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Bridging the Knowledge Gap Between Environmental Ethics and Microplastic Pollution: An Interdisciplinary Approach to Sustainability

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ABSTRACT

The knowledge gap between environmental ethics and the reality of microplastic pollution is examined through an interdisciplinary approach. Microplastic pollution has become a persistent and widespread environmental contaminant, with more than 170 trillion plastic particles estimated to be floating in the world's oceans. Recent studies show that microplastics have been detected in human blood, drinking water, and the global food chain. However, public awareness and policy responses remain behind the severity of the problem. Microplastic pollution is analyzed from ecological, toxicological, and social perspectives, while gaps in the understanding and implementation of environmental ethics are identified. Interdisciplinary approaches integrating natural sciences, social sciences, humanities, and technology are also evaluated. The findings indicate that effective solutions require systemic transformation, including technological innovation, policy reform, a shift toward a circular economy, and changes in public behavior. Recommendations include strengthening interdisciplinary research with more standardized methodologies, implementing evidence-based regulation guided by the precautionary principle, adopting circular economy and extended producer responsibility schemes, and improving environmental education and public literacy. The conclusion emphasizes the urgency of collective action informed by scientific evidence and guided by ethical principles to achieve genuine environmental sustainability.

INTRODUCTION

The global environmental crisis, characterized by climate change, ecosystem degradation, and pollution, has reached a tipping point that demands a comprehensive, coordinated response across sectors of society. The IPCC report confirms that climate change has caused widespread impacts and risks to ecosystems, communities, and the sustainability of human life (IPCC, 2023). In this context, one of the environmental issues receiving increasing attention is microplastic pollution, a form of plastic pollution that has permeated ecosystems ranging from high mountain areas to the deepest ocean (Napper et al., 2020; Peng et al., 2018). This literature review explores the gap between the understanding of environmental ethics and the reality of microplastic pollution, and highlights the importance of interdisciplinary approaches to achieving true environmental sustainability.

Microplastics, defined as plastic particles smaller than 5 millimeters, have become persistent, bioaccumulative, and widespread environmental contaminants worldwide (Arthur et al., 2009; NOAA, 2024). In line with that, Arista (2023) emphasized that the characteristics of microplastics that are very small, stable, and have a large surface area make them easy to interact with other contaminants and potentially enter the food chain. Since microplastics were first widely discussed as environmental pollutants in the early 2000s, research on microplastics has continued to advance rapidly, especially after Thompson et al. (2004) demonstrated the widespread presence of microscopic plastic fragments in the marine environment. Recent studies show that microplastics have been found in oceans, rivers, lakes, farmland, atmospheric air, Arctic snow, and even in the human food chain, including drinking water, table salt, and seafood (Bergmann et al., 2019; Smith et al., 2018; Zhang et al., 2020). Important research in 2022 also detected plastic particles in human blood for the first time, marking a new era in understanding the potential impact of microplastic exposure on human health (Leslie et al., 2022).

Despite growing scientific evidence on the prevalence and potential impacts of microplastics, public awareness and policy responses to this threat still lag significantly behind the severity of the problem. This gap reflects a broader disconnect between theoretical understanding of environmental ethics and actual environmental management practices. In other words, there is a discrepancy between the values of environmental responsibility that people believe in and the consumption behavior they engage in daily life. This raises fundamental questions about how to bridge the gap between knowledge, values, and actions in the context of environmental sustainability.

The objectives of this literature review are to identify and analyze the knowledge gap that exists between the understanding of environmental ethics and the reality of microplastic pollution, evaluate interdisciplinary approaches in addressing the complexity of contemporary environmental problems, exploring potential solutions that integrate scientific, ethical, policy, and social perspectives, and provide practical recommendations for a wide range of stakeholders, including the academic community, policymakers, the industrial sector, and civil society. As such, this study is expected to contribute to a more comprehensive understanding of the sustainability challenges faced and potential pathways to more effective and equitable solutions.

