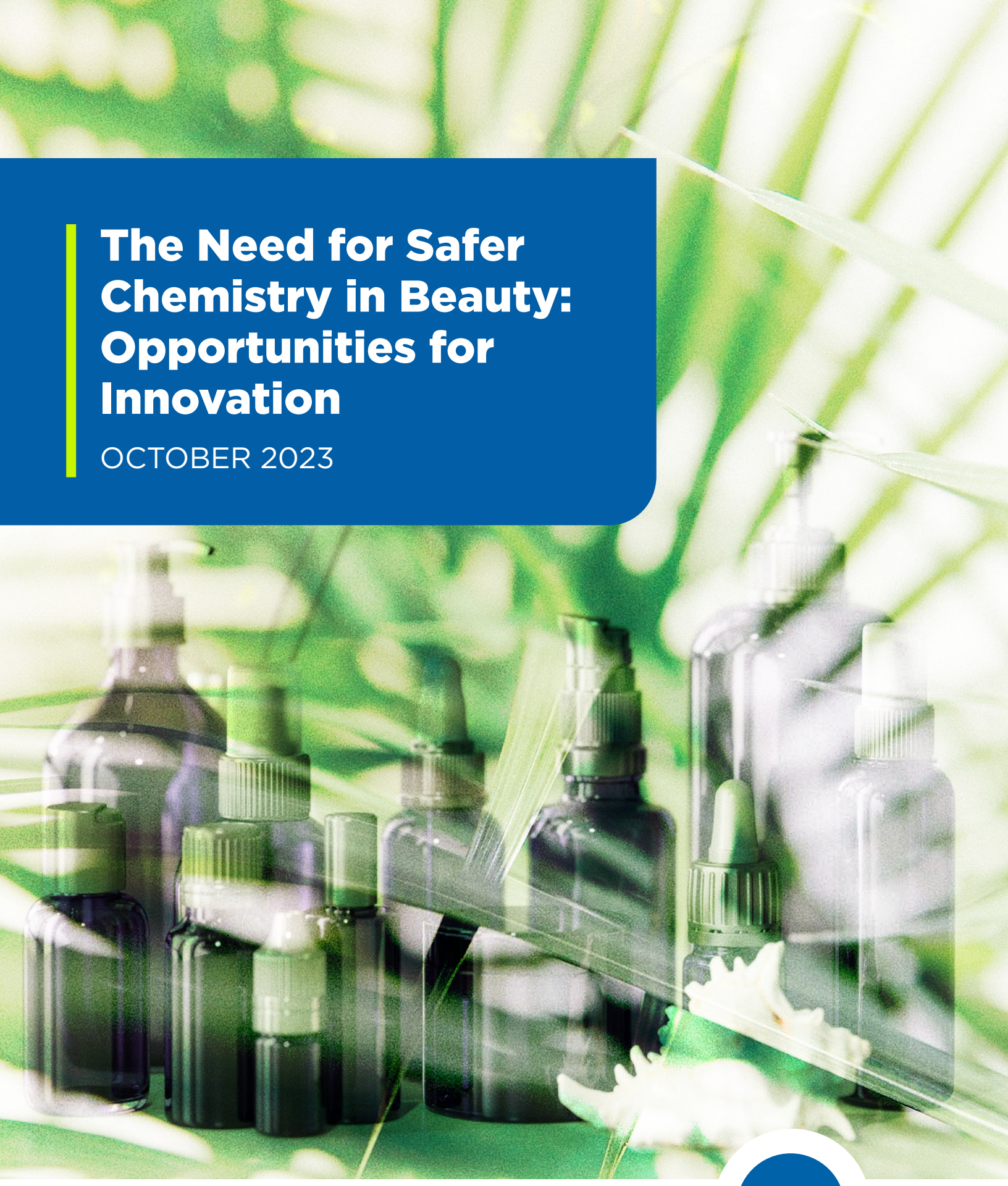

The Need for Safer Chemistry in Beauty: Opportunities for Innovation

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SAFER MADE

About the Authors

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ABOUT SAFER MADE

Safer Made is a venture capital fund that invests in safer products and technologies. People usually choose safer products. We invest in companies that make that choice possible and enable brands and retailers to tell a story of safety and sustainability. Safer Made's General Partners are Adrian Horotan and Marty Mulvihill. For more about Safer Made, see: **www.safermade.net**.

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1. Introduction

1.1 SAFETY AND SUSTAINABILITY AS COMPETITIVE DIMENSIONS

We put personal care and beauty products on our skin every day—from face wash to serums, soap to makeup, we all use products intended to clean, protect, and beautify our skin and hair.

People may find it hard to believe that chemicals in everyday products, including skincare and beauty, may be harmful to human health or the environment. We often assume that what's on the market has been proven safe. Before the industrial revolution we used a smaller number of natural materials, such as wood, glass, metal, and natural fibers, oils and pigments. The industrial revolution caused the rapid creation of tens of thousands of new materials and chemistries, some potentially harmful to humans and the natural world.

Governments in some countries have banned problematic chemicals, such as the insecticide DDT or lead in gasoline, and created policies to reduce workers' exposure to various harmful chemicals, such as benzene. But most of the chemistries and materials in commerce have not been assessed to determine their potential for harm or persistent pollution, and most of those that are known or strongly suspected of being harmful are still legal to use and can be found in manufacturing, consumer products, or in the environment.

Over the last 20+ years we've been learning that some widely used classes of chemicals, for example bisphenols, phthalates, or fluoro-alkyls, may cause chronic health issues. Chemicals that are known carcinogens, endocrine disruptors, chemical sensitizers, and allergens are still commonly used in consumer products, including beauty and personal care products. Advocacy organizations, regulatory authorities, and brands and retailers have identified thousands of chemicals of concern used in personal and home care products.

In the same time frame, we've seen a steady increase in people's awareness of safety and sustainability of beauty products. Once someone becomes aware that ingredients or packaging in products they use may

be harmful, they tend to look for claims, certifications, or brands they trust. They also ask themselves "what else is used in the beauty industry that may be concerning?" This creates a growing demand for safer products that can be seen in all corners of the beauty industry.

One can take a walk through the aisles of a drugstore or retailer and see how many products on the shelves make claims of safety and sustainability. These have become new competitive dimensions; products are gaining market share in nearly every product category. Existing consumer companies have been acquiring successful growing brands (for example, Clorox acquired Burt's Bees, Unilever acquired Seventh Generation, SC Johnson acquired Method, P&G acquired Native). Larger personal care and beauty companies are also reformulating products to keep up with the evolving industry standards, and launching their own brands that compete on the same dimensions (for example, Target's Everspring brand).

1.2 ABOUT THIS REPORT

Our purpose is to enable the next generation of safer products in personal care and beauty by identifying innovation opportunities that will replace hazardous chemistry and materials. We categorize the "Innovation Areas" for safer chemistry and materials based on the intersection of the following attributes:

1. the class of chemicals of concern being removed or reduced ("chemical class"),
2. the functions that chemicals and materials of concern perform in the products ("function"), and
3. the product categories where these chemicals and materials of concern are applied ("product category").

We also elaborate on some of the innovation areas, providing a summary of their state of development, examples of new technologies and of companies working to bring them to market.

In the last section, we provide a survey of the industry-wide initiatives, trends, and tools that promote the adoption of safer chemistry in personal care and beauty.

We intend this report to be useful for people who currently work in the beauty industry as well as people outside the industry, and hope that it moves us closer to a common language for describing and categorizing the hazardous chemistry issues, as well as their potential solutions.

2. Safer Chemistry Innovation in Personal Care and Beauty

2.1 DEFINING INNOVATION NEEDS: CHEMICAL CLASS, FUNCTION, PRODUCT CATEGORY

Making products safer and more sustainable involves finding better ways to deliver the same function that the existing hazardous materials provide. Alternatives may mean new ingredients, materials, form factors, processes, or business models.

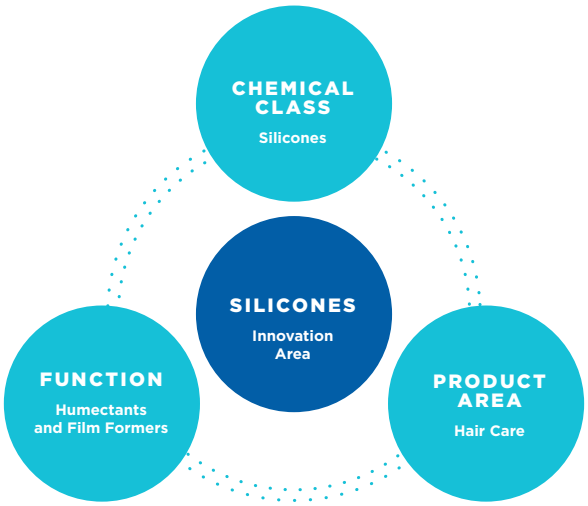
All chemicals and materials belong to certain **classes**, usually based on commonalities in their chemical structures and properties. Some classes contain individual chemicals that are hazardous, and some classes are hazardous in their entirety. Examples of chemical classes include parabens, silicones, or fluoro-alkyls.

Each chemical and material delivers certain **functions** in products. In personal care, examples of functions include humectants, surfactants, preservatives, fragrances, colorants, or packaging.

What products are used for determines their **product category**. Examples of product categories include skincare, hair care, oral care, or color cosmetics.

We identify and name innovation "areas" by bringing together these three taxa (chemical class, function, and product category). An example of an innovation area we named "Silicones" would be finding alternatives for the use of **liquid silicones (chemical class)** as **humectants and film formers (function)** in **hair care (product category)** products. Figure 1 illustrates this example.

FIGURE 1:
LIQUID PLASTICS INNOVATION AREA = CHEMICAL CLASS + FUNCTION + PRODUCT CATEGORY



A SUMMARY OF THE SAFER CHEMISTRY INNOVATION AREAS FOR PERSONAL CARE AND BEAUTY.

* These products are explained in depth throughout this report.

