sustainability

Review

Uncovering Plastic Pollution: A Scoping Review of Urban Waterways, Technologies, and Interdisciplinary Approaches

Peter Cleveland [1,*], Donna Cleveland [2], Ann Morrison [1], Khoi Hoang Dinh [3], An Nguyen Pham Hai [2], Luca Freitas Ribeiro [2] and Khanh Tran Duy [3]

1 School of Future Environments, Auckland University of Technology, Auckland 1010, New Zealand; ann.morrison@aut.ac.nz
2 School of Communication and Design, Royal Melbourne Institute of Technology University Vietnam, Ho Chi Minh 700000, Vietnam; donna.cleveland@rmit.edu.vn (D.C.); an.nguyenphamhai@rmit.edu.vn (A.N.P.H.); luca.freitasribeiro@rmit.edu.vn (L.F.R.)
3 Faculty of Electrical Engineering Technology, Industrial University of Ho Chi Minh City, Ho Chi Minh 700000, Vietnam; hoangdinhkhoi@iuh.edu.vn (K.H.D.); 21123551.khanh@student.iuh.edu.vn (K.T.D.)
* Correspondence: peter.cleveland@autuni.ac.nz

Abstract

Plastic pollution is a growing environmental and social concern, particularly in Southeast Asia, where urban rivers serve as key pathways for transporting waste to marine environments. This scoping review examines 110 peer-reviewed studies to understand how plastic pollution in waterways is being researched, addressed, and reconceptualized. Drawing from the literature across environmental science, technology, and social studies, we identify four interconnected areas of focus: urban pollution pathways, innovations in monitoring and methods, community-based interventions, and interdisciplinary perspectives. Our analysis combines qualitative synthesis with visual mapping techniques, including keyword co-occurrence networks, to explore how real-time tools, such as IoT sensors, multi-sensor systems, and geospatial technologies, are transforming the ways plastic waste is tracked and analyzed. The review also considers the growing use of novel theoretical frameworks, such as post-phenomenology and ecological materialism, to better understand the role of plastics as both pollutants and ecological agents. Despite progress, the literature reveals persistent gaps in longitudinal studies, regional representation, and policy translation, particularly across the Global South. We emphasize the value of participatory models and community-led research in bridging these gaps and advancing more inclusive and responsive solutions. These insights inform the development of plastic tracker technologies currently being piloted in Vietnam and contribute to broader sustainability goals, including SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production), and SDG 14 (Life Below Water).

Keywords: plastic pollution; urban waterways; monitoring technologies; interdisciplinary approaches

check for updates

Academic Editor: Saif Uddin

Received: 7 June 2025
Revised: 18 July 2025
Accepted: 23 July 2025
Published: 1 August 2025

Citation: Cleveland, P.; Cleveland, D.; Morrison, A.; Dinh, K.H.; Hai, A.N.P.; Freitas Ribeiro, L.; Duy, K.T. Uncovering Plastic Pollution: A Scoping Review of Urban Waterways, Technologies, and Interdisciplinary Approaches. *Sustainability* **2025**, *17*, 7009. https://doi.org/10.3390/su17157009

1. Introduction

Plastic pollution in waterways is an escalating environmental and societal challenge with consequences for ecosystems, human health, and economic resilience [1–3]. River systems that once supported communities with potable water, agriculture, and transportation are now increasingly burdened by plastic waste, driven by rapid urban development [4], weak waste management infrastructure [5], and entrenched consumption habits [6,7].

They now serve as primary conduits for mismanaged plastic waste flowing into marine ecosystems [8].

The impacts of plastic pollution go beyond visible debris and include widespread ecological degradation [9]. Microplastics and macroplastics interfere with ecological processes, reduce biodiversity, and threaten the health and livelihoods of people who rely on urban water ecosystems [10,11]. Consistent with efforts to align definitions, this paper uses the terms macroplastics (items larger than 5 mm) and microplastics (items smaller than 5 mm but larger than 1 μm), [8]. These size-based classifications help link observed pollution patterns to potential ecological impacts, while also enabling comparability across studies. Although the focus of this review is primarily on macroplastics transported through urban rivers, recognizing the breakdown processes that generate microplastics is essential for understanding the full scope of pollution dynamics. In densely populated areas, the buildup of plastic waste exacerbates flooding by blocking drainage systems and undermines the economic, cultural, and esthetic value of urban rivers, deterring tourism and increasing public maintenance costs [12]. These pressures are especially acute in Southeast Asia, where rivers such as the Saigon and Mekong are recognized among the top global sources of plastic waste entering the ocean [13,14].

Although awareness has increased, knowledge gaps persist, especially regarding the sources, transport mechanisms, and ecological consequences of plastic waste in urban settings. Scalable, and locally relevant waste management strategies also remain underdeveloped in many regions [15,16]. Addressing these challenges requires collaborative, interdisciplinary efforts that combine environmental science, digital innovation, and community engagement [2,17].

This review synthesizes existing research across four interconnected domains: One, the scope and challenges of urban plastic pollution; Two, advances in research methods and monitoring technologies; Three, innovative and practical solutions; and Four, integrated perspectives that link environmental, technological, and social dimensions. The first category identifies knowledge gaps and explores the implications of plastic transport in urban waterways. The second outlines emerging tools such as multi-sensor systems and computational models that enhance plastic pollution analysis [18–20]. The third addresses interventions, from IoT-based tracking [21] to community recycling initiatives, highlighting the transformative role of low-cost technologies and collaborative practices [22,23]. Finally, the fourth category examines governance, public awareness, and sustainability frameworks, illustrating how cross-sectoral perspectives can shape more effective responses [12,24]. This review was conducted in the context of an ongoing project to develop plastic trackers for deployment in urban waterways in Vietnam [25]. While this review has global scope, drawing on research about plastic pollution across diverse geographies, we place particular emphasis on Southeast Asia due to its recognized significance as a plastic pollution hotspot [6,7,13]. Within this context, examples from Vietnam are highlighted to illustrate how insights from the global literature can inform practice in a specific urban waterway setting. This emphasis supports the intended application of the findings in a Vietnamese pilot project, while acknowledging the broader international relevance of the themes analyzed. This synthesis integrates diverse perspectives and highlights actionable insights to support research, practice, and policy development. It informs the design of scalable, context-sensitive tracking solutions and contributes to broader efforts aligned with Sustainable Development Goal (SDG) 14, on aquatic ecosystem protection [26,27].

The interconnection between plastic pollution in river systems and in the marine environment is central to this review. Rivers act as primary conduits, transferring mismanaged plastic waste from urban and land-based sources into coastal and oceanic systems [8]. These riverine pathways are characterized by dynamic and seasonally variable flows, strongly influenced by rainfall, flood events, and local waste management practices [15,16]. In contrast, marine environments display broader and long-term patterns of plastic accumulation and dispersion, driven by ocean currents and wind systems [4,6,7]. Understanding how these systems are linked, while also acknowledging their differences, is valuable for designing targeted interventions to address sources of plastic leakage and ecological impacts [11,24].

The remainder of this paper is structured as follows. Section 2 details the methodology adopted for the scoping review, including the search strategy, inclusion criteria, and thematic coding process. Section 3 presents the results, organized around four key thematic categories. Section 4 discusses the implications of these findings in relation to technology, policy, and community engagement. Finally, Section 5 concludes with reflections on the study's contributions and future directions for research and practice. To explore these themes, we conducted a structured scoping review detailed in the next section.

2. Methodology

This section outlines the systematic and staged approach used to conduct the scoping review on plastic pollution in urban waterways. It details the research design, thematic development, search strategy, selection process, and analytical techniques used to synthesize findings across disciplines and regions.

2.1. Research Design

This scoping review employed a methodologically structured and iterative process to examine the state of knowledge on plastic pollution and waste management. By integrating empirical findings, theoretical frameworks, and methodological advances, the study aimed to provide a critical synthesis of current literature while identifying persistent gaps and future research opportunities.