RESEARCH METHODS

Study Design

This study uses a systematic literature review (SLR) approach to collect, analyze, and synthesize scientific sources on environmental ethics, microplastic pollution, and interdisciplinary approaches to sustainability. The SLR methodology was chosen to ensure that the process of searching, selecting, evaluating, and synthesizing the literature is carried out in a directed, transparent, and accountable manner. This approach is also appropriate because the topic of microplastics requires cross-disciplinary reading across environmental science, toxicology, public health, public policy, economics, and environmental ethics.

Procedure

Literature Selection

Literature searches are conducted through various academic databases, including Google Scholar, PubMed, Web of Science, Scopus, and ScienceDirect. The main keywords used include microplastic pollution, environmental ethics, interdisciplinary approach, sustainability, environmental health, circular economy, plastic waste management, knowledge gaps, policy implementation, and variations of combinations. The search also includes gray literature such as international organization reports, government policy documents, and relevant non-governmental organization publications.

Inclusion and Exclusion Criteria

Inclusion criteria for the literature selection include: publication within the last 10-year period (2015-2025) to ensure the relevance and up-to-date of the information, with exceptions for classic works or major references in the field of environmental ethics; articles that have gone through the peer review process; direct or indirect relevance to the topic of study; publication in English or Indonesian; and full accessibility to article text. Exclusion criteria include articles without a clear methodology, predatory publications, and articles that are too specific in their geographical or situational context to generalize.

Data Collection

The selection process is carried out through several stages. The first stage involves filtering the title and abstract to identify potentially relevant articles. The second stage involves reading the full texts of articles that passed the initial screening to assess their suitability for the inclusion criteria and study objectives.

The third stage involves the systematic extraction of data from selected articles, including information on the research methodology, key findings, conclusions, and recommendations. The process of grouping articles is performed manually using a selection matrix and a synthesis matrix in Microsoft Excel. Bibliometric mapping software such as VOSviewer is not used because this study focuses on thematic and narrative synthesis rather than keyword or citation network mapping. A total of 150 articles were initially identified through a database search, and 85 were selected for in-depth analysis after a screening and quality evaluation process.

Data Analysis

Data analysis was carried out thematically to identify patterns, themes, and gaps in the literature. The thematic analysis approach was chosen because it can organize and describe the dataset in detail and identify themes that emerge from the articles analyzed. The analysis process involves inductive and deductive coding. The initial themes are determined based on the theoretical framework, while new themes that emerge from the literature are recorded and integrated into the synthesis matrix.

The matrix contains information on the article title, author, year of publication, study focus, methods, main findings, contribution to the topic of microplastics, and its relevance to environmental ethics and sustainability. Narrative synthesis is then undertaken to connect findings from various sources and develop a holistic understanding of knowledge gaps, implementation challenges, and potential solutions in the context of environmental ethics and microplastic pollution.

RESULTS AND DISCUSSION

To provide a comprehensive overview of the reviewed literature, the selected studies were synthesized based on their primary focus, key findings, and contributions to understanding the relationship between environmental ethics and microplastic pollution. This synthesis highlights the major themes emerging from the literature and demonstrates how ecological, toxicological, social, ethical, and policy dimensions are interconnected. The intertopic linkages presented in Table 1 illustrate the interdisciplinary nature of the issue and identify areas where knowledge gaps remain, thereby providing a foundation for discussing integrated strategies toward environmental sustainability.

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Table 1. Literature synthesis and intertopic linkages

