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A review of environmental and health effects of synthetic cosmetics

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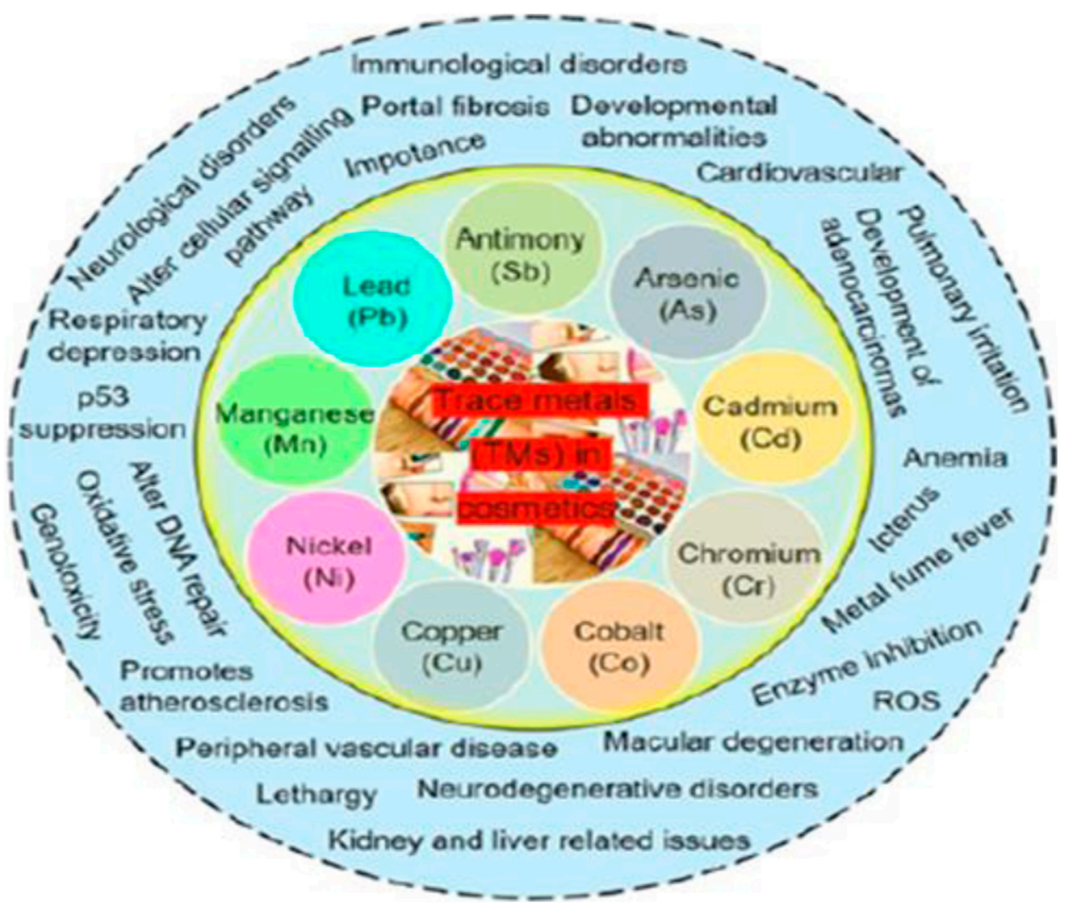
The use of cosmetic products is expanding globally, and with it, so is the range of chemical substances employed in their production. As a result, there is also a higher risk of intoxication, allergic reactions, prolonged chemical exposure, adverse effects, and indiscriminate use. Cosmetic products can contain more than 10,000 ingredients. Most users of synthetic cosmetics are unaware of the harmful effects if they even are. However, it is linked to many diseases like cancer, congenital disabilities, reproductive impairments, developmental systems, contact dermatitis, hair loss, lung damage, old age, skin diseases and reactions, allergies, and harm to human nails. Many beauty products also create a high demand for natural oils, leading to extensive and intensive cultivation, harming natural habitats through deforestation, and contaminating soil and water through pesticides and fertilizers. The adverse effects of hazardous substances in synthetic cosmetics extend beyond human health and influence ecosystems, air quality, and oceans. Thus, this review aims to assess the environmental and health impacts of cosmetics using published scientific articles. The study used a systematic review based on Scopus, Science Direct, Web databases, Scholar Google, and PubMed. The results of this review showed that the formulation of cosmetics until the disposal of their containers could adversely affect environmental and human health.

KEYWORDS

cosmetic pollution, cosmetic impact, cosmetics and human health, cosmetic products, environmental impact, health risks, synthetic cosmetics, waste management



GRAPHICAL ABSTRACT

1 Introduction

The market size of the beauty sector, which is estimated to be $48.8 billion and is still expanding, is enormous. People frequently use makeup to express who they are; individuality and self-expression are significant facets of who we are. However, the effects of the cosmetics business and its products on the environment are significant and cannot be disregarded. The beauty sector has substantial environmental consequences, from excessive packaging waste to the utilization of natural resources like palm and soy. Beauty packaging generates 120 billion garbage units annually, including plastic, paper, glass, and metals that are inadequately recycled and ultimately wind up in landfills, according to the social justice platform It should be emphasized that the Traceability and Verification System is the UNICEF Supply Division. The demand for natural oils from several cosmetic goods also increases, which encourages vast and intense farming, damages natural ecosystems through deforestation, and contaminates soil and water with pesticides and fertilizers (Gutierrez, 2023).

Any substance that is poured, sprinkled, sprayed, inserted into, or otherwise applied to the human body is a cosmetic (Attard and Abstract, 2022) and is used to clean, beautify, promote attractiveness, or alter the appearance without disrupting the body's physiological functions (John Kanayochukwu Nduka, 2019). The body's physiological processes should not be changed during this process by cosmetics. Cosmetics must be efficient, durable, stable, and safe for human use. They are mixes of certain surfactants, oils, and other substances. It is challenging to monitor the safety of every product, with so many being introduced to the market each season, and certain items can contain carcinogenic chemicals (Alam et al., 2019).

According to published research, cosmetic products like lipstick, lip gloss, eye shadow, and henna hair color contain high levels of hazardous lead (Kaličanin and Velimirović, 2016; Łodyga-ChruŘcińska et al., 2018). Triclosan is a common antibiotic likely present in consumer goods and personal care items utilized by 75% of the U.S. population. Following a risk evaluation by the U.S. Food and Drug Administration, Triclosan (TCS) was eliminated from soap products in September 2016 (FDA). Triclosan is still present, but, in high proportions, in various personal care items such as surgical soaps, mouthwash, hand sanitizer, and toothpaste (Weatherly and Gosse, 2017).

Heavy metals are a common constituent in cosmetic goods (Alam et al., 2019). According to Velly et al., lead levels in toothpaste were higher than permitted by U.S. and E.U. guidelines (Vella and Attard, 2019). Polyethylene glycol (PEGs) (favorably used as penetration enhancers), according to Panico et al., may still contain contaminants, including lead, iron, cobalt, nickel, cadmium, and arsenic (Łodyga-ChruŘcińska et al., 2018) described how lead and nickel were present in lipsticks and powders on the Polish market at levels prohibited by European regulations (Łodyga-ChruŘcińska et al., 2018).

Most chemicals are included in cosmetic products as preservatives, surfactants, perfumes, stains, etc. These compounds also improve the items' quality, properties, and shelf lives while improving user appeal (Pereira and Pereira, 2018). However, many of these chemicals also have adverse side effects (Figure 1). Clinical symptoms most frequently reported include conjunctivitis, cosmetic acne, photoallergic/toxic, contact dermatitis, hypo/hyperpigmentation, itching, and corrosive scalp injury. These reactions may occur immediately after application or after repeated use (Mestawet et al., 2018).

Documents show that natural material extracts were employed previously, but synthetic substances are now frequently found in cosmetic items. Some of these artificial additions may endanger the health of consumers. The underarm and breast area's estrogenic cosmetics are being looked into as a potential source of breast cancer (Amasa et al., 2012; Rootid et al., 2022). There have also been reports of birth abnormalities, reproductive issues, and developmental issues (Okereke et al., 2015; Kaličanin and Velimirović, 2016).

Environmental concerns are another issue with cosmetics. The environmental effect of about $400 billion and the expanding worldwide cosmetics and beauty business ranges from the procurement of raw materials to production, distribution, and trash produced by end-users (Chouhan and Himanshu Vig, 2021). Cosmetics impact the oceans, the air quality, and the ecosystems that have sustained flora and fauna for thousands of years, in addition to the local landfills filled with mountains of single-use plastics (Young, 2022). Species are vanishing so that makeup and skincare palettes can be made. In addition to how the items' production and disposal affect wildlife, they also suffer directly from 80 percent of the world's population's continued use of animal testing (European Parliament, 2018).

In contrast to pharmaceutical medications, personal care, and cosmetic items can only be used externally. Due to human activity, such as washing, taking a shower, or taking a bath, they are more likely to enter the environment in large quantities and contribute to more ecological systems. Shampoos, soaps, toothpaste, and shower gels are examples of personal care products that often fall under sanitary practices and should be rinsed off immediately. However, some personal care items, like sanitizers and sunscreen lotion, are leave-on products. Typically, cosmetics are applied to items and left on the skin for at least a few hours (Borowska and Brzóska, 2015). When cosmetics are removed, washed, or used in the shower, they enter sewage treatment facilities, which are ineffective at eliminating all contaminants from substances in personal care and cosmetic goods (Ray et al., 2020). As a result, these chemicals gather with sewage sludge, which is subsequently applied to crops as fertilizer, opening up a route for their entry into the food chain (Juliano and Magrini, 2017).

The most prevalent types of personal care and cosmetic pollutants are organic chemicals (bisphenol-A, p-chloro-m-xylenol, triclosan, grease, fat, and surfactants), which not only harm the aquatic environment but also have an equivalent impact on the plants and human health (Ray et al., 2020). With the increasing popularity of cosmetics, along with reports of toxicity in products sold globally and their adverse effects on both human health and the environment, it is justifiable to closely examine these issues.

However, cosmetics in developing nations like Ethiopia do not require marketing authorization, unlike medicinal products. In the Western world, most countries have laws and regulations on cosmetic safety and labeling (Bilal et al., 2017). As is the case in many other nations, the drug regulatory system does not devote much or any effort to safeguarding the general public and the environment from the negative impacts that these products may have. The companies are in charge of ensuring the safety of the cosmetic products; however, due to various factors, these businesses are business-oriented and pay little to no attention to the cosmetic products' safety. Some of them include the need to alter test procedures, formulas, packaging, and advertising which could increase sector costs (Amasa et al., 2012).

Additionally, some customers choose not to read the labels of cosmetic items to determine the ingredients and other essential details before using them (Bilal et al., 2017). Therefore, the high rate of illiteracy and lax enforcement of laws leave a gap if faulty goods are put onto the market and cause harm to the environment and people. The purpose of this review was to get insight into the effects of harmful substances in synthetic cosmetics on both human health and the environment.

