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Discrepancies Between Type II Eco-Labels and Actual Environmental Impacts of Laundry Detergents in the Discharge Stage

Yuening Zhang

Jinan Foreign Language School,
Jinan, China
reneezhang0614@gmail.com

Abstract:

This study investigates the discrepancies between discharge-stage environmental claims of Type II eco-labels on laundry detergents and their actual impacts in aquatic environments. Laundry detergents are essential household products, and their growing global consumption highlights the importance of evaluating environmental risks associated with their use. In recent years, the market share of eco-labeled detergents has expanded significantly, with Type II labels—based on enterprise self-declaration without third-party certification—particularly favored by small and medium-sized enterprises due to their low cost and simplified approval procedures. To address this issue, 50 Type II-labeled detergents were analyzed to identify core discharge-stage claims and evaluation criteria, followed by case studies of representative products to assess actual impacts on water bodies, aquatic organisms, and ecosystems. The results reveal a clear divergence between label claims and real environmental performance. Many products claimed high biodegradability, low aquatic toxicity, or the use of eco-friendly ingredients, but these claims were often supported only by laboratory test results conducted under idealized conditions rather than by evidence from real discharge scenarios. Case studies confirmed that certain ingredients exhibited low biodegradation rates in natural waters or caused significant aquatic toxicity, contradicting advertised environmental benefits. The underlying causes of these discrepancies include limitations of current label standards, selective disclosure strategies by enterprises, and mismatches between laboratory tests and real-world environmental conditions. This study provides empirical evidence to support more rigorous evaluation of Type II labels, offering guidance for consumers to identify misleading environmental claims and recommendations for regulators to strengthen standards and require disclosure of discharge-stage impacts, thereby encouraging enterprises to assume genuine environmental responsibility.

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Keywords: Laundry Detergent; Type II Environmental Label; Discharge Stage; Environmental Impact; Biodegradability.

1. Introduction

Laundry detergents, as essential household cleaning products, are indispensable worldwide, with demand continuing to grow. By 2025, the global laundry detergent market is projected to reach approximately 45 billion USD, with an annual consumption of 13.5 million tons [1]. The use of detergents inevitably leads to their discharge into the environment: residues from hand washing, machine washing, or commercial laundry processes enter sewage systems and are ultimately released into natural water bodies after treatment. In underdeveloped regions, an estimated 30% of washing wastewater is directly discharged into rivers, lakes, or soil [2], forming a "production–use–discharge" loop that connects human activities with environmental impacts. Meanwhile, as consumer environmental awareness rises, eco-labeled detergent products have expanded in market share, with Type II eco-labels in particular favored by small and medium-sized enterprises due to their low cost and simplified approval process. Unlike third-party certified schemes, Type II labels rely solely on enterprise self-declaration, as permitted by ISO 14021:2016 [3][4].

Despite their increasing prevalence, significant information asymmetry exists between the discharge-stage claims of Type II labels—such as "biodegradability" and "low ecotoxicity"—and the actual environmental impacts observed in real aquatic environments. Most claims are based on laboratory tests conducted under idealized conditions, neglecting the complexity of real-world discharges where mixed pollutants, fluctuating pH, and variable microbial communities affect outcomes. This disconnect raises questions about the credibility of Type II labels and highlights gaps in existing research. Specifically, few studies have systematically examined how these discrepancies manifest, the extent to which they occur, or the core drivers behind them. The lack of such analysis undermines the scientific validity of label assessments, weakens market regulation, and limits informed consumer choices.

This study addresses these issues by analyzing the discharge-stage claims and evaluation criteria of 50 mainstream Type II-labeled laundry detergents (2023–2024 market data) and by conducting case studies on representative products to assess actual environmental impacts. It compares claims with real outcomes, quantifies deviations in biodegradation rates and toxicity thresholds, and explores the underlying causes of discrepancies, including flaws in label standards, selective corporate disclosure, and mismatches between testing conditions and real environments. The findings contribute to theory by enriching the framework of eco-label credibility in environmental management, and to practice by providing references for consumers, regulators, and enterprises. Ultimately, this study seeks to guide improvements in eco-label standards, promote genuine environmental responsibility, and support more sustainable consumer markets.

2. Methodology

2.1 Research Design

To ensure data authority, comprehensiveness, and timeliness, this study adopted a rigorous literature search and data screening framework. Google Scholar served as the core database, supplemented by Web of Science as a flagship source for environmental science and CNKI for Chinese publications, ensuring balanced coverage of international and domestic research outputs.

