Інше

Hutsaliuk Nadiia

Nail Artist, Airbrushing Instructor, Manicure Master

(Warsaw, Poland)

ENVIRONMENTAL ASPECTS OF DISPOSAL OF NAIL SERVICE MATERIALS

Summary. *This scientific article provides a comprehensive analysis of environmental issues related to the disposal of nail industry waste, including varnishes, gels, acrylics, coating removers and other related materials. Particular attention is paid to the study of the chemical composition of this waste and its potential impact on various components of the environment - soil, water resources and atmospheric air. The work examines in detail the methods of processing and disposal of these materials existing in world practice, and also critically analyzes their effectiveness and environmental safety. Based on the conducted research, the authors offer a set of practical recommendations aimed at minimizing the negative impact of nail service waste on ecosystems. The article also contains an analysis of the current state of legal regulation in this area in various countries and promising areas for its improvement.*

Key words: *nail service, environmental aspects, materials.*

Introduction. The nail service industry has demonstrated steady growth in recent decades, turning into a global industry with multi-billion dollar turnover. However, the rapid development of this segment of the beauty market is accompanied by a significant increase in the volume of waste generated, which

creates serious environmental challenges. The main types of waste in this industry are chemical compounds (varnishes, gels, acrylics), packaging materials, disposable tools and consumables, most of which contain highly toxic components. Among the most hazardous substances are formaldehyde, toluene, dibutyl phthalate and various methacrylate derivatives, which, if improperly disposed of, can cause significant damage to the environment.

The relevance of this study is due to several key factors. Firstly, most countries do not have a single centralized system for collecting and recycling nail service waste. Secondly, a significant portion of these materials eventually ends up in ordinary solid waste landfills, where they can decompose for decades, gradually releasing toxic substances into the environment. Thirdly, the growing popularity of long-lasting coatings (such as gel polishes) has led to an increase in the volume of difficult-to-recycle polymer waste in this segment.

The purpose of the presented study is a comprehensive analysis of the environmental risks associated with nail service waste and the development of scientifically based recommendations for improving the system of their disposal. The work uses data from the latest scientific publications in peer-reviewed journals, statistical reports of specialized environmental organizations, as well as current regulatory documents governing waste management in various countries.

The methodological basis of the study includes several complementary approaches: a detailed analysis of the chemical composition of the main types of nail service waste, an assessment of their potential impact on various components of ecosystems using comparative analysis methods, as well as a review of modern recycling technologies in terms of their efficiency and environmental safety. Particular attention in the work is paid to a comparative analysis of the experience of various countries in the field of regulating issues of waste disposal in the beauty industry.

The structure of the article includes six thematic sections, each of which consistently reveals individual aspects of the stated problem. The first section presents the general provisions and methodology of the study. The following parts are devoted to the analysis of the chemical composition of waste, modern methods of disposal, legal regulation, environmentally friendly alternatives and practical recommendations. The final section summarizes the results of the study and formulates promising directions for further work in this area.