2 Approach

This review has selected 215 studies published between 1995 and 2024. An adequate literature analysis has been conducted to examine the most recent data on the chemical components of cosmetics, including epidemiological research addressing risk factors for various diseases. This narrative review considered pertinent studies on synthetic cosmetics, environmental and human health effects, and management issues. The narrative literature review was according to Pereira and Pereira (2018). In this review, we used literature published in English (Wan et al., 2024), and there were no constraints on the year of publication or type of study setting. We also considered some grey literature, including databases and the most recent reports that were released. Case studies, analytical cross-sectional studies, policy review papers, systematic reviews, and other pertinent studies were also considered. Databases including Scopus, Science Direct, Web databases, Scholar Google, PubMed, Environmental Science and Technology, Government and Environmental Organizations, and Regulatory Agencies were employed to access published scientific publications. Grey literature and reference lists for the studies under evaluation were found using Google.

The inclusion criteria for scholarly papers were as follows: Papers should be published in peer-reviewed journals or reputable academic sources, written in English, and provide relevant empirical data, analysis, or theoretical insights on the effects of toxic ingredients in synthetic cosmetics on humans and the environment. They must contain the terms "cosmetic pollution," "cosmetic toxicity," "cosmetic impact," "cosmetic intoxication," "cosmetic risk," "cosmetic danger," "cosmetic and human health," or "cosmetic side effects." Scientific papers that discussed cosmetic surgery, and cosmetic impact written in a non-English language or had no connection to cosmetic impact items were omitted, as per the

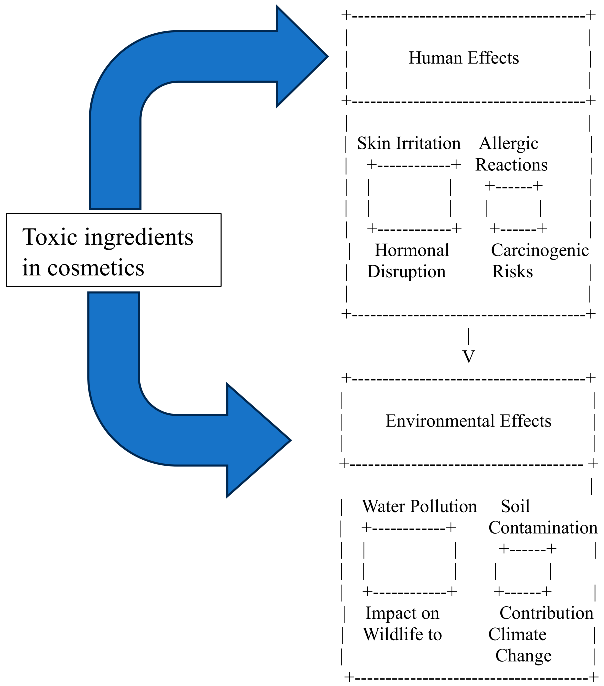


FIGURE 1
Graphic abstract of environmental and health effects of synthetic cosmetics.

exclusion criteria. Reviews and original publications with a toxicological and clinical perspective were among the scientific literature chosen. The primary hazardous chemicals found in cosmetic items are linked to potential health issues in the scientific literature using this technique. The clinical-toxicological connection is made a useful tool to explain and comprehend the adverse effects of using cosmetics through this integrative study, bringing attention to the underutilized use of these items and emphasizing the accompanying health hazards.

The impact of synthetic cosmetics on the environment and health, associated issues, and potential solutions were the focus of this review, which focused on specific studies on the subject. The evidence was compiled and given section by section to make it simple to summarize the results by subject area. Accordingly, the aspects of common toxic chemical compounds that harm human and environmental health are the subject of this article (Siti Zulaikha et al., 2015). This review consists of five sections as follows:

1. Common Hazardous Chemicals in Synthetic Cosmetics
   - Identification and discussion of chemicals posing risks to health and the environment.
2. Consequences of Cosmetics on Environment and Human Health
   - Analysis of the impacts of cosmetic use on ecosystems, wildlife, and human wellbeing.
3. Difficulties in Controlling Substances in Cosmetics
   - Examination of challenges related to regulation, enforcement, and monitoring of cosmetic ingredients.
4. Management Strategy
   - Proposal of strategies and approaches to mitigate risks associated with cosmetic chemicals.
5. Conclusion
   - Summary and key findings from the study.

3 Result and discussion

Chart 1 Show trends in publications and citations on Human Health and ecological effects of synthetic cosmetics (2000–2023). The data for "Chart 1" were obtained from multiple reputable scientific databases, including PubMed, Web of Science, Scopus, and Google Scholar. These databases were chosen due to their comprehensive coverage of scientific literature and their reliability in providing peer-reviewed literature on synthetic cosmetic and their effect.

To gather relevant data, we used specific search strings tailored to identify studies on health and ecological risks associated with cosmetic ingredients. The search strings used are keywords in Figure 2. The search results were filtered to include peer-reviewed articles and reviews published within the last decade. Data were extracted from the selected studies and categorized into health and ecological risks. Synthesizing this data to provide a comprehensive overview of the trends, which were then visualized in "Chart 1."

The Chart titled "Trend in publication and citations on human health and ecological effects of synthetic cosmetics (2000–2023)" illustrates the academic interest and impact of research in this field over 23 years. Publications addressing human health effects are depicted with a blue line, while those addressing environmental effects are shown with a grey line. The trends illustrate the growing academic interest and impact in these fields over the past two decades. The data is divided into four categories: Human health risk publications, Human health risk citations, Ecological risk publications, and Ecological risk citations.

3.1 Human health risk publications (blue line)

The blue line represents the number of publications focused on human health risks associated with synthetic cosmetics. Over the years, this number has remained relatively stable, with minor fluctuations. The number of publications typically stays below 100 per year, indicating a constant but modest level of research activity in this area. This suggests that while there is ongoing interest, the volume of new research published annually has not seen significant growth.

3.2 Human health risk citations (red line)

The red line shows the number of citations for publications on human health risks. Unlike the steady trend in publications, citations exhibit significant fluctuations. Notable peaks occur around 2008 and 2018, indicating periods of heightened academic or public interest in these studies. These spikes may be linked to regulatory changes, high-profile studies, or increased public awareness. However, there is a sharp decline in citations after 2020, suggesting a decrease in the impact or relevancy of earlier studies in recent years.

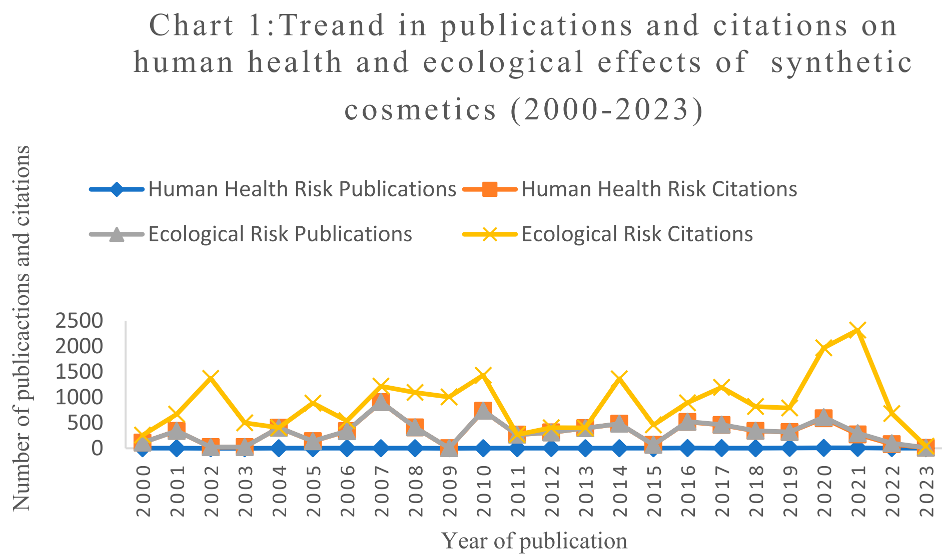


CHART 1
Treand in publications and citations on human health and ecological effects of synthetic cosmetics (2000–2023).

3.3 Ecological risk publications (gray line)

The grey line represents publications on the ecological risks of synthetic cosmetics. These publications are consistently fewer in number compared to those on human health risks, remaining below 50 per year. The trend is relatively flat, showing little variation over the years. This indicates that ecological concerns have not significantly driven an increase in research output, possibly reflecting either a lower priority or fewer resources allocated to this area compared to human health.

3.4 Ecological risk citation (yellow line)

The yellow line tracks citations of ecological risk publications. Citation in this category also shows high peaks, particularly around 2008 and 2018, similar to the pattern observed for human health risk citation but with a much higher magnitude. This suggests that during these peak years, studies on ecological risks had a significant academic or public impact. Following these peaks, there, is a notable decline in citations after 2020, which may indicate a shift in the research focuses or a decrease in the perceived relevance of previous studies.

The overall trend depicted in the chart reveals that while the number of publications on human health and ecological risks od synthetic cosmetics has been stable and relatively low, the impact of these publications, as measured by citations, has experienced significant fluctuations. Picks in citation numbers around 2008 and 2018 highlight periods of increased attention, possibly due to emerging evidence, regulatory changes, or heightened public concern. However, the decline in citations post-2020 suggests shifting interest or a saturation point in the field, where newer studies may be needed to reignite academic and public interest.

3.5 Databases and sources for health risk trends

1. PubMed: A comprehensive database of biomedical literature, PubMed contains numerous studies on the health effects of cosmetic ingredients such as parabens, UV filters, and fragrances. Researchers and healthcare professionals frequently use this database to access peer-reviewed articles on allergic reactions, endocrine disruption, and other health impacts.
2. Scopus: Scopus offers extensive coverage of scientific, technical, medical, and social science research. It includes articles on the long-term health effects of various cosmetic ingredients, regulatory updates, and emerging trends in toxicology and public health.
3. Web of Science: This multidisciplinary database provides access to research articles, conference proceedings, and reviews. It is useful for tracking the latest studies on the health risks of cosmetic ingredients and understanding the evolving landscape of regulatory science.
4. Regulatory Agencies: Regulatory bodies such as the U.S. Food and Drug Administration (FDA), European Chemicals Agency (ECHA), and Health Canada publish guidelines, safety assessments, and updates on restricted or banned substances in cosmetics. These sources provide authoritative information on regulatory trends and health risk assessments.

