How can Less Toxic Compounds Positively Impact the Chemical Production of Cosmetics?

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Cosmetics, which are products applied to the human body to cleanse or improve the skin, face, nails, or hair, are intended to help people feel more comfortable and healthy; however, components of these items can cause serious health and environmental issues. They range from beauty pharmaceuticals such as makeup, hair sprays, and nail polishes, to hygiene products like deodorants, and toothpaste. Some cosmetics have harmful and polluting chemicals included in their composition such as parabens, triclosan, formaldehyde, and heavy metals. These toxins can catalyze the development of different diseases, including cancer, birth defects, low fertility, and numerous others. Additionally, some of them can pollute the environment and cause damage to countless species and to overall biodiversity. Sustainable alternatives for these cosmetics have been increasing in the beauty market. Ingredients like essential oils, bacterial cellulose, and biosurfactants are becoming more present in products' compositions. This literature review analyzes different toxins contained in cosmetics as well as their sustainable alternatives. In addition, it describes the impacts on the chemical industry if these replacements are widely adopted, examining the prices of goods, production costs, and public opinion associated with this change. This information can help guide the beauty market into choosing less damaging options for products and improving consumers' and nature's health.

Introduction

Cosmetics, such as makeup, skincare, nail products, and deodorants, have molded the beauty industry through time, and have been playing important roles in society for many centuries. For instance, lip cosmetics similar to lipsticks were first developed by the Sumerians in 7,000 B.C, and the first modern soap was created by the Phoenicians in 600 B.C., considering that the idea of cleansing has existed for more than 4,000 years[1]. These recipes were passed through generations in the last years, and are still being used and changed by contemporary society.

Cosmetics have been increasing in popularity during the past years. In 2022, the global cosmetics market obtained growth of over 16% in comparison to 2021[2], evidencing the popularity of these products. Hence, cosmetics play an important role in a major beauty industry, being part of many people's daily lives, and contributing to the different businesses and economies. However, a big percentage of the cosmetics sold in the United States contains high levels of toxic industrial compounds, and with the boost in this area, these products are becoming more frequent. Researchers at the University of Notre Dame concluded that more than 50% of the cosmetics available in the United States contain toxins in dangerous concentrations[3]. For instance, some cosmetics contain large concentrations of parabens, triclosan, formaldehyde, heavy metals, and other toxins known for being harmful. Since 2009, 595 cosmetics producers have reported the use of 88 chemicals in more than 73,000 products[4]. Not all of these ingredients can be replaced with less toxic alternatives, but many should be banned from cosmetics. The California Toxic-Free Cosmetic Act (AB 2762-Muratsuchi) banned the use of 24 of the most toxic chemicals on Earth in cosmetics and personal care products[5].

Decreasing the high concentrations of toxins by using less harmful ingredients in cosmetics can help build a better beauty industry with environmentally friendly and healthy products. There are many possible alternatives for the use and production of these toxic compounds, including different ingredients and different industrial strategies. Sustainable cosmetics have been gaining popularity for the past years, as the global sustainable personal care market is expected to have a growth of 9.5% at a compound annual growth rate from 2022 to 2031[6]. The increase of this market could help different brands and industries to expand sales and production while being less polluting and dangerous.

Toxins in Cosmetics

Parabens

Parabens such as methylparaben, ethylparaben, propylparaben, butylparaben, and isobutylparaben are a class of chemicals that have been used in pharmaceuticals and cosmetic products as preservatives due to their antimicrobial properties. They are p-hydroxybenzoic acid esters.

Known for averting the growth of mold, bacteria, and yeasts, parabens increase shelf-life and stability in cosmetics like lotions, makeup, hair products, sunscreen, and antiperspirants[8]. The paraben preservative capability is related to its structure. As it is shown in Figure 1, different parabens have different carbon chains, and past conducted studies proved that the esters with the longest chains present better antimicrobial potential[9]. Parabens are included in the Endocrine-Disrupting Chemicals (EDCs), chemicals or mixtures of chemicals that imitate, block, or interfere with the way the human body's hormones work, and are one example of petrochemical preservatives. Particularly, the use of parabens like isopropylparaben, isobutylparaben, phenyl paraben, benzyl paraben, and methylparaben has been prohibited in cosmetic products (Regulation (EU) No 358/2014). Additionally, the permitted highest level of butylparaben and propylparaben has been reduced, and the incorporation of these in products was forbidden (Regulation (EU) No 1004/2014). Nonetheless, the consumption of these chemicals is still considerably high due to their low price and favorable properties.

