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Healing in a Greener Future: Sustainable Pathways for Dermatology

Henry W. Lim[1,2]

[1]Department of Dermatology, Henry Ford Health, Detroit, Michigan, USA | [2]College of Human Medicine, Michigan State University, East Lansing, Michigan, USA

Correspondence: Henry W. Lim (hlim1@hfhs.org)

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ABSTRACT

Background: Sustainable dermatology requires balancing patient outcomes with environmental stewardship and social responsibility.

Objectives: To examine environmental impacts related to skin health and emerging solutions.

Methods: Targeted literature review.

Results: This review addresses five key domains: formulation chemistry, packaging lifecycle, clinical operations, healthcare equity, and sustainability verification. We highlight emerging solutions, including biodegradable ingredients, circular packaging systems, energy-efficient practices, and teledermatology platforms that expand access to specialized care. The analysis scrutinizes greenwashing risks and the challenges of transforming established practices toward more sustainable alternatives.

Conclusions: We advocate for comprehensive lifecycle assessments, dermatology-specific certification standards, clinical waste minimization protocols, inclusive care models, and further research on biodegradation pathways, consumer behavior, and AI-enabled diagnostic tools that can democratize access while reducing the carbon footprint of care delivery.

1 | Introduction

The World Health Assembly has recently adopted a resolution recognizing skin diseases as a global public health priority, calling for integrated, sustainable approaches to strengthen care and advance universal health coverage [1].

Dermatology products and services create environmental and social impacts through chemical pollutants, packaging waste, energy-intensive clinics, and access inequities. This article examines pathways toward sustainability across five domains: green chemistry formulations, circular packaging approaches, low-carbon clinical operations, teledermatology-enabled access, and robust certification standards. By integrating these approaches, dermatology can advance therapeutic outcomes while minimizing ecological harm and maximizing social benefit.

2 | Green Chemistry and Formulation Innovation

Dermatological products present environmental challenges through ingredient toxicity, resource consumption, and manufacturing processes. Personal care products contain a range of chemical compounds that can persist in aquatic environments, contributing to water pollution and disrupting ecosystems [2]. Specific ingredients like surfactants, which are common in care products and household cleaning products, can be toxic to aquatic and terrestrial organisms when their concentrations exceed regulatory limits [3].

With growing focus on sustainability, there is increasing interest in developing high-quality formulations using alternatives to conventional ingredients. For instance, natural or green substitutes are being explored to replace hydrocarbons, silicones, and preservatives in topical products [4]. While promising, this shift presents challenges in maintaining product performance, highlighting the need for more comparative research to support effective and reliable formulation strategies.

Although some innovations have begun to address these challenges, significant gaps persist between sustainable formulation practices and therapeutic performance requirements. At the same time, rising consumer awareness of environmental impacts (such as the presence of microplastics in cosmetics) is driving industry transformation, with many companies intensifying research and development efforts to align with current and anticipated regulations protecting ecosystems [5].

3 | Rethinking Packaging: From Recyclability to Circularity

Dermatological packaging contributes substantially to plastic waste generation, reflecting broader trends where packaging consumes the most plastic and is a major contributor to municipal solid waste [6]. Bioplastics, derived from renewable biomass sources, are increasingly being explored as alternatives to petroleum-based plastics due to environmental concerns, but gaps exist between bio- and conventional plastics in their applications [6].

A careful evaluation of all aspects is essential when defining strategies to reduce the environmental impact of packaging. A meta-analysis of 71 lifecycle assessment studies revealed that material attributes often regarded as environmentally beneficial, such as recyclability, recycled content, compostability, and biobased composition, do not consistently correlate with lower net environmental impacts across the full lifecycle of packaging [7]. Other characteristics, such as material choice or mass of the packaging can have a greater influence on lifecycle impacts than these commonly emphasized attributes [7].

Refill systems represent a significant opportunity for waste reduction, as research demonstrates they can be an effective option to substantially reduce environmental impacts and generate economic benefits [8]. However, successful implementation of refill strategies depends heavily on consumer adoption willingness, which is directly influenced by convenience factors and the availability of accessible refill infrastructure [8]. These insights highlight the complexity of creating truly sustainable packaging solutions and the need for comprehensive assessment approaches [7].

4 | Low-Carbon Clinics: Energy Efficiency and Waste Reduction

Clinical dermatology operations present measurable environmental impacts amenable to evidence-based interventions. Energy consumption from lighting, heating, ventilation, air conditioning systems, and medical equipment significantly contributes to the carbon footprint of operating theaters, which can be three to six times more energy-intensive than the entire hospital, mainly due to the high demands of heating, ventilation, and air conditioning [9].

Medical waste generation varies by procedure type, with quality improvement studies in dermatology clinics demonstrating that skin biopsy trays alone can generate significant waste, averaging 10.1 wasted items per procedure before intervention [10]. Targeted waste reduction initiatives in dermatology clinics have shown remarkable effectiveness, reducing wasted supplies per biopsy tray from 10.1 to 1.6 following simple interventions focused on standardizing setup and provider education [10]. Anesthetic gases and energy consumption are the primary contributors to greenhouse gas emissions in healthcare settings, with the choice of specific gases offering significant potential for emission reduction [9].