3.6 Databases and sources for ecological risk trends

1. Environmental Science Databases: Databases like Environmental Science and Technology (ES&T) and the Journal of Environmental Management publish research on

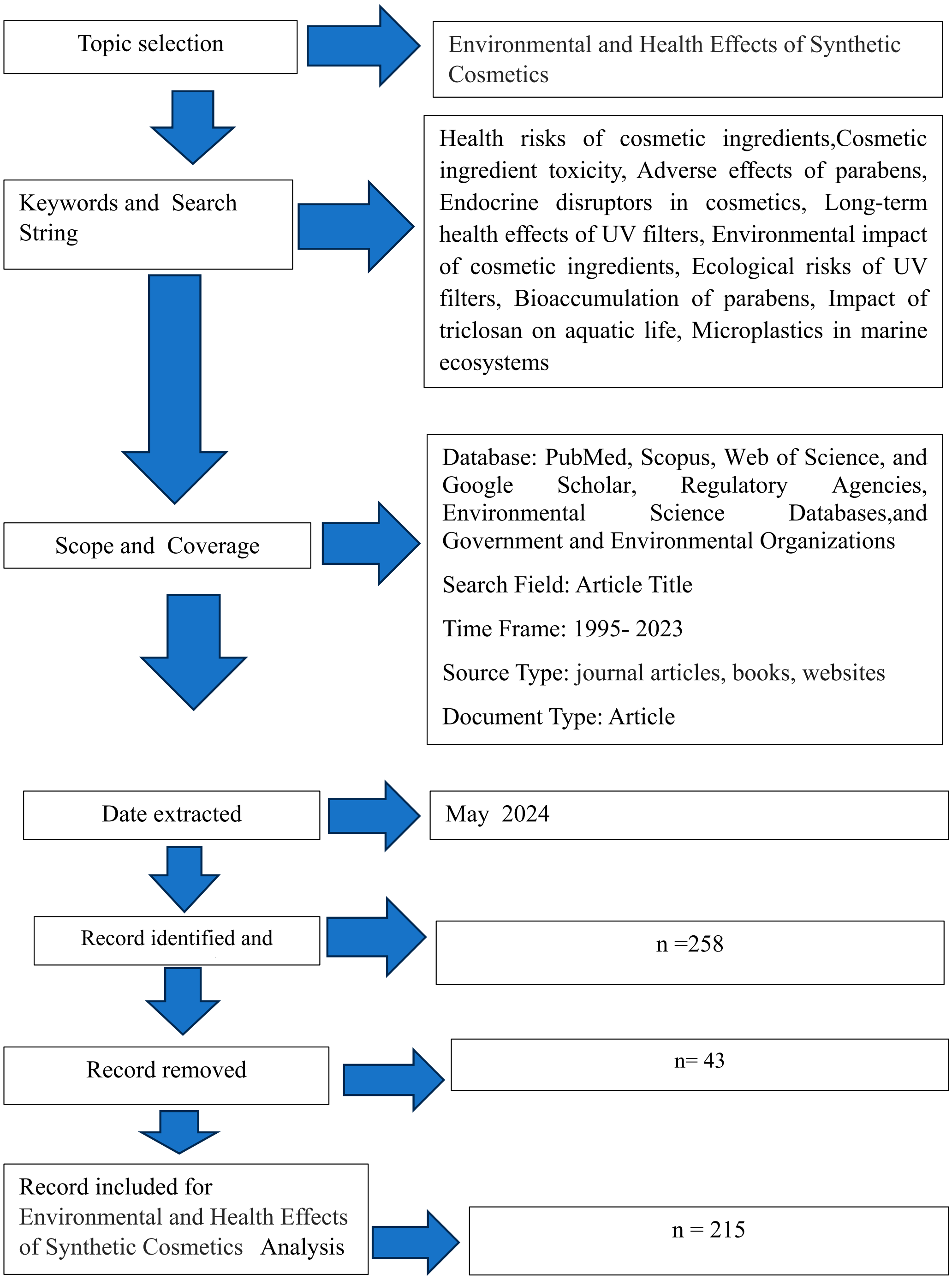


FIGURE 2
Systematic protocol for retrieving the datasets.

the environmental impacts of cosmetic ingredients, including their persistence, bioaccumulation, and toxicity to aquatic life.

2. Google Scholar: A freely accessible web search engine that indexes scholarly articles across various disciplines. It provides access to studies on the ecological effects of ingredients like triclosan, microplastics, and UV filters.
3. ScienceDirect: An extensive database offering access to a large collection of scientific and technical research articles. It covers studies on the environmental behavior and risks of cosmetic ingredients.
4. Government and Environmental Organizations: Reports and publications from organizations such as the U.S. Environmental Protection Agency (EPA), the European Environment Agency (EEA), and the United Nations Environment Programme (UNEP) provide data and analyses on the ecological risks of cosmetic ingredients.

3.7 How the trends are based

3.7.1 Health risks

The trends in health risks are based on a synthesis of findings from clinical studies, toxicological research, and regulatory assessments. These include experimental data on allergic reactions, long-term exposure effects, and endocrine disruption, as well as updates from regulatory bodies on banned or restricted substances.

3.7.2 Ecological risks

The trends in ecological risks are derived from environmental monitoring studies, ecotoxicological research, and reports on the persistence and bioaccumulation of cosmetic ingredients in ecosystems. These studies provide insights into how these substances affect aquatic life, microbial communities, and overall ecosystem health.

3.8 Health and ecological risks of cosmetic ingredients

3.8.1 Health risks of cosmetic ingredients

Cosmetic ingredients, while enhancing appearance and personal hygiene, can pose significant health risks to consumers. These risks range from immediate allergic reactions to long-term health concerns, including hormonal disruptions and chronic illnesses. Understanding these risks is crucial for making informed choices about cosmetic products.

3.8.1.1 Increase in allergic reactions due to parabens and fragrances

Parabens, commonly used as preservatives in cosmetics, have been linked to an increase in allergic reactions. These compounds can cause skin irritation, rashes, and other dermatological issues, especially in individuals with sensitive skin (Rastogi et al., 1995; Zareba et al., 2007). Fragrances, another prevalent ingredient in cosmetics, are also major allergens. Studies have shown that fragrances can cause contact dermatitis and exacerbate conditions like eczema and asthma.

3.8.1.2 Long-term health effects of UV filters and endocrine disruptors

UV filters, such as oxybenzone and octinoxate, are essential in protecting skin from harmful UV radiation. However, these chemicals are also known as endocrine disruptors, capable of interfering with hormone function. Long-term exposure to UV filters has been associated with reproductive issues, developmental problems, and an increased risk of certain cancers. Endocrine disruptors in cosmetics, including phthalates and bisphenol A (BPA), similarly pose risks, affecting thyroid function and metabolic processes over time (Li et al., 2017; Liu et al., 2021).

3.8.1.3 Regulatory updates on banned or restricted substances

Regulatory bodies worldwide are continually updating lists of banned or restricted substances in cosmetics to protect public health. For instance, the European Union's Scientific Committee on Consumer Safety (SCCS) regularly reviews and restricts the use of harmful chemicals like certain parabens, formaldehyde-releasing preservatives, and specific UV filters (Scientific Committee on Consumer Safety, 2021). These regulatory changes aim to mitigate the risks posed by toxic cosmetic ingredients and promote safer alternatives.

3.8.2 Ecological risks of cosmetic ingredients

Cosmetic ingredients not only affect human health but also pose significant ecological risks. These substances can accumulate in the environment, disrupting ecosystems and harming wildlife. Understanding these risks is essential for developing sustainable cosmetic products.

3.8.2.1 Bioaccumulation and persistence of parabens and UV filters in aquatic environments

Parabens and UV filters once washed off the skin, enter aquatic environments through wastewater. Studies have shown that these chemicals persist in water bodies, bioaccumulate in aquatic organisms, and disrupt endocrine functions in fish and other wildlife (Brausch and Rand, 2011). The long-term environmental persistence of these substances raises concerns about their cumulative impact on aquatic ecosystems (Ullah et al., 2017).

3.8.2.2 Impact of triclosan and other antimicrobials on microbial communities and aquatic life

Triclosan, an antimicrobial agent used in many personal care products, has been found to adversely affect microbial communities in aquatic environments. This disruption can lead to antibiotic resistance and negatively impact the health of aquatic life. Research indicates that triclosan can impair reproduction and development in fish, amphibians, and invertebrates (Liu and Wong, 2013).

3.8.2.3 Studies on the effects of microplastics from exfoliants on marine ecosystems

Microplastics, often used in exfoliating products, pose a significant threat to marine ecosystems. These tiny plastic particles are ingested by marine organisms, leading to physical harm, chemical contamination, and disruption of feeding behaviors. Studies have documented the presence of microplastics in various marine species, indicating widespread ecological impact and highlighting the need for biodegradable alternatives (Gago et al., 2018).

3.9 Toxic ingredients in cosmetics

A significant issue in the cosmetics industry is the general lack of consumer awareness about the various chemicals that these products contain. Many individuals are unaware that cosmetics often include a multitude of chemicals, each with its specific purpose. Some of these chemicals can pose risks to our health and the environment. Although not every chemical in cosmetics is harmful, it is crucial to understand the ingredients in the products we use. Opting for products with natural or organic ingredients when possible is a good practice. By educating ourselves about the common chemicals in cosmetics, we can make more informed decisions and take proactive measures to protect both our health and the environment (National Institute of Environmental Health Sciences, 2007; Scientific Committee on Consumer Safety, 2021).

The usage of substances with preservative action, surfactants, perfumes, stains, etc., has expanded today due to innovation, research, and the development of new cosmetic goods (Park, 2023). These ingredients improve the caliber, functionality, and shelf life of cosmetic formulations, but many of them also pose a risk to human health due to frequent, prolonged, and indiscriminate exposure (Whitacre, 2015). Several organizations on a global scale govern the manufacture, quality control, and safety of cosmetic items (European Union, 2009; UNI EN ISO 22716, 2014; Boyer et al., 2017; Sherrow, 2018). These organizations are in charge of modifying the standards and recommendations for the population's safe and healthy use of these products while reducing health hazards (Scientific Committee on Consumer Safety, 2021).

Various organizations, including government agencies (GAO, 2009; Raymond and Krupnick, 2016; Practices et al., 2021), environmental groups (Asfaw et al., 2017), research institutions (Ananthapavan et al., 2021), and industry associations (Ricardo, 2021), may conduct cost-benefit analyses (CBAs) or control CBAs related to toxic ingredients and their impacts on human health and the environment (Arct and Mieloch, 2020). These analyses aim to assess the economic costs and benefits associated with the use of toxic ingredients in products and their potential adverse effects on human health. For example, they may assess the costs and benefits of implementing stricter regulations or bans on certain toxic substances to protect public health.

Cost-benefit analysis plays a crucial role in decision-making processes related to toxic ingredients and their impacts on human health and the environment. By quantifying the economic costs and benefits of different policy options or management strategies, CBAs help stakeholders make informed decisions that balance environmental protection, public health, and economic considerations (Ricardo, 2021).

However, no single organization controls the cost-benefit analysis and ensures user safety when harmful compounds are added to cosmetic items (Barthe et al., 2021).

In the creation of numerous cosmetic goods around the world, several compounds have the potential to be hazardous to both human health and the environment. We also looked at potential health issues associated with cosmetic use and its harmful ingredients.

Cosmetic products like creams, lotions, soaps, lipsticks, mascaras, eye shadows, nail polishes, shampoos, hair dyes, sprays, gels, deodorants, and fragrances may contain ingredients such as triclosan, parabens, phthalates, sodium lauryl sulfate or sodium laureth sulfate (SLS or SLES), mineral oil, formaldehyde, and butylated compounds like butylated hydroxyanisole (BHA) or butylated hydroxytoluene (BHT) (Ad and Mn, 2019; Barabasz et al., 2019; Scott Faber, 2020). About 12,500 industrial chemicals, including carcinogens, insecticides, reproductive poisons, endocrine disruptors, plasticizers, degreasers, and surfactants, were identified by U.S. researchers as being used as cosmetic additives (Naveed, 2014; Sheikh AG, 2018; Lauren, 2019). According to the Cosmetic Ingredient Review (CIR), an estimated 12,500 chemicals are used in cosmetics in the U.S. Only 11 of these chemicals are prohibited in the U.S. Still, more than 1,300 are banned or restricted in the E.U. (Milman, 2019) Several types of cosmetics have been identified to contain aluminum, a lightweight metal, in addition to heavy metals like lead, mercury, cadmium, arsenic, and nickel. These metals are commonly found in color cosmetics, face and body care products, hair cosmetics, herbal cosmetics, and similar items (Kader Mohiuddin, 2019). For a variety of reasons, heavy metals are also added to cosmetics. It is commonly known that heavy metals are harmful (Siti Zulaikha et al., 2015).