	PRODUCT CATEGORY	FUNCTION	CHEMICAL CLASSES	ISSUE	KEY PERFORMANCE CRITERIA	CURRENT ALTERNATIVES / COMMENTS	DESIRED END STATE
Plastic Packaging*	ALL	Packaging (bottles, jars, pumps, etc.) Tools (makeup brushes, wipes, swabs)	PP PET HDPE Polyurethane foam (e.g. makeup sponges) Cotton / rayon / polyester (e.g. wipes)	Plastic pollution	Strength Moisture resistance Corrosion resistance (some) Formulation compatibility and shelf-life Cost	Reduce material use (e.g. smarter, mono-material packaging design Waterless formulations Concentrates + reusable recipient solutions Fiber- based packaging Compostable biobased polymers (PLA, PHA) Recycled materials	Reusable, recyclable, made from recycled materials, compostable packaging and tools
Silicones*	ALL	Moisturizers Humectants Thickeners Emulsifiers	Silicones Acrylates Methacrylates	Plastic pollution Some suspected endocrine disruptors Residual monomers and process aids	Skin feel Film forming Inodorous Ability to work well in formulations Cost	Use of existing naturally-derived polymers New biobased/biodegradable polymers	Ingredients that biodegrade in wastewater, are not aquatic toxicants, and are made from renewable feedstocks
Fragrances*	ALL	Fragrances	3,000 + fragrance chemicals Common use of phthalates to boost longevity.	Some suspected carcinogens, allergens, chemical sensitizers Lack of transparency Sourcing concerns (sustainability, humane treatment)	Desired fragrance, strength, longevity, color, pH, volatility, other formulation specs Traceability of ingredients Cost	Natural and naturally-derived extracts Compounds found in nature, produced via synthetic biology Compounds found in nature, produced via chemistry Fragrance disclosure, transparency and traceability Fragrance formulations that meet RSLs or certifications	Safe, transparent, traceable fragrance chemicals and fragrance formulations consumers can trust
Preservatives*	ALL	Preservatives	Aldehydes Glycol ethers Isothiazolinones Organic acids Parabens BHA, BHT Formaldehyde releasers (DMDM hydantoin, Quaternium-15, etc.)	Some suspected carcinogens, endocrine disruptors, and sensitizers Some are persistent and have aquatic toxicity	Prohibit microorganism growth Non-irritating, non-sensitizing Play well in formulation (color, odor, PH, neutral to emulsions) Cost	Natural extracts that boost preservation Compounds found in nature, produced via synthetic biology Compounds found in nature, produced ia chemistry Multifunctional ingredients that boost preservative efficacy Waterless products Packaging designed to keep products sealed, requiring less preservation	Formulations and packaging that require less preservatives (solids, concentrates, waterless) and safer, biodegradable preservatives
Surfactants	ALL	Surfactants	SLS SLES PEG Surfactants based on palm oil	Sulphate-based surfactants may irritate skin Ethoxylation, the process used to make some surfactants less irritating, uses ethylene oxide and creates the contaminate 1,4-dioxane, both of which are carcinogens Palm oil production impacts on nature and people	Foaming Stain / dirt removal / cleaning performance Emulsifying Gelling Film formation Play well in formulation (color, odor, PH, neutral to emulsions) Cost	Surfactants that breakdown rapidly in nature Surfactants made from renewable feedstocks Surfactants made via synthetic biology processes Existing palm, coconut, and soy-based surfactants work well, but are more expensive and some have land-use and ethical sourcing issues	Surfactants made from renewable or waste feedstocks that have low impact, that work well, and break down in nature
Pigments	COLOR COSMETICS SKIN	Pigments	Carbon black Carmine Oxides Mica Minerals	Heavy metal contamination Occasional use PFAS-based dispersants	Dispersible, stable emulsions Water/sweat resistant FDA registered Economics	Mineral pigments without heavy metal contamination and PFAS dispersants Biobased melanin Biobased carbon black Natural plant-based pigments	Safe, transparent, traceable pigments and pigment formulations
Solvents in Nail Care	COLOR COSMETICS NAILS	Solvents	Formaldehyde Dibutyl Phthalate Toluene Formaldehyde Resin Camphor Xylene Ethyl Tosylamide	Some known carcinogens Some neurotoxicants	Film formation Dry time Durability Gloss and other color effects	Water-based formulations have lacked the durability and performance of solvent systems 7 & 10 free formulations that avoid harmful solvents but may still contain urethanes and acrylates as well as carbonate solvents	Safe and durable water-based nail coating options for both home and salon applications
Dyes and Bleaches	COLOR COSMETICS HAIR	Hair Dyes Bleaching Agents	Para-phenylenediamine (black) Ammonia + ethanolamine and H2O2 + Persulfate (Bleaching)	Respiratory and multiple organ toxicities Skin irritant Caustic	Color fastness Wash resistance Speed of treatment Ease of use	There are few alternatives and they usually have limited effectiveness and durability Natural dyes like henna or melanin are quick to fade	Non-toxic dyes and mild bleaching agents that work across a range of hair types and colors
Hair Straighteners	HAIR CARE	Permanent Hair Straighteners	Cyclosiloxanes Formaldehyde Parabens Diethanolamine Sodium hydroxide Ammonium thioglycolate Phthalates Triclosan Benzophenone-3	Some known carcinogens Some suspected endocrine disruptors	Neutral pH Fast acting Long lasting Less damaging to hair	There are few alternatives and they usually have limited effectiveness and durability Keratin treatments are often marketed as safer but contain formaldehyde or glyoxylic acid that are carcinogenic	Mild and long-lasting solutions
Sunscreen Actives*	OTC	UV Absorbing Chemicals	Oxybenzone Octinoxate Cinoxate Dioxybenzone Ensulizole Homosalate Meradimate Octisalate Octocrylene Padimate O Sulisobenzone Avobenzone	Some suspected carcinogens and endocrine disruptors Suspected coral reef toxicity	Full spectrum SPF protection Not water soluble (for waterproof/sweat proof claims) Compatible with formulations (non-greasy, no white cast, last for hours on skin)	Minerals (TiO2 and ZnO) are the main alternatives and are generally recognized as safe and effective (GRASE). Mineral-based sunscreens are often difficult to apply and leave a white cast on skin. Biobased active ingredients including melanin, mycosporine-like amino acids (MMA), and Gadusol EU approved chemicals including Tinosorb S, Tinosorb M, Mexoryl SX and Mexoryl XL that are regarded as safer than Avobenzone and provide UVA protection. High regulatory barriers (FDA)	Products that work well (full spectrum SPF protection, long lasting) and deliver a positive user experience (easy to apply, invisible) based on active ingredients that are safe for people and coral reefs
Insect Repellants*	OTC	Insect Repellent Actives	DEET	Suspected neuro and reproductive toxicant	Repellency of both tick and mosquitoes demonstrated in human field trials Compatible with formulations that persist in the skin	Natural 25b list ingredients do not persist on the skin and are generally not effective High regulatory barriers (EPA)	Safe products that work well for 4 hours or more
Skin Antimicrobials	OTC	Disinfectants HANDS	Ethanol Isopropyl alcohol Benzalkonium chloride (BZK)	Alcohols are skin drying and can be contaminated BZK is persistent and an aquatic toxicant	Alcohols are skin drying and can be contaminated BZK is persistent and an aquatic toxicant	Biobased short-chain quats High regulatory barriers (FDA)	Effective and safe products
Surface Antimicrobials	OTC	Disinfectants SURFACES	Alcohol Quats Triclosan Bleach Peroxide	Some ingredients are suspected carcinogens Some Quats are persistent, and are linked to aquatic toxicity and microbial resistance	Log microorganism reduction Does not cause dry skin or skin sensitization Play well in formulation (color, odor, PH, neutral to emulsions) Cost	Hypochlorous acid Thymol High regulatory barriers (EPA)	Effective and safe products
Acne Actives	OTC	Acne Treatment Actives	Benzoyl peroxide Retinoids Salicylic Acid Prescription antibiotics	Antibiotic treatments can have significant side effects Skin irritation Photosensitivity	Effectiveness Play well in formulation (color, odor, PH, neutral to emulsions)	Nitrosomonas eutropha Phage serums targeting C-Acne It is hard to determine if both incumbent and alter-native products work well High regulatory barriers (EPA)	Effective and safe products
Lice Treatment Actives	OTC	Lice Treatment Actives	Pyrethrins / pyrethroids Ivermectin	Some ingredients are neurotoxicants	Effectiveness against live lice Effectiveness against eggs Play well in formulation (color, odor, PH, neutral to emulsions)	Heat-based treatments and physical removal work well but are more expensive High regulatory barriers (EPA)	Effective and safe products
Oral Care Actives	ORAL CARE	Active Ingredients	Quats Hexachloradine Triclosan PTFE Floss	Some Quats are persistent and have aquatic toxicity Some ingredients are suspected carcinogens	Antimicrobial effectiveness Play well in formulation (color, odor, PH, neutral to emulsions)	Alcohol and botanical-based mouthwashes Most toothpaste is already antimicrobial as it contains surfactants	Effective and safe products

TABLE 1: SAFER CHEMISTRY INNOVATION AREAS TAXONOMY

2.2 SAFER CHEMISTRY INNOVATION NEEDS A TAXONOMY

Table 1 includes a summary of the safer chemistry innovation areas for personal care and beauty. Some of the innovation areas, such as plastic packaging, cut across all product categories. Note that some of the product categories are classified as Over the Counter Drugs (OTC)[1], not "Cosmetics," and are therefore regulated differently. Since our goal remains the same regardless of the regulatory regime—to elucidate the need for green chemistry innovation in products that go on the skin—we've included them in our taxonomy.

In the next few sections, we will present the Preservatives, Silicones, Fragrances, Plastic Packaging, Sunscreen Actives, and Insect Repellents innovation areas in more detail.

We chose these case studies to highlight active areas of innovation, as well as some of the unique challenges that can be faced when bringing innovation to the market. Each of the innovation areas above warrant examination. The selection of the following six are not meant to imply a prioritization. Rather, these examples show the kind of technical, regulatory, market, and performance considerations that need to be considered while identifying and validating safer alternatives.

[1] www.fda.gov/cosmetics/cosmetics-laws-regulations/it-cosmetic-drug-or-both-or-it-soap

PRODUCT CATEGORY: ALL

FUNCTION: Preservatives

3. Preservatives

CHEMICAL CLASSES	ISSUE	KEY PERFORMANCE CRITERIA	CURRENT ALTERNATIVES / COMMENTS	DESIRED END STATE
Aldehydes	Some suspected carcinogens, endocrine disruptors, and sensitizers	Prohibit microorganism growth	Natural extracts that boost preservation	Formulations and packaging that require less preservatives (solids, concentrates, waterless)
Glycol ethers	Some are persistent and have aquatic toxicity	Non-irritating, non-sensitizing	Compounds found in nature, produced via synthetic biology	Safer, biodegradable preservatives
Isothiazolinones		Play well in formulation (color, odor, PH, neutral to emulsions)	Compounds found in nature, produced via chemistry	
Organic acids		Cost	Multifunctional ingredients that boost preservative efficacy	
Parabens			Waterless products	
BHA, BHT			Packaging designed to keep products sealed, requiring less preservation	
Formaldehyde releasers (DMDM hydantoin, Quaternium-15, etc.)				

TABLE 2: PRESERVATIVES INNOVATION AREA SUMMARY

Personal care and beauty products usually contain ingredients that can break down, and many also contain water, making them susceptible to microbial growth. Preservatives are added to formulations to ensure products are shelf stable for longer than a year and to prevent bacteria, yeast, and mold growth even after opening. The main classes of preservative compounds in personal care and beauty products are alcohols, formaldehyde donors, isothiazolinones, parabens, phenoxyethanol & other phenol derivatives, quaternary ammonium compounds, and organic acids.

According to Grandview Research,[2] the global preservatives market is estimated to be about $5 billion, with roughly 35% for formulated products. The market is expected to grow at a significant rate (~5.1%), driven mainly by the increased use of personal care products in developing countries. The main players in the preservatives market include large chemical

[2] www.grandviewresearch.com/industry-analysis/preservatives-market-report

companies such as BASF, Evonik, and Dow, medium-sized chemical companies such as Arkema, Ashland, Symrise, and Clariant, and many smaller companies.

Successful preservation systems perform well against a wide range of microbes, bacteria, and fungi, and are effective at various levels of product pH. Preservatives should have no negative interactions with other ingredients, no effect on emulsions, no impact on smell and color, and be stable, mix well, and handle variations in temperature. Cost is a major driver in purchasing decisions.

Concerns about health and sustainability have created a demand for safer preservatives. Table 2 shows a summary of the preservative innovation needs. Several preservative classes are known skin irritants including parabens, isothiazolinones, and formaldehyde donors. Formaldehyde donors like Quaternium-15, imidazolidinyl urea, sodium hydroxymethylglycinate, bronopol, and glyoxal are suspected sensitizers, and many fall under regulatory and voluntary use restrictions because formaldehyde is a carcinogen at higher doses. Most common and effective preservatives are synthetic chemicals that are petroleum-derived, making it harder for companies that seek to make natural or biobased product claims.

There are several types of "natural" claims used in the personal care industry. In one use, "natural" can mean the use of molecules that can also be found in nature. For example, benzyl alcohol and caprylyl glycol can be found in plants. The actual ingredients used in beauty products, however, are usually derived via synthetic chemistry.

"Natural" can also refer to "biobased" ingredients, which are derived from renewable feedstocks. These biobased ingredients can either be naturally occurring or new chemistries that are not found in nature. For example, some brands make biobased claims when they use modified caprylyl xylitol, and or other benzyl alcohol derived ingredients, which is made from renewable carbon, even though these specific compounds are not found in nature.

There are a handful of commercial preservative providers that make preservative systems that support these first two types of "natural" claims. Some of the leaders include Evonik's Dr. Straetman's brand which offers renewable phenethylalcohol as well as synthetically derived mixtures of mild chemistries including benzyl alcohol, caprylyl glycol, and benzoic acid. Inolex, Symrise, and Clariant also offer a range of preservative solutions built around similar renewable and synthetic chemistries. Lonza offers fungicide chemistries based on dehydroacetic acid and iodopropynyl butylcarbamate.

COMPANY	TECHNOLOGY / MARKET
Synergio www.synergio.com	The first complete preservative formulation made from plant extracts. Works in a range of emulsions. Has partnered with Symrise.
CurieCo www.curieco.com	Using synthetic biology to engineer new antimicrobial enzymes for personal care.
Avisco www.inulav.com	Extract from a strain of the Inula Viscosa plant, that shows strong antimicrobial activity.
Aequor www.aequorinc.com	A class of marine antimicrobial compounds with diverse applications.

TABLE 3: COMPANIES DEVELOPING BIOBASED PRESERVATIVE FORMULAS.

Whether they are "found in nature" and/or "biobased," these cosmetic preservatives, like other ingredients, need to be listed on the product ingredient label by their chemical names according to the "INCI" (International Nomenclature of Cosmetic Ingredients). These rules were developed by the International Nomenclature Committee (INC) and published by the Personal Care Products Council (PCPC) in the *International Cosmetic Ingredient Dictionary and Handbook*, available electronically as wINCI.