2.2. Research Scope

The review initially focused on ten themes derived from research prompts and guiding questions:

1. Plastic Pollution in Urban Waterways
2. Tracking Technology for Pollution
3. Analysis Techniques for Environmental Data
4. Multi-Sensor Systems for Environmental Monitoring
5. Knowledge Gaps in Plastic Pollution Studies
6. Policy Implications and SDG 14 (Life Below Water)
7. Comparative Case Studies on Urban River Plastic Pollution and Management
8. Broader Environmental and Societal Context
9. Innovative Interventions in Plastic Waste Management
10. Integration of Theoretical Frameworks in Plastic Pollution Studies

These themes reflect the breadth and depth of contemporary research on plastic pollution encompassing foundational inquiries, technical innovations, and interdisciplinary approaches. While each theme is distinct, many of the reviewed studies addressed multiple overlapping issues. For example, papers focusing on policy frameworks often intersected with broader societal considerations and sustainability goals. To avoid redundancy and enhance analytical clarity, the review employed a dominant theme classification strategy. The authors assigned each study to a single theme based on its primary emphasis.

Consolidation into Four Key Areas

Through iterative thematic analysis, the ten themes were consolidated into four overarching categories to improve clarity and analytical coherence.

1. The Scope and Challenges of Urban Plastic Pollution: Focuses on the prevalence, impacts, and existing knowledge gaps in urban and coastal waterways.
2. Advancing Approaches in Plastic Pollution Research: Examines innovations in monitoring, including multi-sensor systems, computational tools, and theoretical approaches such as ecological materialism and post-phenomenology.
3. Innovative Solutions and Practical Interventions: Highlights implementable strategies such as IoT-based systems and case studies demonstrating effective waste mitigation.
4. Integrating Perspectives: Positions plastic pollution within wider societal and ecological frameworks, addressing policy intersections, sustainability goals, and research equity.

This consolidation facilitated a cross-cutting analysis while preserving the specificity of each theme. Each study in the review was assigned to a single theme based on its dominant focus, and each theme was grouped into one of the four categories. While themes remained distinct, several categories were informed by multiple themes. We present in Figure 1 a schematic representation of these relationships between the original ten themes and their corresponding categories.

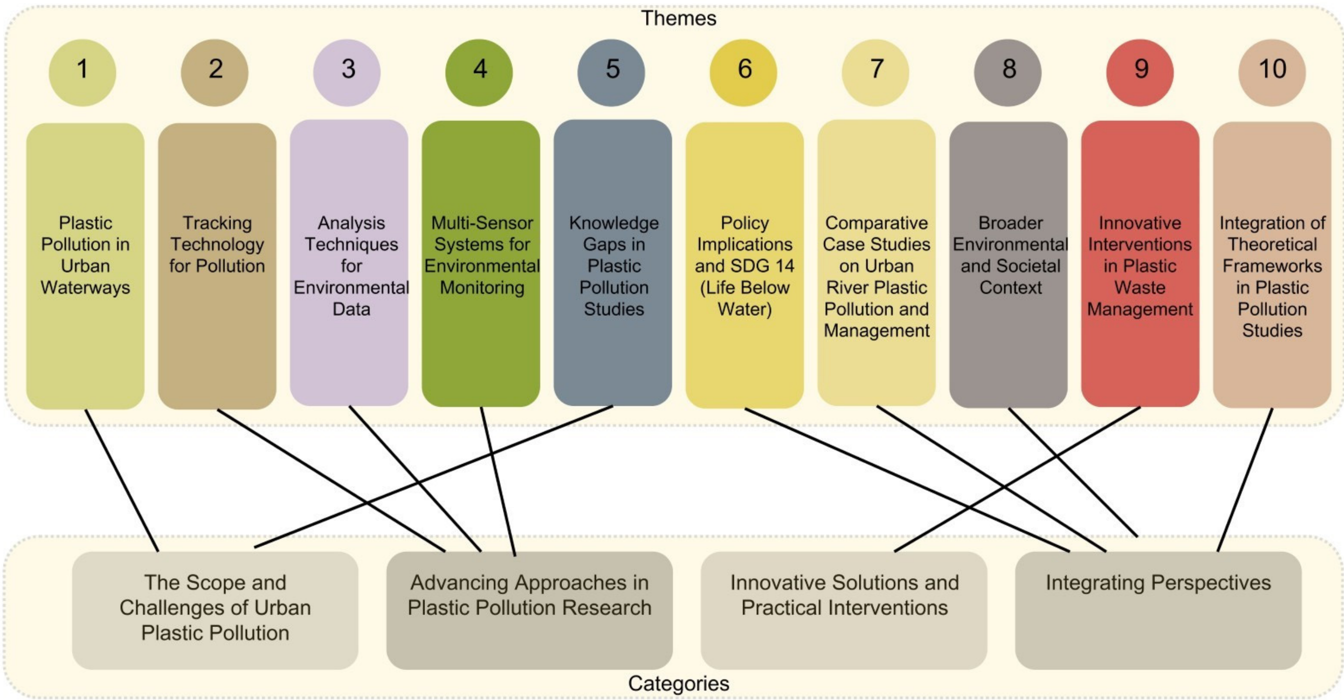

Figure 1. Mapping the consolidation of research themes into four key areas. Source: Created by the authors. The initial mapping was developed through an iterative process involving team discussions and thematic coding of literature metadata in RStudio (packages: tm, SnowballC, igraph, ggraph, tidyverse and pdftools). This workflow supported clustering, frequency analysis, and network visualization. The final diagram was refined in Canva for improved clarity.

Following the visual structure of Figure 1, it is evident that the categories 'Advancing Approaches' and 'Integrating Perspectives' were shaped by multiple themes. For example, 'Advancing Approaches' synthesizes contributions from 'Tracking Technology for Pollution,' 'Analysis Techniques for Environmental Data,' and 'Multi-Sensor Systems for Environmental Monitoring.' In contrast, 'Innovative Solutions and Practical Interventions,' emerged solely from the theme 'Innovative Interventions in Plastic Waste Management.' This one-way relationship, where each theme informs a single category, but categories may be informed by multiple themes, was central and foundational to the analytical structure of this review and supported a clearer synthesis across complex and intersecting strands of research.

2.3. Rationale for Themes

The refinement of themes reflects the interdisciplinary scope of the review and its focus on addressing urgent environmental challenges while situating the research team within broader sustainability discourses. The emphasis on Southeast Asia, a key contributor to global plastic leakage, reinforces the regional relevance of the study [7,8].

Moreover, the themes were selected to align with global policy agendas, including SDG 12 (Responsible Consumption and Production) and SDG 14 (Life Below Water), ensuring that the review contributes to international efforts on environmental governance. The consolidation bridges ecological, technological, and socio-economic dimensions, promoting a holistic and systems-oriented understanding of plastic waste.

2.4. Search Strategy

2.4.1. Databases Used

Primary searches were conducted using Scopus, Web of Science, and Google Scholar. Additional searches targeted high-impact journals in environmental science, sustainability, and waste management. Author-based searches were also carried out to explore broader research outputs relevant to Vietnam and comparable regional contexts.

2.4.2. Keywords and Boolean Operators

Search queries used the following combinations:

- "plastic pollution" AND "urban rivers"
- "IoT OR Internet of Things" AND "waste monitoring"
- "SDG 14 OR sustainable development goals"
- "microplastics AND ecological impacts"
- "waste management strategies AND post-phenomenology"

2.4.3. Search Criteria

The search was limited to English-language studies published between 2016 and 2024 to ensure currency. While the geographic focus prioritized Southeast Asia, global comparative studies were also included.

2.5. Selection Process

2.5.1. Inclusion and Exclusion Criteria

Included studies met one or more thematic criteria, provided empirical evidence, theoretical insight, or robust methodological contributions. Exclusions applied to studies published prior to 2016, gray literature, and non-peer-reviewed work (excluding five relevant pre-prints).