3.10 Environmental and health effects of cosmetics

3.10.1 Health effects of cosmetics

Cosmetic compounds are emerging environmental contaminants that are hazardous to human health (Juliano and Magrini, 2017).

People encounter toxic metals through multiple exposure pathways. Many consumers use these products daily and thereby expose themselves to the risk of these toxic metals. Numerous studies have shown that cosmetics components may harm the environment (Juliano and Magrini, 2017; Issac and Kandasubramanian, 2021; Young, 2022) and human health (Okereke et al., 2015; Nduka and Kelle, 2018; Ad and Mn, 2019). It has been documented that the use of cosmetics can cause cancer, mutation, reproductive damage, and endocrine disruption (Amasa et al., 2012). Some chemicals used in personal care products can negatively affect the hormone system, even at low concentrations (Vandenberg et al., 2012; NYS Health Foundation, 2013). Endocrine-disrupting substances like parabens and phthalates may be most dangerous during fetal and early postnatal development when organ and neurological systems are forming (Francisco et al., 2012; Nassan et al., 2017; Bouyssi-Kobar et al., 2019; Adegoke et al., 2021). Endocrine disorders and several types of cancer have been related to exposure to these substances. For instance, endocrine disruptors have been associated with breast cancer since it is known that they alter how women's bodies use estrogen. Endocrine disruptors have also been linked to immune system damage, which increases susceptibility to health problems (Adegoke et al., 2021). Many cosmetics have also been connected to severe hazards like infections and burns (Biskanaki et al., 2023). Hair loss, blisters, nosebleeds, bleeding gums, and a loss of taste and smell have all been connected to formaldehyde-based on "keratin treatments," which are used to straighten hair (Scott Fabber, 2020). Plenty of proof exists indicating that personal care items are tainted with heavy metals, as reported by Siti Zulaikha and co-authors in 2015, along with supporting visual data (Siti Zulaikha et al., 2015).

More than 10,000 chemicals can be found in cosmetic products (Kaličanin and Velimirović, 2016). The European Union has stricter rules, and its precautionary approach recognizes that substances linked to cancer and birth abnormalities are not allowed to be added to cosmetics. A total of 1,328 substances known or suspected of causing cancer, genetic mutation, reproductive damage, or birth defects are prohibited from cosmetics under E.U. regulation.

Comparatively, the U.S. FDA has only forbidden or limited the use of 11 substances in cosmetics. European Union legislation, in contrast to American law, mandates pre-market safety evaluations of cosmetics, mandatory registration of cosmetic products, government approval for the use of nanomaterials, and outlaws the use of animals in cosmetic testing (European Union, 2009; FDA, 2022; Onel et al., 2019; Gautam et al., 2022).

Heavy metals such as lead, arsenic, mercury, aluminum, zinc, chromium, and iron are found in various personal care products like lipstick, whitening toothpaste, eyeliner, and nail polish (Siti Zulaikha et al., 2015). While some metals are added deliberately as ingredients, others appear as contaminants. These metals pose significant risks to human health and the environment.

Lead: Lead exposure from cosmetics has been linked to various health issues, including developmental delays in children, reproductive problems (Environmental, 2019), and neurological damage. Chronic exposure to lead can lead to kidney damage, hypertension, and impaired cognitive function.

Mercury: Mercury is a potent neurotoxin that can accumulate in the body over time, leading to neurological disorders, kidney damage, and skin rashes. Prolonged mercury exposure can also impair cognitive function and affect fetal development in pregnant women (EPA, 2001).

Cadmium: Cadmium exposure from cosmetics has been associated with lung damage, kidney dysfunction, and bone disorders. Long-term exposure to cadmium may increase the risk of cancer and disrupt hormonal balance in the body (Ramelli et al., 2012; Genchi et al., 2020; Charkiewicz et al., 2023).

Arsenic: Arsenic is a carcinogen that can cause skin lesions, respiratory issues, and cardiovascular problems. Chronic exposure to arsenic has been linked to various types of cancer, including skin, lung, bladder, and liver cancer (Palma-Lara et al., 2020; Speer et al., 2023).

The presence of these toxic metals in synthetic cosmetics highlights the importance of rigorous testing and regulation to ensure product safety and protect consumer health. Consumers should be aware of the potential risks associated with certain ingredients and prioritize products that are certified to meet safety standards (Canada, 2007).

3.10.2 Safety assessment of ingredients in cosmetics

Impurities such as heavy metals are frequently found in cosmetic and personal care products. This explains why the concentration of heavy metals found in the products was so low. Their presence in cosmetics does not necessitate their labeling as product contaminants. Even if the harmful metals were only present in trace amounts, they are known to accumulate and cause poisoning. If permitted to build up over time, the gradual release of these metals into the human body could be detrimental to the biological system. Because of these metals' lengthy half-lives, they may build up in the body's organs. The uncertainty factor is applied to risk characterization in the last stage of the safety assessment of cosmetic compounds. The MoS is the name given to this uncertainty factor.

The World Health Organization (WHO) generally considers a margin MoS value of 100 as a benchmark for determining the safe use of a substance (Siti Zulaikha et al., 2015).

3.11 Carcinogenic and non-carcinogenic risk analysis of different harmful substances found in various types of cosmetics

3.11.1 Non-carcinogenic analysis

Health risks associated with heavy metals are assessed by estimating risk levels and categorizing them as either carcinogenic or non-carcinogenic hazards. So, the hazard index (HI), Systemic Exposure Dosage (SED), and MoS were used to estimate the non-cancer health risks of different harmful substances found in various types of cosmetics.

To assess non-carcinogenic risk, especially from exposure to chemicals, two primary metrics are used: the Hazard Quotient (HQ) and HI. These are commonly applied in human health risk assessments (Nduka et al., 2016; Eticha et al., 2018b; Arshad et al., 2020). The HQ value < 1 is considered to be safe while that greater than 1 is unsafe for human health. The HQ level was calculated using Equation 1.

Hazard Quotient (HQ): is used to estimate the risk of non-carcinogenic effects from a single substance.

$$HQ = \frac{SED}{RfD} \tag{1}$$

The SED value was calculated by an expression:

$$SED\left(\frac{\frac{mg}{kg}}{d}\right) = \frac{Cs \times AA \times SSA \times F \times RF \times BF}{BW} \times 10^{-3} \tag{2}$$

where, Reference Dose (RfD): is the maximum acceptable oral dose of toxic substance, established by a regulatory agency like EPA. It represents a daily exposure level that is assumed to be without significant risk of adverse effects on life. SED is the systematic exposure dose, Cs indicates metal concentration in the sample (mg/kg), SSA is the surface area of skin onto which the product is applied (cm^2), AA shows the quantity applied (g/cm^2), RF is the retention factor, F indicates the application frequency of a product/day, BF is the bioaccessibility factor, 10^{-3} (mg/kg) is used as unit conversion factor, BW is the average body weight (70 kg) (Eticha et al., 2018b; Arshad et al., 2020).

HI: is used to estimate the risk of non-carcinogenic effects from exposure to multiple chemical substances (Equation 3) (Eticha et al., 2018b; Arshad et al., 2020). It is the sum of the Hazard Quotient for all chemicals considered.

$$\text{HI} = \sum HQi \tag{3}$$

HQi: The Hazard Quotient for each chemical.

The HI value in sample hydroalcoholic gel samples tested in the study is less than 1. The HI levels were much less than 1, meaning that the samples were safe for human health (Arshad et al., 2020). The study conducted on Health Risk Assessment of some Cosmetic Products sold in Keffi Markets, Nasarawa State Nigeria revealed that HI, pressed powder, dental powder, eye shadow, and eyeliner, 9.61×0^3, 6.0×10^4, 7.2×10^6, and 1.0×10^9 respectively. Results are in agreement with those reported by Health Canada (2016). HI levels for the lotion and sunblock were greater than 1 at both 50% and 100% bio-accessibility, which demonstrated that excessive use of these products may cause health risks to consumers. In the case of hair dye, foundation, whitening cream, and lipstick, HI values reported by Abed Elaziz et al. (2016) were also less than 1 for different facial cosmetics.

3.11.2 Carcinogenic analysis

The carcinogenic analysis is realized by the evaluation of the probable cancer risks due to exposure to heavy metals. The ILCR is the incremental probability of a person developing any type of cancer over a lifetime as a result of 24 h per day exposure to a given daily amount of a carcinogenic element for 70 years. The permissible limits of ILCR for one or more heavy metals are $10^{-6} < \text{ILCR} < 10^{-4}$ and computed as reported previously (Equation 4) (Arshad et al., 2020).

$$\text{LCR} = SED \times SF \tag{4}$$

where SF represents the carcinogenicity slope factor (mg/kg/d)/-1 and it approximates the cancer risk per unit intake dose of an agent to cause cancer over an average lifetime.

The study conducted (Gnonsoro et al., 2022) on Health Risk Assessment of Heavy Metals (Pb, Cd, Hg) in Hydroalcoholic Gels of Abidjan, Côte d'Ivoire depicted that the mean values of ILCR for lead and cadmium are $2.59 \times 10^{-8} \pm 1.15 \times 10^{-8}$ and $4.78 \times 10^{-9} \pm 1.56 \times 10^{-9}$ respectively. For a single heavy metal, an ILCR below 1×10^{-6} poses an insignificant cancer risk and can be disregarded, whereas an ILCR exciding 1×10^{-4} signals a significant health concern due to the heightened risk of cancer. Therefore, the hydroalcoholic gel samples tested in the study did not pose a carcinogenic risk through dermal sensitivity for lead and cadmium.

In the context of cosmetic products, assessing carcinogenic risk involves analyzing exposure through ingestion, inhalation, and dermal contact.

Ingestion of cosmetic products generally occurs through incidental ingestion of lip products or accidental ingestion by children. This pathway necessitates careful calculation of doses based on product usage and the concentration of harmful substances, coupled with regulatory measures to limit such substances in lip and oral care products (FDA, 2022; Salles et al., 2023).

Inhalation exposure is significant for aerosolized products like sprays, powders, and perfumes. Here, risk factors include the concentration of airborne particles, the frequency of use, and environmental ventilation. Proper risk assessment involves estimating inhalation rates and using inhalation-specific toxicological data, with mitigation strategies such as regulating volatile organic compounds (VOCs) and promoting safe usage practices (Oh and Kim, 2020; SCCS, 2023).

Dermal contact is the primary exposure pathway for most cosmetics, which are applied directly to the skin. This involves considering skin permeability, product formulation, and application frequency. The risk is assessed by evaluating the product's concentration, the surface area exposed, and absorption rates, with regulatory measures ensuring the exclusion of known carcinogens and comprehensive safety testing of ingredients (Chedik et al., 2024).

Integrating these pathways into a comprehensive risk assessment allows for a complete understanding of carcinogenic risks associated with cosmetics, ensuring products meet safety standards and maintain consumer safety and confidence (Canavez et al., 2021; Canada, 2007).

Maximum Allowed Limit: Regulatory limits for hazardous metals in various cosmetic products as specified by different health agencies.

Lead (Pb) and Cadmium (Cd) are common hazardous metals found in synthetic cosmetics. Table 1 provides examples of these metals in various cosmetic products and their associated carcinogenic risk assessments.