Finally, "natural" can also refer to plant extracts or other molecules that are found in nature and derived through processes that do not alter their molecular structure. One of these companies is Synergio (Table 3), offering a complete preservation solution based on plant extracts. Plant extracts can be listed on product labels by plant name as opposed to chemical names.

Some "natural" preservatives may allow companies to make a "Preservative Free" claim on the package. Preservative free claims are allowed when no registered preservatives are added to the formulation, and the relative stability of the product is derived from ingredients that deliver the preservative function in parallel with some other function. Examples include benzyl alcohol, which is also a fragrance, and caprylyl glycol, which is also an emollient. Some of the natural extracts, as they are usually combined with benzoate boosters, would not be able to make the "Preservative Free" claim because benzoates are registered preservatives. Since preservation is necessary for safe, shelf-stable products, we believe "Preservative Free" claims may undermine the functional importance of this ingredient class and should not be used.

Many natural preservative formulations have issues with smell or color, have limitations in the types of microorganisms they control, the pH range they are active in, or the type of products they work with. The beauty industry needs a fully natural, extract preservative that works well against a wide range of microorganisms and within a wide pH range.

There are several young companies developing new, biobased preservative systems that could be applied to personal care and beauty products, included in Table 3.

Another way to reduce dependence on preservatives is to eliminate the water in formulations, and/or seal the product inside the packaging (e.g. airless packs), avoiding contamination. Examples of companies formulating personal care products without water include Nohbo[3] (personal care pods and soap swatches), Susteau[4] (powder shampoo), and LUSH[5] (solid shampoo bars). This approach has an added advantage, as removing water from the formula may allow for alternatives to traditional plastic packaging, and it makes products lighter, reducing their transportation carbon footprint, and cost.

The demand for green chemistry innovation for preservatives has been clear for several years. From 2016-2018, members of the Green Chemistry and Commerce Council (now known as Change Chemistry),[6] including Aubrey Organics, Colgate-Palmolive, Method, Aveda, Henkel, Procter & Gamble, BabyGanics, Johnson & Johnson, Seventh Generation, Beautycounter, L'Oreal, and Unilever, participated in a project known as "The Preservative Challenge" to identify safer preservatives as a key area of innovation, and to develop a set of specifications[7] for what a safer, more sustainable preservative solution would need to look like. The group's findings remain relevant for chemical innovators today.

[3] nohbo.com
[4] susteau.com
[5] www.lushusa.com
[6] www.greenchemistryandcommerce.org
[7] www.greenchemistryandcommerce.org/documents/GC3PreservatvesCriteria1.pdf

PRODUCT CATEGORY	FUNCTION
ALL	Moisturizers Humectants Thickeners Emulsifiers

4. Silicones

CHEMICAL CLASSES	ISSUE	KEY PERFORMANCE CRITERIA	CURRENT ALTERNATIVES / COMMENTS	DESIRED END STATE
Silicones Acrylates Methacrylates	Plastic pollution Some suspected endocrine disruptors Residual monomers and process aids	Skin feel Film forming Inodorous Ability to work well in formulations Cost	Use of existing naturally derived polymers New biobased/ biodegradable polymers	Ingredients that biodegrade in wastewater, are not aquatic toxicants, and are made from renewable feedstocks

TABLE 4: SILICONES INNOVATION AREA SUMMARY

Silicones are a part of the larger category of "liquid plastics," which are synthetic polymers added to products to perform a variety of functions including as moisturizers, emollients, thickeners, emulsifiers, and conditioners. Silicones can also minimize irritation caused by other harsh chemicals and surfactants. Silicones (and other polymers) are made from repeating chains of chemical units called monomers. Synthetic polymers are not naturally occurring.

Silicones are a class of polymers built around the silicon, oxygen, and carbon monomer shown in Figure 2. They usually appear as clear fluids but can also be made into elastomers and polymers, used in many beauty products, medical products and cooking devices. Examples of silicone ingredients used in beauty products include amodimethicone, dimethicone, and cyclopentasiloxane.

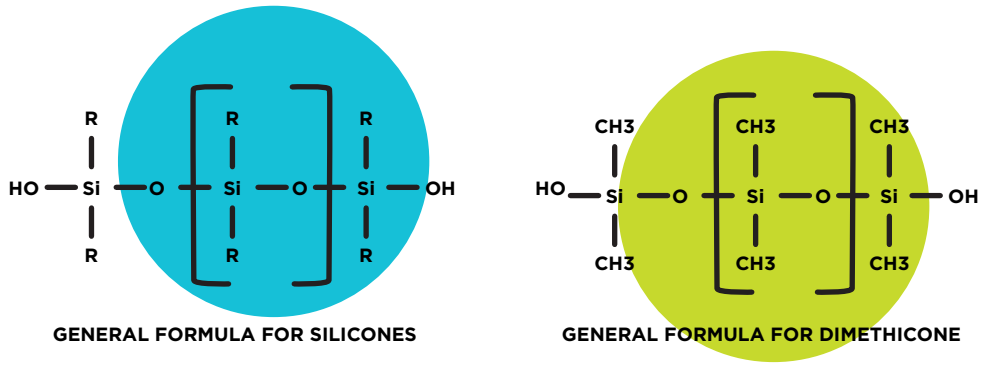


FIGURE 2: STRUCTURES OF SILICONES AND DIMETHICONE.

Silicones are not biodegradable. Depending on their volatility, chemical composition, and molecular weight, some silicones may breakdown by hydrolysis and oxidation in the environment. The fate and transport of these chemicals in the environment—meaning how they move through the ecosystem and where they end up—and their potential health hazards are still being evaluated.

Some cyclic silicones have been shown to interfere with human hormonal signaling and have been classified as potential endocrine disruptors and reproductive toxicants. Most of the hazard is associated with the cyclic silicone (D4 and D5), which are used in hair and skincare products. These types of silicones are volatile and have been identified as air pollutants in some urban areas.

Given regulatory and health concerns associated with cyclic silicones, we believe they should be avoided whenever possible. Linear silicones (e.g. dimethicone) are safer, but still made from non-renewable resources and persist in the environment. Silicones should be replaced with biobased options when available. In addition to environmental health concerns, some consumers look for silicone-free products for performance reasons. The oily nature of silicone-containing products may clog pores or weigh down hair.

Given the wide range of materials in the silicones class, and the multiple functions they play, the alternative chemistries will have to be diverse. Some alternatives that deliver the functions of silicones, are derived from renewable resources, and are safer for human health and the environment include:

- **Citropols**—a new class of low molecular weight liquid polymers that are made from renewable forest product feedstocks (terpenes). These products have the INCI names polycitronellol and polycitronellol acetate and are made by P2 Science[8] in a variety of molecular weights and formulations. P2 Science's Citropol-based products deliver a wide range of functions currently achieved using silicones, ranging from low molecular weight (D4/D5 cyclic silicones) to high molecular weight (from 1000 to 10,000 cPs) to an alternative for petrolatum. P2 Science has also developed a line of Citropol-based haircare ingredients (CitroComplex) that can be used to replace dimethicone as a conditioner and detangling agent.

- **Fatty acid esters**—derived from plant oils and can be modified to have similar properties to some of the silicones. Fatty acid esters are made by Inolex.[9] The company has developed a wide range of silicone alternatives for different functions such as emulsifiers, film-forming agents, and emollients.

- **Long-chain (C12 to C20) alcohols**—emollients that can also modify viscosity and promote emulsion stability without the use of silicones. Fatty alcohols are not strictly silicone replacements and may be used alongside silicones in some formulations. Regardless, they perform some of the same functions as silicones and are often an important functional component of silicone-free formulations. Palmityl alcohol (C14), Cetyl alcohol (C16), Stearyl alcohol (C18), and Cetearyl alcohol (mixed cetyl-stearyl alcohol) are common ingredients, often derived from palm oil. However, the cultivation of palm oil has come under scrutiny for deforestation, poor labor practices, and environmental degradation. Alternatively, Behenyl alcohol (C22) and Brassica alcohol (C16-C24, derived from cabbage wax), do not come from palm oil.

Silicones are a versatile class of ingredients that have been used in personal care formulations for years. Some brands are looking for alternatives to silicones in

[8] p2science.com/citropol
[9] inolex.com

order to move away from synthetic and petroleum-derived ingredients and avoid the health concerns and regulatory pressure on the cyclic silicones.

The existing replacement options fill many of the performance requirements but are often more expensive and require some modifications to formulations to work as well in final products. Both P2 Science and Inolex have application labs that help brands incorporate these new ingredients in their formulations. Table 5 includes a summary of the alternatives to silicones for the most common functions.

In the coming years, we expect personal care and beauty brands to phase out of cyclic silicones due to regulatory and market pressure, and to move away from silicones entirely.

SILICONE / FUNCTION	ALTERNATIVES
D5 cyclic silicone replacement, low viscosity silicone replacement	Citropol V5, LexFeel WOW, LexFeel D5, LexFeel 7
Silicone 20, low viscosity silicone replacement for slip and lubrication	Citropol 1a, LexFeel N5
Silicone 100, dimethicone emollient replacement	Citropol HA, LexFeel Natural
Silicone 350, medium viscosity silicone replacement for anti-frizz and lubrication	Citropol H, LexFeel N350
Silicone replacement for conditioning in hair care	Citropol T, CitroComplex Hair, AminoSensy HC, Emulsense HC
Higher molecular weight dimethicone emollient and viscosity modifier	CitroVisc 1000, CitroVisc 5000, CitroVisc 10K, LexFeel N20, LexFeel N200, LexFeel N350
Replacement for silicone and PFAS containing pigment dispersions	CitroSperse

TABLE 5: SILICONE ALTERNATIVES

PRODUCT CATEGORY	FUNCTION
ALL	Fragrances

5. Fragrances

CHEMICAL CLASSES	ISSUE	KEY PERFORMANCE CRITERIA	CURRENT ALTERNATIVES / COMMENTS	DESIRED END STATE
3,000 + fragrance chemicals Common use of phthalates to boost longevity/ persistence.	Some suspected carcinogens, allergens, chemical sensitizers Lack of transparency Sourcing concerns (sustainability, humane treatment)	Desired fragrance, strength, longevity/ persistence, color, pH, volatility, other formulation specs Traceability of ingredients Cost	Natural and naturally derived extracts Compounds found in nature, produced via synthetic biology Compounds found in nature, produced via chemistry Fragrance disclosure, transparency, and traceability Fragrance formulations that meet RSLs or certifications	Safe, transparent, traceable fragrance chemicals and fragrance formulations consumers can trust

TABLE 6: FRAGRANCES INNOVATION AREA SUMMARY

Fragrances are both a consumer product category (also known as perfumes) and an ingredient class that imparts scent to most beauty and personal care products. Even "unscented" products sometimes have "masking fragrance[10]" ingredients.

Perfumes (cologne, perfume, body spray, mists) are made by consumer product companies, such as Chanel or COTY. Fragrance formulations that are used to add scent to personal care, beauty, and home care products are made by specialized fragrance houses such as Givaudan, Firmeich, IFF, or Symrise.

The global perfume market size was valued at USD 50.85 billion in 2022.[11] The global fragrance ingredients market was estimated at USD 26 Billion in 2017.[12]

A significant part of the innovation conversation in fragrance is about ingredient disclosure. The fragrance industry has an entrenched practice of selling ready-to-use blends for which they do not disclose the ingredients. They regard the formulations of fragrance blends as trade secrets and guard them accordingly.

The US federal law governing the industry allows for using the generic word "fragrance[13]" on product ingredient labels, without the

[10] www.epa.gov/sites/default/files/2015-02/documents/fragrance-free_criteria.pdf
[11] www.grandviewresearch.com/industry-analysis/perfume-market#:~:text=Report%20Overview,5.9%25%20from%202023%20to%202030
[12] www.leffingwell.com/top_10.htm
[13] www.fda.gov/cosmetics/cosmetic-ingredients/fragrances-cosmetics

requirement to further disclose the chemical constituents that make up the fragrance formulation. Yet, certain ingredients in fragrance blends can trigger skin allergies or irritations, systemic sensitivity, or respiratory problems.

The recent update to US federal cosmetics law, "The Modernization of Cosmetics Regulation Act[14]"(December 2022) requires some disclosure of potential allergens in fragrances. While the rules have yet to be fully defined, we hope they will require that certain substances known to have allergenic potential be disclosed on the product ingredient list.

The European Union (EU) rules on fragrance allergens require disclosure of 26 substances known to be allergens, both synthetic fragrances and natural extracts such as benzyl alcohol, citronellol, farnesol, geraniol, limonene, and methyl 2-octynoate. The EU is expected to broaden this regulation by adding 62 additional allergens to the list. Since many companies manufacture products for the global market, US and EU harmonization would make labeling less onerous for companies, allow for common language for customers, and lead to green chemistry innovation.