We note that while highly relevant publications, such as the Research Handbook on Plastics Regulation [28] and recent studies on institutional interlinkages in marine plastic pollution, Managing institutional interlinkages for the protection of marine environment in the East Asian seas region and beyond: The case of marine plastic pollution [29], offer important contributions, these were not included in this review due to their classification as gray literature or because they fell outside the defined scope of peer-reviewed sources. These works highlight evolving perspectives and should be considered in future research.

The review developed with Vietnam's urban waterways as its core application, but the literature sampled included a global corpus. Studies were selected based on thematic and methodological relevance, regardless of their origin. Research locations were also recorded for geographic trend analysis.

2.5.2. Screening Process

To ensure transparency and rigor, a multi-stage screening approach was applied:

1. Title and Abstract Review: Initial screening based on relevance.
2. Full-Text Analysis: Evaluation against thematic and methodological criteria.
3. Duplicate Removal: Elimination of redundant studies.

2.6. Data Extraction

Data attributes from each study were systematically extracted and recorded (see Table 1). These included: research objectives, geographic focus, methodology, key findings, and alignment with SDGs. Thematic classification and theoretical framework applicability were also documented.

Table 1. Extracted data attributes. Source: Created by the authors through manual extraction and thematic classification of 110 studies reviewed.

Attribute	Description
Thematic Mapping	Mapped each study to one or more of the ten key themes
Research Objectives	Primary goals of the study.
Geographic Location	Countries or regions studied.
Methods	Methodological tools and approaches used.
Key Findings	Major results and contributions.
SDG Alignment	Connection to relevant Sustainable Development Goals.

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework guided the review, ensuring transparency in selection and reporting. Thematic coding and analysis were performed using RStudio (version 4.4.1), which is an Integrated Development Environment (IDE). This software is widely used for statistical computing, data analysis, and data visualization. Analyses relied on packages including pdftools, stringr, tm, SnowballC, wordcloud, RColorBrewer, topicmodels, LDAvis, igraph, ggraph, ggplot2, tidyverse, sf, rnaturalearth, rnaturalearthdata, readxl, Manu, and HiveR. These supported text mining and natural language processing, unsupervised machine learning through topic modeling, keyword co-occurrence analysis, network and spatial visualizations. For replicability and transparency, a workflow for the principal operations in R can be found in Supplementary Materials, R Workflow and Code Overview.

2.7. Synthesis Approach

2.7.1. Qualitative and Quantitative Analysis

A mixed-methods approach was used to synthesize the findings. Qualitative thematic analysis was complemented by quantitative metrics such as keyword frequency and co-occurrence analysis. This analysis was conducted using RStudio's text mining and data manipulation packages to ensure depth and clarity.

2.7.2. Validation and Rigor

To ensure methodological consistency, data extraction was cross-verified and reviewed by multiple team members. Inclusion/exclusion decisions were made through consensus to minimize bias.

Ethical research principles guided the process, including transparency in methods, equitable representation of regional perspectives, and clear reporting of limitations. This approach was taken to enhance the reliability and reproducibility of the review.

3. Results

Building on the methodology described in Section 2, this section synthesizes findings from the scoping review, organizing insights across four overarching categories: One, The Scope and Challenges of Urban Plastic Pollution; Two, Advancing Approaches in Plastic Pollution Research; Three, Innovative Solutions and Practical Interventions; and Four, Integrating Perspectives. These represent key dimensions of plastic pollution and waste management, capturing the relationship between foundational issues, research methodologies, practical applications, and broader societal concerns.

To deepen insight and engagement, the results are supported by a series of visualizations that offer both quantitative and qualitative perspectives on the research landscape. These include analyses of thematic alignment with global sustainability goals, temporal publication trends, and keyword co-occurrence networks. These tools are presented where they offer meaningful contributions to understanding research directions, knowledge gaps, and areas of opportunity.

The results reveal the inherently interdisciplinary nature of plastic pollution research, encompassing environmental science, policy analysis, socio-economic studies, and technological innovation. At the same time, they expose persistent challenges, particularly thematic imbalances and the absence of standardized research methods, which limit progress toward sustainable, scalable solutions.

The following subsections explore each theme in depth, drawing on the visualizations and textural analysis to trace the development of the field, outline current priorities, and identify pathways for future research and practice.

3.1. Thematic Overview and Distribution

The results of this scoping review reveal a broad and thematically diverse research landscape. While the initial analysis identified ten distinct themes, these were later consolidated into four overarching thematic categories: The Scope and Challenges of Urban Plastic Pollution, Advancing Approaches in Plastic Pollution Research, Innovative Solutions and Practical Interventions, and Integrating Perspectives. These consolidated categories provide a structured lens for examining the multi-dimensional nature of plastic pollution and waste management, highlighting both established areas of focus and underexplored opportunities for further research.

The Themes in the Literature Bubble Map (Figure 2) shows how the ten original themes are distributed across the reviewed publications. Bubble size corresponds to the number of papers engaging with each theme, determined through quantitative frequency analysis of keyword occurrences across the dataset. Overlapping areas indicate thematic co-occurrence, where individual studies address multiple themes. These relationships were identified through text mining and organized into a matrix, which guided the spatial arrangement of themes in the final visualization.

The most prominent theme in the dataset was 'Policy Implications and SDG 14 (Life Below Water)', which is represented by the largest central bubble with 93 occurrences, highlighting its importance in current research. This is followed closely by five medium sized bubbles: 'Knowledge Gaps in Plastic Pollution Studies' which occurred 81 times; 'Integration of Theoretical Frameworks in Plastic Pollution Studies', 73 times; 'Plastic Pollution in Urban Waterways', 69 times; 'Broader Environmental and Societal Context', 67 times, and 'Innovative Interventions in Plastic Waste Management', 64 times. Together these themes reflect concentrated scholarly engagement across both foundational and emerging areas. The remaining four themes are represented by smaller bubbles, indicating lower frequency: 'Analysis Techniques for Environmental Data' appeared in 55 instances, 'Comparative Case Studies on Urban River Plastic Pollution and Management' in 41; 'Tracking Technology for Pollution in 29, and 'Multi-Sensor Systems for Environmental Monitoring in 20. This distribution highlights both dominant research priorities and areas of relative neglect within the existing body of literature, particularly around sensor technologies and regionally grounded comparative analyses.

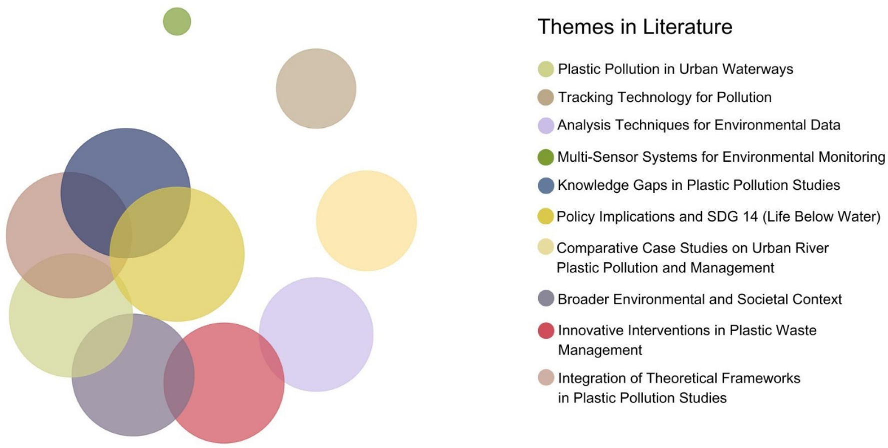

Figure 2. Bubble Map illustrating the frequency and Co-occurance of research themes. Source: Created by the authors. Bubble sizes represent the number of reviewed publications (110) addressing each of the ten themes. Frequencies were calculated using a text mining process in RStudio and plotted using (packages: ggplot2, dplyr, tidyr, and Manu). A logarithmic transformation of frequency values (log(frequency + 1) × 2) was applied to enhance proportional visibility in the visualization. Bubbles are arranged in a reversed spiral, with more frequently occurring themes placed centrally. Overlapping areas indicate thematic intersections based on the co-occurrence of themes within individual studies.

