualitative results. Among the different brands of hair dye in the six studies, the highest HQ values for Cd in both adults and children were reported by Amhimmid et al. (2022), while the lowest HQ values were reported by Khalili et al. (2018).

Table 10: Quantities Of Non-Carcinogenic Risk Assessment Parameters

n	Hazard Quotient						Study
	Child		*HI*	*Adult*		*HI*	
	Cd	*Pb*		*Cd*	*Pb*		
4	1.86×10^{-5}	6.09×10^{-4}	6.28×10^{-4}	3.63×10^{-3}	6.36×10^{-5}	3.69×10^{-3}	Albugami et al. (2024)
8	8.96×10^{-6}	6.39×10^{-4}	6.48×10^{-4}	6.92×10^{-7}	6.68×10^{-5}	6.75×10^{-5}	Khalili et al. (2018)
1	4.64×10^{-3}	2.20×10^{-2}	2.67×10^{-2}	3.58×10^{-4}	2.30×10^{-3}	2.65×10^{-3}	Amhimmid et al. (2022)
3	bdl	6.89×10^{-3}	6.89×10^{-3}	bdl	7.19×10^{-4}	7.19×10^{-4}	Iwegbue et al. (2016)
2	2.68×10^{-4}	2.58×10^{-3}	2.85×10^{-3}	2.08×10^{-5}	2.69×10^{-4}	2.90×10^{-4}	Hussein (2013)
2	5.10×10^{-4}	1.30×10^{-3}	1.81×10^{-3}	1.04×10^{-4}	1.36×10^{-4}	2.39×10^{-4}	Ozbek & Akman (2016)

Similarly, the highest HI values for both adults and children were reported by Amhimmid et al. (2022), while the lowest HI values were reported by Khalili et al. (2018).

According to the Environmental Protection Agency (EPA 1997), a hazard quotient greater than 1 indicates a harmful effect. Since all the values in this study are less than 1, the hair dyes can be considered safe for human health. However, this calculation could be affected by the method of obtaining the mean concentration between all the samples identified in each study, which may require further investigation into specific brands

➢ *Carcinogenic Risk*

After calculating the non-carcinogenic risks, the study then estimates the potential health effects in terms of carcinogenicity by calculating the carcinogenic risk (CR). The formula used for the calculation of CR, for three exposure routes, and TCR (total carcinogenic risk) are shown in Table 11. By multiplying the calculated average daily dose, also known as the carcinogenic daily intake, with the cancer slope factors given by the Environmental Protection Agency of the United States, the study can identify the carcinogenic risk of specific heavy metals traced from products or other substances.

Table 11: Quantities Of Carcinogenic Risk Assessment

n	Total Carcinogenic Risk						Study
	Child		*Total*	*Adult*		*Total*	
	Cd	*Pb*		*Cd*	*Pb*		
4	7.84×10^{-8}	1.80×10^{-8}	9.64×10^{-8}	2.21×10^{-5}	1.89×10^{-9}	2.21×10^{-5}	Albugami et al. (2024)
8	3.79×10^{-8}	1.89×10^{-8}	5.67×10^{-8}	4.04×10^{-9}	1.99×10^{-9}	6.03×10^{-9}	Khalili et al. (2018)
1	1.96×10^{-5}	6.50×10^{-7}	2.03×10^{-5}	2.09×10^{-6}	6.83×10^{-8}	2.16×10^{-6}	Amhimmid et al. (2022)
3	bdl	2.03×10^{-7}	2.03×10^{-7}	bdl	2.14×10^{-8}	2.14×10^{-8}	Iwegbue et al. (2016)
2	1.13×10^{-6}	7.61×10^{-8}	1.21×10^{-6}	1.21×10^{-7}	8.00×10^{-9}	1.29×10^{-7}	Hussein (2013)
2	5.91×10^{-7}	3.83×10^{-8}	6.29×10^{-7}	6.06×10^{-7}	4.03×10^{-9}	6.10×10^{-7}	Ozbek & Akman (2016)

In the study conducted by Ahhimmid et al. (2022), a significant carcinogenic risk value was calculated. The highest value, 1.95×10^{-5}, was found for a single heavy metal, specifically cadmium, among the six studies that examined both cadmium and lead content. However, for lead, the total carcinogenic risk for both children and adults ranged from 8.00×10^{-9} to 2.03×10^{-7}.