Including specific examples of carcinogenic risk assessments for hazardous metals in synthetic cosmetics enhances the study's relevance. It provides a clear, detailed understanding of the potential carcinogenic risks and regulatory standards, helping to inform both consumers and regulatory bodies about the safety of cosmetic products.

Table 2 also suggests that certain cosmetics, especially eyeshadow, and lipstick, have relatively high HI values for certain metals, indicating a potential risk of adverse health effects from exposure to these metals through cosmetics. This suggests the need for further assessment and possibly regulation to ensure consumer safety.

The SED predicts the number of chemicals that enter the human body by various exposure means and is computed as Equation 2 (Arshad et al., 2020).

According to the study conducted by Eticha et al. (2018a), on the determination of levels and exposure risks of metals in lipsticks, the result revealed that the calculated SED (μg/kg bw/day) and MoS of heavy metals from the lipstick products. The SED of cadmium and zinc from the samples ranged from 7.98×10^{-8} to 1.61×10^{-6}, and $4.02 \times 10^{-}5$ to 8.04×10^{-5} μg/kg bw/day for 50% and 100% bioaccessibility scenarios (Eticha et al., 2018a).

The study done in Nigeria on Concentrations and exposure risks of some metals in facial cosmetics indicates the SED of cadmium, lead, and chromium in lipstick samples in the range of 1.96×10^{-5} to 3.92×10^{-5}, 6.61×10^{-5} to 1.13×10^{-4}, and 5.43×10^{-5} to 1.09×10^{-4} μg/kg bw/day respectively at both 50% and 100% bioaccessibility (Iwegbue et al., 2016).

At 50% and 100% bioaccessibility, the MoS for cadmium and zinc chromium in lipsticks are 5.10×10^{6} to 2.55×10^{6}, 3.72×10^{8} to 1.86×10^{8}, and 5.53×10^{6} to 2.76×10^{6}, respectively (Iwegbue et al., 2016). The MoS for zinc and cadmium in lipsticks at 50% and 100% bioaccessibility, respectively, is 2.49×10^{6} to 1.24×10^{6} and 1.25×10^{9} to 6.27×10^{8}, according to (Eticha et al., 2018a). Nonetheless, the World Health Organization (WHO) states that a product's MoS value is safe to use if it is greater than 100 and that a value up to 100 is acceptable (Iwegbue et al., 2016; Eticha et al., 2018a; Arshad et al., 2020).

Another study suggests that in the samples of hair dye, foundation, whitening cream, and lipstick MoS was greater than 100, which revealed that the evaluated samples were safe for use. However, in lotions and sun-blocks- blocks the MoS values for Cd, Cr, and Pb were below 100, which indicated that these products are not safe for use, particularly concerning Heavy metal contamination. In different cosmetic products analyzed (Usman et al., 2021) levels of MoS were found to be higher than 100 while MoS for lipsticks was almost similar to the previous study as reported by Arshad et al. (2020) (Equation 5).

$$MOS = \frac{NOAEL}{SED} \quad (5)$$

Nevertheless, if the amount of metal in the samples is above the WHO's recommended threshold of 100, which indicates that a material is acceptable for use, continued use of the products may cause these metals to accumulate to dangerously high levels in the human body. It is advised that regular monitoring systems and the establishment of maximum allowable levels for heavy metals in cosmetic products be put in place to mitigate any potential dangers to human health linked with the use of cosmetics.

The analysis suggests that while these harmful substances are present in cosmetics, the risks associated with their non-carcinogenic and carcinogenic exposure are relatively low when used as directed. However, it's essential to consider cumulative exposure from multiple sources and potential synergistic effects when evaluating overall risk. Additionally, continuous monitoring and regulatory oversight are crucial to ensuring the safety of cosmetic products.

The values in Table 2 depend on various factors such as cosmetics brand (Arshad et al., 2020), frequency of use, exposure pathways, and individual factors such as age and health status.

3.11.3 Environmental effects of cosmetics

Cosmetic ingredients can enter the environment through various pathways, including but not limited to, direct discharge (Paulsen, 2015; Tsiouli and Fytianos, 2023) from manufacturing facilities (Juliano and Magrini, 2017) into water bodies, runoff (Oluwole et al., 2020). from urban areas during rainfall events., leaching from landfills (Ejeromedoghene et al., 2021; Tsiouli and Fytianos, 2023) where cosmetic products are disposed of Yadav. (2023), and via personal use and disposal practices such as washing off products in sinks and showers (Tsiouli and Fytianos, 2023). Additionally, microplastics and other solid particles from cosmetic formulations can accumulate in soil and water bodies through wastewater treatment effluent or direct release, further contributing to environmental contamination (Juliano and Magrini, 2017; Pereira and Pereira, 2018; David and Niculescu, 2021; Young, 2022).

The most significant pathway for cosmetic ingredients to enter the environment is through wastewater discharge (Khalid and Abdollahi, 2021). This is particularly concerning because wastewater treatment plants may not effectively remove all cosmetic ingredients, leading to their release into aquatic environments (Juliano and Magrini, 2017). Once in aquatic systems, these compounds can persist, bioaccumulate, and biomagnify through the food chain (Li et al., 2023). They can also transform more harmful substances through processes like photolysis and oxidation. Ultimately, many of these compounds end up in water bodies such as rivers, lakes, and oceans, where they can have adverse effects on aquatic ecosystems and potentially enter the human food chain through seafood consumption (Ghosh et al., 2023; Osman et al., 2023).

They discharge into the atmosphere, water, and soil throughout the production process, posing major environmental dangers. According to a US Government Accountability Office review, nanoparticles with antibacterial capabilities that are never provided in large enough numbers may interfere with the beneficial activity of microorganisms in water treatment facilities and render the suggested water for reuse ineffective. Titanium dioxide nanoparticles used for disinfection and to break down contaminants may also be able to drive other organic transformations and have an impact on atmospheric photochemical processes. Similarly, a study done by the University of Toledo discovered that nano-TiO_2, a substance that is thought to be near home, lowered the organic processes of microorganisms after an hour of exposure. As a result, it has been proposed that these particles, which wind up at civic sewage treatment plants, might damage creatures that are essential to maintaining the ecosystem (Gupta et al., 2022).

The effluents from wastewater treatment plants and sewage sludge, which are frequently used as a fertilizer, are probably the most significant sources of pollution. Ultraviolet filters (UVFs), often used in the production of cosmetics, can directly enter water bodies when washed off the skin during recreational activities such as swimming, or bathing, as well as indirectly through wastewater from the use of personal care products, washing clothes, and industrial discharges (Juliano and Magrini, 2017).

Ultraviolet filters (UVFs) are chemicals used in sunscreens and other cosmetics to protect the skin from harmful ultraviolet radiation. Common UV filters include oxybenzone, octinoxate, and avobenzone.

Ecological risk assessment (ERA) of UV filters, such as oxybenzone, octinoxate, and avobenzone, is a critical area of study due to their widespread use in sunscreens and personal care products. These chemicals are designed to absorb or reflect UV radiation, protecting human skin from harmful effects. However, their release into the environment through activities such as swimming, bathing, and wastewater discharge raises significant ecological concerns.

Ultraviolet filters can be highly toxic to various aquatic organisms. For example, oxybenzone has been shown to cause coral bleaching by promoting viral infections in coral cells, disrupting their symbiotic relationship with algae. This can lead to the loss of coral reefs, which are crucial for marine biodiversity (Wood, 2018; Miller et al., 2021; Mozas-Blanco et al., 2023). Similarly, octinoxate has been found to cause developmental issues in fish and invertebrates, impacting reproduction and population dynamics (Schlumpf et al., 2008).

Many UV filters are lipophilic, meaning they can accumulate in the fatty tissues of aquatic organisms. This bioaccumulation can lead to biomagnification up the food chain, posing risks to predators, including birds and mammals that consume contaminated fish and invertebrates. Persistent UV filters can remain in the environment for extended periods, further exacerbating their ecological impact (Peng et al., 2017).

Several UV filters have been identified as endocrine disruptors (Table 3). They can interfere with the hormonal systems of aquatic organisms, leading to altered reproductive behaviors, growth patterns, and developmental processes. For instance, studies have shown that UV filters like 4-MBC (4-methylbenzylidene camphor) can affect the endocrine system of fish, leading to decreased fertility and altered sex ratios (Wang et al., 2016; He et al., 2021).

Parabens, commonly used as preservatives in cosmetics to inhibit microbial growth, include methylparaben, ethylparaben,

TABLE 1 Health risk assessment of hazardous metals in synthetic cosmetics.

Hazardous metal	Example product	Maximum allowed limit	Incremental lifetime cancer risk (ILCR)	References
Lead (Pb)	Lip Products	10 ppm	$2.59 \times 10^{-8} \pm 1.15 \times 10^{-8}$	Gnonsoro et al. (2022)
Lead (Pb)	Eye Pencil, Lipstick, Tattoo	10 ppm in lip products; 3 μg/g for eye pencil, lipstick, and tattoo	$2.59 \times 10^{-8} \pm 1.15 \times 10^{-8}$	Health Canada (2007)
Cadmium (Cd)	Eye Pencil, Lipstick, Tattoo	3 μg/g	$4.78 \times 10^{-9} \pm 1.56 \times 10^{-9}$	Gnonsoro et al. (2022)
Lead (Pb)	Various Cosmetics	Not specified	$2.59 \times 10^{-8} \pm 1.15 \times 10^{-8}$	Gnonsoro et al. (2022)
Cadmium (Cd)	Various Cosmetics	Not specified	$4.78 \times 10^{-9} \pm 1.56 \times 10^{-9}$	Gnonsoro et al. (2022)

TABLE 2 MoS, SED, and HQ value of some toxic metal ingredients present in cosmetics products.

Toxic metal ingredients	Type of cosmetic	MoS	SED	HQ	References
Cd	Lipstick	2.55×10^{6}	3.92×10^{-5}	3.5	Iwegbue et al. (2016), Tunde (2024)
	Eyeshadow (mg/kg/d)	2.37×10^{7}	2.11×10^{-10}	1.6	Guerranti et al. (2022), Albugami et al. (2024)
	Lotion (mg/kg/d)	1.13×10^{1}	4.41×10^{-2}	0.59	Arshad et al. (2020)
Pb	Lipstick	3.02×10^{6}	1.32×10^{-4}	5	Tunde, 2024; Li et al. (2021)
	Dental powder (μg kg-1dw day-1)	2.41	0.1658		Ibrahim et al. (2019)
	Eyeshadow (mg/kg/d)	5.39×10^{8}	1.48×10^{-8}	3.2	Guerranti et al. (2022), Albugami et al. (2024)
	Lotion (mg/kg/d)	8.71×10^{1}	4.82×10^{-1}	1.30	Arshad et al. (2020)
Cr	Lipstick	2.76×10^{6}	1.09×10^{-4}	4	Iwegbue et al. (2016), Tunde et al. (2024)
	Dental powder (μg kg-1dw day-1)	6.59	0.0455		Ibrahim et al. (2019)
	Eyeshadow (mg/kg/d)	1.05×10^{4}	2.38×10^{-4}	7.93×10^{-2}	Guerranti et al. (2022)
	Lotion (mg/kg/d)	3.09×10^{1}	4.86×10^{-2}	0.28	Arshad et al. (2020)
Ni	Lipstick	9.29×10^{6}	2.15×10^{-4}	5	Iwegbue et al. (2016), Tunde et al. (2024)
	Eyeshadow (mg/kg/d)	2.65×10^{6}	8.29×10^{-7}	4.14×10^{-5}	Guerranti et al. (2022)
	Lotion (mg/kg/d)	1.21×10^{3}	4.45×10^{-1}	0.90	Arshad et al. (2020)

and butylparaben. These substances can enter aquatic systems via wastewater, where they pose toxic risks to various forms of aquatic life such as algae, crustaceans, and fish. The endocrine systems of these organisms can be disrupted by parabens, causing reproductive and developmental issues (Mozas-Blanco et al., 2023). Despite being biodegradable, the pervasive use and continual release of parabens result in their accumulation in the environment, creating long-term ecological risks (Mozas-Blanco et al., 2023).