Parabens are easily absorbed by the body by dermal or oral exposure, where they are distributed systemically, metabolized by esterases, and excreted in urine and bile[10]. They have been detected in human tissues, blood, breast milk, placenta, and urine. Similar to other EDCs, parabens, when exposed to individuals, can be linked with poor reproductive health in women[11]. A recent study that obtained data from the Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS) associated urinary parabens concentration with earlier breast development, pubic hair development, and menarche in girls, and earlier genital development in boys[11]. Further, a reduction in the odds of live birth and an inferior day three embryo condition have been correlated with paraben exposure[12]. In spite of that, some recent studies' results are not consistent with the previously cited associations. One of the The Environment And Reproductive Health (EARTH) Study presented results that indicate that urinary paraben concentrations are not associated with fertilization rates, mature oocyte counts, and proportion of high embryos[10]. Some explanations to this disagreement include a lower urinary paraben concentration in some studies, and a misclassification of paraben exposure, since they are short-lived chemicals.

Paraben exposure has also been related to the high incidence of breast cancer. For instance, the 2005 annual quadrant frequency of breast cancer in Britain describes that 54% of breast cancers are located in the upper outer quadrant, and that this percentage has been rising since 1979[12]. A popular belief is that this rate is solely associated to the slightly greater amount of breast epithelial tissue in the region; however, studies show elevated levels of genomic instability in outer regions of the human breast, associating the increase in breast cancer to the extensive use of cosmetic products in the underarm area[12]. Parabens have been identified in 99% of human breast tissue samples, and their presence can stimulate sustained proliferation of human breast cells, and discourage the suppression of breast cancer cell growth by hydroxytamoxifen. Additionally, long-term exposure (more than 20 weeks) to parabens can result in an increased invasive activity in human breast cancer cells, which can be associated with the metastatic process[13].

Triclosan

Triclosan (TCS) is a lipid-soluble organic compound, with antimicrobial properties. It is widely used in personal care products, such as shampoos, toothpaste, hand soaps, deodorants and sunscreens, as a preservative (disinfectant or antiseptic) to control bacteria spread. As it is shown in Figure 2, the triclosan structure is composed of two functional groups: phenol, which is a 5-chloro-2-(2,4-dichlorophenoxy), and ether, which is a 2,4,4-trichloro-2-hydroxydiphenyl ether[14].

Nonetheless, its extensive use in products has as a consequence the release of domestic sewage in the environment, which is considered as the most crucial source of pollution[8]. Because of its lipophilic nature, with low aqueous solubility, TCS is not only omnipresent in aquatic systems, but also in sediments, being one of the 10 most frequently detected organic compounds in wastewater pollutants[8,14,15]. Conducted studies obtained the concentrations of TCS in different situations: rivers contaminated by domestic or industrial wastewater reported concentrations up to 177 ng/L, freshwater reported concentrations up to 800 ng/kg, fishes contained maximum concentrations of 11.7 nmol/kg and certain plants that were grown in soil with TCS concentration of 34.2 mol/kg dry weight (dw) reported concentration of 31.8 mol/kg dw[14,16]. In addition, previous studies estimated over 110.000 kilograms of released TCS into wastewater in the United States per year, with the sources being life, industrial, and personal care products[14]. These are of extreme importance, since the primary fount of human exposure to triclosan is the use of products like soaps and deodorants[17].

Triclosan is one of the most toxic antibacterial chemical compounds, resulting in prejudicial environmental problems such as teratogenicity, hatching delay, and mortality in the embryos and larvae of zebrafish, toxic consequences to algae species, changes in the composition of bacterial communities, and disruption of the endocrine system in fish, having potential to lead to its own bioaccumulation in plants, algae, and animals[8,15]. Furthermore, TCS can be transformed into other derivatives, resulting in even worse consequences. Chlorinated compounds derived from TCS are highly poisonous and even more toxic than triclosan itself, presenting great environmental persistence and, sometimes, carcinogenic activities[15].