The fragrance industry trade association (IFRA) estimates that there are over 4,000 chemicals in use in fragrance blends created by its members. While IFRA does have health and safety data for many of these chemicals, most of this data is not available to the public.

Women's Voices for the Earth, an environmental health organization, found in an analysis[15] published in 2018 that "one-third of all the fragrance chemicals currently in use have been flagged as potentially toxic by scientists around the world." Another organization, Breast Cancer Prevention Partners (BCPP), released a 2018 report[16] on the presence of harmful fragrance chemicals linked to cancer, hormone disruption, reproductive harm, and respiratory toxicity in a variety of household products. About three quarters of the toxic chemicals found in the products tested by BCPP were fragrance chemicals.

Consumers love scented products. The demand for creams, shampoos, mists, deodorants, and perfumes that smell good drive market growth. At the same time, there is a growing awareness of allergies, irritation, chemical sensitivity, and speculation about undisclosed fragrance ingredients. This awareness and push for greater transparency is a part of the broader clean beauty movement and coupled with a growing interest in natural and safe fragrance ingredients.

In 2017, Unilever[17] was the first major global brand to announce and implement the disclosure of fragrance ingredients accounting for 0.01% (or higher) of the weight of their product formulations. Customers can find the list of these fragrance ingredients on SmartLabel,™[18] an industry-backed digital label platform.

In 2019, clean beauty online retailer Credo[19] announced a new Fragrance Transparency Policy, which required its approximately 100 brand partners to categorize their products based on the type of fragrance used. The categories are Fragrance Free, Essential Oils, Certified Organic, Natural, Naturally Derived, and Synthetic. Credo also asked brand partners to fully disclose all fragrance

[14] www.fda.gov/cosmetics/cosmetics-laws-regulations/modernization-cosmetics-regulation-act-2022
[15] womensvoices.org/2018/09/28/how-well-is-the-fragrance-industry-managing-the-toxicity-of-fragrance-ingredients
[16] www.bcpp.org/wp-content/uploads/2018/09/BCPP_Right-To-Know-Report_Secret-Toxic-Fragrance-Ingredients_9_26_2018.pdf
[17] www.unileverusa.com/news/press-releases/2019/unilever-completes-landmark-fragrance-disclosure
[18] smartlabel.org
[19] credobeauty.com/blogs/clean-scene/what-doesnt-smell-good-about-fragrance

ingredients voluntarily. About 70% of its brands managed to meet the requirements of this policy. Independent beauty brands that seek clean formulas made with natural ingredients, and full disclosure of their formulations, often find that fragrance suppliers refuse to fully disclose the formulations of the fragrance blends they provide.

In addition to some health concerns and a lack of transparency, the fragrance industry is facing the high cost of materials, particularly for high quality, natural ingredients. For example, pure essential oils are more expensive than synthetic blends. Sustainability issues, particularly for ingredients like sandalwood[20] and vanilla,[21] are also factors in availability and costs.

Apart from scent molecules, fragrance formulations also include solvents and fixatives. Phthalates are often used as solvents and fixatives in fragrance formulations. Five phthalate esters are used in fragrance formulas: dimethyl phthalate (DMP), diethyl phthalate (DEP), dibutyl phthalate (DBP), benzyl butyl phthalate (BBP), and diethyl hexyl phthalate (DEHP). The most used is DEP, which has no use restrictions in the US or EU and is regarded as the safest phthalate. Many of the other phthalates (including DEHP, BBP, and DBP) are restricted for use in cosmetics in the EU. Phthalates are odorless, have high boiling points, and are excellent solvents for many fragrance molecules. As fixatives, phthalates help fragrances persist on skin and fabric, resulting in a long-lasting fragrance experience.

Phthalates are known endocrine disruptors and reproductive toxicants and do not need to be disclosed when used in fragrance blends. Brands and consumers looking to avoid phthalates in formulated products should avoid all scented products, find products that offer complete fragrance ingredient disclosure, or purchase brands that attest to using suppliers with phthalate-free fragrance blends.

There are several functional alternatives to phthalates for fragrance solvents and fixatives. Dipropylene glycol and isopropyl myristate are examples of two alternative cosmetic ingredients that are commercially available from several producers.

P2 Science[22] has developed a high performance, biobased, fragrance fixative using their Citropol platform, called Citropol F. Adding Citropol F to a fragrance formulation can improve the odor longevity of a consumer product scent from about 30 minutes to about 5 hours.

Fragrance is a key performance characteristic for many consumer products. Fragrances elicit strong consumer responses and help develop brand loyalty. Formulating safe, long-lasting fragrances, free of allergens and phthalates, has been a challenge for brands focused on safety and sustainability. There needs to be greater transparency between fragrance suppliers and brands and between brands and consumers. As transparency increases, we expect that the transition to solvents and fixatives that are not phthalates will accelerate, and brands will be able to formulate safe and compelling scents for their customers.

[20] www.cosmeticsdesign-asia.com/Article/2019/05/29/Securing-sandalwood-Demand-for-sustainability-and-quality-boosts-Australia-s-dominance
[21] www.idhsustainabletrade.com/sustainable-vanilla-initiative-svi
[22] p2science.com

PRODUCT CATEGORY	FUNCTION
ALL	Packaging (bottles, jars, pumps, etc.) Tools (makeup brushes, wipes, swabs)

6. Plastic Packaging

CHEMICAL CLASSES	ISSUE	KEY PERFORMANCE CRITERIA	CURRENT ALTERNATIVES / COMMENTS	DESIRED END STATE
PP PET HDPE Polyurethane foam (e.g. makeup sponges) Cotton / rayon / polyester (e.g. wipes)	Plastic pollution	Strength Moisture resistance Corrosion resistance (some) Formulation compatibility and shelf-life Cost	Reduce material use (e.g., smarter, mono-material packaging design Waterless formulations Concentrates + reusable recipient solutions Fiber-based packaging Compostable biobased polymers (PLA, PHA) Recycled materials	Reusable, recyclable, made from recycled materials, compostable packaging, and tools

TABLE 7: PLASTIC PACKAGING INNOVATION AREA SUMMARY

The look, feel, and practicality of packaging is one of the most notable elements of personal care and beauty products, from product development to functionality to brand marketing. Compared to other material inputs, packaging usually accounts for the single highest material cost. Packaging also accounts for a significant part of a product's waste and carbon footprint.

The global cosmetic packaging market is projected to grow from $30.98 billion in 2021 to $40.96 billion in 2028.[23] According to a popular statistic,[24] 120 billion skincare and cosmetic packages are created annually.

Most of the packaging in the beauty industry is made from new or "virgin" plastic, which is made from petrochemicals using numerous different feedstocks, additives, and other chemical inputs. Conscious consumers have been trained to look for the "chasing arrows"

[23] www.fortunebusinessinsights.com/cosmetic-packaging-market-102130
[24] www.plasticpollutioncoalition.org/blog/2022/1/25/the-ugly-side-of-beauty-the-cosmetics-industrys-plastic-packaging-problem

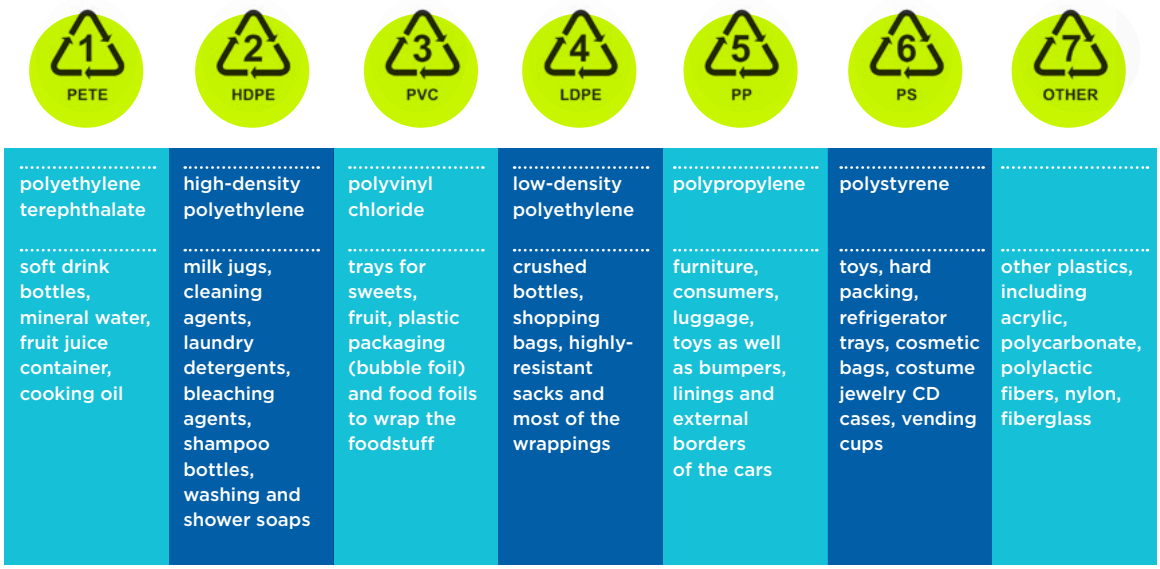


FIGURE 3: MAIN TYPES OF PLASTIC RESINS AND THEIR TYPICAL USES[25]

symbol on packaging, which identifies the type of plastic resin. This information is needed to determine if the resin type is eligible for recycling. The main types of plastic resins and their typical uses are shown in Figure 3.

The building blocks of some types of plastic packaging (especially PVC and Styrene) can be inherently toxic, and some plastics contain toxic chemicals such as Bisphenols, Phthalates, and Fluorinated chemistry (PFAS). A technical report released by the UN in May 2023, titled "**Chemicals in Plastics**," provides an overview of chemicals that are often used, and argues that the health impacts and pollution these chemicals cause be addressed. An analysis of about 7,000 substances associated with plastics shows that more than 3,200 of them have one or more hazardous properties.[26]

The chasing arrows symbol is more commonly used in food packaging rather than personal care and beauty packaging. Smaller packages and components–for example, caps, pumps, or makeup items–often have no chasing arrows symbol or resin codes. Regardless of whether the resin type is identified, beauty components are rarely recycled.

Recycling requires separating plastics from other materials in waste streams, and then separating plastics by type, since they have different chemistries, different end-of-life viabilities, and cannot usually be mixed. Most Material Recovery Facilities (MRFs), where the items in the recycling bin end up, are not equipped to sort items that are smaller than two inches on one side. The use of mixed materials (different plastic types fused together or metal and plastic fused together), or soft plastic formats (pliable or squeezable forms, bags, and films) further complicates separation. Finally, the printing and designs on the packaging further increases contaminants and decreases the likelihood of recyclability.

The cost of separating different materials is a significant factor in the total cost of materials

[25] www.wcpsolutions.com/news/plastic-recycling-codes-explained
[26] sdg.iisd.org/news/unep-reports-on-current-state-of-knowledge-on-chemicals-in-plastics

recovery. For the economics of recycling to work, the total cost of materials recovery should be lower than the market price for the recovered materials. A further complication to successful recycling is that there is no end market for plastic resin codes 3 (PVC), 4 (LDPE), 6 (Styrene), and 7 ("Other" resins, including biobased plastics).

Curbside recycling bins are widely available and many people make efforts to place their waste plastic in them. However most plastic waste ends up in the landfill, incinerator, or in the environment. Plastic waste in the environment elicits a strong negative emotional reaction from most people and causes damage, especially in oceans, leading to microplastic pollution, ingestion, and animal entanglement.

A small amount of plastic from curbside bins actually gets recycled. The belief that curbside recycling happens contributes to the status quo of unsustainable packaging design.

Most plastic packaging for the personal care and beauty industry is made in Asia, and shipped to distributors, warehouses, contract manufacturers, and/or facilities that batch and fill products. The chemical and energy use, as well as other environmental and worker impacts of manufacturing, are often not well understood and difficult to ascertain.

Despite the various issues highlighted above, plastic packaging does have advantages when compared to other materials such as glass or metal:

- Plastic acts as an effective inert barrier for a variety of products with different active ingredients and pH levels, which helps to keep products stable for long periods of time.
- Plastic needs less secondary packaging.
- Plastic containers are less likely than glass to break in use or transport.
- Plastic is light which means a lower carbon footprint from transportation.
- Plastic is inexpensive both because the raw material is relatively cheap, and because it is fast and easy to convert from pellets to final packaging items such as bottles, jars, or films.