Synthesis Topics	Main Literature	Intertopic Connectivity	Implications of the Knowledge Gap
Definition, source, and characteristics of microplastics	Arthur et al. (2009); Thompson et al. (2004); NOAA (2024); Arista (2023)	Microplastics are defined as small particles derived from primary sources and the fragmentation of plastic waste, and are characterized by stability and ease of interaction with contaminants.	There is still a gap in public understanding that plastic pollution comes not only from visible plastic waste, but also from small particles that are difficult to observe.
Global distribution and human exposure	Bergmann et al. (2019); Zhang et al. (2020); Eriksen et al. (2023); Leslie et al. (2022)	Findings on microplastics in the ocean, atmosphere, food, drinking water, and human blood show that this issue is cross-ecosystem and cross-regional.	Scientific evidence on the spread of microplastics has not been fully aligned with policy responses and changes in people's behavior.
Ecological and health impacts	Wright & Kelly (2017); Smith et al. (2018); Prata et al. (2020); Lim (2021)	Toxicology and ecological studies link microplastics to organism disorders, food chains, and potential human health risks.	More standardized research is needed so that scientific uncertainty does not become a reason to delay preventive measures.
Environmental ethics and ecological justice	Rolston (2012); Callicott (2013); Simbolon (2016)	Environmental ethics emphasizes human moral responsibility to ecosystems, while studies of water pollution demonstrate the importance of evidence-based environmental monitoring and management.	The main gap lies between normatively recognized sustainability values and inconsistent waste-consumption and management practices.
Policy, circular economy, and environmental education	Borrelle et al. (2020); UNEP (2021); Arista (2023); Adinugraha (2022)	Microplastic solutions need to connect innovations in biodegradation, regulations, the circular economy, producer responsibility, and digital media-based environmental literacy.	An interdisciplinary approach is needed to translate scientific knowledge into sustainable policies, industry change, and societal behavior.

Global Dimension of Microplastic Pollution

Microplastic pollution is a multidimensional environmental problem that significantly impacts ecosystem health, biodiversity, and human health. Based on an analysis of the literature, the scale of the microplastic problem has reached alarming proportions. The study by Eriksen et al. (2023) estimates that more than 170 trillion plastic particles are floating on the surface of the world's oceans, with a total weight of about 2.3 million tons. This figure shows an exponential increase over previous estimates and reflects the uncontrolled acceleration in global plastic production and consumption.

The main sources of microplastics in the environment can be categorized as primary and secondary. Primary sources include microplastics in cosmetic products and personal care products, the release of microplastic fibers from the washing of synthetic textiles such as polyester, nylon, and acrylic, vehicle tire abrasion that produces large amounts of microplastic particles in urban environments, as well as pre-production plastic pellets or nurdles that are lost during the transportation and manufacturing process of plastic products. These sources show that microplastics come not only from visible plastic waste but also from everyday activities that often go unnoticed.

Meanwhile, secondary sources of microplastics arise from the fragmentation and degradation of macroplastic waste in the environment via photodegradation, mechanical degradation, and biodegradation. This degradation process is affected by a variety of environmental factors, including UV radiation, temperature, humidity, microbial activity, and environmental chemical conditions. Research shows that plastics in marine environments can fragment into microplastics within a few months to several years, depending on the polymer type and environmental conditions. In this context, Arista (2023) emphasizes that plastic decomposition can also involve biological mechanisms mediated by microorganisms, including bacteria, fungi, and algae. However, the effectiveness, the species involved, and the underlying enzymatic mechanisms still require further study.

Ecological and Health Impacts

The ecological impacts of microplastic pollution are multifaceted and affect different levels of biological organization, from individual organisms to ecosystems as a whole. At the organismal level, microplastics have been shown to cause a wide range of adverse effects, such as digestive system disorders due to microplastic ingestion, oxidative stress and inflammatory responses, endocrine disorders due to exposure to chemical additives in plastics such as phthalates, bisphenol A (BPA), and flame retardants, as well as behavioral changes and decreased reproductive success. These impacts can affect population dynamics and the long-term survival of species.

At the ecosystem level, microplastic pollution can alter the structure of biological communities, disrupt food chains, and affect key ecosystem functions, including nutrient cycling and primary production. Microplastics can also act as vectors for the transfer of chemical contaminants and microbial pathogens, thus creating additional exposure pathways for organisms. This condition has the potential to increase the overall toxicity of environmental contamination and expand its ecological impact.

