

Application of Green Toxicology in Personal Care Products

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ABSTRACT

This research paper discusses green toxicology. Toxic substances are everywhere in our daily lives. Toxicology is usually applied in public health because all the drugs used for humans' health are made of chemicals. With the application of toxicology, people can acknowledge the adverse effects of the drugs on people's health. Then, people could develop safer drugs for people's health—a little different from toxicology, green toxicology concerns both health and environmental impact. Green toxicology is a type of toxicology that applies toxicology to sustainable development and production in society. It uses toxicity testing in earlier stages of the production cycle to be time and cost-efficient. When green toxicology is applied to drug production, the production process would think about how to produce safer products with fewer adverse effects on people and the environment. As green toxicology relates to the impacts of toxins on the environment and people, the effects of contaminants on people's health should be explored. Every material that people use is made up of harmful or beneficial chemical substances. Because much of the information about the chemicals has not been revealed until now, many products that people use, such as personal care products, might consist of toxic substances. Personal care products should be composed of safe products because many of those contact people's bodies and skin. Utilizing green toxicological methods in the production of personal care products is crucial. By examining the chemicals used and the production cycles, the possible solution by application of green toxicology will be stated.

Introduction

These days, the concept of toxicology and green chemistry plays a significant role in people's daily lives. A fundamental principle in the world supports this idea: every substance is composed of chemicals. While the chemicals that compose substances are essential in our lives, they also pose risks to our health and environment. This dual nature of chemicals drives scientists to study toxicology. Toxicology is a branch of science dedicated to studying the adverse effects that occur in living organisms due to exposure to chemicals (Smith). It provides significant information to the people and applies to today's life by limiting people's exposures to harmful substances, thereby preventing negative health effects (National Institute of Environmental Health Sciences).

In the field of toxicology, there are many study methods that could address the toxic substances. Some of the study methods include epidemiological studies, controlled clinical studies, toxicology in vivo experiments, and toxicology in vitro experiments (Axispharm). While all of these methods have advantages, they also have limitations. Epidemiological studies could identify the interactions between chemicals and determine the effects on the population, but they are time-consuming, costly, and have difficulties determining the exposure of the chemicals. They can prescribe the limiting exposure conditions for controlled clinical studies, but they also require high costs and are limited to small populations. The last method, toxicology in vitro test, is easy to control and needs fewer human and material resources; however, it cannot reflect all the toxic effects of the chemicals. Currently, the field of toxicology is still growing, hoping for the decrease of human health risks by the toxins.

As this branch of science evolved and expanded over time, toxicology encompasses more specialized and specific branches, each focusing on distinct aspects of toxicology. The branches of toxicology include chemical toxicology, aquatic toxicology, forensic toxicology, and medical toxicology. Each branch addresses specific societal problems and provides critical thoughts into how chemicals impact people. Chemical toxicology, for instance, studies the adverse effects that occur in living organisms due to exposure to chemicals. It aims to understand how chemicals interact with biological systems. By studying chemical toxicology, people could assess safer products and develop strategies to mitigate harm. Among the various branches of toxicology, this research paper will delve into green toxicology. Green toxicology aims to develop safer chemicals and materials by considering their potential toxicity throughout their entire life cycle, from design and production to use and disposal. The paper will explore the chemicals in our daily lives, especially in personal care products, and their potential toxicity. Moreover, it will pose a possible solution for the toxins in the products, affecting the environment and people's health.

Green Toxicology



Figure 1. Principles of green toxicology (Krebs, McKeague)

Green toxicology gives new insights into how people approach developing and producing new products and chemicals. In the 1990s, Paul Anastas and John Warner proposed the 12 principles of Green Chemistry, which became the fundamentals of green toxicology (de Marco et al.). The principles stated about eco-friendly approaches when products are synthesized and processed. Some of the main principles are stated in Fig. 1. The basis of green toxicology is the application of predictive toxicology principles with the goal of facilitating sustainable practices and constructing future manufacturing processes in a safer and more environmentally conscious manner (Lackmann et al.). This section will explain the fundamental principles of green toxicology, its differences from traditional approaches, and its significant role in the discovery and production of safer products.