3.2. Key Observations from the Bubble Map

3.2.1. Policy Implications and SDG 14 (Life Below Water)

Representing the largest bubble, Policy Implications and SDG 14 underscores the central role of aligning research with global sustainability priorities, particularly those related to marine ecosystem health. The prominence of this theme reflects a widespread recognition of the urgency to address plastic pollution within the framework of the United Nations Sustainable Development Goals and emphasizes the growing role of regulatory action and transboundary cooperation in pollution mitigation policy.

This theme is situated within Category 4: Integrating Perspectives, which draws attention to the socio-ecological and policy dimensions of plastic pollution. The dominance within the literature points to a global consensus around the importance of policy-driven, actionable solutions for protecting aquatic environments.

3.2.2. Clustered Themes and Overlaps

Five medium-sized bubbles form a closely grouped cluster, reflecting both significant scholarly attention and overlapping research foci:

1. Knowledge Gaps in Plastic Pollution Studies (Theme 5/10) aligns with Category 1: The Scope and Challenges of Urban Plastic Pollution, highlighting ongoing uncertainties about degradation pathways and the socio-economic drivers of plastic waste.
2. Integration of Theoretical Frameworks in Plastic Pollution Studies (Theme 10/10) is categorized under *Integrating Perspectives*, illustrating the growing interest in conceptual tools such as ecological materialism and post-phenomenology to better frame and interpret plastic pollution.
3. Plastic Pollution in Urban Waterways (Theme 1/10) also falls under Category 1, reinforcing the importance of urban rivers as major pathways for plastic flow into marine ecosystems.
4. Broader Environmental and Societal Contexts (Theme 8/10) is linked to Category 4, reflecting recognition of the interconnected impacts of pollution on communities, public health, and cultural practices.
5. Innovative Interventions in Plastic Waste Management (Theme 9/10) is mapped to Category 3: Innovative Solutions and Practical Interventions, signifying a growing interest in local recycling systems, IoT-enabled tracking, and the development of bioplastics.

Together, these clustered themes represent a dynamic and overlapping space in the literature, where technological, ecological, and social dimensions are increasingly integrated.

3.2.3. Smallest Bubble: Multi-Sensor Systems for Environmental Monitoring

The smallest bubble represents Multi-Sensor Systems for Environmental Monitoring (Theme 4/10), mapped into Category 2: Advancing Approaches in Plastic Pollution Research. Despite its relatively limited presence in the literature, this theme reflects the emerging potential of integrating advanced technologies to track and analyze plastic waste. At present, many studies still rely on analog methods, simulations, or isolated sensor systems, underscoring a clear opportunity for future development in this space. The limited coverage suggests a research gap where new technological capabilities could substantially enhance understanding and intervention.

3.2.4. Implications of the Thematic Distribution

The bubble map reveals clear disparities in research emphasis. While themes such as Policy Implications and SDG 14 have attracted significant attention, others, particularly Multi-Sensor Systems, remain comparatively underexplored. This uneven distribution suggests that, while regulatory frameworks and marine health are well established areas of concern, there is a critical need to extend research efforts toward terrestrial ecosystems, real-time monitoring innovations, and community-driven solutions.

The clustering of mid-sized bubbles, Knowledge Gaps, Broader Contexts, and Innovative Interventions, further emphasizes the interdisciplinary character of plastic pollution research. These intersections indicate a field in transition, increasingly characterized by the blending of social, technological, and ecological perspectives. Meanwhile, the small footprint of sensor-based research reaffirms the importance of Category 2: Advancing Approaches, which calls for greater integration of emerging technologies into environmental monitoring practices.

3.3. Category One: The Scope and Challenges of Urban Plastic Pollution

Understanding the challenges posed by plastic pollution began with a foundational analysis of its wide-reaching impacts on urban ecosystems. Urban rivers, in particular, serve a dual function, as both recipients and transporters of plastic waste, connecting land-based sources to marine environments. These waterways function as critical conduits, channeling plastic debris into oceans and exacerbating global pollution flows. As Meijer et al. note, "results suggest that small and medium-sized rivers account for a substantial fraction of global emissions" [7] (p. 6). This finding highlights the disproportionate influence of urban river systems and the pressing need for locally targeted interventions. One significant yet under acknowledged contributor to plastic pollution in urban waterways is wastewater discharge [8]. Even in systems with centralized treatment, microplastics can remain in treated effluent, while in areas with incomplete infrastructure, untreated domestic wastewater enters rivers directly. For instance, in Ho Chi Minh City's Nhieu Loc canal, concentrations of microplastics measured by one study reached 666.67 pieces/m^3 near the outlet of the sewer system which decreased downstream to 25 pieces/m^3, this trend was attributed to stagnant water amalgamating with the wastewater inputs at the canal's headwaters [14].

To assess how current research aligns with global sustainability goals, we developed a heatmap based on the thematic coding of the 110 reviewed publications. This heatmap illustrates the intersection between specific research themes and the United Nations Sustainable Development Goals. Thematic coding was conducted using RStudio, applying text-mining, topic modeling, dependency parsing, and named entity recognition (NER) to categorize studies according to their SDG relevance. Each cell in the matrix represents the total count of occurrences in reviewed publications that explicitly addressed both the corresponding research theme and SDG target, with overlaps counted once per document to avoid duplication. A co-occurrence matrix was used to quantify how often each theme was linked to individual SDGs, with log-transformed frequencies applied to visualize relative emphasis and reduce bias from high-frequency counts (Figure 3).

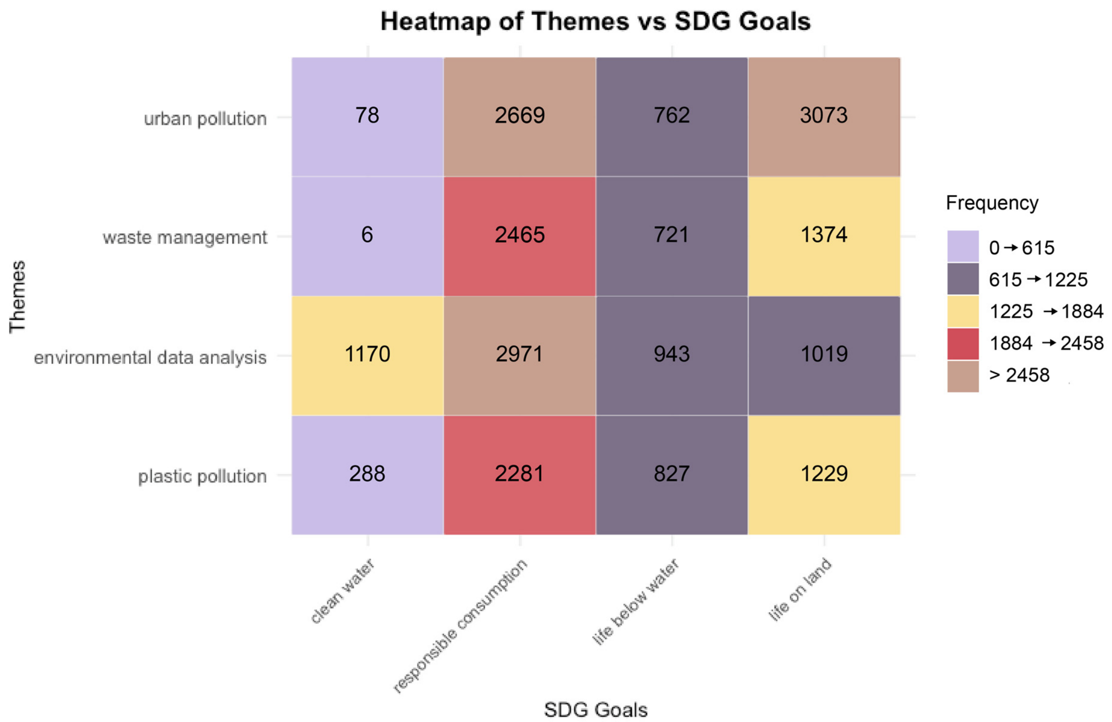

Figure 3. Heatmap illustrating the alignment of research themes with SDGs. Source: Created by the authors. Generated using RStudio (packages: ggplot2, dplyr). Based on thematic coding and frequency counts from 110 publications. Color intensity reflects normalized frequencies. A co-occurrence matrix was used to calculate how often each theme intersected with an SGD, with log-transformed values applied to adjust for dominant counts. Final formatting was completed in Canva.