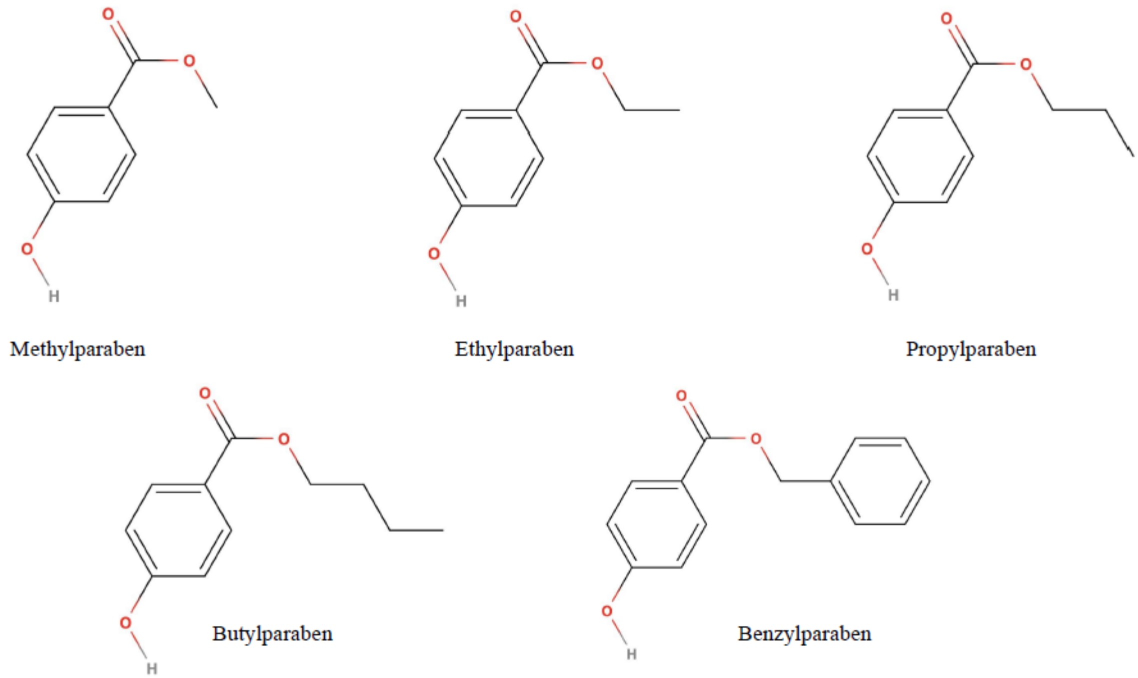

Fig. 1 Structure of the most common parabens in cosmetics[7]

Triclosan, when exposed to humans, can represent a huge risk to health. TCS has many possible routes and ways of achieving the humans and their systems. Since fishes, sea animals and plants can accumulate TCS, alimentation can be one of the routes to this exposure. In addition to food, breast milk represents a big route of exposure to triclosan, placing infants only on breastfeeding at risk. TCS concentration in breast milk has already been described as high as 2.1 mol/kg, and as young children have immature drug metabolizing pathways, they can be vulnerable to the impact of the chemical in the body[14]. After disposal, triclosan drains into underground and to surface waters. As a consequence, TCS can reach humans by contaminated water. In drinking water, TCS concentration is normally below parts per billion, not representing health risks to humans. However, in some studies, these levels have been discovered as higher than the estimated acceptable daily consumption, which is 0.17 nmol/kg per day[14].

Formaldehyde

Formaldehyde (FA) is an aliphatic aldehyde and is commonly used in cosmetics such as eyelash glue, makeup, nail polish, and hair straightening treatments. It has a relatively low cost and a high purity, being one of the most important industrial chemicals[18]. However, FA is commonly known for presenting risk to serious health problems because it is carcinogenic[8].

Following the United States, European Union, and General Staff Officer legislations, a maximum of 0.2% w/w (2000 ppm) of free formaldehyde concentration is allowed in cosmetics and household products[19]. In spite of that, past studies evaluated some products as exceeding this quantity, with concentrations up to 0.72% (in EU products)[19].

The continuous and prolonged exposure to FA is linked with diverse health problems, such as various types of cancer, allergies, and mutagenic effects[8]. Previous studies have also suggested that FA can contribute to the excess of tumors in tissues that are in direct contact with the chemical. One specific study, for instance, reported 13 observed cases of nasopharyngeal cancer in the high-exposure category while only 6.3 were expected. This result evidenced a huge rise in the relative risk of developing the cancer, which is statistically significant[20]. In addition, long-term exposure to FA can lead to an increased chance of myeloid leukemia progression[21]. As a consequence, formaldehyde products can boost the intensity, or even cause serious health conditions.

Heavy metals

Heavy metals are metals with high densities and atomic weights or numbers, such as arsenic, cadmium, mercury, lead, chromium, titanium, and zinc. Some of them are essential for humans in small quantities, like iron, providing nutrients to the body's system. However, when offered in higher quantities, they can be very toxic[22,23].