One of the distinctive features of green toxicology is its proactive stance towards toxicity assessment. Unlike traditional approaches that involve identifying toxic substances only after large-scale manufacturing, green toxicology focuses on the early stages of the manufacturing process. By looking at the early stages before manufacturing on a large scale, it is more effective to identify and eliminate toxic chemicals from the production of new materials and chemicals. This green toxicological approach not only saves resources but also minimizes

the environmental risks associated with toxic compounds in finished products. In contrast to the green toxicological method, traditional toxicology often relies on post-production testing, frequently involving animal testing. While the traditional method also provides valuable data to people, it is inefficient in terms of both time and cost. Green toxicology, by moving toxicity assessment to the early part of the production process, reduces the need for extensive post-production testing, involving a lot of time and money, and the associated ethical concerns regarding animal welfare.

In the European Union (EU), regulatory bodies recognized the importance of green toxicology in protecting human health and the environment. The REACH (Registration, Evaluation, Authorisation, and Restriction of Chemicals) regulation is a prime example of legislative measures desired to restrict the use of toxic chemical substances (Hartung). The legislative REACH not only provides a high level of protection for the health of humans but also assesses rigid regulations on the environmental impact of chemicals. To regulate the toxicological problems more effectively in the world, REACH published a list of chemical substances for use by various organizations, reflecting a devotion to promoting sustainable and safe chemical manufacturing and aligning closely with the principles of green toxicology (see fig. 2). There are organizations other than REACH worldwide, such as SETAC, Society of Environmental Toxicology and Chemistry. SETAC plays a pivotal role on a global scale in addressing environmental crises related to toxicology and chemicals. The workers of SETAC research about the chemicals and collaborate with other organizations to serve as a driving force in advancing green toxicology worldwide (SETAC). By fostering international cooperation and knowledge sharing, organizations like REACH and SETAC significantly contribute to the ongoing development of sustainable green toxicological practices.

Substance name	EC No.	CAS No.	Date of inclusion	Reason for inclusion
Isobutyl 4-hydroxybenzoate	224-208-8	4247-02-3	17-Jan-2023	Endocrine disrupting properties (Article 57(f) - human health)
bis(2-ethylhexyl) tetrabromophthalate	-	-	17-Jan-2023	vPvB (Article 57e)

Figure 2. ECHA list of substances of very high concern for Authorisation (ECHA)

In conclusion, green toxicology provides an advanced approach to chemical manufacturing that prioritizes the identification and elimination of toxic chemicals at the earliest stages of manufacturing. It offers a more efficient, ethical, and sustainable alternative to the traditional toxicological approach, ultimately promoting a safer and greener future for producing materials and chemicals. Legislative measures like REACH and the global efforts of organizations like SETAC emphasize the growing importance of green toxicology in pursuing safer and more environmentally friendly chemical manufacturing practices.

Toxins in Personal Care Products

Most people worldwide use personal care products at least once in their life. Personal care products would include items such as shampoos, lotions, and cosmetics. In the past, these personal care products had problems with toxic chemicals. While these products were initially designed to enhance our well-being and appearance,

people became more concerned with the toxic chemicals composing the personal care products. Many personal care products contain a range of toxic chemicals, and using the products can have adverse effects on people's health. Since most of the products are used in people's daily lives and have direct contact with people's skin or body, the toxic chemicals in the products could directly impact people's health. Some toxic chemicals in cosmetics that affect the health of people are parabens and phthalates.

Parabens are used as preservatives in cosmetic products. It prevents the growth of harmful bacteria in cosmetic and skincare products (FDA). However, some studies suggest that parabens harm the human body by acting like the hormone estrogen. Increased paraben input would disrupt the hormone cycle, leading to irregular periods, weight gain, and a raised risk of breast cancer. Common parabens used in cosmetics are methylparaben, propylparaben, butylparaben, and ethylparaben. Combinations of these parabens with other preservatives protect cosmetics from a broad range of microorganisms.