The heatmap reveals strong thematic alignment between urban plastic pollution research and SDG 15, Life on Land, followed closely by SDG 12, Responsible Consumption and Production, particularly in relation to waste systems and land-based pollution sources. In contrast, SDG 6, Clean Water and Sanitation, is notably underrepresented, despite its clear relevance to urban river systems and freshwater quality. This discrepancy suggests a persistent gap in research attention to inland freshwater pathways, which play a critical role in linking terrestrial waste flows with marine pollution. Strengthening the focus on these systems, as both recipients and conduits of plastic waste, represents an important opportunity for future research. These insights reinforce the need to embed urban river management more fully within sustainability frameworks. Plastic pollution in urban waterways intersects with multiple ecosystems and socio-economic dimensions, requiring solutions that address both aquatic and terrestrial contexts through integrated planning and governance.

The heatmap data further underscores this imbalance. SDG 12 and SDG 15 showed the strongest alignments across all categories, with particularly high scores in themes such as Urban Pollution (2669 and 3073) and Environmental Data Analysis (2971 and 1019). In contrast, SDG 6 recorded extremely low counts, most notably just 6 instances in the Waste Management category. This limited representation is surprising given the importance of clean water infrastructure and the plastic pollution lifecycle. These results suggest that while considerable research addresses consumption and terrestrial impacts, the freshwater systems that link them to marine environments remain underexplored. Greater emphasis on these inland systems, including rivers and canals, could be critical for developing comprehensive, upstream solutions to plastic pollution.

Southeast Asia stands out in this global picture due to its acute vulnerability. Rapid urbanization, population growth, and limited infrastructure have made the region a major contributor to plastic leakage [8]. In Vietnam, the Saigon River offers a salient case where poorly regulated waste disposal and limited recycling capacity have led to severe macroand microplastic contamination [30]. This example reflects broader trends seen in other urban river systems, where industrial runoff and household waste converge.

Seasonal fluctuations further complicate the picture. Strady et al. [31] employed hydrological modeling in the Mekong Delta that demonstrated how rainfall dramatically influences plastic concentrations. "In the Day River, the influence of rainfall on the observed concentrations was also suggested as higher concentrations were observed during the sampling of the rainy season than during the one of the dry seasons" [31] (p. 6). These findings amplify the importance of accounting for temporal variability in both monitoring design and policy responses.

Despite growing interest, methodological fragmentation remains a core challenge. Research studies vary widely in their approaches, from manual macroplastic collection to microplastic filtration and image-based techniques, making cross study comparisons difficult. Inconsistent definitions, particularly around size thresholds for microplastics, further hinder standardization [32]. Addressing this issue will require the development of globally accepted metrics and data protocols to support more coordinated efforts.

Plastic pollution is not only an environmental problem; it has deep socio-economic dimensions. In many developing contexts, urban rivers provide essential services for drinking water, food, and industry. Their degradation poses a serious public health risk. Along the Saigon River, communities have reported declining fish stocks and rising water treatment costs due to plastic contamination [14,32]. Cultural values also intersect with environmental use, as rivers often serve ritual and recreational roles. Mitigation strategies could therefore be locally adapted, culturally sensitive, and community informed.

Addressing these challenges will require multi-pronged interventions that combine digital innovation, inclusive governance, and place-based community engagement. While decentralized and community-led waste systems have shown promise [33], their success depends on integration with formal infrastructure and sustained policy support. The results of the heatmap further highlight the need to elevate underrepresented issues, like the impact of terrestrial waste systems on aquatic ecosystems, within both scholarly research and policy agendas.

Knowledge Gaps

Despite significant advancements in understanding plastic pollution, several critical gaps remain, particularly regarding its long-term impacts and management in urban waterways. A recurring issue across the literature is the limited understanding of degradation pathways and the fate of plastics in urban ecosystems. As Emmerik et al. note, "Estimates of floating plastic mass transport and export into the ocean are still highly uncertain due to limited data, and insufficient understanding of the driving processes" [15] (p. 2). This highlights the need to bridge laboratory-based research with real-world field studies that reflect complex, site-specific dynamics.

Another major gap is the lack of longitudinal studies that examine the cumulative effects of plastic pollution on biodiversity and ecosystem health. While many cross-sectional studies document the presence of plastics in aquatic organisms, they fall short of capturing long-term ecological consequences. As Khuyen et al. observed, "monitoring of microplastic pollution is still a big challenge because the distribution of plastic debris is affected by different factors in the marine environment" [32] (p. 537). Sustained, multi-year monitoring programs, particularly those involving inter-institutional collaboration, are needed to assess temporal trends and inform adaptive responses.

A further barrier is the fragmentation of research efforts, where studies are often isolated, leading to siloed data, duplicated methodologies, and a lack of comparative frameworks. Transitioning to open-access data infrastructures, where datasets are shared across platforms, could consolidate knowledge and accelerate insights. Drawing from advances in marine bird conservation [34], the field would benefit from dynamic, real-time data systems that notify researchers, policymakers, and practitioners of emerging pollution trends. Such platforms would enhance transparency, facilitate regional collaboration, and ensure research outputs are accessible and actionable. As in marine bird conservation efforts [34], there is a need to move beyond small-scale, disconnected studies. Open, interoperable infrastructures would help unify monitoring initiatives and support faster, evidence-based decision-making at both local and global levels.

In addition, future research should aim to assess and visualize the scope, duration, and impact of existing monitoring efforts. Many initiatives are short-lived or lack sustainability planning. Although our review did not include longitudinal charts, due to the absence of consolidated datasets, we identify this as a clear priority for future work. Long-term programs, coupled with visual tracking of project life spans and results, would provide a more comprehensive picture of progress and persistent gaps.

Another underexplored area is the influence of behavioral and cultural factors on plastic waste generation and disposal. In Vietnam, for example, state generated plastic waste policies have grown, yet actual compliance remains inconsistent due to a mix of socio-cultural and economic barriers [35]. Understanding these dynamics might require different interdisciplinary approaches that integrate perspectives from sociology, economics, and environmental science.

Finally, geographic disparities in the literature continue to limit the generalizability of findings. While Southeast Asia, especially Vietnam, receives significant attention as a plastic pollution hotspot, the research landscape remains uneven. Much of the current work focuses on major river systems such as the Mekong, while smaller waterways and inland systems remain underrepresented (see Figure 4).

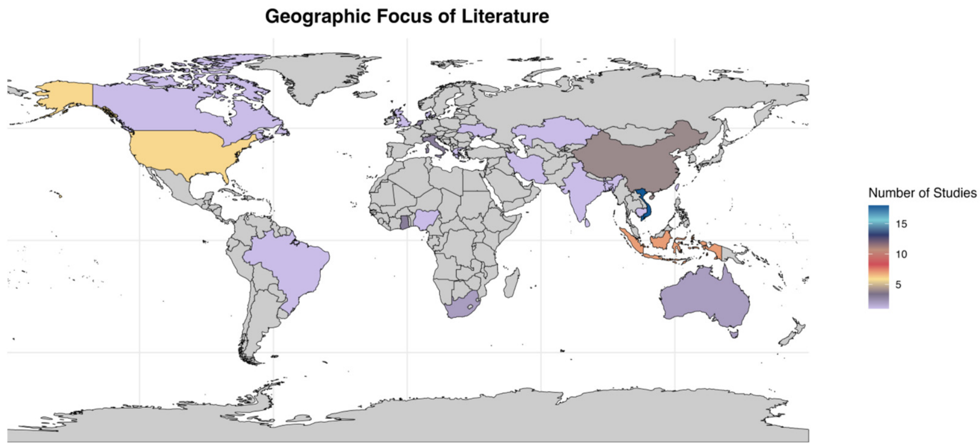

Figure 4. Global distribution of Plastic Pollution Research. Source: Created by the authors using geocoded metadata from 110 studies. Data processed and visualized in RStudio (ggplot2, sf, rnaturalearth, rnaturalearthdata, dplyr, and readxl). Map shows geographic spread and concentration of research outputs, highlighting underrepresented regions.