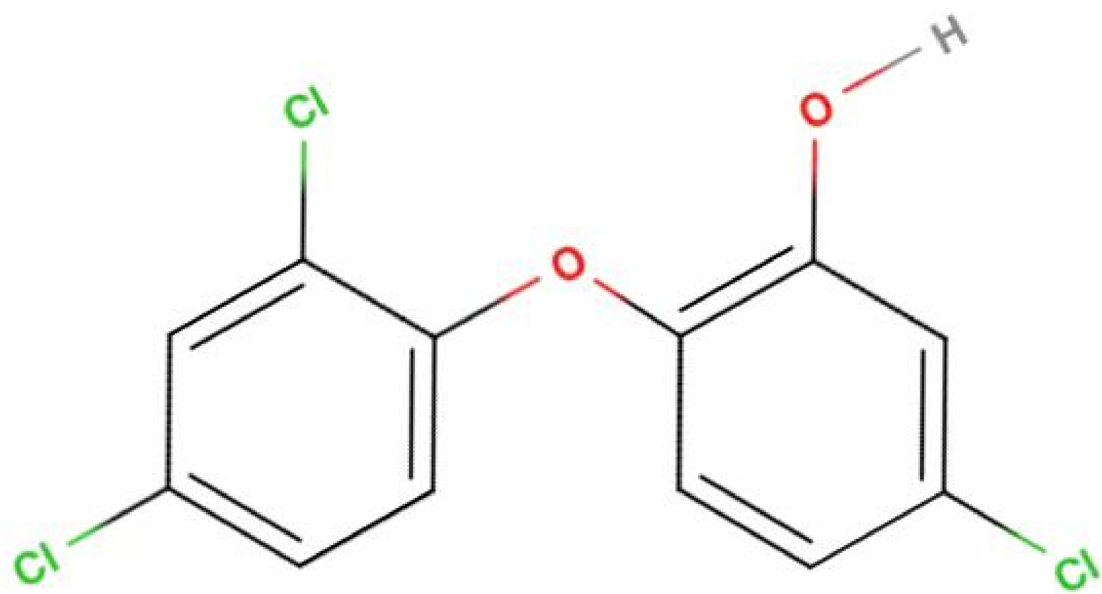

Fig. 2 Structure of triclosan [14]

Heavy metals are applied to different types of cosmetics, like skin whitening products, face creams, deodorant, eye cleansers, shampoos, and makeup [22,24]. The frequent exposure to heavy metals by cosmetic products can result in their absorption through the skin and systemic exposure, which has been linked to various health problems. They can cause the inactivation of regulatory molecules and inhibition of the neurotransmitter [23]. As shown in Figure 3, cancer, reproductive and developmental disorders, neurological, cardiovascular, blood, skeletal, immune system, kidney, lung and renal problems, and hair loss can be associated with this frequently high contact [23,25]. The image also presents many other risks and conditions that the constant exposure to heavy metals can cause in humans' systems.

Additionally, heavy metals also pose several environmental risks. Due to their long-term persistence in the environment, significant levels of some metals can accumulate in the food chain. When in sediments and soils, these can pass to aquatic habitats, groundwater, and plants, leading to the accumulation of these toxins in animals and humans, through the transfer process [22,26]. These bioaccumulations in living beings can result in toxicity and ill-effects on biota, causing death of fishes or other aquatic animals. As a consequence, the diversity of species and the ecological balance are compromised [27].

Phenoxyethanol

Phenoxyethanol is an organic compound with preservative and antimicrobial capabilities, acting against bacteria, and yeasts. It can be used in products like lotions, makeup and creams. As specified by the European Scientific Committee on Consumer Safety, phenoxyethanol is safe for all consumers at a concentration of 1% in cosmetics, when used as a preservative. Furthermore, it is not a volatile chemical, and is not classified as a reproductive toxicant [28]. As a consequence, it is considered by some producers and consumers as a safe alternative for other toxic and unhealthy preservatives.

However, some published information and data conflict with the phenoxyethanol safety. The chemical has already demonstrated toxicity to the liver, to the kidney, and to corneal and conjunctival epithelial cells. Besides, it can also present risk to human meibomian gland epithelial cells (HMGECs).

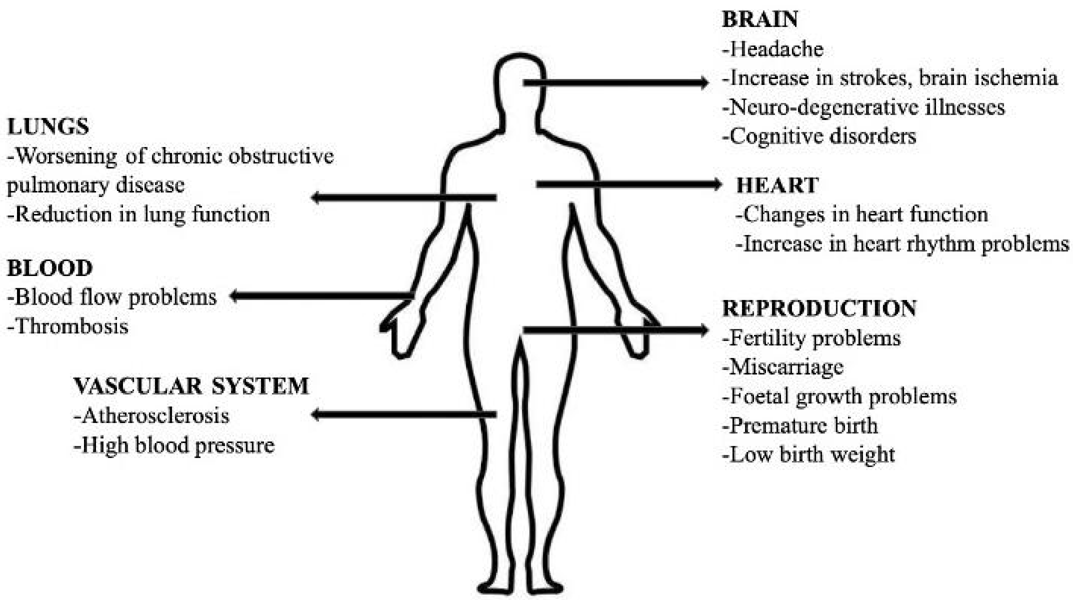

Fig. 3 The effects of heavy metals in different humans organs[23]