6.1 ALTERNATIVES TO VIRGIN PETROLEUM-BASED PLASTIC PACKAGING

Over the last few years, we have seen increasing brand and consumer demands for packaging options that are innovative, sustainable, and provide better material disclosure. Currently, the main alternatives to single use plastic packaging are:

- Waterless and concentrated refillable products
- Recycled plastics
- Glass containers
- Aluminum containers and tubes
- Biobased polymers and fiber

The choices and tradeoffs will depend on the application and function, economics, availability of alternatives, availability of end-of-life options, and other variables.

6.1.1 WATERLESS AND CONCENTRATED PRODUCTS

One of the best ways to make packaging more sustainable is to reduce or eliminate plastic packaging or to create plastic components that can be used through multiple cycles of use (i.e. refillable or reusable). This often requires product redesign. This category includes waterless and concentrated products.

Waterless products can be delivered without the use of plastic, or with minimal plastic, and without the carbon footprint associated with shipping high-water content products. Concentrated formulations allow for simpler, lighter packaging for refills, if used with a durable and refillable container.

A brand designing for sustainability is Nohbo[27], which makes shampoo, conditioner, shower gel, and lotion in dissolvable or concentrated pods and slips. These products can be delivered using paper or cardboard boxes that have only a light plastic or biobased plastic liner.

Other examples include Susteau[28] and LUSH Beauty,[29] which are brands that create concentrated or waterless formulas, some that do not require packaging, and employ recycled content in packaging.

Outside personal care and beauty, a few brands of home cleaning products, such as Grove Collaborative[30] and Blue Land,[31] have pioneered the use of concentrated formulas with refillable containers. However, customer expectations for skin feel and direct contact experience can make designing and delivering personal care and beauty products in concentrated formats more difficult.

Another way to deliver products without packaging is by dispensing them from bulk recipients into refillable containers. A company currently working on this is Good Filling,[32] which is making bulk personal care product machines that can refill containers at locations such as apartment buildings. This model may work in laundry and cleaning, but may be challenging in personal care and beauty.

[27] nohbo.com
[28] susteau.com
[29] www.lushusa.com/stories/article_10-things-lush-packaging.html
[30] www.grove.co
[31] www.blueland.com
[32] www.goodfilling.com

6.1.2 RECYCLED PLASTIC

Another way to increase plastic packaging sustainability is to use recycled plastic resin. This not only reduces the use of virgin petroleum-based plastic but also creates demand for recycled materials, improving the economics of the recycling process. Recycled plastic materials are becoming more widely available, but they tend to cost more compared to virgin materials. Due to impurities, recycled plastics have some disadvantages in terms of color (e.g., they usually have a tint and cannot be made in bright white) and have less strength/flexibility compared to virgin plastics, which may lead to the need to use slightly more material. Plastic, unlike metals or glass, cannot be recycled more than once.

Virgin plastics are cheaper than recycled plastic resins. For example, the price of a virgin PET bottle is usually less expensive, sometimes significantly, than a PET bottle that has 50% recycled content. To be useful for packaging again, plastics need to be separated by the type of resin, not be mixed with other materials (such as metalized films), need to be light in color (darker plastics are not usually recycled), and clean.

Skincare brand Aveda was one of the pioneers of the use of recycled plastic for its products[33] by using recycled PET. Many beauty brands are planning to increase their use of recycled content, especially those that want to be compliant with various retailer programs.

6.1.3 GLASS AND ALUMINUM

Virgin petroleum-based plastic can also be replaced with glass or aluminum. These materials are widely recycled in North America and the EU. Both are also inert and do not degrade into or leach toxic chemicals.

Glass is heavy, it can break, and is rarely recycled back into containers, usually ending up as a sand/aggregate alternative in construction or covering landfills. Glass bottles are more expensive than virgin plastic.

Aluminum is lightweight and one of the materials with the highest recycling rates, as it is both valuable and relatively easy to separate. However, aluminum is significantly more expensive than virgin plastic—about 2 to 3 times the cost of the same size container. Aluminum containers also often need to be coated on the inside with a layer of plastic, to keep the metal from interacting with the product.

An example of an innovative company working to design and deliver metal packaging solutions for the beauty industry is Verity Case[34], which has created a line of reusable and recyclable metal packaging solutions.

[33] www.aveda.com
[34] www.veritycase.com

6.1.4 FIBER

Plastics containers such as jars, bottles, and tubes, can also be replaced with fiber containers. Fiber still needs to be lined with plastic for moisture barrier, but it can significantly reduce the use of plastic and be recycled if the fiber recipient can be easily separated from the liner.

An example of an innovative company in this space is Ecologic Brands,[35] who makes packaging in the form of a cardboard bottle made from recycled paper and cardboard, using easy to separate plastic liners (or pouches) to hold the product. These liners can also be made from recycled plastic. Ecologic's paper bottles and jars reduce the use of plastic by up to 70% per item. Examples of brands that use Ecologic's packaging include L'Oreal's Seed Phyto Nutrients and Seventh Generation. The company was bought by manufacturing services company Jabil in 2021.

6.1.5 BIOBASED PLASTICS

Biobased plastics, such as PHA (polyhydroxyalkanoates) or PLA (poly lactic acid), have emerged as potential alternatives to petrochemical plastics. They tend to have a lower carbon footprint compared to petrochemicals, are deemed to be biodegradable compared to traditional resins, and some of them could meet compostability standards.

PLA and PHA are part of the larger family of biobased polyesters, but there are some differences between them. A key difference is PHA's higher potential to biodegrade in various environments, including the marine environment. This conclusion is based on studies using lab samples but generalizing it without thorough field testing may be premature. Apart from the environmental conditions, biodegradability is also influenced by many of the material attributes, including molecular weight, crystallinity, physical shape, and additives used. All biodegradability claims need to be validated on individual final items.

Biobased plastics are mostly made from agricultural feedstocks, with the associated impacts on land and water, and are generally more expensive than virgin petroleum-based plastics. Biobased plastics can also contain petrochemicals in the material blend or as additives.

While the use of bioplastics may be a step in the right direction, we should differentiate between the biodegradable and compostable concepts, and briefly discuss the evolving composting standards, the significant absence of widely available composting infrastructure, and the potential for bioplastics to create difficulties for both recycling and composting facilities operators.

Biodegradability implies a material may break down in nature under the action of physical elements, such as water and UV light, and by being consumed by microorganisms. The best examples of biodegradable materials are plant materials (leaves, wood, etc.) that, with few exceptions, biodegrade in place under the action of local microbiological flora adapted to eating them. This form of natural biodegradation is a major contributor to nutrient cycles and necessary for healthy ecosystems.

[35] www.ecologicbrands.com

When we look at human-made materials, we approximate biodegradability by simulating certain types of natural environments in the lab, and seeing how materials biodegrade under those conditions. Human-made materials like bioplastic will travel globally and may end up in environments with variable conditions, including heat or cold, humidity, and the presence or absence of various aerobic or anaerobic microorganisms. It is impossible to simulate all Earth's environments in the lab, and for that reason, claiming that something is "biodegradable" without indicating precisely under what environmental conditions can be misleading.

Compostability is a particular case of biodegradability with defined conditions in terms of temperature (usually around 40C), humidity (usually 80% or higher), and the presence of certain (usually aerobic) microorganisms. Compostability implies active management and acceleration of the degradation process rather than leaving it to natural conditions. Over the last few years, we've seen significant growth in the volume of packaging that makes compostable claims. Compostability especially makes sense in food packaging in situations where packaging items may end up mixed with food waste, making separation and cleaning difficult.

Most industrial composters collect compostable organic materials, then process them at scale to turn them into usable soil. Biobased plastic items usually take longer to compost than yard or food waste, making it more costly and complicating composting operations. Many commercial composters see the biobased plastic items in their waste streams as a nuisance.

Outside of a few large organizations and a growing number of large cities, the public generally lacks access to composting infrastructure. Composting infrastructure has been growing, especially in large cities like San Francisco and Seattle, and in institutional settings, such as universities, but it still needs to be developed in most places. However, without composting infrastructure that also works for compostable bioplastics, the promise of compostable consumer packaged goods cannot be realized. When biobased plastic packaging items end up in landfills, the sustainability impact is limited to a better carbon footprint than virgin petrochemical plastic.

Backyard composting, which people practiced for a long time, has been growing in popularity in North America over the last 20 years but is somewhat limited. A recent encouraging advancement is the development of in-home compostable appliances, such as Lomi,[36] that create and control the composting conditions, making the process faster and more user friendly. Significant growth in composting infrastructure, both public and private, would go a long way in making compostable packaging a solid sustainable option.

In addition to the difficulties of composting biobased plastics (PLA, PHA, starch-based bioplastics), recycling advocates have expressed concern that they have the potential to be mixed up with traditional PET during optical sorting. Mixing these resins harms the thermal stability, strength, and melt-flow properties of the resulting rPET.

Ideally, bioplastic packaging items should indicate how consumers should dispose of them so that they do not end up being mixed with other plastics in the recycling stream.

[36] lomi.com

6.2 ORGANIZATIONS AND ASSOCIATIONS WORKING TO REDUCE PLASTIC POLLUTION

There are several not-for-profit organizations working to improve the personal care and beauty packaging options on the market.

Pact Collective[37] is a nonprofit organization co-founded by Credo and MOB Beauty to end packaging waste sent to landfill. Pact works with stakeholders to push for packaging that can be truly recycled in curbside collection programs, or better yet, refilled and used again. Pact members can also sponsor "hard-to-recycle" collection programs in stores or by mail so that empty packaging can be diverted from landfill and recycled whenever possible. Members include larger brands like Sephora and Ulta, packaging suppliers, independent brands, tech platforms, and solutions-providers.

The Ellen MacArthur Foundation's New Plastics Economy[38] initiative is a vision of a circular economy in which plastic never becomes waste. The vision has several key points including:

- Eliminating problematic or unnecessary plastic packaging through redesign, innovation, and new delivery models
- Supporting reuse models
- Moving toward a world where plastic packaging is free of hazardous chemicals, and the health, safety, and rights of all people involved are respected

6.3 BRAND AND RETAILER PACKAGING COMMITMENTS

In the past few years, consumers and beauty stakeholders have learned more about the issues associated with plastic packaging and they are increasingly asking for more sustainable options. Brands and retailers are establishing initiatives and setting goals for improving their packaging. Some publicly announced goals are sometimes vaguely worded, for example "recyclable by 2025," and may not be achievable without significant innovation, design changes, and/or structural changes in waste management.

Examples of commitments from brands and retailers to improve their packaging include:

- Credo Beauty 's Sustainable Packaging Guidelines[39]—Started in 2020, with the first goal being to eliminate single use sachets or small packets that are commonly used for sampling, as well as sheet plastics and other items that are used once and thrown away. Credo prohibits the use of PVC and will also require that packages made of plastic be at least 50% recycled content and that the resin type is identified on the packaging.
- In 2022, Target announced[40] "Target Zero," a collection that features products and packaging designed to be refillable, reusable, or compostable, made from recycled content, or made from materials that reduce the use of plastic. Target intends to reduce annual total virgin plastic in their owned brand packaging by 20% by 2025.
- The Responsible Packaging pillar in Sephora's Clean + Planet Positive[41] program states that the retailer must reduce, recycle, and reimagine the way they package, which means no single-use items or unnecessary materials, designing with recyclability in mind, and innovating with refillable components, post-consumer recycled content (PCR), biomaterials, and plant-based inks.

[37] www.pactcollective.org/the-packaging-problem
[38] ellenmacarthurfoundation.org/topics/plastics/overview
[39] credobeauty.com/pages/sustainability
[40] corporate.target.com/press/releases/2022/03/target-announces-target-zero-a-new-curated-collect
[41] www.sephora.com/beauty/eco-friendly-beauty

- L'Oreal has made public commitments[42] to optimize packaging, use recycled materials, and make it possible for containers and packaging to be refilled. L'Oreal's Kiehl[43] brand has pledged that 80% of the plastic packaging contains post-consumer content, and that "by 2030, all brand plastic packaging will use recycled or biobased content, exploring as well alternative formats such as refillable and rechargeable products".

- MOB Beauty[44] is a smaller brand that intends to be a leader in packaging sustainability and innovation. All their makeup packaging is made from PET and PP resins with at least 50% post-consumer recycled content. And all are refillable and customizable so the customer can make purposeful choices and create less waste.

Examples of tools that help brands source more sustainable packaging include:

- Source Green,[45] a plastic-reduction software tool that helps beauty brands and other CPG companies to choose vetted plastic solutions that meet their needs.