In this mapping, Sub-Saharan Africa and South America are particularly underrepresented, which limits the global applicability of current insights. Expanding the geographic scope of research, especially to include underexamined contexts within Southeast Asia, would help generate a more inclusive, comparative understanding of plastic pollution dynamics across diverse ecological and socio-economic settings.

3.4. Category Two: Advancing Approaches in Plastic Pollution Research

Building on the foundational understanding of plastic pollution dynamics, this section examines the tools, methodologies, and analytical frameworks used to study and mitigate the issue. Advances in sensor technologies, computational analysis, and cross-sectoral research have significantly expanded the field, enabling researchers to collect and interpret data with greater precision and contextual awareness. Here, we trace the evolution of these approaches and highlight emerging trends through two key visualizations, a Temporal Trend Graph and a Keyword Co-occurrence Network. These tools help illustrate shifts in research priorities, disciplinary intersections, and directions for future exploration.

3.4.1. Temporal Evolution of Research Focus

The Temporal Trend Graph (Figure 5) charts the annual distribution of plastic pollution research publications from 2016 to 2024, revealing a steady upward trajectory. Notably, the number of publications peaked in 2021, when 19 studies were published. This surge coincides with a global increase in awareness of plastic-related issues, exacerbated by the COVID-19 pandemic. The pandemic resulted in unprecedented levels of plastic consumption, particularly through personal protective equipment (PPE) and single-use packaging, which catalyzed a wave of new research aimed at understanding the environmental consequences [36]. In parallel, an influx of interdisciplinary interest, from behavioral science and policy analysis to environmental monitoring, contributed to the expansion of research outputs during this period [37,38].

While Figure 5 provides a useful overview of growth over time, a closer look at the thematic composition of 2021 publications reveals deeper insights. That year, five medium-sized themes dominated the literature: Policy Implications and SDG 14 (Life Below Water), Knowledge Gaps, Innovative Interventions, Integration of Theoretical Frameworks, and Plastic Pollution in Urban Waterways. Among these, Policy Implications and SDG 14 was the most frequently addressed. This trend aligns with a wave of international and national regulatory actions, including expanded commitments to the Basel Convention and intensified negotiations at the United Nations Environment Assembly for a binding plastics treaty [8].

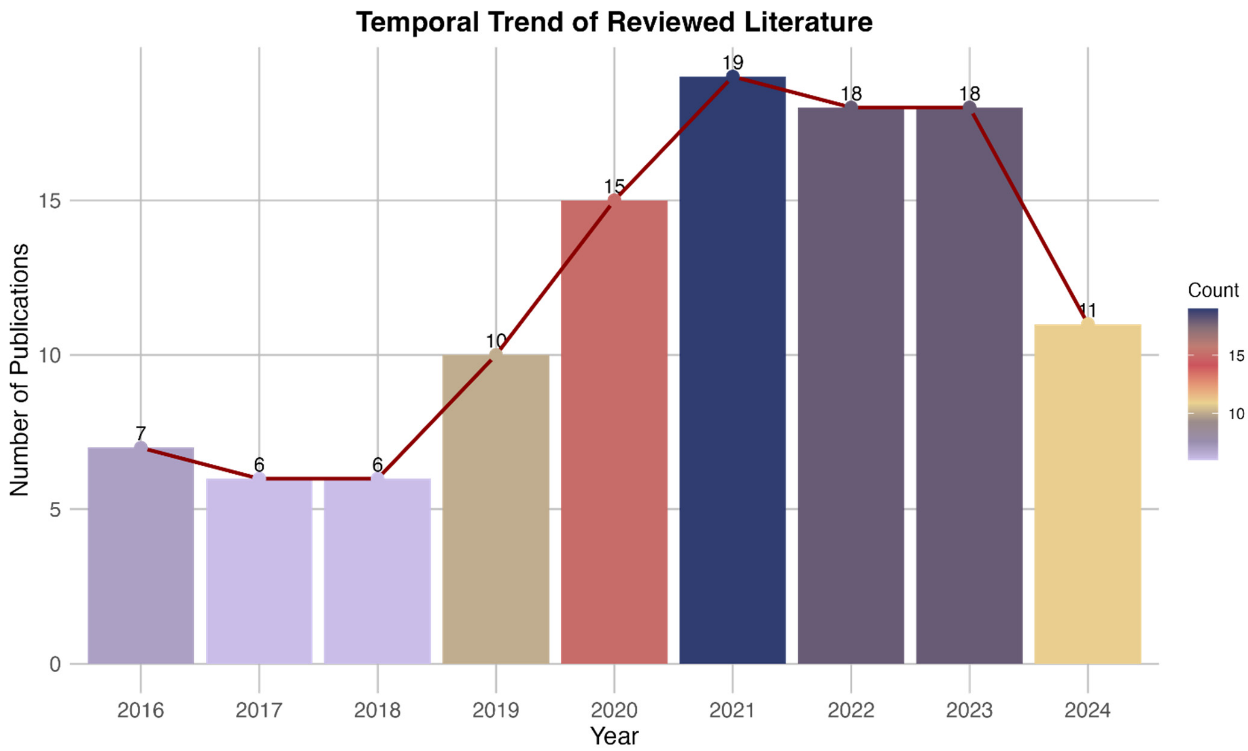

Figure 5. Temporal trend in Plastic Pollution Research (2016–2024). Source: Created by the authors. Based on publication year metadata from 110 reviewed studies. Plotted using RStudio (packages: ggplot2, dplyr). Shows a steady rise in research activity, with a peak in 2021 linked to pandemic related shifts in plastic use and research focus.

The prominence of this theme indicates that researchers were not only documenting plastic pollution but also critically engaging with governance frameworks as a means of intervention. The sharp rise in attention to SDG 14 mirrors developments in coastal and riverine countries, particularly in Southeast Asia, where policy responses such as Vietnam's National Action Plan for Marine Plastic Waste were actively assessed and discussed in the literature [35]. To complement these findings, Figure 6 presents a summary of the publications from 2021, showing the distribution of themes, geographic focus, and contributing journals. Studies from this year frequently explored the intersections between policy development, urban plastic flows, and tracking technologies.

The data confirms a strong research emphasis on policy and technological innovation, with many studies rooted in global or Southeast Asian contexts. Thematic emphasis on multi-sensor monitoring systems and community-driven waste management supports the broader narrative of a research agenda increasingly shaped by complexity, integration, and responsiveness to emerging challenges. These patterns also align with trends identified throughout the review, reinforcing the field's evolution toward greater interdisciplinarity. The studies highlighted in Figure 6 show a shift from siloed disciplinary approaches toward a more integrated framework that connects technology, policy, and ecological impact in addressing urban plastic pollution.

2021 Publications on Plastic Pollution

Summary of themes, geographic focus, and sources.