Past research showed that a brief exposure to phenoxyethanol can lead to notable reduction of the activity in the PI3K-PKB/Akt pathway- a signal transduction pathway- as well as cellular death[29,30]. As a consequence, this chemical can not be addressed as only and primarily a safe product for cosmetics, and its negative impacts need to be considered.

Sustainable Alternatives

Essential oils

Essential oils (EOs) are constituted by the mixture of different volatile hydrocarbons, being products of the secondary metabolism of plants and having the property of emanating a scent[31,32]. EOs contain an efficient antifungal and antibacterial action, being a great alternative for petrochemical preservatives and for parabens and triclosan[22]. Due to their aroma and fragrance compounds, they have the ability to kill germs or interrupt their growth, being effective preservatives. Essential oils also present other benefits, such as a rise in collagen production and an intensification of the treatment of skin dyschromia[32]. EOs have in their composition monoterpenes, sesquiterpenes, oxygenated monoterpenes, oxygenated sesquiterpenes, phenolics, and other hydrocarbons that can prevent the carcinogenesis process in the initiation and the progression stages[33].

As for the environment, essential oils are much less toxic than chemicals like parabens, holding some characteristics that can bring benefits to nature. For instance, EOs contain repellent activity due to the presence of monoterpenes and sesquiterpenes, being natural environmentally friendly substitutes for synthetic chemicals used to control insects and arthropods[34].

Essential oils have been tested and defined as safe alternatives for toxins in cosmetics, as it is shown on Table 1. Nevertheless, some of these oils are more likely than others to cause unfavorable reactions in humans. For example, some oils can contain higher concentrations of allergens or adulterants, and the oxidation of their compounds can cause skin reactions because of the oxides and peroxides formed[35]. However, these risks represent only a possibility, not describing a response that every user would have.

Bacterial Cellulose

Bacterial cellulose (BC) is a biodegradable polymer that is a sustainable alternative for diverse toxins in cosmetics, such as synthetic polymers[36]. Differing from plant cellulose, bacterial cellulose has a thin structure, a high degree of crystallinity, and is inert to human metabolism[32]. Known for its properties, such as purity, high porosity, water retention, and skin adhesion, BC can be used in the composition of facial masks, scrubs, and personal cleansing formulations, increasing the skin's hydration[37,38].

Compound	Role in Cosmetics	Benefits	Risks
Parabens (toxin)	• Antifungal and antibacterial action	• Increase shelf-life and stability in cosmetics	• Have been related to the high incidence of breast cancer and poor reproductive health in women
Triclosan (toxin)	• Antifungal and antibacterial action	• Antimicrobial properties	• Release of domestic sewage in the environment (pollution) • Risk to human health
Essential oils (sustainable alternative)	• Antifungal and antibacterial action	• Rise in collagen production • Intensification of the treatment of skin dyschromia • Can prevent the carcinogenesis process in the initiation and the progression stages	• Can cause unfavorable skin reactions on humans

Table 1 Differences between parabens, triclosan, and essential oils

Considering its structure, bacterial cellulose allows beneficial cosmetics' ingredients to penetrate better on the skin[38]. Since it guarantees a moist environment and ideal conditions for tissue regeneration, BC has been also used for a long time in wound care, including reconstitution of burnt and cut skin[37,39]. Past studies proved BC's potential as a skin wound healing material, a treatment for diseases in the oral cavity, and a hydrating compound for human skin, without presenting any harm[40]. As a consequence, the BC production by microorganisms does not indicate risks and is considered beneficial for the environment, making the polymer a sustainable alternative for other toxins[41].

Biosurfactants

Biosurfactants are amphipathic molecules, and their origin is from microbials. Surfactants are compounds that can be used as cleaning, emulsifying, wetting, and suspending agents, foam boosters, and solubilizers[42]. In cosmetics, they are mainly applied in detergents and soaps, once they have the capability of reducing the tension between phases, making the cleaning process and hygiene possible. However, surfactants are synthesized chemically, being toxic ingredients. Additionally, they have a persistent nature, and their constant use can result in environmental problems. As a consequence, biosurfactants represent a sustainable alternative for these toxins, once they can easily be degraded by microorganisms, can be produced from cheap raw materials, and present low toxicity[43].