Chemical composition of nail service waste and its toxicity

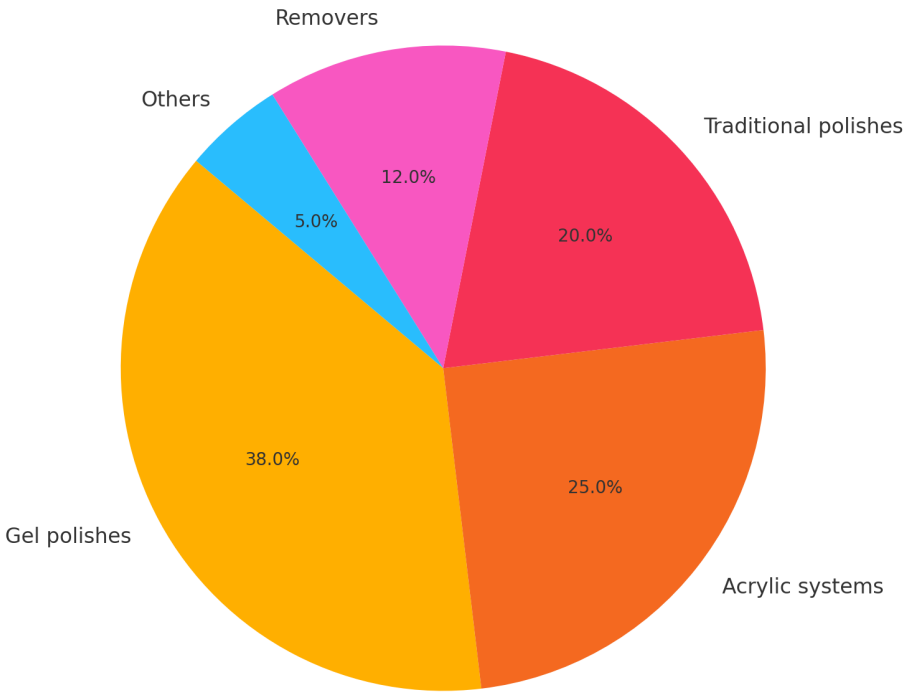
Waste from the nail service industry is a complex multi-component mixture of various chemical compounds, many of which are highly toxic. The bulk of this waste is nail polishes and their derivatives, including modern hybrid forms - gel polishes, which combine the properties of traditional polishes and gel systems. Chemical analysis shows that these products contain three main groups of hazardous substances: volatile organic compounds (VOCs), plasticizers and various polymer resins. Among VOCs, toluene, formaldehyde and acetone are particularly dangerous, which are not only toxic in themselves, but also contribute to the formation of ground-level ozone, which is a key component of photochemical smog.

The greatest environmental threat among all components of nail coatings is posed by formaldehyde resins, which are widely used as hardeners and strengthening agents. Numerous studies confirm that formaldehyde has pronounced carcinogenic properties and can accumulate in the body, causing systemic disorders. No less dangerous are phthalates (especially dibutyl phthalate), which are used as plasticizers to give coatings elasticity. These compounds are known endocrine disruptors - they disrupt the hormonal system and can cause serious reproductive disorders in both humans and animals. Of particular concern is the ability of phthalates to bioaccumulate - they gradually accumulate in living organisms, passing along the food chain. Nail polish removers, an integral part of nail service, also make

a significant contribution to environmental pollution. Most of these products contain acetone, ethyl acetate or their mixtures - highly volatile compounds that easily evaporate into the atmosphere, contributing to the formation of smog. When released into water bodies (which often happens when used liquids are flushed down the drain), these substances disrupt the gas balance of aquatic ecosystems, inhibiting the vital activity of phytoplankton, the main producer of oxygen in the aquatic environment. Long-term exposure to even small concentrations of these solvents leads to changes in the structure of aquatic communities, reducing their biodiversity and sustainability. Acrylic nail extension systems pose a particular problem, as they form strong polymer structures after curing that are extremely resistant to natural decomposition. Research shows that when acrylic polymer particles enter the environment, they gradually fragment into microplastics, which are then included in food chains. In recent years, numerous scientific studies have confirmed the presence of acrylic microparticles in the bodies of various marine life, from plankton to commercial fish species. This fact is particularly alarming, since acrylic polymers can absorb various toxic substances on their surface, increasing their negative impact on living organisms. Thus, a comprehensive analysis of the chemical composition of nail service waste allows us to conclude that it poses a high potential danger to the environment and human health. The presence of volatile toxic compounds, endocrine disruptors and stable polymeric materials in this waste creates a cumulative effect that significantly increases the environmental risk. This circumstance requires the development of special, scientifically based approaches to the disposal of these types of waste, taking into account their specific chemical composition and behavior in various environments.

Graph 1. Distribution of nail service waste by type (2023)

Note: More than 60% of waste is made up of difficult-to-decompose polymeric materials



Modern disposal methods and their efficiency

Currently, several main methods of disposal of nail service waste are used in world practice, each of which has its own advantages and significant limitations. The most common method remains burial at specialized landfills for solid municipal waste, where up to 70-80% of all waste from the beauty industry ends up. However, this method demonstrates extremely low environmental efficiency, since most chemical components of nail materials do not decompose in natural conditions for decades. During a long stay in landfills, toxic substances are gradually washed out by precipitation, penetrating into groundwater and contaminating surrounding soils. Studies have shown that within a radius of 1-2 km from landfills accepting beauty

waste, the concentration of formaldehyde in soil water exceeds the MAC by 3-5 times.