No	Publication Title	Year	Journal/Source	Geographic Focus	Research Theme(s)
7	Global Plastic Pollution Observation System to Aid Policy	2021	Environmental Science & Technology	Global	1, 2, 5, 6, 10
12	Individual and Situational Determinants of Plastic Waste	2021	BMC Psychology	Netherlands	5, 6, 9, 10
20	Source, Sea and Sink—A Holistic Approach	2021	Science of the Total Environment	Southern Caribbean	1, 2, 5, 6, 7, 9
23	Innovative Use of Plastic for a Clean Environment	2021	Urban Science	Ghana	1, 5, 6, 9, 10
24	Energy Efficient Watchman for IoT Networks	2021	ETRI Journal	Global	3, 4, 6, 9, 10
31	Municipal Solid Waste Collection Systems	2021	Waste Management & Research	Europe	5, 6, 9, 10
37	Effects of Urban Hydrology on Plastic Transport	2021	ACS EST Water	United States	1, 3, 5, 6, 7, 9
45	Transfer Learning for Waste Bottle Segmentation	2021	Advances in Intelligent Systems	Global	2, 3, 9
59	Anthropogenic Litter in Urban Rivers	2021	Environmental Pollution	Global	1, 3, 5, 6, 8, 10
61	Satellite Sensors for Monitoring Plastics	2021	Remote Sensing	Global	2, 3, 4, 6, 10
64	Microplastics in Ho Chi Minh City	2021	Marine Pollution Bulletin	Vietnam	1, 3, 5, 6, 8
65	Ecological and Health Risks in Saigon River	2021	Environmental Science & Pollution Research	Vietnam	3, 5, 6, 8
66	Motivation for Waste Management Policy	2021	Journal of Environmental Planning & Management	Vietnam	5, 6, 9, 10
80	Plastic Waste Accumulation Model in Indonesia	2021	ISPRS Int'l Journal of Geo-Information	Indonesia	1, 2, 3, 5, 6, 7, 8, 9, 10
88	Low-Cost Sensors for Air Pollution	2021	Preprints	Greece	2, 3, 4, 8, 10
92	Toxic Effects of Airport Runoff	2021	Sustainability	Europe	3, 5, 6, 8, 9, 10
101	China's Plastic Import Ban Impact	2021	Nature Communications	Global	1, 5, 6, 8, 10
106	Atmospheric Monitoring System Optimization	2021	Journal of Sensors	China	3, 4, 8, 9, 10
109	Artificial Fish Swarm for Water Monitoring	2021	Journal of Sensors	Global	2, 3, 4, 8, 10

Figure 6. Publications on plastic pollution in 2021. Source: Created by the authors using metadata from reviewed literature filtered by publication year (2021).

3.4.2. Multi-Sensor Systems for Environmental Monitoring

Multi-sensor systems have emerged as an important advancement in environmental monitoring, enabling more integrated and dynamic approaches to data collection [39,40]. Unlike traditional methods that typically rely on manual sampling or single-point measurements, these systems deploy a combination of sensors to capture multiple environmental parameters simultaneously [41]. This multiplex capability allows for a more subtle and holistic understanding of pollution dynamics, which are particularly valuable in planning targeted interventions across variable conditions.

While single-sensor approaches remain effective for monitoring specific parameters, multi-sensor configurations enable researchers to observe complex interactions between hydrological, atmospheric, and biological processes. For example, integrated camera systems and flow sensors have been used to measure floating plastics in riverine environments, significantly improving the accuracy of flux estimates [42]. Also, remote sensing technologies, such as satellite imagery and unmanned aerial vehicles (UAVs), have expanded the monitoring scale, making it possible to assess macroplastic distribution across broader spatial zones [43]. These innovations help address critical knowledge gaps in understanding the spatiotemporal variability of plastic transport, a challenge long noted in the literature. Emmerik et al. emphasize the difficulty of generating consistent datasets due to methodological inconsistencies and limited comparability between studies [44].

The emergence of Internet of Things (IoT)-enabled networks has further enhanced monitoring potential [45]. These systems often integrate sensors capable of detecting microplastics, measuring water quality parameters, tracking flow rates, and transmitting real-time data to centralized platforms for automated analysis. Such networks enable continuous, scalable observation of pollution events, offering insights that were previously difficult to obtain with analog systems. Despite their promise, the widespread deployment of multi-sensor systems faces several barriers. These include high setup and maintenance costs, technical complexities, and the absence of standardized calibration protocols across different geographic and institutional contexts [46]. Overcoming these challenges will require collaborative investment in low-cost, interoperable technologies and the development of shared methodological standards to ensure global comparability and reproducibility.

3.4.3. Data Analysis Techniques: Complex Sensor Systems

The increasing volume of data generated by multi-sensor systems has necessitated the use of advanced analytical techniques capable of extracting meaningful, context-sensitive insights. These approaches span traditional statistical models and newer computational tools, including machine learning and natural language processing, each contributing distinct strengths to the analysis of plastic pollution.

We find that statistical models continue to serve as the analytical backbone of environmental monitoring, offering tested frameworks for interpreting trends, variability, and correlation across diverse datasets. For instance, Strady et al. applied seasonal models to examine the relationship between river discharge rates and plastic transport, uncovering significant temporal fluctuations [31]. This example underscores the importance of integrating dynamic, time-sensitive variables into predictive models to improve their reliability.

Machine learning techniques have also emerged as particularly effective for processing large and complex datasets. Convolutional neural networks (CNNs), for example, have been used to identify and classify plastic types from image data, demonstrating high levels of accuracy in segmentation tasks [47]. These applications illustrate the scalability and adaptability of machine learning in supporting automated, high-throughput environmental monitoring across varied contexts.

The Keyword Co-occurrence Network (Figure 7) further illustrates the thematic architecture of plastic pollution research. Developed through text mining of the reviewed literature, the network visualizes the frequency and strength of relationships between key methodological and topical terms. Central nodes such as “plastic pollution”, “monitoring technologies”, and “data analysis” reveal the prominence of technology-focused inquiry [46]. In contrast, peripheral nodes like “community engagement”, suggest underexplored intersections between technological solutions and social dimensions, pointing to a need for more interdisciplinary integration.

Geospatial tools, particularly Geographic Information Systems (GIS), further extend analytical capacity by enabling spatial visualization and correlation. These systems are especially useful for mapping pollution hotspots and linking spatial data with socio-economic indicators. For example, Khuyen et al. used GIS alongside hydrological datasets to identify critical plastic pollution zones along the Saigon River, revealing strong spatial associations with industrial zones and informal settlements [32]. Such findings are descriptive, and they inform targeted interventions with the aim of optimizing policy and resource allocation strategies [35].