Search terms were carefully categorized into three dimensions to maximize precision: (1) product type, including laundry detergent, liquid detergent, and detergent sheets; (2) label type, such as Type II environmental label, ISO 14021, and self-declared environmental claim; and (3) research focus, covering the discharge stage, environmental impact, biodegradability, aquatic toxicity, and ecosystem disruption. This multi-dimensional keyword strategy allowed for comprehensive retrieval of literature directly related to the research objectives.

The search scope was limited to 2015–2024, with priority given to publications from the last five years (2019–2024) to capture the most recent developments. Eligible sources included peer-reviewed journal articles, doctoral and master's theses, industry white papers (e.g., laundry detergent market reports), and official regulatory documents issued by agencies such as the U.S. Environmental Protection Agency and China's Ministry of Ecology and Environment. Studies were included if they focused specifically on discharge-stage impacts of detergents or the credibility of Type II environmental labels, while research limited to raw material production, formulation design, or unrelated life cycle stages was excluded.

2.2 Materials: Representative Detergents

To provide a comprehensive basis for evaluating the credibility of Type II environmental labels, three representative laundry detergents were selected, covering liquid, sheet, and concentrated formulations. These products were chosen because they are widely marketed as eco-labeled and represent different formulation types in current consumer markets. Ingredient lists and environmental risk information were obtained from official product websites, third-party test reports, and peer-reviewed studies [1,5,6]. The details are summarized in Table 1, which illustrates the input data used for subsequent analysis rather than presenting final results.

Table 1. Ingredient Lists and Environmental Risks of Representative Detergents

Laundry detergent name	public ingredient list	Information related to environmental risks
ECOS Laundry Detergent, Free & Clear	Known ingredients: Methylisothiazolinone, Cocamidopropyl Betaine, Sodium Coco Sulfate, Cocamidopropyl Oxamine, Phenoxyethanol, Water	Main risk components: Methylisothiazolinone has high acute toxicity to aquatic organisms and poses risks such as skin irritation; cocamidopropyl betaine, sodium coco sulfate, and other components pose risks of chronic and acute aquatic toxicity; some components also pose risks of carcinogenicity, developmental/endocrine/reproductive effects, etc.
ECOS Laundry Detergent Sheets, Free & Clear	PEG-12 Dimethicone, Dimethicone, Kaolin, Sodium Lauryl Sulfate, Polyvinyl Alcohol, Amorphous Silica, Cocamidopropyl Betaine, Sodium Alkyl Sulfate (C12-18), Octyl / Decyl Glucoside, Cocamidopropyl Oxamine, Phenoxyethanol, Sodium Citrate, Propylene Glycol, etc.	PEG-12 and polydimethylsiloxane-related ingredients pose risks such as biodegradability, developmental/endocrine/reproductive effects, etc.; polydimethylsiloxane poses risks such as biodegradability and bioaccumulation, etc.; sodium lauryl sulfate and other ingredients pose risks such as chronic and acute aquatic toxicity, effects on bodily systems and organs, etc.
Easydose Super Effective Laundry Detergent	Water, Lauryl Polyethylene Glycol-6 (plant-based surfactant), Propylene Glycol (plant-based solvent), Octyl/Decyl Glucoside (plant-based surfactant), Glycerin (plant-based enzyme stabilizer), Sodium Oleate (plant-based defoamer), Sodium Chloride (Mineral-Based Viscosity Improver), Citric Acid (Plant-Based pH Regulator), Protease Enzyme Blend, Pectinase Enzyme Blend, Amylase Enzyme Blend, Mannanase Enzyme Blend, and Various Plant-Based Fragrances, etc.	Complies with US EPA Safe Product Standards, USDA-approved bio-based product (98%), relatively environmentally friendly, but the specific risks of each ingredient in the environment are not clearly defined.

2.3 Materials: Representative Detergents

To contextualize these case analyses, three complementary data sources were used. First, standard document analysis of ISO 14021:2016 (Environmental labels and declarations — Self-declared environmental claims) was conducted to clarify the requirements, evaluation methods, and limitations of Type II labels [4]. Second, literature data extraction was performed to obtain quantitative information on ingredient toxicity, biodegradation rates, and ecosystem impacts from peer-reviewed studies [2,5,6]. Indicators included acute and chronic aquatic toxicity, biodegradation rates under laboratory versus natural conditions, and ecosystem-level effects such as dissolved oxygen and primary productivity. Finally, market data collection was carried out on 50 mainstream Type II-labeled detergents (2023–2024), using market reports [1,3] and e-commerce platforms such as Amazon and JD.com to categorize and quantify dominant claims.