- SPICE Packaging Tool,[46] allowing users to measure the environmental footprint of any cosmetics packaging. This platform was co-developed by 25 leading beauty companies based on its SPICE Methodology.

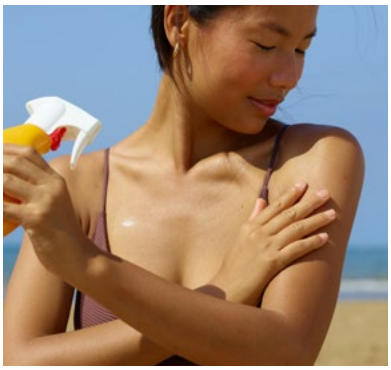
[42] www.loreal.com/en/group/about-loreal/our-purpose/reducing-plastic-packaging
[43] www.loreal.com/en/articles/brands/kiehls-sustainable-program
[44] mobbeauty.com/pages/about-us#sustainable-materials
[45] www.sourcegreen.co
[46] open-spice.com/tool

PRODUCT CATEGORY	FUNCTION
OTC	UV Absorbing Chemicals

7. Sunscreens

CHEMICAL CLASSES	ISSUE	KEY PERFORMANCE CRITERIA	CURRENT ALTERNATIVES / COMMENTS	DESIRED END STATE
Oxybenzone Octinoxate Cinoxate Dioxybenzone Ensulizole Homosalate Meradimate Octisalate Octocrylene Padimate O Sulisobenzone Avobenzone	Some suspected carcinogens and endocrine disruptors Coral reef toxicity	Full spectrum SPF protection Not water soluble (for waterproof/ sweat proof claims) Compatible with formulations (non-greasy, no white cast, last for hours on skin)	Minerals (TiO2 and ZnO) are the main alternatives and are generally considered safe. Mineral-based sunscreens are often difficult to apply and leave a white cast on skin. Biobased active ingredients including melanin, mycosporine-like amino acids (MMA), and Gadusol. EU approved chemicals including Tinosorb S, Tinosorb M, Mexoryl SX and Mexoryl XL that are regarded as safer than Avobenzone and provide UVA protection. High regulatory barriers (FDA)	Products that work well (full spectrum SPF protection, long lasting) and deliver a positive user experience (easy to apply, invisible) based on active ingredients that are safe for people and coral reef

TABLE 8: SUNSCREENS INNOVATION AREA SUMMARY



Safe and effective products protecting people from ultraviolet (UV) radiation are a matter of public health. The Food and Drug Administration (FDA), which is responsible for regulating sunscreen active ingredients and products in the United States, estimates[47] that cancers attributable to UV radiation are responsible for 10,000 deaths per year in the US.[48] The consumer market is growing for sunscreens and other skincare products related to sun and blue light exposure.

[47] cen.acs.org/business/consumer-products/Cloudy-outlook-sunscreen-ingredients-US/100/i42
[48] cen.acs.org/business/consumer-products/Cloudy-outlook-sunscreen-ingredients-US/100/i42

The FDA regulates sunscreen as an over-the-counter drug rather than a cosmetic, which means that unlike cosmetics, there is significant oversight and control over the ingredients used, efficacy testing, and what claims brands can make. All new UV filter ingredients must go through a lengthy and expensive new drug application (NDA) process and be approved by the FDA before being used as an active ingredient in sunscreen products.

All sunscreen products contain active ingredients that prevent UV radiation from penetrating the skin. These UV filters work by either absorbing or by scattering the UV light.

The level of protection from UV is measured by the Sun Protection Factor (SPF). The UV light spectrum is divided into UVA and UVB. UVA includes the light frequencies closer to the visible light spectrum. UVA penetrates the skin deeper than UVB and causes most of the aging and wrinkling attributable to sun exposure. UVB has higher frequencies than UVA and penetrates the skin to a lesser extent, but exposure can cause sunburns. Both UVA and UVB exposure can cause skin cancer. Dermatologists recommend sun protection products that block both UVA and UVB. As UVB has more visible and immediate effects (i.e., sunburn) the Sun Protection Factor (SPF) measurement is skewed towards filtering UVB more than UVA.

The FDA oversees the approval of new UV filtering active ingredients. The high cost of approval has discouraged companies from registering new active ingredients with the FDA. Table 9 includes a list of the currently approved UV-filters as well as some of the more common UV-filters used outside of the US, where sunscreens are regulated as cosmetics rather than drugs. Each filter is also given specific use limits per the FDA and SCCS in EU, which vary by chemical and may be different in the US when compared to the EU.

In 2019, the FDA asked[49] companies to reevaluate the safety and effectiveness of the current chemical UV filter ingredients. The FDA's preliminary action found that only two ingredients, zinc oxide and titanium dioxide, could be classified as safe and effective, based on the currently available public information. There have been several studies that have raised concerns about the skin absorption, photostability, and endocrine-disrupting effects of many of the existing chemical UV-filters. There has also been research that suggests the potential for some chemical UV-filters to cause damage to coral reefs. Further studies are underway.

There are several UV-filters companies are no longer using and have chosen not to support with data in the current FDA review. These UV filters are likely to lose approval and be removed from the monograph at the end of the FDA review. These UV-Filters include: Cinoxate, Dioxybenzone, Padimate O, Sulisobenzone, and Aminobenzoic acid (PABA).

There are a handful of chemical UV-filters that have been used extensively outside of the US and do seem to have a better safety profile.

7.1 NEW UV-FILTERS

There is a need for new, safe UV-filters. To solve this problem, a few young companies have taken inspiration from naturally occurring mechanisms for UV-protection to develop new ingredients.

Melanin is the pigment in our skin that protects us from UV radiation. Researchers at Avisa Myko[50] have found a way to produce Melanin using fermentation.

[49] www.fortunebusinessinsights.com/cosmetic-packaging-market-102130
[50] www.plasticpollutioncoalition.org/blog/2022/1/25/the-ugly-side-of-beauty-the-cosmetics-industrys-plastic-packaging-problem

TABLE 9: UV FILTERS APPROVED IN US AND EU

UV-FILTERS CURRENTLY APPROVED IN US

UV-FILTER	UVA/UVB	SAFETY CONCERNS	COMMENTS
Titanium Dioxide	UVA+UVB	Minimal, not skin absorbed	Customer experience and formulation challenges
Zinc Oxide	UVA+UVB	Minimal, not skin absorbed	Customer experience and formulation challenges
Aminobenzoic acid (PABA)	UVB	Readily absorbed, Known Allergen, Likely Endocrine Disrupting Chemical (EDC)	Already avoided by most companies.
Trolamine Salicylate	UVB	Readily Absorbed, Blood Toxicity, Allergen, Likely EDC	Likely to lose FDA approval. Already avoided by most companies.
Avobenzone	UVA+UVB	Not photostable	Needs to be used with other filters/stabilizers. Allowed at a maximum of only 3% in any formula.
Oxybenzone	UVA+UVB	Readily Absorbed, Likely EDC, Allergen, DNA damage, has been associated with coral reef damage	Commonly used, but increasingly under pressure because of data indicating potential human and environmental concerns.
Cinoxate	UVB	Readily absorbed	Not commonly used, not an effective filter
Dioxybenzone	UVA+UVB	Absorbed, not photostable, discoloration with UVA	Not commonly used, waterproof
Ensulizole	UVB	Not photostable	Water soluble, found in moisturizers, not in full-body sunscreens
Homosalate	UVB	Readily Absorbed, Likely EDC, has been associated with coral reef damage	Common in many products
Meradimate	UVA	Allergen, off smell	Not commonly used
Octinoxate	UVB	Absorbed, potential EDC, Allergen, has been associated with coral reef damage	
Octisalate	UVB	Absorbed, Analgesic, mild floral odor	Commonly used as a booster, relatively weak on its own
Octocrylene	UVB+someUVA	Absorbed, potential allergen, not a likely EDC, has been associated with coral reef damage	A photostabilizing ingredient, commonly used with other ingredients, to boost stability and efficacy
Padimate O	UVB	Absorbed, not photostable, potential carcinogen	Not commonly used
Sulisobenzone	UVA+UVB	Modest Absorption, Irritation, Allergen	Not commonly used, used as UV stabilizer in other products.

UV-FILTERS CURRENTLY APPROVED OUTSIDE US

UV-FILTER	UVA/UVB	SAFETY CONCERNS	COMMENTS
Bemotrizinol	UVA+UVB	Not absorbed, not estrogenic, photostable	US approval likely, oil soluble
Bisoctrizole	UVA+UVB	Not absorbed, not estrogenic, photostable	Not water or oil soluble, formulated as a suspension
Amiloxate	UVB	Low hazard	
Enzacamene	UVB	Potential EDC	Restrictions in Denmark and Japan
Octyl triazone	UVB	Photoreactive, Allergen	PABA derivative
Diethylhexyl butamido triazone	UVA+UVB	Not absorbed, photostable	Oil soluble
Terephthalylidene dicamphor sulfonic acid (ecamsule)	UVA	Not absorbed, photostable	Exclusive to L'Oréal and its brands
Drometrizole Trisiloxane	UVA+UVB	Photostable	Exclusive to L'Oréal and its brands

Mycosporine-like Amino Acids (MAA) are a class of naturally occurring molecules found in marine organisms and microbes that protect them from UV damage and a range of other oxidative stress pathways. These compounds have been the subject of extensive research but have not yet successfully been incorporated into sun-protection products. HelioBioSys[51] is using naturally occurring cyanobacteria to make MAAs available for use in personal care formulations. HelioBioSys has found a way to grow cyanobacteria that produce compounds including mycosporine-like amino acids (MAAs), extracellular polysaccharides (EPS), and phycocyanin. Gadusol Labs,[52] a company that found a way to express a few common MAAs in host organisms for fermentation, was acquired[53] in 2022 by Arcaea, a spin-out from Ginko Bioworks[54].

Soliome[55] has created a new class of peptide-based UV-filters that can be designed to work in both the UVA and UVB portions of the spectrum.

All these new active ingredients would require FDA premarket approval through a new drug application to make claims about UV protection.

7.2 IMPROVED FORMULATIONS

Mineral-based sunscreen actives (titanium dioxide, zinc oxide) work well and are considered safe, but products with these active ingredients tend to be more difficult to apply on the skin and can leave white traces, leading to a poor customer experience.

Mineral-based formulations have improved in recent years as formulators have found new ways to process, modify, and formulate with zinc oxide and titanium dioxide. Many formulations now use film-forming additives including silicones to improve the ease of application and skin feel of the formulations. Some brands also add color to offset the white cast.

Examples of innovative brands that compete in the mineral sunscreens space include AllGood,[56] Minu,[57] and Kinship[58].

There are clear demands for safer sunscreen ingredients and functions. Unfortunately, the need for FDA approval has slowed innovation in UV-Filter ingredients in the United States. A DSM representative estimated[59] the cost of approval for Bemotrizinol in the US to be $5 to 6 million dollars, even after it has been tested and used in the EU for years. Despite the high-cost barrier, there may be other new ingredients ready for commercialization if the FDA were to streamline the processes for approval. Unfortunately, in the current situation, companies seeking approval for new ingredients may need to prepare for a lengthy process.

We expect to continue to see new ingredients come to market in the EU and Asia. Some of these may improve US formulas by being used as UV filter boosters alongside other approved ingredients. The current FDA rules allow some ingredients with UV-filtering capacity to be used in a limited fashion, as boosters that improve the performance of the approved active ingredients. We also expect further improvements to the mineral formulations.

[51] www.heliobiosys.com/technology
[52] www.gadusollabs.com
[53] www.prnewswire.com/news-releases/arcaea-the-beauty-company-pioneering-innovation-through-expressive-biology-announces-acquisition-of-gadusol-laboratories-301589734.html
[54] www.ginkgobioworks.com
[55] soliome.com
[56] allgoodbodycare.com
[57] www.minuminerals.com
[58] lovekinship.com/products/self-reflect-zinc-oxide-mineral-sunscreen
[59] cen.acs.org/business/consumer-products/Cloudy-outlook-sunscreen-ingredients-US/100/i42

PRODUCT CATEGORY	FUNCTION
OTC	Insect Repellent Actives

8. Insect Repellents

CHEMICAL CLASSES	ISSUE	KEY PERFORMANCE CRITERIA	CURRENT ALTERNATIVES / COMMENTS	DESIRED END STATE
DEET	Suspected neuro and reproductive toxicant	Repellency of both tick and mosquitoes demonstrated in human field trials Compatible with formulations that persist in the skin	Natural 25(b) list ingredients do not persist on the skin and are generally not effective High regulatory barriers (EPA)	Safe products that work well for 4 hours or more

TABLE 10: INSECT REPELLENTS INNOVATION AREA SUMMARY

Insect repellents are applied to skin and/or clothing to prevent mosquitoes, ticks, and other insects from landing and biting. Insect repellents are considered pesticides and are regulated by the Environmental Protection Agency (EPA) under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). New active ingredients and product formulations are rigorously evaluated for safety and efficacy. All safety and efficacy claims must be approved by the EPA before the product may be sold.