The study by Ahhimmid et al. (2022) showed the highest total carcinogenic risk for children for all three routes of exposure (dermal, inhalation, and ingestion) for both cadmium and lead, with a value of 2.03×10^{-5}. On the other hand, the lowest total carcinogenic risk was found in the study by Khalili et al. (2018), with a value of 5.67×10^{-8}. For adults, the highest total carcinogenic risk was found in the study by Albugami et al. (2024), with a value of 2.21×10^{-5}, while the lowest risk was found in the study by Khalili et al. (2018), with a value of 6.03×10^{-9}.

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IV. CONCLUSION

To summarize, this systematic review aimed to assess the health risks, both carcinogenic and non-carcinogenic, of human exposure to lead and cadmium in hair dyes. The review analyzed both qualitative and quantitative data from related studies published between 2013 and 2025.

The qualitative findings revealed people's Knowledge, Attitudes, and Practices (KAP) towards hair dye use and their awareness of potential carcinogenic risks. The review of four studies showed that women were more likely to use hair dye, with participants ranging in age from 16 to 76 years old. Hair dye was commonly used to cover gray hair, improve appearance, and follow fashion trends. However, a significant number of participants were unaware of the potential carcinogenic hazards associated with hair dye use. Some participants also reported experiences of dry hair, scalp irritation, hair damage, and hair loss as a result of using hair dye.

On the other hand, the quantitative results focused on the levels of lead and cadmium in hair dyes and their corresponding health risks. Six studies reported the mean levels of lead and cadmium in black hair dyes, with one study finding a lead content of 5.85 parts per million (ppm). This indicates the presence of lead in hair dye products and highlights the need for strict monitoring and regulation of heavy metal content. The average daily doses (ADD) of cadmium exposure through dermal absorption were found to vary for both children and adults, depending on factors such as frequency of use, duration of contact, and skin permeability. The range of ADD values is crucial in understanding potential risks and making informed decisions about product safety. The study also reported a range of ADD values for lead ingestion, with some studies reporting levels below detection limits. The hazard index (HI) and hazard quotient (HQ) values for lead and cadmium also varied, with some studies reporting the highest values and others reporting the lowest.

Overall, this systematic review highlights the potential health risks associated with hair dye use, particularly in terms of lead and cadmium exposure. It emphasizes the need for increased public awareness and safer practices in hair dye usage.

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REFERENCES

[1]. Aguilera, A., Bautista, F., Gogichaishvili, A., & Garcia-Oliva, F. (2021). Health risk of heavy metals in street dust. *Frontiers in Bioscience*, 26: 327–345. doi:10.2741/4896.

[2]. Ahmed, M., Ahmad, M., Sohail, A., Sanaullah, M., Saeed, A., Qamar, S., Wani, T.A., Zargar, S., Alkahtani, H.M., & Khalid, K. (2024). Multivariate Statistical Analysis of Cosmetics Due to Potentially Toxic/Heavy Metal(loid) Contamination: Source Identification for Sustainability and Human Health Risk Assessment. *Sustainability*, 16(14), 6127.

[3]. Akers, R. (2023). Does Hair Dye Cause Cancer?. Healthline.

[4]. Albugami, M.M., Buzaid, A., Shah, F., & Ahmed, A.Y. (2024). Assessment of the Color Effect on Cadmium and Lead Contents in the Most Popular Cosmetics in the Saudi Market. *Research Square*. doi:10.21203/rs.3.rs-4119052/v1

[5]. Amhimmid, W.K., Fatah, S.A., & Altabeeb, S.S. (2022). Determination of Typical Heavy Metals in Hair Dyes Brands Selected from Libyan Markets. *World Journal of Pharmaceutical and Medical Research*.