Triclosan, an antimicrobial agent found in numerous personal care products like soaps, toothpaste, and deodorants, poses environmental risks (Table 3). It can persist in aquatic environments, where its presence is toxic, leading to significant water contamination issues (Al et al., 2016).

3.11.3.1 Air pollution

Volatile organic compounds (VOCs) are air pollutants found in various cosmetics, including fragrances, deodorants, hair sprays, hair mousses, hair styling gels, nail paint removers, shaving creams, and antiperspirants (Lisa and Benson, 2017; USEPA, 2021). According to a recent study, these goods considerably contribute to carbon dioxide emissions (McDonald et al., 2018). The study found that half of the VOCs released in 33 major cities come from household and cosmetic goods. One study discovered that, in some situations, the VOC from deodorants, hairsprays, and fragrances emit the same quantity of chemical vapors as autos. However, it was noted that the balanced ratio was more a result of decreased pollution from automobiles than increased pollution from cosmetics (McDonald et al., 2018). Let's not overlook the environmental impact of the numerous components produced from fossil fuels that are used in packaging and beauty products. Carbon pollution is a significant concern even when natural ingredients are extracted and processed in non-sustainable methods.

TABLE 3 Cosmetic ingredients and their health effect.

Toxin	Personal care products containing toxin	Health effect	References
Triclosan	Deodorants, mouthwash, hand sanitizer, shaving cream, soaps, fragrances, and toothpaste	Liver fibrosis, triclosan-resistant bacteria, immune system impairment, endocrine disruptor, thyroid function, thyroid homeostasis, and immunological response impairment There may be a negative impact on the human immune system because high urine triclosan levels are associated with a higher prevalence of allergies and hay fever in youngsters. Cancer-causing factors	NYS Health Foundation (2013), Yueh and Tukey (2016), Weatherly and Gosse (2017), Ray et al. (2020); Scott (2020)
Parabens and their compound (methylparaben, ethylparaben, propylparaben, butylparaben, isopropylparaben, isobutylparaben)	Creams, lotions, lipsticks, other wet cosmetics, powders, antiperspirants, and perfumes	Parabens can potentially be endocrine disruptors and may have immunological or allergic consequences. Human breast cancer cells are shown to become more migratory and aggressive when exposed to parabens *in vitro*. High urine paraben concentrations have also been linked statistically to sperm DNA damage and promote cancerogenic and reduced amounts of reproductive hormones in men	Prusakiewicz et al. (2007), NYS Health Foundation (2013), Barabasz et al. (2019), Ray et al. (2020)
Formaldehyde	Nail polish, nail glue, eyelash glue, hair gel, hair-smoothing products, baby shampoo, body soap, body wash, and color cosmetics	The National Toxicology Program has designated formaldehyde as a substance known to cause cancer in humans. Nasopharyngeal, sinonasal, and lymphohematopoietic cancers, particularly myeloid leukemia, have all been related to occupational exposure, mainly through respiratory pathways. Causes allergic reactions and eye and respiratory system irritation. Exposure to formaldehyde has been linked to cancer-causing effects and reproductive impacts such as spontaneous abortions, congenital abnormalities, low birth weights, and endometriosis	Department of Health and Human Services (2016), Sheikh AG (2018), Scott Faber (2020)
Toluene	Toluene is a solvent used in nail polish, nail treatment, hair dyes	High amounts can cause upper respiratory tract irritation, central nervous system depression, and neurobehavioral impairment in humans. Massive exposure may result in fluid buildup in the lungs and respiratory arrest. Toluene affects the developing fetus and is hazardous to the brain and neurological system	NYS Health Foundation (2013), Scott Faber (2020)
Phenol	Soap, cleaning lotions	Skin corrosive, impact tumor promoter, local tissue irritation, irregular heartbeat, vomiting, darker urine, liver damage, damage to blood-forming organs, collapse, cause mutagenic and cancerogenic	Ray et al. (2020)
UV filters and Benzophenone-4	Sunscreens, soap, shampoos, antiperspirants and hair sprays	The harmful impact on reproduction and development, hormonal disorders, and endocrine disruption	Sharifan and Morse. (2016), Ray et al. (2020)
Phthalates/its compounds (dibutyl phthalate (DBP), Di-2-ethyl hexyl phthalate (DEHP), Diethyl phthalate (DEP))	Color cosmetics, fragranced lotions, body washes, hair care products, nail polish	Disrupt the endocrine system in the human reproductive system, adult men's sperm DNA damage from exposure to some phthalates has also been connected	NYS Health Foundation (2013), Mesquita et al. (2021)
Butylated compounds (BHA (butylated hydroxylanisole), BHT (butylated hydroxyl toluene))	Lip products, hair products, makeup, sunscreen, antiperspirant/deodorant, fragrance, creams	Cancer, irritability, toxicology of the reproductive and developmental systems, and disruption of the endocrine system. The National Toxicology Program classifies BHA as "reasonably presumed to be a human carcinogen."	Department of Health and Human Services (2016), Ad and Mn (2019), Made Safe (2022)

(Continued on following page)

TABLE 3 (*Continued*) Cosmetic ingredients and their health effect.

Toxin	Personal care products containing toxin	Health effect	References
1,4-dioxane	shampoo, liquid soap, bubble bath), hair relaxers	The EPA has classified 1,4-Dioxane, which is produced as a byproduct during production, as a "probable human carcinogen." Also noted were organ toxicity and inflammation	Group (2007), NYS Health Foundation (2013)
Carbon black	A pigment used in eyeliner, mascara, nail polish, eye shadow, brush-on-brow, lipstick, blushers, rouge, makeup, and foundation	Increases the likelihood of developing lung illness, the prevalence of cardiovascular disease, and induces cancerous growth	Scott (2020) 19 20, 21
per- and poly-fluoroalkyl substances	sunscreen, foundation, concealer, eyeliner, shaving cream, and hairspray	Injure the unborn child, raise the chance of cancer, compromise the immune system, and mess with hormones	Scott Faber (2020)
Polyethylene Glycols (PEGs)	used in creams	Genotoxicity and systemic toxicity are possible side effects when used on damaged skin	Ad and Mn (2019)
Petrolatum	used in hair care products to make they shine	Petrolatum may contain polycyclic aromatic hydrocarbons (PAHs), which could be linked to cancer, allergies, and skin irritability	Ad and Mn (2019)
Sodium Lauryl Sulfate (SLS)	toothpaste, shampoos, and lotions	Patients with some types of ulcers may experience longer and more discomfort due to human exposure to 1,4-Dioxane contamination. It is regarded as a lung, skin, and eye irritant, and liver cells, heart muscles, and brain cells are all damaged. It messes with the immune system, affects the eye muscle, and triggers allergic skin reactions. When combined with other chemicals, it is highly reactive and produces molecules that cause cancer	NYS Health Foundation (2013), Sheikh AG (2018)
Siloxanes	Deodorant creams	As an endocrine disruptor that interferes with the action of human hormones and a potential reproductive toxin, cyclotetrasiloxane may reduce human fertility	Okereke et al. (2015)
Lead and related compounds	Lipstick, eye shadow, blush, powders, shampoos, and lotions	It may also impact the reproductive system because it is hepatotoxic, neurotoxic, and nephrotoxic. The system is a potential human carcinogen that affects circulatory and heart health and fetal development through the placenta	Scott Faber (2020), Attard and Abstract (2022)
Mercury and related compounds	Skin-lightening creams and soaps	Symptoms of kidney damage include skin rashes, discoloration, scarring, decreased skin resistance to bacterial and fungal infections, anxiety, sadness, and psychosis. Peripheral neuropathy is another side effect, and the developing fetus is particularly affected. When pregnant women eat seafood that contains methylmercury, the mercury can pass from the mother to her infant through breast milk, potentially causing neurodevelopmental impairments to the child	Zero Mercury Working Group (2010), WHO, (2011); Scott Faber (2020)

(Continued on following page)

TABLE 3 (*Continued*) Cosmetic ingredients and their health effect.

Toxin	Personal care products containing toxin	Health effect	References
Cadmium	Lipsticks, eye shadow, eye makeup, eyebrow pencil	In human tissues, irritant dermatitis builds up before being gradually discharged into the bloodstream. But often, it attaches to keratin. The skeletal, reproductive, metabolic, respiratory, and renal systems are affected systemically. It may induce oxidative stress, which can lead to human cancer and has been linked to osteoporosis, diabetes, lung cancer, and kidney damage. It also accelerates the aging process of the skin	IARC (1987), Okereke et al. (2015), Attard and Abstract (2022)
Nickel	Eye shadow	The respiratory system is impacted by allergens and dermatitis, increasing lung and nose cancer risk. A human carcinogen was also reported	Ahlström et al. (2019), Attard and Abstract (2022)

3.11.3.2 Water pollution

Toxic chemicals in beauty products leach from our bodies into the oceans, from our bathrooms to spending hot summer days at the beach. Sometimes dangerous compounds are found in shampoos, sunscreens, creams, and lotions that end up in the environment and endanger wildlife. Every year, 14,000 tons of sunscreen end up in the water and on coral reefs. The immense devastation of coral reefs in the world's oceans is caused in part by oxybenzone. It has been discovered that chemical additives, such as butylated hydroxytoluene (BHT), sodium lauryl sulfate, and butylated hydroxy anisole (BHA), can significantly alter the biochemistry of aquatic life. These poisonous compounds sometimes kill fish, in addition to reducing the animal plankton population. Some of these pollutants remain in the water supply even after sewage treatment (Barabasz et al., 2019).

3.11.3.3 Microbeads

The presence of microplastics in the marine environment is a problem that is receiving more attention and is now acknowledged as one of the growing concerns since it could harm animals and pose hazards to the health of marine ecosystems. Additionally, early research has shown that microplastics are widely distributed in much inland water, with a higher concentration than in the coastal environment (Wu et al., 2018). Microplastics have become prevalent environmental contaminants in both freshwater and marine ecosystems (Limonta et al., 2019). Plastic packaging is only one component of the plastic pollution brought on by beauty products. Plastic microbeads are used as exfoliants in body scrubs and other beauty treatments, and they are little plastic flecks no larger than 5 mm (Issac and Kandasubramanian, 2021). Innumerable microplastics flush into water bodies when products that contain microbeads are used. They draw pollutants in when fish ingest them and finally by people. Microbeads exacerbate the already severe plastic pollution problems in the world's oceans. Although the U.S. and the U.K. have outlawed microbead production, they still come across them in some products. Nothing prevents cosmetic firms operating in nations without microbead regulations from utilizing hazardous plastic (Young, 2022).