The impact on human health is a growing concern as evidence of microplastic exposure is widespread. The study by Leslie et al. (2022) found microplastic particles in human blood samples, marking an important milestone in understanding the bioavailability and potential health impacts of microplastics. The main routes of exposure include the consumption of contaminated food and water, inhalation of microplastic particles in the air, and dermal absorption. Potential health effects of concern include chronic inflammation, oxidative stress, disruption of the gut microbiome, immune dysfunction, and, in the long term, possible carcinogenesis.

Gaps in Environmental Ethics

Environmental ethics, as a branch of moral philosophy, provides a normative framework for understanding human moral obligations to the natural environment. A variety of approaches to environmental ethics have been developed, from anthropocentrism, which emphasizes the instrumental value of the environment for human well-being, to biocentrism and ecocentrism, which recognize the intrinsic value of non-human life and ecosystems. However, an analysis of the literature reveals a substantial gap between widely accepted ethical principles and actual practices in environmental management and consumption behavior.

The first gap is the discrepancy between reported environmental awareness and actual behavior. The survey shows that the majority of people express concern for environmental issues and support sustainability principles. However, actual consumption behavior often does not align with reported values. This phenomenon is known as the gap between attitudes and behaviors, or between values and actions, which reflects the complexity of factors influencing human behavior, including structural barriers, social norms, habits, and competing priorities.

The second gap concerns environmental justice. The distribution of the environmental burden from microplastic pollution is uneven, with marginalized communities, developing countries, and future generations bearing disproportionate impacts. High-income countries are responsible for most of the historical production and consumption of plastics, while low- and middle-income countries are often destinations for plastic waste exports and face greater challenges in waste management. These injustices raise fundamental ethical questions about responsibility, compensation, and resource allocation for mitigation and adaptation.

The third gap arises from the tension between short-term economic growth and long-term environmental sustainability. Conventional economic models that emphasize GDP growth as a key indicator of progress often fail to account for environmental externalities and the degradation of natural capital. In the context of plastic pollution, the global plastics industry is worth hundreds of billions of dollars. It provides millions of jobs, thus creating a strong economic inertia against transformative change. Addressing these gaps requires reimagining economic models and adopting more holistic well-being metrics that account for ecological health and social justice.

Interdisciplinary Approach: A Conceptual Framework

The literature shows a strong consensus that a monodisciplinary approach is inadequate for addressing the complexity of contemporary environmental issues, such as microplastic pollution. An interdisciplinary approach that integrates knowledge, methods, and perspectives from a variety of disciplines offers the potential for a more holistic understanding and more effective solutions. This approach differs from multidisciplinary approaches, in which different disciplines work in parallel, and from transdisciplinary approaches, which involve the integration of academic and non-academic knowledge, as it emphasizes the true synthesis of different disciplinary perspectives.

In the context of microplastic pollution, an interdisciplinary approach integrates knowledge from various domains. Natural and environmental sciences provide insight into the sources, distribution, fate, and ecological impacts of microplastics. Health sciences explore the pathways of exposure, bioavailability, and toxicological effects on human and animal health. Social sciences analyze the behavioral, cultural, and institutional dimensions of plastic production and consumption. Economics evaluates the costs and benefits of various mitigation strategies and explores alternative economic models, such as the circular economy. Political science and public policy examine governance mechanisms, policy-making processes, and the effectiveness of implementation. Ethics and philosophy provide a normative framework for evaluating moral responsibility and justice, while communication science explores strategies to increase public awareness and facilitate behavior change.

Integration of Science and Policy

The relationship between science and policy is a critical area where knowledge gaps are often most obvious. Although the scientific understanding of microplastics has advanced rapidly, translating this knowledge into effective policy still faces various obstacles. These barriers include scientific complexity and uncertainty, differences in time frames and priorities between the science community and policymakers, limited resources, and resistance from established interests.

To bridge this gap, several strategies have been identified in the literature. First, the establishment of interdisciplinary expert panels that can provide science-based input to policymakers. Models such as the Intergovernmental Panel on Climate Change (IPCC) demonstrate the potential effectiveness of such mechanisms. However, challenges in the context of

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microplastics include research fragmentation and a lack of global coordination.