An alternative disposal method is high-temperature incineration in special incinerators, which allows to significantly reduce the volume of waste (up to 90% by weight). However, this process is accompanied by the formation of secondary pollutants - dioxins, furans and volatile compounds of heavy metals that enter the atmosphere. Modern waste incineration plants are equipped with multi-stage gas purification systems, but even they do not ensure complete neutralization of all hazardous substances. A particular problem is the combustion of acrylic polymers, which produces hydrogen cyanide - an extremely toxic compound. According to the EPA, the share of dioxin emissions from the incineration of beauty waste is about 8% of the total volume in the country. The most promising direction is considered to be the development of specialized methods for the chemical neutralization of hazardous components. In recent years, technologies have emerged for the catalytic decomposition of formaldehyde using nanosized catalysts based on titanium and cerium oxides, allowing this toxicant to be converted by 95-98% into safe carbon dioxide and water. Rectification and adsorption purification methods are successfully used to process acetone-containing waste, making it possible to return up to 85% of the solvent to the production cycle. In Japan and South Korea, experimental installations for the depolymerization of acrylic waste to produce reusable monomers are already operating.

In the EU countries and some US states, systems for the separate collection of beauty waste are being actively introduced directly in salons. Special containers for varnishes, gels and acrylics are installed in work areas, after which the filled containers are sent to specialized recycling plants. For example, the BeautyCycle program in California collected and recycled more than 120 tons of nail service waste in 2022. However, the economic efficiency of such programs remains low -

the cost of recycling 1 kg of waste is $ 8-12, while the cost of disposal does not exceed $ 0.5-1.

Despite the emergence of new technologies, a global system for the environmentally friendly disposal of beauty waste is still absent. The main obstacles are the high cost of recycling, the lack of infrastructure in most regions and a weak legislative framework. Solving these problems requires a comprehensive approach, including the development of technologies, improvement of the regulatory framework and the creation of economic incentives for all market participants - from manufacturers to salons and end consumers.

Legislative regulation of waste disposal

Legal regulation of waste disposal from nail services varies significantly in different countries, reflecting the level of environmental awareness and the development of recycling infrastructure. The European Union has the strictest regulatory system based on the principles of REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals). Directive 2009/48/EC strictly limits the content of toxic substances (formaldehyde, toluene, DBP) in cosmetic products, including nail polishes. Since 2021, additional restrictions on microplastics have been introduced within the framework of the European Green Deal, which directly affects acrylic systems. Manufacturers are obliged to ensure the full life cycle of products, including their disposal, which is enshrined in the waste directive 2008/98/EC.

In the United States, regulation is carried out at the federal and state levels through the mechanisms of the Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA). Some nail service waste is classified by the EPA as hazardous waste and falls under the Resource Conservation and Recovery Act (RCRA). However, enforcement of regulations in small businesses (beauty salons) remains insufficient - according to OSHA, only 35% of salons complied with