ACTIVE INGREDIENT	NUMBER OF REGISTERED PRODUCTS	COMMENTS
DEET	230	Health concerns, irritation, can damage gear
IR3535	45	Launched with Skin-so-Soft line, used with UV filters for combined products
Picaridin	40	Less irritating than DEET
p-Menthane-3,8-diol (found in Oil of Lemon Eucalyptus)	6	Extract from Lemon Eucalyptus leaves
2-Undecanone	1	Mimikai
Nootkatone	0	Active approved in 2020, no products approved as of Feb 2023

TABLE 11: EPA REGISTERED INSECT REPELLANT ACTIVE INGREDIENTS

There are six EPA registered active insect repellent ingredients. Products are also individually evaluated and approved, formulation by formulation. There are currently a few hundred registered products that can make claims about efficacy, duration, and disease prevention. Table 11 includes the list of the currently registered active insect repellent ingredients.

In addition to the registered products, there are also products that use active ingredients included in a FIFRA 25(b) exemption, such as citronella oil, geraniol, lemongrass oil, mint oil, and soybean oil. The products sold through the 25(b) exemption offer some protection but do not undergo field testing for efficacy and are not allowed to make claims about duration, effectiveness, or disease prevention.

Diethyltoluamide (DEET) was developed in the 1940s to protect soldiers when deployed in tropical environments. DEET is effective against a variety of insects, including ticks, flies, and mosquitos. DEET is thought to work by disrupting both odor receptors and chemical receptors, disorienting and discouraging landing by insects. At high doses or with prolonged exposure, DEET has been shown to be a neurotoxicant in humans. Formulations are now restricted to using less than 30% DEET in some jurisdictions. DEET is also a solvent and can dissolve or damage synthetic polymers including elastane, rayon, polyester, and other common fabrics.

The insect repellant market has been dominated by products based on DEET. Consumers often express concerns about ingredient safety, user experience because of the oily residue and strong odor, and damage that can be caused to synthetic fibers by DEET as reasons they would be willing to try new products.

The adoption of products based on alternative registered ingredients such as Picaridin or IR25 25 has been slow. These active ingredients are perceived to have lower efficacy compared to DEET and the alternative products are often undifferentiated in their branding and messaging.

The recent rise in public awareness about vector borne diseases such as Zika and Lyme Disease, have brought renewed attention and demand to the insect repellent product category.

Most brands market their products based on the strength of protection—not as products people should like to use, but as products people need to use if they want protection. There is an opportunity for brands that resonate with parents and women to market products in a positive way that encourages people to enjoy using them, similar to how other active topical products like sunscreens are marketed.

Several new brands like Murphy's Naturals[60], Wondercide[61] and Kinfield[62] have moved their brand positioning in this direction. Home care or skin care brands such as Aunt Fannie's[63] and Babyganics[64] have also started carrying insect repellents. These brands area all selling products that use ingredients from the 25(b) exemption list mentioned above, and are not allowed to make claims related to efficacy or duration.

The category of insect repellent products has had three recently approved new active ingredients: Oil of Lemon Eucalyptus (OLE), 2-Undecanone, and Nootkatone.

New brands launched by existing large companies are based on OLE include Zevo[65] launched by P&G and STEM[66] launched by SC Johnson.

Mimikai[67] is one of the few new brands that has gone through the process of bringing a fully registered insect repellent to market using the new active ingredient 2-Undecanone. The EPA approved an eight-hour efficacy claim for the mosquito repellent product and a four-hour efficacy claim as a tick repellent. This puts the product performance on par with DEET-based repellents. Mimikai expects to launch in 2024 and will be positioned as a product people enjoy using, focused on the needs of women and parents.

There are no products using Nootkatone yet registered with the EPA.

[60] www.murphysnaturals.com
[61] www.wondercide.com
[62] kinfield.com/collections/bug
[63] auntfannies.com/product/mosquito-wipes
[64] babyganics.com/products/natural-insect-repellent-spray-6oz.html
[65] zevoinsect.com
[66] stemforbugs.com
[67] www.mimikai.com

9. Other Innovation Trends in Personal Care and Beauty

Several recent innovation trends in personal care and beauty are complementary to and reinforcing the need for safer chemistry and materials. These trends include increasing transparency, concentrated formulations, biobased ingredients, the microbiome, inclusiveness, and new active ingredients.

Increasing transparency and information about ingredients, materials, and sourcing practices helps inform brand and consumer decisions about product safety and sustainability. Beauty and personal care products sold directly to customers are required by the Food and Drug Administration to disclose intentionally added ingredients on the product label, except for ingredients that create the fragrance. This informs and empowers consumers to avoid potential allergens and other chemicals of concern. However, this system can still be improved to cover all ingredients including fragrances (see Section 5 on Fragrances).

We think it would be beneficial for people to have access to more information on ingredient sourcing and potential chemicals of concern, including contaminants. Some of this additional information—such as warnings about potential contamination or sourcing issues, rather than ingredient-specific data—may be found using third-party applications including Clearya,[68] Smart Label,[69] Cosmethics,[70] EWG's Healthy Living App[71], or the Skin Deep[72] database.

Chemists and formulators working for beauty brands use the ChemFORWARD[73] toxicology database, and the formulation and compliance databases by Novi[74] and Good Face Project[75] to increase ingredient-specific transparency.

Concentrated formulations are a way to reduce packaging. We explore some of the efforts in Section 6 on Packaging. It will take innovation in surfactants, formulation, packaging, and product design to make high-performance personal care and beauty concentrates a commercial reality. Products that successfully implement concentrated formats will have sustainability, shipping, and logistics advantages, making them enticing for brands that sell directly to consumers.

Biobased ingredients are often proposed as solutions to synthetic chemicals of concern. There are several brands that market all-natural, biobased, and organic products. We discuss these marketing terms and some of the challenges of replacing traditional synthetic chemicals with natural extracts in Section 3 on Preservatives, and touch on

[68] www.clearya.com
[69] smartlabel.org
[70] cosmethics.com
[71] www.ewg.org/apps
[72] www.ewg.org/skindeep
[73] www.chemforward.org/news/introducing-safer-by-chemforward
[74] www.noviconnect.com
[75] www.thegoodfaceproject.com

specific biobased chemical innovations in the other sections. Examples of companies bringing biobased ingredients to market include companies such as Amyris,[76] Debut,[77] Ginko Bioworks,[78] and Evolved by Nature[79]. Newer companies including Dispersa,[80] Sironix,[81] Chibotanic,[82] Exopolymer,[83] Ecovia[84], and Sparxel[85] are also making new biobased ingredients for the personal care market.

Microbiome awareness in skin health has been growing after the success of probiotic ingredients in the food and beverage categories. There are a growing number of companies working on influencing the microbiome to improve skin health, including Parallel Health,[86] Symbiome,[87] Mother Dirt,[88] Ellis Day,[89] and Cybele[90].

Increasing inclusiveness in clean beauty has been top of mind for some leading retailers and emerging clean brands, some of which are led by women of color creating products designed with their specific needs in mind. Clean beauty products designed for women of color are needed in all product categories, but the need may be greatest for products that address specific needs, such as hair straighteners and conditioners for highly textured hair. Examples of innovative companies include Aja Labs[91] and Rebundle,[92] which offer hair extensions made from renewable resources without the use of harmful chemicals. Brands like Unsun,[93] Akasha Be Well,[94] Pholk Beauty,[95] Naturaz,[96] Rizo Curls,[97] and OurX[98] offer a wide range of personal care, haircare, and beauty products formulated with safer chemicals.

New active skincare ingredients, such as new forms of retinol, hyaluronic acid, niacinamide, bakuchiol, and collagen, are worth mentioning for their ability to grab customer attention. Some of these ingredients may have concerns associated with their sustainable sourcing, and some have data gaps on their hazardous potential. However, they are not known chemicals of concern and they enable claims related to skin health and appearance. There is a significant demand for new and unique ingredients that enable differentiated cosmetic claims. New ingredients should be carefully evaluated for both safety and potential sustainability concerns.

[76] amyris.com
[77] www.debutbiotech.com
[78] www.ginkgobioworks.com
[79] evolvedbynature.com
[80] www.dispersa.ca
[81] sironixrenewables.com
[82] www.chibotanic.com
[83] www.exopolymer.com
[84] www.ecoviarenewables.com
[85] sparxell.com
[86] www.parallelhealth.io
[87] symbiome.com
[88] mightynest.com/shop/brands/mother-dirt
[89] www.ellisdayskinscience.com
[90] cybelemicrobiome.com
[91] www.ajalabs.co
[92] rebundle.co
[93] www.unsuncosmetics.com
[94] akashabewell.com
[95] pholkbeauty.com
[96] www.naturaz.com
[97] rizoscurls.com
[98] ourx.co

10. Industry Wide Initiatives and Trends for the Adoption of Safer Ingredients

Personal care and beauty customers are increasingly asking for products made with natural ingredients, free of certain chemicals, and made without animal testing. Customers want a more customized product offering that addresses the needs of diverse skin tones and conditions. In addition, many customers have come to expect that product performance claims are backed by clinical studies, and sustainability claims are backed by trusted certifications or company verification programs.

The rising bar in consumer expectations is likely the result of access to information and community conversations afforded by the internet, and a general increase in awareness of animal welfare issues, pollution, climate change, and of toxic or untested ingredients in consumer products. Claims about the safety and sustainability of products become new competitive advantages for brands looking to differentiate themselves. Competition between brands then reinforces consumer expectations and raises the bar further.

As a result, there has been a proliferation of retailers, brands, and products that make safety and sustainability claims, sometimes with little action to back them up. Fortunately, the implementation of meaningful product standards is also taking place.

These industry changes have had ripple effects through the supply chain, brought new ingredients and materials to market, and triggered the creation of new marketplaces and databases for better ingredients and packaging.

10.1 COMPANY INGREDIENT POLICIES AND "FREE OF" FORMULATIONS

In the past 10 years, there has been an increase in the number of brands and retailers that make "free of" claims in their product marketing to indicate that the products are formulated without ingredients of concern. Often mentioned ingredients include parabens, SLES (Sodium Laureth Sulfate), oxybenzone, and synthetic fragrances. Silicones, sulfates, and petrochemicals are also mentioned, though most brands are not clearly defining these large chemical groups and the accuracy of some claims is questionable. For example, "petrochemicals" and "synthetic chemicals" are synonymous, and one can find plenty of synthetic chemicals on the ingredient lists of many products making "petrochemical free" claims.

While there are some concerns about misleading "free of" claims, many brands and retailers have implemented more meaningful Restricted Substances Lists (RSLs), which often have suggestive consumer-facing names, like Beautycounter's Never List™, The Honest Company's NO List™, and Credo's The Dirty List®.

These companies' publicly available restricted substance lists (RSLs) tend to be quite short, categorized and defined by ingredient name, function, and reasons that they are avoided. However, the RSLs adopted by these companies for their internal use are much longer and can include thousands of discrete chemicals that are restricted. These more comprehensive RSLs are used when working with contract manufacturers and suppliers, channel partners, and third-party databases and certifiers.

RSLs are also more common at major retailers that have made commitments to remove some of the more problematic ingredients in beauty and other product categories. See for example the chemicals policies of Sephora,[99] Target,[100] Amazon,[101] CVS Health,[102] and Rite Aid[103] which include restrictions on ingredients like phthalates, parabens, formaldehyde, nonylphenol ethoxylates, triclosan, and toluene from personal and home care products.

In addition to claims about avoided ingredients of concern, brands use a variety of other somewhat related marketing claims such as "Gluten Free," meaning without the gluten protein, "Cruelty Free," meaning not tested on animals or "Vegan," meaning made without animal-derived ingredients.

10.2 THE RISE OF CLEAN BEAUTY

The "natural," "green," "safer," and/or "clean" segment of the beauty industry (depending on one's definition or choice of marketing terms) has been growing steadily since the early 2000s. The category experienced growth even during the 2008 recession and has been growing faster than conventional beauty.[104] Customers are increasingly demanding products made with natural ingredients, free of chemicals of concern, and made with more sustainable packaging. These three tenets–naturally sourced, nontoxic, and sustainable ingredients—are generally included in the understanding of "clean beauty" though the lack of an agreed upon definition can lead to confusion or misuse.