5 | Social Sustainability: Equity, Teledermatology and Inclusive Care

Disparities in access to care undermine the social pillar of sustainable dermatology across multiple dimensions, as discussed in another article of this special issue [11]. Sustainable sourcing practices for dermatological ingredients prioritize regenerative approaches that replenish ecosystems, while promoting fair wages and safe working conditions that encourage social equity throughout supply chains [12].

Geographic and socioeconomic disparities contribute to "dermatology deserts," where access to care is limited or nonexistent. In much of Africa, dermatologist shortages are severe, with fewer than one specialist per million people in many regions—most concentrated in private, urban centers [13]. In the USA, longitudinal analysis revealed an increasing gap in dermatologist density between urban and rural areas with Black and Hispanic patients with chronic inflammatory skin diseases facing substantial structural obstacles such as transportation difficulties, work conflicts, family responsibilities, and limited provider diversity [14]. Economic barriers are particularly pronounced, with patients delaying specialist care due to cost and medication expenses [14].

Teledermatology offers promising solutions to these access challenges, with particularly strong benefits observed among Medicaid users in younger individuals, male patients, and nonwhite populations [15]. This suggests its potential to help reduce disparities for groups that have historically faced barriers to in-person care.

Artificial intelligence can significantly expand equitable dermatological care access through mobile applications that provide accurate diagnosis support for a wide spectrum of skin diseases across rural and urban settings, as demonstrated in a large-scale study involving over 5000 patients with skin of color in India [16]. This technology holds particular promise for addressing geographic and demographic disparities in dermatological care access, serving as a point-of-care clinical decision support tool that maintains high diagnostic accuracy regardless of practice setting or patient skin tone [16].

An example of constructive efforts to address inequities is the work of the International Foundation for Dermatology (IFD) of the International League of Dermatological Societies, which supports over 26 projects worldwide through grant programs, working groups and education initiatives aimed at improving skin health in low-resource settings [17].

Altogether, these multifaceted disparities highlight that achieving social sustainability in dermatology demands systematic attention to economic, geographic, and cultural barriers that limit equitable access to care.

6 | Transparency and Certification: Fighting Greenwashing With Robust Metrics

Evaluating sustainability claims for dermatological products requires standardized metrics and independent verification. Current certification systems vary in methodology and stringency, with environmental rating ecolabels proliferating under diverse methodologies that often confuse rather than inform consumers, as demonstrated in a recent European study [18]. Healthcare sustainability metrics frequently have serious deficiencies, including being borrowed from other sectors, lacking standardization, and failing to address potential negative environmental effects of clinical practices [19].

Studies examining plastic product sustainability claims, relevant to dermatological packaging, reveal concerning greenwashing practices, with products marketed as biodegradable showing no evidence of degradation in environmental testing, deceiving consumers and potentially leading to improper disposal [20].

Biodegradability testing protocols exist but face implementation challenges, as standard methodologies like OECD 301 guidelines may not fully represent real environmental conditions. For example, polymeric excipients such as polyvinyl pyrrolidone (PVP) and certain Eudragit derivatives used in formulations show minimal biodegradation ($< 10\%$) even after extended testing periods of 42 days, indicating their environmental persistence [21].

These inconsistencies highlight the need for improved certification frameworks specifically designed for dermatological products, with clear metrics that are relevant, scientifically robust, transparent, and feasible to implement [18].

7 | Conclusions—Roadmap for Greener Dermatology

The trajectory toward a greener dermatology sector demands a multipronged strategy. Formulators must embrace green chemistry and invest in robust biodegradability testing that reflects real-world conditions. Packaging designers should move beyond piecemeal attributes to system-level lifecycle assessments, incentivizing refill models and circular supply chains. Clinicians and clinic administrators are tasked with optimizing energy and waste workflows, selecting low-impact anesthetic agents, and embedding sustainability into standard operating procedures. Addressing access to care issues will require sustained investment in teledermatology infrastructure, culturally competent care pathways, and policy advocacy to ensure that cost and geography do not preclude access.

Artificial intelligence represents a transformative opportunity in this landscape, with potential to optimize resource allocation, enhance teledermatology diagnostic accuracy across diverse skin types, and enable data-driven sustainability decisions throughout supply chains. Critically, the development of a unified, sector-specific certification framework will provide the transparency and accountability necessary to combat greenwashing and guide stakeholders toward meaningful progress.

Future research should focus on advanced testing of novel biodegradable polymers, longitudinal studies of consumer behavior in refill and recycling programs, quantitative analyses of the ability of teledermatology to address access to care challenge, and the refinement of social sustainability metrics. By integrating environmental, clinical, and social dimensions, the dermatology community can realize a truly holistic vision of healing—one that nurtures both skin health and planetary well-being.

Author Contributions

Henry W. Lim contributed to conception and design, drafting the article, review and final approval of the version to be published.

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Ethics Statement

The author has nothing to report.

Conflicts of Interest

Henry W. Lim - Investigator: Incyte, La Roche-Posay, Pfizer, PCORI; Consultant: ISDIN, Beiersdorf, Ferndale, L'Oréal, Eli Lilly, Zerigo Health, Skinosive, Kenvue, NAOS, and Cantabria labs; Speaker, educational session: La Roche-Posay, Cantabria labs, Pierre Fabre, NAOS, Uriage, Pfizer, and ISDIN.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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