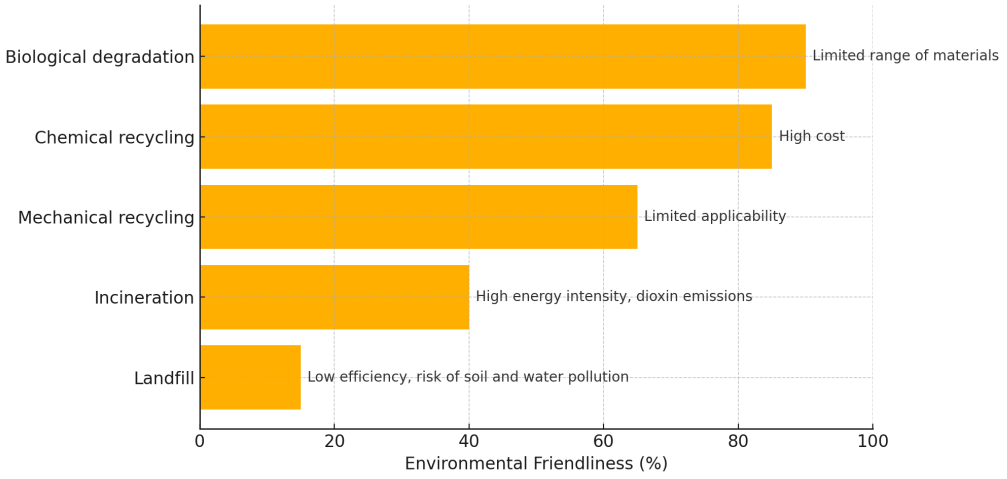
all chemical waste disposal requirements in 2022. The most progressive regulations are in California, where a mandatory beauty waste disposal program through licensed companies has been in effect since 2020. In Ukraine, legal regulation of this area is in its infancy. Nail service waste formally belongs to hazard class IV (low hazard), although it contains substances that individually have a higher hazard class. According to Government Decree No. 712, salons are required to enter into waste disposal contracts with licensed operators, but in practice this requirement is met in less than 20% of cases. There is no system for separate collection of beauty waste, and fines for violations are minimal, which does not encourage compliance.

A positive example is Japan, where the national program "Beauty Zero Waste" has been in effect since 2018. Within its framework, a network of specialized beauty waste collection centers has been created (more than 1200 across the country), and recycling standards have been developed for each type of material. Manufacturers are required to pay an environmental fee (3-5% of the cost of the product), which goes to finance recycling. Thanks to this system, Japan recycles up to 65% of beauty waste - the highest rate in the world.

To improve the legislative framework, the following measures are needed: harmonization of international standards (possibly within the ISO framework), introduction of extended producer responsibility (EPR), tightening control over small businesses through a licensing and certification system. Particular attention should be paid to economic incentives - tax breaks for "green" salons, subsidies for the purchase of equipment for primary waste processing, creation of public-private partnerships in the field of recycling.

Graph 2. Comparison of disposal methods by environmental friendliness

Note: The efficiency scale takes into account the full life cycle and secondary impacts



Alternative eco-friendly materials

In response to environmental challenges, the nail service industry is actively developing alternative, safer materials. The most significant achievement was the creation of "5-free", "7-free" and even "10-free" varnishes, from which the main toxic components (formaldehyde, toluene, DBP, camphor, etc.) are excluded. The leader in this segment is Zoya, whose products comply with USDA Organic standards. However, the problem with such varnishes is their lower wear resistance (2-3 days versus 7-10 for traditional ones), which limits their popularity.

A breakthrough direction has become water-soluble varnishes based on polyurethane dispersions. Their key advantage is the absence of volatile organic solvents (VOC content less than 5 g / l versus 300-500 g / l in conventional varnishes). The technology developed by Kure Bazaar allows you to create coatings with decent wear resistance (4-5 days). However, the cost of such products is 30-40% higher than traditional ones, and the application process requires special preparation of the nail plate.

Innovative photoinitiators based on plant extracts (for example, curcumin derivatives) have appeared in the gel polish segment, replacing toxic compounds such as benzophenone. BioSeaweed Gel offers a system that is 92% composed of components of natural origin. The main drawback is the need to use a UV lamp for polymerization, which maintains the risk of free radical formation.

Alternatives based on polylactide (PLA), a biodegradable polymer made from corn starch, have been developed for acrylic systems. Such compositions, offered by EcoNails, decompose by 70% in 6 months in industrial composters. However, their mechanical properties are still inferior to traditional acrylics - the maximum extension length does not exceed 2-3 mm.

A promising direction is the development of the concept of a "circular economy" in nail service. For example, Nailberry launched a program for taking back used bottles (return 5 bottles = 15% discount on purchase). Another innovation is reusable metal containers for varnishes with replaceable cartridges (ReNailed system). These approaches allow to reduce the volume of packaging waste by 40-60%.