Online retailer Credo Beauty is a good example of this evolution. Launched in 2015 and considered the retail leader in "clean beauty" it defines clean beauty as a "movement" and clean products as ones that were created with ingredient and packaging safety, sustainability, ethics, and transparency in mind. The Credo Clean Standard™, launched in 2018, sets up the criteria all brand partners must comply with in order to sell products on the Credo platform. The standard requires RSL compliance, proper ingredient labeling and disclosures, and the verification of natural and organic claims.

[99] www.sephora.com/beauty/clean-beauty-products
[100] corporate.target.com/sustainability-governance/responsible-resource-use/chemicals/chemical-policy/
[101] toxicfreefuture.org/blog/amazon-announces-new-policy-to-restrict-toxic-chemicals
[102] www.cvshealth.com/news/sustainability/removing-chemicals-of-consumer-concern.html
[103] www.riteaid.com/corporate/chemical-policy
[104] www.nutritionaloutlook.com/view/consumers-don-t-just-want-clean-label-beauty-products-they-want-clean-label-products-that-really-work

The two largest specialty beauty retailers, Sephora and Ulta, also have clean beauty programs. Sephora denotes compliant brands with its "Clean at Sephora" seal, launched in June 2018. Clean at Sephora features products formulated without SLS, SLES, parabens, formaldehyde, phthalates and mineral oils, and other ingredients. Sephora updated its RSL to add new restrictions in 2019, 2021 and 2022.[105]

Ulta Beauty has a program called "Conscious Beauty at Ulta". The program is for eligible brands only, but it represents a growing segment in Ulta's product offering.

In 2022, the global cosmetics market size was estimated at $262.21 billion and is expected to expand at an annual growth rate of about 4% over 5 years.[106] The Clean Beauty Market is forecasted at $37.65 billion by 2028 from $5.89 billion in 2023, implying an annual growth rate of about 45% over the five-year period.[107]

Clean beauty is not a niche category, but is still somewhat new, and may experience growing pains. On the consumer side, these include a proliferation of definitions and standards and associated consumer confusion. On the supply side, these might include a lack of ingredient data on how brands measure performance relative to the common tenets of clean beauty—chemical safety, sustainable sourcing, responsibility for the product end-of-life, and ethical/humane manufacturing practices.

[105] www.sephora.com/beauty/clean-beauty-products

[106] www.grandviewresearch.com/industry-analysis/cosmetics-market#:~:text=The%20global%20cosmetics%20market%20size,4.2%25%20from%202023%20to%202030

[107] www.globenewswire.com/en/news-release/2023/02/07/2602666/28124/en/Global-Clean-Beauty-Market-Report-2022-A-37-65-Billion-Market-by-2028-Skincare-Haircare-Makeup-and-Color-Cosmetics-Market-Size-Insights-Competition-Covid-19-Impact-and-Forecasts.html

10.3 INDUSTRY COLLABORATIONS

Organizations in the beauty industry, like in other sectors, come together in the form of trade associations, advocacy groups, and working groups to collaborate in setting up common standards, share best practices, reduce costs for the whole industry, or to protect their interests from perceived threats, including regulatory burdens.

A leading trade association is The Personal Care Products Council,[108] the largest US national trade association representing global cosmetics and personal care products companies who are "committed to safety, quality and innovation". Another trade association is The Independent Beauty Association[109] which has the mission "To foster the success of entrepreneurial companies in the independent cosmetic and personal care industries." It offers members education and networking and promotes "reasonable legislation".

Some examples of collaboration for safety and sustainability include:

- The ChemFORWARD "Know Better, Do Better" initiative that brings together industry-leading beauty companies like Sephora, Ulta Beauty, Credo, Beautycounter, and The Honest Company, ingredient supplier Inolex, and non-profit organization Environmental Defense Fund. These organizations have come together in May 2023 to promote the use of safer chemistry and improve chemical hazard data to enable informed decision making.
- Beautycounter's Counter Act Coalition unites beauty brands to advocate for smarter state and federal policies that protect both companies and environmental health.
- The Campaign for Safe Cosmetics' Business Leadership Circle brings clean beauty brands together to learn more about the link between chemicals of concern and cancer and to advocate for change.
- GC3's Preservative Competition[110] (2016-2017) brought together major CPG companies, leading independent brands, ingredient suppliers and academic researchers to explore the need for preservative hazard assessments and define the criteria for new, green-chemistry-based preservative systems

Examples of industry initiatives for responsible sourcing include:

- The Responsible Mica Initiative (RMI),[111] a global coalition of multiple organizations committed to establishing a fair, responsible, and sustainable mica supply chain in the states of Jharkhand and Bihar, India that will eliminate unacceptable working conditions and child labor by 2030.
- The Roundtable on Sustainable Palm Oil (RSPO),[112] a global, not-for-profit organization focused on bringing together organizations from across the palm oil supply chain to develop and implement global standards for sustainable palm oil.

Examples of collaborations for sustainable packaging include:

- Pact Collective,[113] a nonprofit membership organization, "for beauty, by beauty," launched in April 2020 with the mission to end beauty packaging waste in landfills. Members include packaging suppliers, brands, and major beauty retailers.

[108] www.personalcarecouncil.org
[109] independentbeauty.org
[110] greenchemistryandcommerce.org/projects/innovation/preservatives-project
[111] responsible-mica-initiative.com
[112] rspo.org
[113] www.pactcollective.org

- Sustainable Packaging Coalition[114] is a membership-based collaborative and a leading voice on sustainable packaging for the food and beverage industry, beauty industry, and other fast moving consumer goods.

- The U.S. Plastics Pact[115] brings together businesses, not-for-profit organizations, government agencies, and research institutions to work toward a common vision of a circular economy for plastics, as outlined by the Ellen MacArthur Foundation's New Plastics Economy Initiative.

10.4 NON-PROFIT ORGANIZATIONS

Some nonprofit organizations have been pushing the industry for change with mandates to protect the health of consumers and workers, the environment, animal welfare, or to call for products that serve the needs of customers with different skin tones.

- People for the Ethical Treatment of Animals (PETA) and The Humane Society of America were early leaders in the animal welfare movement, and have called for the end of testing cosmetics on animals. Animal testing is no longer common practice in the US and most other markets. However, some countries like China still require animal testing for approval of new ingredients. This can put developers of new ingredients and brands in a bind as not being approved globally means an inability to compete on a global scale and certain rejection from some brands. Performing the animal testing required for approval in China would mean breaking brand commitments and make the ingredient unsaleable in certain markets.

- The Campaign for Safe Cosmetics,[116] composed of several different environmental health and consumer health organizations, has educated and engaged millions of consumers with the goal of moving the industry toward ingredient transparency and safer products for everyone. The Campaign is housed at the nonprofit organization Breast Cancer Prevention Partners which works to eliminate the environmental links to breast cancer and prevent the disease before it starts.

- The Environmental Working Group (EWG),[117] a national nonprofit based in Washington, DC and founded in 1993, spotlights harmful beauty industry standards, speaks out against outdated government legislation, and runs the Skin Deep™ database which scores cosmetics products based on ingredient hazards. Skin Deep has approximately 10 million annual users.

[114] sustainablepackaging.org
[115] usplasticspact.org
[116] www.safecosmetics.org
[117] www.ewg.org

10.5 CERTIFICATION, LABELS, AND CONSUMER TOOLS

There are dozens of certifications or standards that beauty brands can use to verify their suppliers and convey their commitments to their customers. Some are about business values and practices, like B Corp, while most in the personal care and beauty space are specific to ingredients or packaging used. Examples of claims include organic, "natural" or "naturally derived" ingredients, "free of" or "made without" chemicals of concern.

Some of the leading labels and certifications include:

- B Corp[118] Certification is the only certification that measures a company's entire social and environmental performance. The B Corp Certification doesn't just convey where companies may do well today but also commits companies to improving their performance over a longer-term period.
- Blue[119] has two levels of certification, run by the nonprofit organization Oceanic Global–Product Seal and a Packaging Seal.
- Cosmos/EcoCert[120] is natural origin certification according to the international COSMOS standard or the private Ecocert standard. All the products marketed with the Ecocert logo are verified from composition to processing and packaging.
- Cradle to Cradle®[121] is a comprehensive multi-category methodology that weighs materials safety for humans and environment, product circularity, emissions, clean water and soil, and social aspects.
- EWG Verified™ [122] screens unwanted chemistry (allergenic, endocrine disrupting, carcinogenic, environmentally harmful) and requires full ingredient transparency and Good Manufacturing Practices.
- Made Safe[123] is a certification and label that maintains a Restricted Substance List that limits the use of harmful chemicals in a wide array of consumer products.
- The Leaping Bunny[124] seal for cosmetics and household products verifies that the company does not conduct or commission animal testing for ingredients or finished product.
- NATRUE[125] certification is specific to the skincare and beauty industry, only allowing natural, naturally derived, and nature-identical ingredients. Certification is available both for raw materials and finished products.

[118] usca.bcorporation.net/why-certify
[119] oceanic.global/projects/the-blue-standard
[120] www.ecocert.com/en-US/certification-detail/natural-and-organic-cosmetics-cosmos
[121] c2ccertified.org/topics/beauty-cosmetics-personal-care
[122] www.ewg.org/ewgverified/about-the-mark.php
[123] madesafe.org
[124] www.leapingbunny.org
[125] natrue.org

10.6 INGREDIENT DATABASES AND TECHNOLOGY SOLUTIONS

The beauty industry supply chain has historically been rather opaque, meaning there are not many ingredient or material providers or contract manufacturers that freely offer chemical, environmental performance, or worker safety data. As the clean beauty segment grows so does demand for RSL compliant products and supplier performance reporting on various environmental, social and governance criteria. Brands ask for accountability and transparency, which translates into additional requirements for a more common language as well as data reporting and auditing.

Various databases, data tools, and tech platforms have been developed to offer solutions for ingredient selection, traceability, tracking, hazard reporting, carbon footprint and other environmental and social criteria reporting. Some use global standards and reporting in their cross-industry auditing (e.g., EcoVadis), while others are designed to be more specific to the brand (e.g., providing tools for compliance with beauty retailers' policies).

Some providers of information tools include:

- ChemFORWARD[126] is a science-based, nonprofit organization that offers a subscription for ingredient hazard data across sectors. ChemFORWARD allows for broad access for manufacturers and retailers to utilize the best available science on safer alternatives for proactive chemical management.
- EcoVadis[127] launched in 2007 and has grown to become the world's largest and most trusted provider of business sustainability ratings, creating a global network of more than 100,000+ rated companies.
- Good Face Project[128] helps beauty formulators design transparent, sustainable, and compliant products based on science and real-time regulatory requirements and retail standards.
- Novi Connect[129] helps brands, retailers and suppliers navigate compliance, increase supply chain transparency, and find more sustainable packaging and formula options, in addition to connecting the right suppliers to indie brands.
- Scivera Lens[130] allows companies to screen formulations for sourcing and product development to proactively identify potential issues and find safer alternatives, and to understand the company's "chemical footprint."

The personal care and beauty industry is moving in a safer, more sustainable, and more inclusive direction. There is significant opportunity for ingredient, packaging, and manufacturing innovation, greater data access (i.e., safety, sourcing, carbon footprint), and marketplace growth.

[126] www.chemforward.org
[127] ecovadis.com
[129] www.thegoodfaceproject.com
[130] www.noviconnect.com
[131] www.enhesa.com/sustainablechemistry/our-solutions/sciveralens

11. Final Thoughts

The trend toward products that are safer for human health and the natural world will continue to accelerate. Within the beauty and personal care sector, "clean beauty" has become a growing subcategory, with major retailers and brands offering products that differentiate on safety and sustainability. Further evolution will rely on continuing ingredient, product, and packaging innovation that helps early adopters differentiate from competitors and create safer and more sustainable products and packages.

The taxonomy presented in Section 2 outlines areas where innovation is needed. Development in these areas will enable new performance and new claims while replacing harmful chemicals.

Innovation is likely to come from both small and large companies and may be driven by new brands and retail platforms.

We have seen innovation in the sector move rapidly at times—often driven by consumer awareness about specific ingredient issues coupled with the availability of safer alternatives. But the need for safety data and greater transparency on material sources and chemical disclosure, as well as testing for safety and efficacy, will require patience.

The benefits for our collective health, the health of the natural world, and the business opportunities are well worth the effort of pursuing safer chemistry innovation in the personal care and beauty space.

Safer Chemistry Innovation in Personal Care and Beauty

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