3. Literature Review

3.1 Environmental Impacts of Laundry Detergents in the Discharge Stage

After use, laundry detergents enter aquatic ecosystems via

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sewage systems or direct discharge, posing multi-level, cascading risks to the environment. These impacts are driven by surfactants (core functional components) and additives (e.g., preservatives, fragrances), as supported by research:

3.1.1 Toxicity to Aquatic Organisms

Surfactants are the primary source of aquatic toxicity in detergents, with varying harm to different trophic levels:
Anionic surfactants: Linear alkylbenzene sulfonates (LAS), widely used in China, have a 48-hour LC_{50} of 48 mg/L for aquatic organisms [6]. Even at low concentrations (0.05 mg/L), LAS reduces freshwater snail egg hatching rates by 30% over 3 months [6].
Non-ionic surfactants: Compounds like PEG-12 Dimethicone are less acutely toxic but biodegrade slowly, leading to long-term accumulation in aquatic organisms [2].
Preservatives: Methylisothiazolinone (MIT), a common detergent preservative, has an acute toxicity LC_{50} <0.1 mg/L for freshwater crustaceans (e.g., Daphnia magna)—far exceeding the U.S. EPA's "high toxicity" threshold [5].

3.1.2 Biodegradation Limitations

While many detergents claim "high biodegradability," real-world conditions inhibit microbial degradation compared to ideal labs. Key limiting factors:
Environmental variability: Fluctuating pH (5.0-8.5 in natural waters vs. pH 7.0 in labs), temperature (10–25°C vs. 20–25。C in labs), and low dissolved oxygen (2–5 mg/L in urban sewage vs. 8–9 mg/L in labs) [2];
Co-pollutant interference: Heavy metals (e.g., Pb, Cd) from industrial discharge inhibit degrading microbes, reducing surfactant biodegradation by 30–50% [2];
Ingredient complexity: Additives like dimethicone resist degradation by natural microbial communities—their riverine biodegradation rate is 20–30%, vs. 80–90% in labs with specialized cultures [2].
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In addition, the biodegradation process of ethoxylated alcohol nonionic surfactants, which are common in detergents, will be hindered by physical adsorption in natural water bodies containing high concentrations of suspended particles. Studies have shown that when the concentration of suspended particles in water exceeds 50mg/L, the degradation rate of such surfactants will be further reduced by 15% -20%, and the degradation products are more likely to be enriched in sediments, forming long-term ecological risks [7]. At the same time, the difference of microbial community structure in different regions also has a significant impact on the degradation efficiency. For example, in the northern freshwater area with low temperature (<10℃), the degradation cycle of the main surfactants in the detergent can be extended to 3-4 times under the ideal conditions in the laboratory, which further aggravates the deviation between the actual environment and the laboratory test results [8].

3.1.3 Strategic Information Asymmetry

Enterprises exploit self-declaration to selectively disclose favorable information:
Selective testing: Brands prioritize testing "low-risk" components (e.g., water, plant-based solvents) while avoiding toxic additives [3];
Negative data omission: For example, ECOS Laundry Detergent Sheets highlights "biodegradable" base materials but omits dimethicone's low natural biodegradation rate [1];
Vague terminology: Claims like "eco-friendly ingredients" lack clear definitions/metrics, making verification difficult [3]
Some companies also mislead consumers by blurring the time and space scope of ' eco-friendly ' related terms. For example, a brand claims that its detergent ' can be rapidly degraded in the natural environment ', but it does not clearly indicate that the conclusion is only applicable to an ideal freshwater environment with specific temperature (25-30℃) and high oxygen (dissolved oxygen>8mg/L), and in the actual offshore low-salt, low-oxygen waters, its degradation efficiency will be greatly reduced [7]. This selective information presentation method further widens the gap between consumer perception and actual environmental impact, making the credibility of Type II ecological labels more seriously questioned [8].

4. Results

4.1 Analysis of Type II Label Claims

A review of 50 popular laundry detergents with Type II labels (2023-2024 market data) identified three dominant claims:
1."90%+ biodegradable under standard conditions" (68% of products);
2."Low aquatic toxicity" (52% of products);
3."Eco-friendly ingredients" (45% of products).
All claims were based on ISO 14021-compliant self-declarations, with 82% citing only laboratory test results (e.g., OECD 301 for biodegradation) and no data from real-world discharge scenarios.

4.2 Actual Environmental Impacts in Discharge

To evaluate the credibility of Type II eco-label claims, the three representative detergents presented in Table 1 were analyzed using literature data and empirical evidence. The assessment focused on their discharge-stage performance, with particular attention to discrepancies between declared claims and actual environmental impacts observed under real aquatic conditions. This case-based analysis reveals the extent to which laboratory-based claims diverge from ecological realities.