Recommendations for reducing environmental impact

A systemic solution to the problem of nail service waste disposal requires a set of interrelated measures at different levels. At the legislative level, the primary task is to revise the classification of beauty waste taking into account its real danger. It is necessary to allocate it into a separate category with special handling rules, as has been done for medical or electronic waste. In Ukraine, this can be implemented by amending Federal Law No. 89 "On Production and Consumption Waste".

It is extremely important to introduce an extended producer responsibility (EPR) system, which obliges companies to finance the collection and disposal of their products at the end of their service life. EU experience shows that such measures increase the recycling rate by 3-5 times. In parallel, mandatory product

labeling should be introduced indicating the composition and method of disposal, similar to energy labels on household appliances.

At the industry level, it is necessary to develop waste collection infrastructure. A three-stage system seems optimal: 1) special containers in salons; 2) district collection points; 3) regional recycling centers. Financing can be provided through an environmental fee (1-2% of the cost of the service), which is practiced in Canada. "Green" certificates and environmental ratings are effective in stimulating salons.

Technological solutions should be developed in two directions: improving recycling methods (implementation of catalytic, enzymatic and plasma technologies) and developing new biodegradable materials. Research in the field of biopolymers based on chitin, alginates and cellulose has particular potential. State support for such developments through grants and tax incentives can accelerate their entry into the market.

Environmental education of all participants in the process plays a key role. Mandatory courses on environmental safety (similar to the sanitary minimum) should be introduced for nail service technicians. Consumers should be informed through marketing campaigns and a bonus system for waste disposal (for example, discounts for brought bottles).

International cooperation should be aimed at harmonizing standards (through ISO or WHO), exchanging best practices and joint research projects. The creation of a global database on the composition of beauty products and their impact on the environment is especially relevant.

Conclusion. The conducted study demonstrates that the problem of disposal of nail service waste is a complex set of environmental, technological and regulatory challenges. Analysis of the chemical composition of this waste revealed the presence of many highly toxic components (formaldehyde, phthalates, acrylates), which, if

improperly handled, cause significant damage to the environment. Of particular concern is the combination of volatile organic compounds in the waste, which contribute to the formation of smog, and stable polymeric materials that turn into microplastics.

Existing disposal methods (burial, incineration) demonstrate low environmental efficiency, while modern recycling technologies (catalytic decomposition, solvent regeneration) have not yet become widespread due to high cost and lack of infrastructure. Legal regulation in most countries does not correspond to real environmental risks, which leads to the uncontrolled release of hazardous substances into the environment. The way out of the current situation is seen in the implementation of a comprehensive strategy, including:

- Improvement of the legislative framework (introduction of EPR, tightening of standards)
- Development of collection and processing infrastructure
- Stimulation of the development and implementation of environmentally friendly materials
- Systematic environmental education

Special prospects are associated with the development of circular economy principles in the beauty industry - from the design of biodegradable products to the creation of closed cycles of material use. International cooperation in this area can significantly accelerate the transition to a sustainable model of nail service that combines aesthetic qualities and environmental safety.

Further research should focus on the development of cost-effective recycling technologies, in-depth study of the migration of toxic components in the environment and assessment of the long-term effects of the introduction of alternative materials. Only an interdisciplinary approach will help find a balance between the development of the industry and the preservation of ecosystems.

Literature

1. European Chemicals Agency (ECHA). (2021). *Restriction Proposal for Formaldehyde and Formaldehyde Releasers in Nail Products*. Helsinki: ECHA.
2. U.S. Environmental Protection Agency (EPA). (2020). *Hazardous Waste Regulations for Cosmetics: RCRA Subtitle C Guidance*. Washington, DC: EPA.
3. Kang, S., & Lee, H. (2019). "Microplastic Pollution from Acrylic Nail Waste in Aquatic Systems." *Environmental Science & Technology*, 53(12), 6789–6798.
4. California Air Resources Board (CARB). (2022). *Volatile Organic Compound (VOC) Emissions from Nail Products*. Sacramento: CARB.
5. Beauty Industry Sustainability Working Group. (2021). *Best Practices for Nail Salon Waste Recycling*. New York: BISWG.
6. World Health Organization (WHO). (2020). *Phthalates in Cosmetics: Health and Environmental Risks*. Geneva: WHO.