Furthermore, synthetic surfactants are more aggressive to the skin, causing irritation, allergies, reduction of skin barrier, and increase of transepidermal water loss. Microbial surfactants present low skin toxicity, and extensive adaptability to different pHs, temperatures, and salinities, being healthier for humans[44].

The Cosmetic Industry

During the past years, the sale of toxic cosmetics has been decaying, and sustainable, environmentally friendly and healthy products have been increasing their popularity. American legislators proposed the "Safe Cosmetics Act of 2011", suggesting that the United States Food and Drug Administration ensures that all cosmetics and other beauty products do not have harmful ingredients in their composition, which must always be clear on the packaging. Besides, the proposal demands that the use of chemicals related to cancer, birth defects, and other health problems is banned from the production of cosmetics[45].

However, toxic products continue to be sold. They are largely sold for people who live in "underdeveloped geographical areas" and/or areas with a large Black community[46]. According to a past research made in Boston, 50% more of the hair products sold and available in a predominantly Black and poor neighborhood (Roxbury) were considered prejudicial to human health compared to the products sold in a neighborhood with less Black and poor residents (Beacon Hill)[47]. Therefore, more sustainable products need to be implemented in these areas, and their populations must obtain acknowledgement about the cosmetics they consume.

Changes in the compositions of cosmetics can influence the consumers behavior, the industry's costs, the selling prices, the product's chemical production, and countless other factors. Past conducted studies proved that while buying sustainable cosmetics and other products, consumers feel that they are helping nature by making a positive contribution[48]. Other studies showed that protecting the environment is not a priority, but health, ego, self-expression, and status display are[49]. Either way, safe, certified and environmentally friendly products have been progressively demanded by consumers[8]. Offering the sustainable option can contribute to the buyer's health. As the customers will most likely feel positive about the purchase, independently of the reason, they will proceed to look for more healthy options in the market, helping not only the environment, but also their own well-being.

The application of new green ingredients can also benefit the producers. For instance, biosurfactants can be obtained by the use of very cheap raw materials that are available in huge quantities. For example, hydrocarbons, carbohydrates, and lipids can be the source for the carbon[43]. Furthermore, bacterial cellulose production is majorly made by the use of Henstrin-Schramm medium, a composition to grow Komagataeibacter, and this method represents a high cost to the industries. However, the implementation of agro or industrial wastes has been proven effective for the production of sustainable BC and represents a cost-effective alternative[50]. In short, these costs can contribute to a cheaper production, and consequently, to an advantage of beauty brands.

It is not easy, however, to transform the production of toxic cosmetics into the production of sustainable ones. As it is shown in Figure 4, there are many points and factors that should be considered when idealizing the adaptation.

Cosmetics small and medium industries can face different challenges when transitioning to sustainability[52]. For instance, keeping up with productivity while creating high-quality products with limited workforce skills and old equipment can present numerous difficulties for the industries[53]. However, by improving the manufacturing process and the social/ environmental benefits, and increasing demand and financial production, it is possible to succeed[51].

Conclusion

The use of and exposure to toxins like parabens, triclosan, formaldehyde, and heavy metals can result in serious complications in both humans and nature. For humans, these chemicals can aggravate or initiate conditions like different types of cancer, reproductive disorders, cardiovascular, immune system, kidney, lung, and renal problems, among numerous others. Furthermore, these toxins can harm the environment, generating their own accumulation and pollution. Considering these consequences, sustainable cosmetics can benefit the consumers a lot, helping them reach a better health and build better conditions for life. These alternative products can also assist the producers. Understanding what ingredients and chemicals can be prejudicial for the population's health or for the environment can avoid the production of many toxic cosmetics, averting the increase or aggravation of different diseases or conditions, and natural problems. Moreover, these solutions can be cost effective for the industries, also contributing to the sales, as it is proven by the obtainment process of biosurfactants and bacterial cellulose, which can be cheap and economic. Alternatives like essential oils, bacterial cellulose, and biosurfactants prove that cosmetics' properties can still exist independently of what are the compounds in their composition, and how they were obtained. It is also important to make sure that a possible solution does not create new problems, as it is the case of phenoxyethanol, which can also be toxic in some contexts. The increase in production and distribution of sustainable cosmetics will lead the way to a better environment and future, as less ecological issues will be caused by toxins and less negative health impacts will be suffered by