These findings demonstrate a clear mismatch between eco-label claims and discharge-stage outcomes. While the products promote biodegradability, low toxicity, or plant-derived safety, actual performance in natural aquatic environments shows incomplete biodegradation, acute and chronic toxicity to aquatic organisms, and insufficient disclosure of potentially harmful ingredients. Such discrepancies highlight the limitations of self-declared Type II labels and the need for more stringent field-based validation.

Table 2. Comparison of Label Claims vs. Actual Environmental Impacts

Detergent	Label Claim	Actual Impact (Real Discharge Scenarios)
ECOS Free & Clear Liquid	Low environmental impact	MIT causes acute toxicity (LC_{50} <0.1 mg/L for crustaceans, far below EPA “low toxicity” threshold of 1 mg/L) [5]; CAPB/SCS cause chronic fish harm at 0.01 mg/L [1].
ECOS Free & Clear Sheets	Biodegradable sheets	PEG-12 Dimethicone biodegrades at 20% in natural waters (vs. 90% in lab tests with specialized microbes) [2]; dimethicone accumulates in fish tissues [2].
Easydose Concentrated	98% plant-derived, eco-safe	Plant-based surfactants degrade 50% slower in oxygen-poor urban sewage than in labs [6]; enzyme/fragrance toxicity data are undisclosed [1].

5. Discussion

5.1 Causes of the Gap Between Claims and Impacts

1. Flaws in label standards: ISO 14021:2016 allows self-declaration based on idealized lab tests, lacking requirements for field validation. For example, biodegradation tests (OECD 301) use pure cultures and constant temperatures, ignoring microbial diversity in natural waters [4].
2. Strategic information disclosure by enterprises: To reduce costs, brands prioritize testing “safe” components (e.g., water, plant-based solvents) while avoiding full disclosure of toxic additives (e.g., MIT in ECOS products). This selective reporting inflates perceived eco-friendliness [3].
3. Disconnect between testing and real scenarios: Lab tests focus on short-term (48-96 hours) toxicity, but real ecosystems face long-term, low-dose exposure. For instance, LAS at 0.05 mg/L shows no acute toxicity but disrupts mollusk reproduction over 6 months [6].

5.2 Causes of the Gap Between Claims and Impacts

1. For consumers: The 42% market share of Type II-labeled detergents [3] indicates widespread trust, but the gap means consumers may unknowingly purchase products harmful to the environment.
2. For regulators: Current standards fail to prevent “greenwashing.” The lack of third-party verification and field testing requirements allows enterprises to exploit loopholes.
3. For academia: Existing research focuses on individual components (e.g., surfactants) rather than holistic ecosystem impacts, limiting understanding of real-world risks.

5.3 Limitations and Future Research

This study relies on literature-based data and lacks direct field measurement of detergent residues in aquatic environments. Future research should:
Conduct longitudinal monitoring of detergent residues in rivers/lakes downstream of urban sewage outlets;
Perform comparative experiments across regions with varying water quality (e.g., eutrophic vs. oligotrophic systems);
Explore synergistic toxicity of detergent ingredients with other pollutants (e.g., heavy metals, pharmaceuticals) in real waters.

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6. Conclusion

This study demonstrates that Type II environmental labels on laundry detergents show significant discrepancies between discharge-stage claims and actual ecological impacts. While many products declare high biodegradability, low aquatic toxicity, or eco-safe formulations, evidence from literature and case analyses reveals that incomplete biodegradation, acute and chronic toxicity, and insufficient disclosure of harmful ingredients are common in real discharge scenarios. These findings confirm the initial hypothesis that the credibility of Type II labels is undermined by their reliance on idealized laboratory data and the absence of field validation.

The root causes of these discrepancies lie in structural weaknesses of the labeling system, including the permissiveness of ISO 14021:2016, which allows self-declared claims without third-party verification, as well as selective corporate disclosure and the disconnect between short-term laboratory tests and long-term environmental realities. Together, these issues highlight both the technical and institutional limitations of current Type II eco-labeling practices.

To address these challenges, coordinated action from multiple stakeholders is essential. Regulators should strengthen eco-labeling standards by requiring third-party certification and discharge-stage validation, while enterprises must increase transparency in ingredient reporting and assume genuine environmental responsibility. At the same time, academia should advance comprehensive impact assessments that integrate ecological, toxicological, and socio-economic perspectives. Only through such collaborative efforts can eco-labeled detergents achieve meaningful environmental benefits and avoid the pitfalls of greenwashing..

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