Second, the development of a platform to facilitate ongoing dialogue among scientists, policymakers, and other stakeholders. These platforms can take many forms, including knowledge intermediaries, liaison organizations, and shared knowledge-production mechanisms that involve various actors in the research and decision-making process. Third, the implementation of the precautionary principle amid scientific uncertainty. This principle states that the lack of full scientific certainty should not be used as an excuse to delay action when there is a risk of serious or irreversible harm.

Circular Economy as a Transformative Paradigm

The transition from the traditional linear economic model, i.e., take-away, to the circular economy represents a fundamental paradigm shift in the way people produce and consume goods. The circular economy aims to maintain the value of products, materials, and resources in the economy for as long as possible, minimize waste generation, and optimize resource use through strategies such as design for durability, reuse, repair, remanufacturing, and recycling.

In the context of plastics, the circular economy involves several key strategies. First, product redesign to reduce plastic use, improve recyclability, and eliminate unnecessary or problematic plastics. This includes eliminating single-use plastic packaging when viable alternatives are available, standardizing plastic materials to facilitate recycling, and designing products that consider the entire lifecycle from production to end-of-life.

Second, the development and expansion of the use of more sustainable alternative materials. This includes bioplastics made from renewable resources such as corn starch or sugarcane, as well as biodegradable plastics under certain environmental conditions. However, it is important to note that not all bioplastics or biodegradable plastics are automatically better for the environment. A comprehensive lifecycle assessment remains necessary to evaluate the relative impacts of various alternatives. Third, the implementation of extended producer responsibility (EPR), which is a scheme that makes manufacturers responsible for the entire life cycle of their products, including end-of-life management.

The Role of Education and Social Transformation

Changing people's behavior is essential to tackling microplastic pollution, but achieving sustainable, large-scale behavioral change faces significant challenges. The literature in environmental psychology and behavioral science identifies a variety of factors that influence proenvironmental behavior, including knowledge and awareness, values and norms, self-efficacy, infrastructure and structural barriers, and social and cultural contexts.

Environmental education plays an important role in building understanding of microplastics and their impacts, as well as empowering individuals to take action. However, research shows that increased knowledge alone is not enough to produce behavioral changes. A more holistic approach is needed, considering various behavioral determinants. Effective strategies include integrating environmental education into the formal curriculum from elementary to tertiary levels, with an emphasis not only on information transmission but also on the development of critical thinking, problem-solving, and action competencies. The findings of Adinugraha (2022) also show that YouTube-based learning media can increase students' knowledge of urban forests and their vegetation, suggesting that digital media can be considered a relevant means of environmental literacy for microplastic issues.

Effective public awareness campaigns need to be designed based on the principles of persuasive communication and take into account specific audience goals. The use of social media and digital platforms offers the potential to reach a wide audience in an engaging, interactive way. However, it is important to avoid approaches that are overly frightening or make people feel overwhelmed, as such strategies can lead to defensiveness or apathy rather than constructive action.

Broader social transformation is also needed to create a context in which sustainable choices become social norms and innate choices. It involves changes in cultural values, institutional structures, and economic systems that support sustainable consumption. Social movements, civil society organizations, and local communities play a critical role in driving bottom-up change, while public policy and corporate leadership can facilitate top-down change.

CONCLUSION

The findings highlight significant gaps between theoretical environmental ethics and the practical realities of microplastic pollution. While scientific knowledge of the prevalence, distribution, and potential impacts of microplastics has advanced considerably, translating this knowledge into effective action at the policy, industry, and societal levels remains a major challenge. The identified gaps span scientific, policy, economic, social, and ethical dimensions, underscoring the need for an interdisciplinary approach that integrates the natural sciences, social sciences, humanities, and technology. Effective solutions require the integration of robust scientific research, evidence-based policymaking, technological innovation, economic transformation, and social mobilization. Ultimately, addressing microplastic pollution depends on bridging the gaps between knowledge and action, values and behavior, and short-term interests and long-term sustainability. Comprehensive, collaborative, and transformative efforts are essential to achieve environmental sustainability and safeguard a healthy planet for future generations.

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