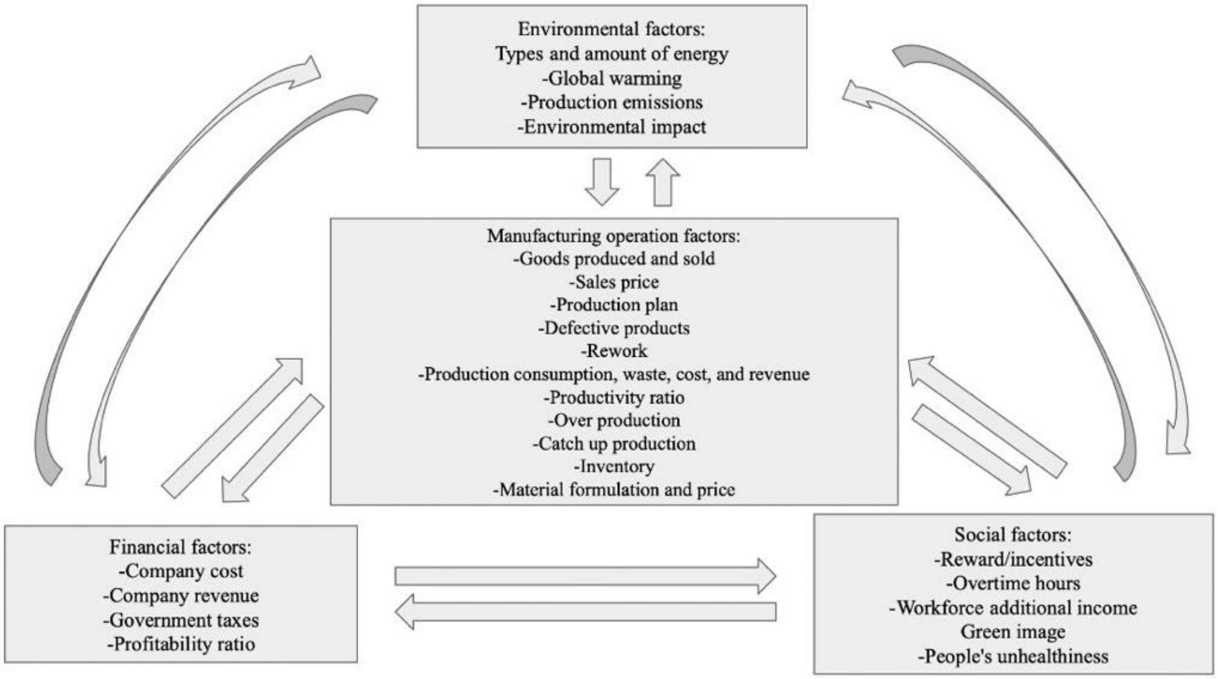

Fig. 4 Industry and production factors that must be considered during the transition [51]

the consumers. These products not only do not present harm to nature and to different species, but are also safe for humans. Consequently, sustainable cosmetics are an attractive solution to a polluting and damaging already existing market, contributing to a more environmentally friendly and healthy beauty industry.

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References

1 Z. Draelos, *Dermatologic Clinics*, **18**, 557–559.
2 D. Petruzzi, *Statista*, 3137 –.
3 J. Sieff, *New Study Finds. Notre Dame News*.
4 S. Faber, *Www.ewg.org*.
5 C. Chung and A. Meyer, *JD Supra*, – – – – – –4502322.
6 P. Guaruraj, R. D. P. C. M. Size, Share and Forecasts, *Allied Market Research*.
7 K. Harley, K. Berger, K. Kogut, K. Parra, R. Lustig, L. Greenspan, A. Calafat, X. Ye and B. Eskenazi, *Human Reproduction*, **34**, 109–117.
8 M. Bilal, S. Mehmood and H. Iqbal, *Cosmetics*, **7**, 13.
9 M. Ferrarini, *Quimica Nova*.
10 L. Mínguez-Alarcón, L. Frueh, P. Williams, T. James-Todd, I. Souter, J. Ford, K. Rexrode, A. Calafat, R. Hauser and J. Chavarro, *The Science of the Total Environment*, **833**, 155191.
11 E. Hager, J. Chen and L. Zhao, *International Journal of Environmental Research and Public Health*, **19**, 1873.
12 P. Darbre and P. Harvey, *Journal of Applied Toxicology*, **28**, 561–578.
13 P. Darbre and P. Harvey, *Journal of Applied Toxicology*, **34**, 925–938.
14 L. Olaniyan, N. Mkwetshana and A. Okoh, *SpringerPlus*, **5**, year.
15 M. Yueh and R. Tukey, *Annual Review of Pharmacology and Toxicology*, **56**, 251–272.
16 K. Kimura, Y. Kameda, H. Yamamoto, N. Nakada, I. Tamura, M. Miyazaki and S. Masunaga, *Chemosphere*, **107**, 393–399.
17 M. Allmyr, M. Adolfsson-Erici, M. McLachlan and G. Sandborgh-Englund, *Science of the Total Environment*, **372**, 87–93.
18 H. Gerberich and G. Seaman, *Formaldehyde. Kirk-Othmer Encyclopedia of Chemical Technology*.
19 A. Jairoun, S. Al-Hemyari, M. Shahwan, S. Zyoud and A. Ahames, *Cosmetics*, **7**, 93.
20 A. Blair, R. Saracci, P. Stewart, R. Hayes and C. Shy, *Scandinavian Journal of Work, Environment Health*, **16**, 381–393.
21 L. Zhang, L. Freeman, J. Nakamura, S. Hecht, J. Vandenberg, M. Smith and B. Sonawane, *Environmental and Molecular Mutagenesis*.
22 R. Mayildurai, A. Ramasubbu and N. Velmani, *Semantic Scholar*, – – – – – – – – – 053 68 1 455 624 7 314368 4369869 8.
23 M. Nazal and H. Zhao, *Heavy Metals. BoD – Books on Demand*.
24 A. ALqadami, M. Abdallah, Z. ALOthman and K. Omer, *International Journal of Environmental Research and Public Health*, **10**, 361–374.
25 C. Palpandi and K. Kesavan, *Asian Pacific Journal of Tropical Biomedicine*, **2**, 358– 367.
26 E. Emenike, K. Iwuozor and S. Andiobi, *Biological Trace Element Research*.
27 G. Pandey, *ResearchGate*.
28 B. Dréno, T. Zuberbier, C. Gelmetti, G. Gontijo and M. Marinovich, *Journal of the European Academy of Dermatology and Venereology: JEADV*, **33 Suppl 7**, 15–24.