[6]. Attard, T. & Attard, E. (2021). Heavy Metals in Cosmetics. *Environmental Impact and Remediation of Heavy Metals*. doi:10.5772/intechopen.102406

[7]. BBC. (2017). Hair Dye Dangers Warning for Children.

[8]. Campaign for Safe Cosmetics. (n.d.). Lead and Other Heavy Metals.

[9]. Chauhan, A.S., Bhadauria, R., Singh, A.K., Lodhi, S.S., Chaturvedi, D.K., & Tomar, V.S. (2010). Determination of Lead and Cadmium in cosmetic products. *Journal of Chemical and Pharmaceutical Research*, 2(*6*): 92–97.

[10]. Chisvert, A., Miralles, P. & Salvador, A. (2018). Hair Dyes in Cosmetics: Regulatory Aspects and Analytical Methods. Analysis of Cosmetic Products (2nd ed.). *Elsevier*. doi:10.1016/B978-0-444-63508-2.00008-4

[11]. Environmental Protection Agency (EPA). 2025. Exposure Assessment Tools by Routes - Ingestion.

[12]. Environmental Protection Agency (EPA). 2025. Exposure Assessment Tool by Routes - Inhalation.

[13]. Environmental Protection Agency. (2025). Human Health Risk Assessment.

[14]. European Commision. (2003). Introduction to Risk Assessment.

[15]. Faria-Silva, A.C., Mota, A.L., Costa, A.M., Silva, A.M., Ascenso, A., Catarina, R., Marto, J., Ribeiro, H.M., Carvalheiro, M., & Simoes, S. (2022). Application of Natural Raw Materials for Development of Cosmetics Through Nanotechnology. Nanotechnology for the Preparation of Cosmetics

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar1551

Using Plant-Based Extracts. *Elsevier*. doi:10.1016/B978-0-12-822967-5.00014-X

[16]. Food and Agriculture Organization. (n.d.). Planning and Conducting KAP Surveys.

[17]. Ghaderpoori, M., Jafari, A., Kamarehie, B., & Yousefi, M. (2019). Health risk assessment of heavy metals in cosmetic products sold in Iran: the Monte Carlo simulation. doi: 10.1007/s11356-019-07423-w

[18]. Goumenou, M. & Tsatsakis, A. 2019. Proposing New Approaches for the Risk Characterization of Single Chemicals and Chemical Mixtures: The Source Related Hazard Quotient (HQs) and Hazard Index (HIs) and the Adversity Specific Hazard Index (HIa). *Elsevier*. doi:10.1016/j.toxrep.2019.06.010

[19]. Hayes, E. (2019). What You Need to Know Before Dyeing Your Child's Hair. Family Friendly.

[20]. He, L., Michailidou, F., Gahlon, H., & Zeng, W. (2022). Hair Dye Ingredients and Potential Health Risks from Exposure to Hair Dyeing. *ACS Publications*. doi:10.1021/acs.chemrestox.1c00427

[21]. Holland, K. (2017). Get the Lead Out of Men's Hair Dye. *Healthline*.

[22]. Hussein, H.J. (2013). Evaluation of the Concentration of SOme Heavy Metals in Hair Dyes in Baghdad. *International Journal of Science and Research*.

[23]. Iwegbue, C.M.A., Onyeloni, S.O., Bassey, F.I., Tesi, G.O., Ogboru, R.O., & Martineigh, B.S. (2016). Safety Evaluation of Metal Exposure from Commonly Used Hair Dyes and Tattoo Inks in Nigeria. *Journal of Environmental Health*.

[24]. Jafarzadeh, N., Heidari, K., Meshkinian, A., & Conti, G.O. (2022). Non-carcinogenic Risk Assessment of Exposure to Heavy Metals in Underground Water Resources in Saraven, Iran: Spatial Distribution, Monte-carlo Simulation, Sensitive Analysis. *Environmental Research*, 204. *Elsevier*. doi:10.1016/j.envres.2021.112002

[25]. Johnbull, O., Abbassi, B., & Zytner, R.G. (2019). Risk assessment of heavy metals in soil based on the geographic information system-Kriging technique in Anka, Nigeria. *Environmental Engineering Research*, 24(1): 150–158. doi:10.4491/eer.2018.130