Parabens are widely used in cosmetics as preservatives, valued for their antimicrobial properties. The FDA acknowledges their role but also highlights possible health risks due to their estrogen-like effects, which can disrupt hormonal cycles, potentially leading to irregular periods, weight fluctuations, and increased breast cancer risk. The omnipresence of parabens in personal care items—from shampoos to moisturizers—means frequent exposure, with common types like methylparaben and propylparaben known to be absorbed through the skin, accumulating in the body. The extent of health effects can vary, with some reversible upon cessation of exposure, while others, particularly related to hormonal disruption, may be irreversible, manifesting as reproductive issues or developmental disorders.

Green toxicology advocates replacing parabens with safer alternatives, like benzoic acid, to avoid adverse health effects and environmental damage. By integrating safer substances in the early product development stages, green toxicology ensures the creation of sustainable, non-toxic personal care products. This approach aligns with the FDA's guidance and is supported by research cited by entities like 'Beautiful with Brains', which suggests the use of benign antifungal agents as viable substitutes (Gio).

Another common toxic chemical contained in cosmetics is phthalates. Phthalates are a “colorless, odorless, [and] oily liquid” that makes plastics more durable. It functions as a stabilizer in perfumes and other fragrance products (FDA). The personal care products that might contain phthalates are nail polishes, hair sprays, cleansers, and shampoos. Like parabens, phthalates also have side effects when they are continuously exposed to people. Women excessively exposed to phthalates have a risk of recurrent miscarriages in the reproductive period. Also, phthalates might affect allergies, early puberty, lower IQ, ADHD, and asthma. Because humans are easily exposed to these toxic, harmful chemicals, there should be a solution to protect humans from the side effects of using the products (FDA).

Phthalates in various cosmetics as durability enhancers face scrutiny due to potential health risks. The FDA acknowledges phthalates' role in nail polish and hair spray products but warns of exposure-related issues like hormonal disturbances and developmental concerns (FDA). The frequent use of phthalate-containing cosmetics heightens concerns about chronic exposure leading to conditions such as allergies, early puberty, and respiratory problems, some of which may have irreversible effects due to their endocrine-disrupting properties.

Green toxicology promotes safer alternatives, reducing health and environmental risks. One such alternative, Di(isononyl)cyclohexane-1,2-dicarboxylate (DINCH), is cited for not affecting hormone regulation crucial for pregnancy, positioning it as a favorable substitute in cosmetics (NIST). Proactive testing and elimination of harmful substances like phthalates from production cycles exemplify green toxicology's commitment to safety. This sustainable approach aligns with organizations like SETAC, emphasizing the importance of safe chemical manufacturing and use in personal care products. The industry can ensure consumer safety and contribute to environmental preservation by adopting such measures.

In a green toxicological approach, the earlier stage of the production cycle of personal care products should be altered in a way that reduces the toxic chemicals. The production cycle of personal care products encompasses various stages, crucially impacted by green toxicology principles. It begins with the conception

of the cosmetic itself and extends through research and development (R&D), where ingredients are scrutinized for safety and efficacy, following through to the manufacturing process and packaging. Green toxicology asserts its influence primarily during the R&D phase, advocating for the use of non-toxic, environmentally benign ingredients before production scales up.

The impact of green toxicology is evident in legislative changes and industry shifts towards safer ingredients. For example, the European Union's REACH program has been instrumental in restricting toxic substances in cosmetics, aligning with green toxicology goals (Hartung). Similarly, SETAC emphasizes life cycle assessments to minimize environmental impact (SETAC)

Advancements in green toxicology have identified safer alternatives, such as DINCH in place of phthalates (Boss) and organic acids like benzoic acid instead of parabens (Gio). These shifts are geared towards reducing health risks and environmental damage, though quantifying the full impact remains complex. As the industry continues to evolve, green toxicology principles are set to shape manufacturing practices further, driving innovation towards non-toxic alternatives that ensure consumer safety and environmental preservation.

Solution for the Toxins

The toxins in personal care products need to be solved so that those toxins do not affect people's health. There are a number of solutions that can be taken to address the problem of toxins in personal care products. One solution is simply avoiding products that contain toxic chemicals. However, avoiding all toxins might be difficult because if people try to do so, they will have limited products to use. Not all the products would be replaceable, leading to the consumers needing to buy the specific product with the toxins. Hence, another solution is needed to address this issue.