29 J. Wang and Y. Liu, *Experimental Eye Research*, **196**, 108057.
30 B. Hemmings and D. Restuccia, *Cold Spring Harbor Perspectives in Biology*, **4**, 011189– 011189.
31 A. Filho, J. Filho and C. Castro, *Journal of Biotechnology and Biodiversity*, **8**, 104–11.
32 G. Buchbauer, *The Detailed Analysis of Essential Oils Leads to the Understanding of Their Properties A*, https://img.perfumerflavorist.com/files/base/allured/all/document/2016/02/pf.0011.pdf.
33 Y. Bhalla, V. Gupta and V. Jaitak, *Journal of the Science of Food and Agriculture*, **93**, 3643–3653.
34 L. Nerio, J. Olivero-Verbel and E. Stashenko, *Bioresource Technology*, **101**, 372–378.
35 J. Sharmeen, F. Mahomoodally, G. Zengin and F. Maggi, *Molecules*, **26**, 666.
36 T. Almeida, A. Silvestre, C. Vilela and C. Freire, *International Journal of Molecular Sciences*, **22**, 2836.
37 R. Bianchet, A. Cubas, M. Machado and E. Moecke, *Bibliometric Review. Biotechnology Reports*, **27**, 00502.
38 Z. Niyazbekova, G. Nagmetova and A. Kurmanbayev, *Biotechnology. Theory and Practice*.
39 A. Cubas, R. Bianchet, I. Reis and I. Gouveia, *Polymers*, **14**, 4576.
40 T. Oliveira, T. Segato, G. Machado, D. Grotto and A. Jozala, *Molecules*, **27**, 8341.
41 H. El-Saied, A. Basta and R. Gobran, *Polymer-Plastics Technology and Engineering*, **43**, 797–820.
42 H. Ahmadi-Ashtiani, A. Baldisserotto, E. Cesa, S. Manfredini, H. Zadeh, M. Gorab, M. Khanahmadi, S. Zakizadeh, P. Buso and S. Vertuani, *Cosmetics*, **7**, year.
43 F. Md, *Journal of Petroleum Environmental Biotechnology*, **3**, 57710157 2.
44 X. Vecino, J. Cruz, A. Moldes and L. Rodrigues, *Critical Reviews in Biotechnology*, **37**, 911–923.
45 L. Vogel, *Canadian Medical Association Journal*, **183**, 1169– 1170.
46 P. Celestine, *Righting the Imbalance in Toxic Cosmetics*, https://www.justice.org/resources/publications/trial-magazine/2020-may/righting-the-imbalance-in-toxic-cosmetics.
47 J. Ortega, *Blogs.edf.org*.
48 S. Brückel and S. Schneider, *ResearchGate*.
49 M. Cervellon and L. Carey, *Critical Studies in Fashion Beauty*, **2**, 117–138.
50 H. El-Gendi, T. Taha, J. Ray and A. Saleh, *Cellulose*.
51 U. Amrina, A. Hidayatno and T. Zagloel, *Journal of Open Innovation: Technology, Market, and Complexity*, **7**, 225.
52 U. Amrina, A. Hidayatno and T. Zagloel, *Journal of Industrial Engineering and Management*, **14**, 311–328.
53 A. Belhadi, Y. Sha'ri, F. Touriki and S. Fezazi, *Journal of Industrial and Production Engineering*, **35**, 368–382.