[26]. Khalili, F., Mahvi, A.H., Nasseri, S., Yunesian, M., Yaseri, M., & Djahed, B. (2018). Health Risk Assessment of Dermal Exposure to Heavy Metals Content of Chemical Hair Dyes. *Iranian Journal of Public Health*. doi:10.18502/ijph.v48i5.1807

[27]. Lewis, J. (2022). True Colors: Unmasking Hidden Lead in Cosmetics from Low- and Middle-Income Countries. *Environmental Health Perspective*, 130(4): 042001. doi:10.1289/EHP9220

[28]. Li, Y.W., Qang, J., Ju, T.Z., Wang, L.N., Zhang, S.N., & Zha, X.H. (2017). Heavy metal pollution characteristics and human health risk assessment in soils from different functional areas of Baiyin, Gansu, China. *Chinese Journal of Ecology*, 36, 1408–1418.

[29]. Miletic, A., Lucic, M., & Onjia, A. (2023). Exposure Factors in Health Risk Assessment of Heavy Metal(loid)s in Soil and Sediment. *Metals*. doi:10.3390/met13071266

[30]. National Human Genome Research Institute. (2025). Carcinogen. *National Institutes of Health*.

[31]. Ozbek, N., & Akman, S. (2016). Determination of lead, cadmium and nickel in hennas and other hair dyes sold in Turkey. *Regulatory Toxicology and Pharmacology*. doi:10.1016/j.yrtph.2016.05.013

[32]. Petite, M. (2024). How Often Should You Dye Your Hair Without Damage?. *Cosmetic World*.

[33]. Raksha Shetty, B., Jagadeesha Pai, B., Salmataj, S.A., & Naik, N. (2024). Assessment of Carcinogenic and non-carcinogenic risk indices of heavy metal exposure in different age groups using Monte Carlo Simulation Approach. *Scientific Reports*, 14, 30319. doi:10.1038/s41598-024-81109-3

[34]. Saah, S.A., Boadi, N.O., Sakyi, P.O., & Smith, E.Q. (2024). Human health risks of lead, cadmium, and other heavy metals in lipsticks. *Heliyon*. doi:10.1016/j.heliyon.2024.e40576

[35]. Saleh, F.A.F., Saif, R.N.A., Murshed, D.M.A, & Abdulmageed, B.M.A. (2020). Determination of Cadmium in some cosmetic products. *Preprints*. doi:10.20944/preprints202009.0731.v1

[36]. Sarim, M., Jan, T., Khattak, S.A., Mihoub, A., Jamal, A., Saeed, M. F., Soltani-Gerdefaramarzi, S., Tariq, S.R., Fernandex, M.P., & Mancinelli, R. (2022). Assessment of the Ecological and Health Risks of Potentially Toxic Metals in Agricultural Soils from the Drosh-Shishi Valley, Pakistan. *Land*, 11, 1663.

[37]. SPRING. (n.d.). The KAP Survey Model (Knowledge, Attitudes, and Practices).

[38]. Staff, M.M. (2024). Toxins in Hair Dye: What is the Safest Way to Dye Your Hair Without Chemicals?. *Million Marker*.

[39]. Times of India. (2025). Dangerous Side Effects of Colouring Your Hair Frequently.

[40]. Whelan, C. (2023). Hair Dye Allergy. *Healthline*.

[41]. Zarei, F., Dehghani, A., Ratanasiri, A., Ghaffari, M., Raina, S., .. Jarrahi, A.M. (2024). ChecKAP: A Checklist for Reporting a Knowledge, Attitude, and Practice (KAP) Study. *National Library of Medicine - National Center for Biotechnology Information*. doi:10.31557/APJCP.2024.25.7.2573

[42]. Zheng, X., Zhao, W., Yan, X., Shu, T., Xiong, Q., & Chen, F. (2015). Pollution Characteristics and Health Risk Assessment of Airborne Heavy Metals Collected from Beijing Bus Stations. *International Journal of Environmental Research and Public Health*. doi:10.3390/ijerph120809658