To reduce and stop using toxic chemicals in personal care products, people could support legislation that would restrict the usage of toxins in the products. Already, some countries passed laws that ban the use of toxins in cosmetics, especially phthalates and parabens. For example, the European Union has restricted over 1,300 chemicals to be used in cosmetics (Milman). Not only the EU but also the United Kingdom and Germany banned the use of a number of harmful chemicals in cosmetics (Inouye). By people supporting their country or legislation, certain chemicals would be prohibited from the field of personal care products. Eventually, in the future, many toxins will be reduced in personal care products, not affecting the health of people negatively.

Another solution for the problem is consumers supporting the development of safer alternatives to the toxins. Currently, a number of companies are working on developing new ingredients that can be used in personal care products without health risks. If the consumers support the companies, consumers will be able to get safer personal care products. Also, the use of new alternatives would allow the companies to promote the products more by them being environmentally friendly. Then, the toxic products would get eliminated from the market, having no concerns in health when using the products. In exploring alternatives to harmful toxins, we must consider the detoxification process which involves replacing harmful chemicals with safe and effective counterparts, without sacrificing the product's functionality. For instance, according to NIST, research into phthalate alternatives like DINCH has shown promising results in maintaining product integrity while reducing health risks. The challenges in finding alternatives are multifaceted, involving economic, regulatory, and technical aspects. As the Environmental Working Group highlighted, regulatory discrepancies between countries can impede progress. Furthermore, quantifying the benefits, such as a reduction in adverse health effects or environmental impact, is crucial for a compelling argument for change. The FDA provides guidelines on acceptable levels of chemicals, which can serve as benchmarks for reduction. These points underscore the necessity of a comprehensive approach to reforming product safety standards, as indicated by the SETAC's life cycle assessment framework. For phthalates and parabens, as mentioned in the previous section, there are some alternatives. Di(isononyl)cyclohexane-1,2-dicarboxylate (DINCH) is one of the alternatives of phthalates, which is used in the current cosmetics field. In a study by researchers, DINCH was proven that it does not interfere

“with regulating the signaling of specific hormones required for pregnancy,” unlike phthalates (NIST). Organic acids, such as benzoic acid would be a solution for parabens. Even though the acids can only kill fungi, not bacteria, it does not have health risks that parabens might cause (Gio). By replacing the toxic chemicals with the best alternatives, the personal care products could be safer.

In the context of green toxicology, it is imperative for companies to initiate the testing for toxic chemicals early in the production cycle and rigorously work towards their elimination. Proactive measures should aim for specific reductions, such as a 50% decrease in the usage of prioritized chemicals like phthalates within a five-year span, ensuring concentrations do not surpass 100 parts per million. Upon identification of toxins, a coordinated information campaign must be undertaken by toxicologists, regulatory bodies such as the EPA and FDA, and advocacy groups like the EWG. This campaign should educate global manufacturers on the dangers of these chemicals, compelling them to label products accordingly and advocate for legislative bans where necessary. Starting with one or two lead countries to set the precedent, this strategy could create a domino effect, encouraging a global phase-out of the most harmful substances. Concurrently, scientists must be tasked with the development of safe and effective alternatives to these chemicals, ensuring the continuity and quality of personal care products.

Conclusion

In today’s world, the presence of toxic chemicals in daily lives raises important issues about the impacts of chemicals on human health and the environment. This research paper explored the field of toxicology, specifically green toxicology, highlighting the critical role that green toxicology plays in protecting both human well-being and the planet. As a response to the challenge that toxic chemicals are also in the production processes of products, green toxicology emerges as a sustainable approach to tackling the toxicity issues. This toxicity assessment plays a significant role in manufacturing personal care products. Various toxic chemicals are used in personal care products, which affects people’s health. Thus, people should be aware of the chemicals and try to find safer alternatives in a green toxicological approach. Green toxicology advocates for safer alternatives that prioritize the individuals’ well-being and the environment of the planet. As people advance and develop through life, the principles of green toxicology will continue to play a pivotal role in shaping a safer and more sustainable future.

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