3.11.3.4 Unsustainable resource consumption

Cosmetics products seriously deplete natural resources. For instance, palm oil, a plant-based ingredient, can be found in more than 2,300 cosmetic products (under 20 various names) (Young, 2022). Only tropical regions within 10 degrees of the equator support the growth of palm oil. Between 2015 and 2018, vendors in Southeast Asia alone cleared 500 square miles of rainforest due to rising demand for the commodity (Final Countdown, 2018). Deforestation frequently occurs using fire, which releases tons of carbon dioxide, much more than the trees sequester. Moreover, primates are undoubtedly the direct victims of the widespread degradation of rainforests caused by palm oil. According to Orangutan Foundation International, between 1,000 and 5,000 orangutans are murdered annually in palm oil concessions (Orangutan Foundation International, 2015). The mica mining sector is rife with deforestation as well. The mineral is frequently used to give cosmetics a shine for 4,249 of the goods evaluated by the Environmental Working Group (EWG), including lipsticks and eye shadows (Singh, 2019). Furthermore, two of the world's most disadvantaged and underpaid individuals work in both industries, palm oil, and mica extraction from the ground. The processes used in mining, harvesting, and manufacturing require a lot of labor and are frequently done in hazardous environments.

3.11.3.5 Transport/logistics of beauty products

The logistics and distribution of cosmetics are environmentally detrimental as well. Many cosmetic items are manufactured abroad, and when they are sent to international markets, a significant carbon footprint is left behind.

915 million tons of carbon dioxide were created by the aviation sector in 2019 alone, accounting for roughly 2% of total CO_2 emissions caused by human activity annually (Jarošová and Pajdlhauser, 2022) These carbon emissions hasten the effects of global warming, which causes several more environmental issues.

Customers are urged to buy their cosmetics from local vendors or even make their own to stop this practice (Sadie, 2020).

For instance, short supply chains and transit routes can help minimize emissions (Cherrafi et al., 2022). Cosmetic enterprises have to pay attention to the spread of possible invasive species through logistical procedures and product movements (Ashdaq

TABLE 4 Different parts of plants used as cosmetic ingredients.

Part of plant	Specific plant species	Compound to be extracted	Cosmetic application	Impact on plant species	References
Bark	*Cinnamomum verum*	Cinnamaldehyde, Eugenol, Cinnamic Acid, Coumarin, Polyphenols, Tannins, Volatile Oils	antimicrobial protection, antioxidant support, anti-inflammatory effects, and skin brightening	The loss of bark from a plant can expose the inner tissues to environmental stressors, pathogens, and physical damage. This can disrupt the plant's vascular system, leading to decreased nutrient and water transport, and ultimately affecting its overall health and survival	Hwang et al. (2014), Nestby (2020), Kowalczyk et al. (2024)
Flowers	*Dendrobium*	Pelargonidin, sinapic, ferulic acids	Skin firming and whitening	Flowers are crucial for plant reproduction through pollination. The loss of flowers can prevent the plant from producing seeds and fruits, impacting its ability to reproduce and potentially reducing genetic diversity within the population. Additionally, flowers often attract pollinators essential for the reproduction of other plant species in the ecosystem	Wang et al. (2019); Faccio (2020)
Fruit	*Castanea sativa*	Ellagic acid/polyphenolic	Anti-aging formulations, Skin brightening products, Anti-inflammatory creams, Moisturizers and emollients, Sun care products, and Hair care products	Fruits contain seeds, which are essential for the propagation and dispersal of many plant species. The loss of fruits can hinder the plant's ability to reproduce and spread its genetic material to new areas. It can also impact the plant's interactions with seed-dispersing animals, potentially affecting the plant's survival and distribution	Pinto et al., (2017), Pinto et al. (2021)
Leaves	*Azadirachta indica*	Nimbidin, Nimbin, Quercetin, Nimbolinin, Nimbinin	Anti-inflammatory, Anti-bacterial, Skin-soothing, Antioxidant, Antifungal	Leaves are crucial for photosynthesis, the process by which plants convert sunlight into energy. The loss of leaves can significantly reduce a plant's ability to produce food and energy, leading to stunted growth, weakened defenses against pests and diseases, and, in severe cases, plant death	Vanderplanck et al. (2020), Haji et al. (2023), Rodrigues et al. (2023)
Nuts	*Butyrospermum parkii*	Triglycerides, Oleic Acid, Stearic Acid, Linoleic Acid, Tocopherols (Vitamin E), Phytosterols, Allantoin	Moisturizers, body butters, lip balms, hair conditioners, and massage creams, to provide hydration, nourishment, and protection to the skin and hair	Nuts are seeds enclosed in a hard shell, often dispersed by animals. The loss of nuts can prevent the plant from reproducing and spreading its seeds to new locations. Additionally, nuts may serve as a food source for wildlife, and their loss can disrupt ecological relationships within the ecosystem	Esposito et al. (2017), Helmstetter et al. (2020)
Pollen	*Carthamus tinctorius*	Linoleic acid	Antioxidants	Pollen is essential for plant reproduction through pollination. The loss of pollen can prevent fertilization and seed production, ultimately impacting the plant's ability to reproduce and maintain its population size	Chamer et al. (2015), Bergman and Kandel (2017), Faccio (2020)

(Continued on following page)

TABLE 4 (*Continued*) Different parts of plants used as cosmetic ingredients.

Part of plant	Specific plant species	Compound to be extracted	Cosmetic application	Impact on plant species	References
Roots	*Glycyrrhiza glabra*	Glycyrrhizin or licorice	anti-inflammatory, antioxidant, and skin-soothing	Roots anchor the plant in the soil and absorb water and nutrients from the environment. The loss of roots can destabilize the plant, making it more susceptible to wind, water erosion, and physical damage. It can also compromise the plant's ability to access essential resources, leading to decreased growth and survival	Weryszko-Chmielewska et al. (2012), Cerulli et al. (2022)
Seeds	*Simmondsia chinensis*	jojoba oil (wax esters), vitamin E, phytosterols, omega-9 fatty acids, and polyphenols	skin and hair care	Seeds are crucial for the propagation and dispersal of many plant species. The loss of seeds can prevent the plant from reproducing and establishing new individuals in suitable habitats, ultimately affecting its population dynamics and long-term survival	Sandha and Swami (2009), Weryszko-Chmielewska et al. (2012), Inoti. (2017); Faccio (2020), Gad et al. (2021)

et al., 2023). Organisms that are brought into an environment where they do not normally reside are referred to as invasive species (Scanes, 2017). Highly aggressive species that have no natural rivals or predators may proliferate and endanger native species by becoming invasive (Nikolovska, 2016). The composition and operation of ecosystems may occasionally be disturbed by these biological invasions, which can also have significant financial consequences.

Particularly cosmetic businesses that use imported fresh and raw plant-based materials may be vulnerable to this (Cooney, 2004). To prevent the spread of potentially invasive alien species, businesses should take action. You should take the precautionary principle into account (CBD, 2002). Arriving items with biological raw materials and fresh ingredients should always be thoroughly inspected visually for potential stowaways (such as insects). If "contamination" is seen, the offending organism has to be eliminated. The possible measures are the identification of possible gateways for potentially invasive species in the company (i.e., goods entrance), process description and procedure for "contaminated" material, and development of protocols for documentation of material contamination (Gisp and Jackson, 2007).

3.12 Risks to the biodiversity/flora and fauna of ecosystems

Loss of biodiversity is the term used to describe the reduction in diversity within a species, an ecosystem, a region, or the planet itself (David Elisha and Jebbin Felix, 2020). Because it undermines ecosystems' ability to operate and puts them in danger of disturbance, biodiversity loss is a concern because it negatively affects both individual animals and ecosystems as a whole (Chandellier and Malacain, 2021). As a result, life on Earth is left with fewer resources and is less able to satisfy its requirements.

Many cosmetic products are made using organic, plant- and animal-derived components (Abattoir, 2015). These include biologically derived ingredients having beneficial qualities for cosmetic applications, such as essential oils, pigments, and surfactants. Biodiversity is becoming a key concern for the cosmetics sector due to rising customer demand for natural components and sustainable cosmetic products (European Business and Biodiversity Campaign, 2010).

The production or collection of biological raw materials often has the greatest direct and indirect detrimental consequences on biodiversity. The primary environmental effects include the (indirect) use of land for resource extraction, the exploitation of ecosystems and habitats, pesticide and fertilizer contamination, and agricultural practices that encourage erosion (Wassie, 2020). A conspicuous illustration of this is the continued destruction of significant portions of primary rainforest for the increasingly widespread cultivation of palm oil (Murphy et al., 2021). In the case of wild collection, the ecological sustainability of the resource collection is reliant on the good conservation status of the employed species and its population (Leaman, 2008). Improper harvesting techniques or other factors might have a detrimental impact on preservation. Factors influencing the preservation negatively are improper harvesting methods or harvesting times as a harvesting rate above the regeneration capacity of the species. The Candeia tree *(Eremanthus erythropappus),* which produces the anti-inflammatory alpha-bisabolol, which is used in several skin creams and is native to the Amazonian rainforest, is a good example of this (Queiroz and Cajaiba, 2016).

There is a possibility of harmful consequences on biodiversity even at the very end of the value chains for cosmetics. For instance, many of the cosmetics' active components wind up in sewage water and are incapable of being filtered in typical sewage treatment facilities (European Business and Biodiversity Campaign, 2010). Such "Xenobiotic" (bio-incompatible) substances wind up in rivers and streams, where they are likely to accumulate in aquatic creatures and, for example, impair reproduction (Ravindra et al., 2019).

Since the use of materials from protected or endangered species, as well as biological raw materials and ingredients from areas with high biodiversity can be extremely important to the success of cosmetic companies, corporate management should modify its environmental policy to support the objectives of the UN Biodiversity Convention (Lojeng, 2022).

Environment and Sustainability Managers as well as auditors should assess to what extent the strategic importance of biodiversity is known as well as anchored in the company (Burby, 2013). To accomplish this, it is recommended to analyze the corporate mission and environmental policy.

Without appropriate action, the loss of biodiversity will keep accelerating, with unexpected impacts on the economy and society (David Elisha and Jebbin Felix, 2020). The following elements are the main causes of biodiversity loss on a global scale: habitat degradation and ecological devastation, excessive use of natural resources (Hens and Boon, 2003; Gebretsadik, 2016; Bar et al., 2023).

3.12.1 Risks to the flora

Synthetic cosmetics pose several risks to flora, which refers to the plant life within a particular ecosystem (Elisha and Terry, 2021; Faccio, 2020). These risks primarily stem from the production, usage (Nduka and Kelle, 2018), and disposal of synthetic cosmetics, as well as the ingredients contained within them (Juliano and Magrini, 2017; Lafforgue and Lafforgue, 2021).

Chemical Pollution: Synthetic cosmetics often contain various chemicals, such as parabens, phthalates, sulfates, and synthetic fragrances (Washington State Department of Ecology (Ecology), 2023). When these products are washed off during bathing or disposed of improperly, these chemicals can find their way into water bodies through sewage systems (Juliano and Magrini, 2017). Once in the water, they can negatively impact aquatic flora by disrupting their growth, reproduction, and overall health (Gonsioroski et al., 2020; Issac and Kandasubramanian, 2021).

Soil Contamination: Improper disposal of synthetic cosmetics, such as dumping unused products or washing them off directly onto soil, can lead to soil contamination (Bowen, 1975). Chemicals from these cosmetics can leach into the soil, affecting the microbial communities essential for nutrient cycling and plant growth (Yadav, 2023). Contaminated soil may also hinder the germination of seeds and the growth of plant roots (Paulsen, 2015; Yu et al., 2022).

Habitat Destruction: The production of synthetic cosmetics often involves the extraction of natural resources, such as minerals and petroleum (Martins and Marto, 2023). This extraction process can lead to habitat destruction, particularly in biodiverse areas rich in flora. Deforestation, soil erosion, and habitat fragmentation are some of the consequences that can directly harm plant species and disrupt ecosystems (European Business and Biodiversity Campaign, 2010).

Invasive Species Introduction: Some synthetic cosmetic ingredients, especially microplastics and non-biodegradable substances, can inadvertently introduce invasive species into natural habitats (Lauren, 2019; Osman et al., 2023; Ziani et al., 2023). For example, microbeads used in exfoliating scrubs can enter water bodies and act as vectors for the spread of invasive plant species, disrupting native flora and outcompeting indigenous plants.

Air Pollution: The production and transportation of synthetic cosmetics contribute to air pollution through the release of greenhouse gases and other pollutants. Air pollution can negatively impact plant health by interfering with photosynthesis, damaging leaf surfaces, and altering soil pH levels through acid rain deposition, ultimately affecting the composition and distribution of flora within ecosystems (Florentina and Io, 2011; Acwin Dwijendra et al., 2023).

Different parts of the plant (Table 4) can provide ingredients for cosmetic and personal care products (Faccio, 2020).

It has been documented that components taken from plant parts such as bark, flowers, fruit, leaves, nuts, petals, pollen, seeds, roots, sprouts, stems, and other types of plant parts are used to create cosmetic products (Gupta and Prakash, 2013). This may result in plant species disappearing from the environment. As a result, plant biodiversity declines. This contributes to additional global warming through deforestation, which once more has a detrimental impact on human welfare (Sagbo, 2021; Nadeeshani Dilhara Gamage et al., 2022).

The loss of different plant parts used as ingredients in cosmetic formulations can have significant ecological and physiological consequences for the plant species involved, potentially affecting their growth, reproduction, and survival in their natural habitats.

3.12.2 Risk on fauna

Without appropriate action, the loss of biodiversity will keep accelerating, with unexpected impacts on the economy and society (Spangenberg et al., 2012). The following elements are the main causes of biodiversity loss on a global scale: habitat degradation and ecological devastation, excessive use of natural resources (Spangenberg et al., 2012; David Elisha, 2021; Hatipoglu, 2023).

Most often, factory farms serve as the primary locations where pigs are slaughtered for their meat, and where portions of their bodies are processed to produce the cosmetic ingredient "glycerine" (Abattoir, 2015; National Pork Board, 2009). For instance, factory farms seriously harm the ecology (Anomaly, 2015). Due to the high concentration of phosphorus and nitrogen in factory-farmed pigs' feces, when it contaminates areas outside the farm, it may cause a great deal of harm (Chemiczne and Wody, 2012; Fiut and Urbaniak, 2016).

Water gets excessively enriched in minerals and nutrients due to eutrophication, which is caused by run-off pollution from waste pits at factory farms. As a result, there is an excessive development of algae, which frequently causes the water's oxygen levels to drop. Fish and other aquatic plant and animal life are subsequently killed as a result. 'Dead zones' are places where this happens (Yang et al., 2008).

In addition to being exploited and slaughtered for their meat, skin, and milk, cattle are also used to produce tallow and other cosmetic elements from their carcasses. Because so many cattle are produced for these purposes and because cattle emit such large amounts of greenhouse gases, these businesses are always bad for the environment (Durrans, 2013).

Every year, many millions of fish are murdered for food, oils, and substances like guanine. The effects on the ecology and, naturally, the fish, who suffer and perish, are very harmful (Kibria, 2024).

Oceans encompass 70% of the planet (Wang, 2021). The entire ocean ecology may collapse if we do end up with fishless or almost fishless oceans in the future, as is anticipated (Durrans, 2013). Species that depend on fish for sustenance would become extinct if humans wiped them off. Algae, kelp, plankton, krill, and worms would all suffer greatly without the symbiosis that all these species form in nature. The effects on the environment are mind-boggling (Bert, 2016).

4 Challenges in managing cosmetic ingredients

Managing cosmetic ingredients poses several challenges (Raj and Chandrul, 2016), including:

1. Regulatory Complexity: The regulation of cosmetic ingredients varies greatly between regions and countries, making it challenging for companies to comply with different standards and requirements (Mohd Riyaz Beg, 2016; Raj and Chandrul, 2016; Singh et al., 2018; Ferreira et al., 2022; Abed et al., 2024). Harmonizing regulations globally can be difficult due to differing priorities, cultural attitudes, and scientific interpretations.
2. Ingredient Transparency: Lack of transparency regarding the ingredients used in cosmetic products can make it difficult for consumers to make informed choices (Bibby, 2018; Standard, 2020; Santoro, 2022). Some ingredients may be listed under generic terms or trade names, obscuring their true nature and potential risks (Lafforgue and Lafforgue, 2021).
3. Data Gaps in Safety Information: Many cosmetic ingredients lack comprehensive safety data, especially concerning long-term exposure and potential interactions with other chemicals (Amasa et al., 2012; Steiling, 2016; Panico et al., 2019; Scientific Committee on Consumer Safety, 2021). This makes it challenging to assess their environmental and health impacts accurately.
4. Emerging Contaminants: New cosmetic ingredients are continually being developed, and their environmental fate and toxicity may not be fully understood (Juliano and Magrini, 2017). These emerging contaminants can pose challenges for monitoring and management efforts.
5. Microplastics and Nanoparticles: Microplastics and nanoparticles are commonly used in cosmetics for various purposes, such as exfoliation and UV protection (Leslie, 2014; Gupta et al., 2022; Ziani et al., 2023). However, their small size makes them difficult to remove during wastewater treatment, leading to their accumulation in the environment and potential ecological harm.
6. Sustainable Sourcing: Many cosmetic ingredients are derived from natural resources, such as plants and minerals (McMullen and Dell'Acqua, 2023). Unsustainable sourcing practices can lead to deforestation, habitat destruction, and loss of biodiversity, posing challenges for both environmental conservation and the long-term availability of these ingredients.
7. Consumer Behavior and Awareness: Despite increasing interest in sustainability and environmental issues, consumer behavior and awareness regarding the environmental impacts of cosmetics may still be limited (Rocca et al., 2022; Martins and Marto, 2023). Educating consumers and encouraging them to make more sustainable choices can be challenging.

Addressing these challenges requires collaboration among governments, industry stakeholders, scientific experts, and consumers to develop robust regulatory frameworks, improve ingredient transparency, enhance safety assessment methodologies, promote sustainable sourcing practices, and raise awareness about the environmental impacts of cosmetics (Iswahyudi et al., 2024).

5 Certifications

Certification in the cosmetic industry serves several purposes, primarily to assure consumers that products meet certain standards of safety, quality, and environmental responsibility. However, the necessity and effectiveness of certification in this industry are subjects of ongoing debate, particularly in light of the "greenwashing" phenomenon.

Greenwashing refers to the practice of companies making exaggerated or misleading claims about the environmental or ethical benefits of their products or practices (Aparna and Murugan, 2024). In the cosmetics industry, this often manifests as brands labeling their products as "natural," "organic," or "eco-friendly" without sufficient evidence to support these claims. Greenwashing can mislead consumers who are seeking genuinely sustainable or environmentally friendly options, leading them to choose products that may not align with their values (Lopes et al., 2023).

Several factors contribute to the prevalence of greenwashing in the cosmetics industry:

1. Lack of Regulation: The cosmetics industry is not as heavily regulated as other sectors, such as pharmaceuticals or food. This lack of oversight allows companies to make unsubstantiated claims without facing significant consequences (Alexa, 2021).
2. Complexity of Ingredients: Consumers may have difficulty understanding ingredient lists and deciphering which products are truly environmentally friendly or sustainable (Komis, 2022). This confusion can make them more susceptible to greenwashing tactics.
3. Market Demand: There is growing consumer demand for natural and eco-friendly products (Baviskar et al., 2024), leading companies to capitalize on this trend by marketing their products as such, even if their claims are not entirely accurate.
4. Competitive Pressure: Companies may feel pressured to engage in greenwashing to remain competitive in the market, especially if they perceive that consumers are increasingly prioritizing sustainability (Lopes et al., 2023; Quicanga, 2023).

To combat greenwashing and provide consumers with more reliable information, various certification schemes have been developed in the cosmetics industry. These certifications typically involve rigorous testing and evaluation of products to ensure they meet specific standards for ingredients, manufacturing processes, and environmental impact (U.S. FDA, 2021). Some of the most widely recognized certifications include:

1. USDA Organic: This certification verifies that products meet the United States Department of Agriculture's standards for organic production, including the use of organic ingredients and environmentally friendly practices (U.S. Department of Agriculture, 2011).
2. Ecocert: Ecocert is an independent certification body that verifies the natural and organic content of cosmetics and ensures they meet certain environmental and ethical standards (ECOCERT Greenlife, 2022).
3. COSMOS: COSMOS (Cosmetic Organic and Natural Standard) is a Europe-wide standard for organic and natural cosmetics. It sets criteria for ingredients, manufacturing processes, packaging, and labeling to ensure products are environmentally friendly and sustainable (COSMOS, 2023).
4. Leaping Bunny: The Leaping Bunny certification is awarded to companies that have demonstrated their products are cruelty-free, meaning they were not tested on animals at any stage of development (Guide, 2020).

These certifications were chosen for their widespread recognition and credibility within the cosmetics industry. While there are other certifications available, these four are among the most well-established and trusted by consumers seeking genuinely sustainable and ethically produced cosmetics. However, consumers need to remain vigilant and critically evaluate the claims made by brands, as greenwashing tactics continue to evolve and adapt. Additionally, efforts to improve regulation and transparency in the industry can help reduce the prevalence of greenwashing and ensure consumers can make informed choices about the products they purchase.

6 Conclusion

Cosmetic items have a big impact on the environment and human health. Because some items contain chemical substances, there is a chance that they will cause health problems like allergies, sensitivities, and skin irritation. Certain ingredients in cosmetics, such as phthalates and parabens, have been connected to hormone disruption, which may affect the development and health of the reproductive system. Furthermore, several chemicals, including coal tar compounds and formaldehyde, have been identified as carcinogenic, which raises questions about potential long-term health effects, such as an elevated risk of cancer.

Regarding the environment, throughout their existence, cosmetic products have contributed to several types of pollution. The manufacturing process has the potential to emit contaminants into the air and water during production, which could worsen the local community's public health issues and cause environmental damage. In addition, the discarding of cosmetics especially those that include microplastics may contaminate ecosystems and waterways. Because microplastics can be consumed and cause harm at different stages of the food chain, the buildup of tiny particles in the environment is a concern to marine life and wildlife. Furthermore, the production, packing, and shipping of cosmetics all have a carbon footprint that contributes to climate change and exacerbates environmental problems worldwide. All things considered, tackling the effects of cosmetics on the environment and human health requires extensive initiatives meant to advance safer ingredients, environmentally friendly manufacturing processes, and conscientious consumer behavior.

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YW: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Supervision, Writing–original draft, Writing–review and editing.

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