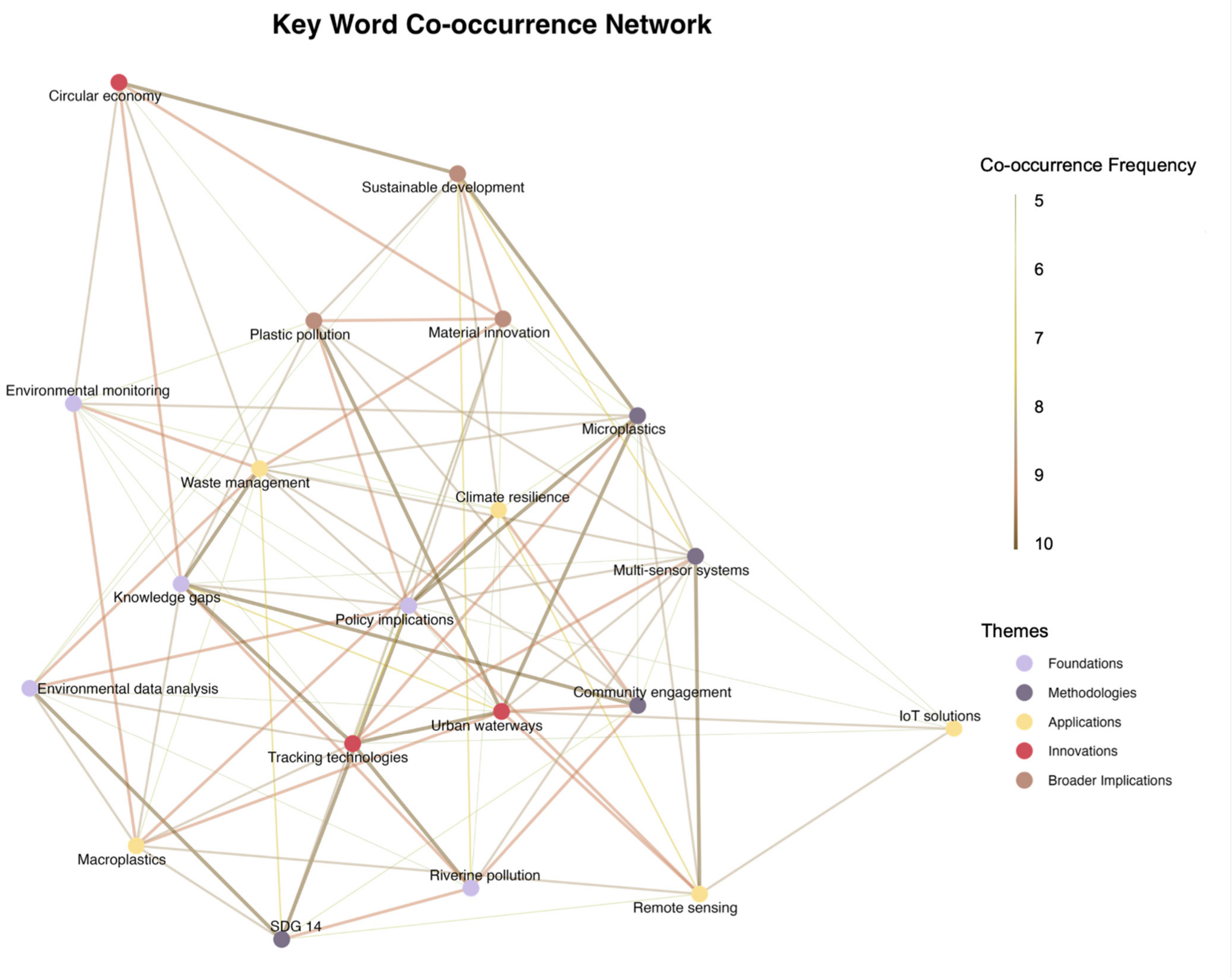

Figure 7. Source: Created by the authors. Network generated in RStudio using igraph, ggraph, tidyverse, and Manu packages. Node size indicates keyword frequency; edge thickness represents co-occurance strength (threshold ≥ 5). The Fruchterman-Reingold layout was applied to visualize key thematic clusters and relationships within the literature.

3.4.4. Bridging Gaps and Advancing Research

Despite recent progress, significant barriers remain in ensuring equitable access to advanced tools and methodologies in plastic pollution research [48,49]. Many of the most promising techniques, such as machine learning models and IoT-integrated sensor networks, require high computational power and specialized technical expertise, which limits their uptake in resource-constrained environments [26,50]. However, these constraints are not solely technical. Structural limitations, including restrictive data sharing protocols, institutional gatekeeping, and uneven funding mechanisms, also inhibit wider adoption and collaboration [2].

Current access models tend to privilege researchers affiliated with universities or government agencies, leaving independent researchers, community organizations, and citizen scientists with limited access to real-time data and analytic platforms [23]. This exclusion not only perpetuates inequalities in research capacity but also reduces the diversity of perspectives informing plastic pollution solutions. Addressing these disparities will require deliberate policy shifts. Open access databases, shared repositories, and decentralized monitoring platforms can facilitate broader engagement and co-ownership of data across sectors. Expanding the availability of user-friendly, low-cost analytical tools could also empower local actors to contribute meaningfully to pollution tracking and intervention design. Capacity-building initiatives, particularly in the Global South, alongside cross-border partnerships and knowledge-sharing programs, will be essential to support inclusive, long-term research ecosystems [3].

The methodologies discussed throughout this section underscore the transformative potential of technology when coupled with equitable access and interdisciplinary collaboration. Multi-sensor systems, GIS mapping, and machine learning applications have the power to link foundational scientific knowledge with localized, context-sensitive interventions. Yet, realizing this potential depends on overcoming barriers related to affordability, standardization, and institutional openness.

When aligned with broader insights from the Temporal Trend Graph and the Keyword Co-occurrence Network, these methodological innovations offer a pathway toward an understanding of plastic pollution dynamics, one that is both technically robust and socially responsive. This integrated approach could help shape more effective solutions to one of the most complex environmental challenges of our time.

3.5. Category Three: Innovative Solutions and Practical Interventions

Building on the methodologies explored in the previous section, this part of the review examines how innovative applications and real-world interventions are being deployed to address the global challenge of plastic pollution. These approaches reflect the transformative potential of technological tools, grassroots initiatives, and interdisciplinary frameworks that operate across both local and global contexts [51]. By drawing on insights from foundational research and emerging monitoring technologies, the examples presented here illustrate how the field is increasingly moving from analysis to actionable solutions.

3.5.1. Innovative Interventions

Innovative approaches to plastic waste management are becoming critical tools in reducing pollution at scale. These strategies often challenge conventional waste systems by integrating community participation, circular economy principles, and technological advancements to build more resilient infrastructures. One compelling example comes from Can Tho City, Vietnam, where researchers documented a circular economy model that linked household-level plastic segregation with formal municipal recycling. The study highlighted how multi-layered interventions, combining education, sorting infrastructure, and coordinated collection, can effectively reduce plastic leakage while strengthening local engagement [52].

Biodegradable alternatives to conventional plastics also represent a growing area of interest. Hira et al. examined the adoption of bioplastics in developing countries, highlighting both their environmental promise and the complexity of their deployment. Key concerns include consumer confusion over degradability claims, inequitable access to certified products, and the unintended consequences of large-scale bioplastic production, such as potential increases in food prices and land use conflicts [3]. It is important to note that the terms biodegradable plastics and bioplastics are sometimes used interchangeably in public discourse but are technically distinct. Bioplastics generally refers to materials derived from biological sources like starch or cellulose and may or may not be biodegradable. This is different to biodegradable plastics, which are defined by their ability to break down under specific environmental conditions, regardless of the source of feedstock. This distinction has significant policy and consumer implications, particularly in contexts where public understanding of these categories remains limited [14,16,20].

Southeast Asia has also seen progress through decentralized urban waste management. In Ho Chi Minh City, for example, a pilot initiative established neighborhood-based plastic shredding and sorting stations. This model significantly reduced plastic inflow into nearby waterways and demonstrated the viability of community interventions tailored to local waste streams [30].

Despite these successes, many innovations face persistent barriers, including financial constraints, limited technical capacity, and socio-cultural resistance. As Gacutan et al. emphasize, successful implementation depends not only on technical innovation but also on enabling policy environments, trust-building, and cultural sensitivity [50].

3.5.2. IoT-Based Solutions

The integration of IoT technologies into plastic pollution research has opened new avenues for real-time tracking, data collection, and adaptive response systems. These technologies enhance situational awareness and optimize resource deployment across waste management operations.

Sensor-based IoT networks have been implemented to monitor plastic pollution in urban waterways, combining flow meters, visual sensors, and microplastic detectors to track the movement and accumulation of plastic waste. These systems have enabled more targeted responses, leading to improved accuracy in identifying hotspots and deploying cleanup or prevention efforts [15,53].

In Vietnam, smart waste bins equipped with geolocation and fill-level sensors have been used to streamline collection routes, reduce operational costs, and increase recycling rates. These examples illustrate how IoT can serve not only environmental goals but also operational efficiency and urban resilience [14].

IoT platforms also support predictive analytics, enabling stakeholders to anticipate pollution events and intervene proactively. By integrating IoT data streams with machine learning algorithms, it becomes possible to forecast plastic accumulation trends, identify patterns of illegal dumping, or pre-empt infrastructure overload. This shift from reactive to predictive management supports the principles of adaptive governance and long-term planning [54].

However, the deployment of IoT systems is not without challenges. High initial costs, concerns around data privacy and cybersecurity, and uneven technological infrastructure across regions remain key barriers to equitable adoption. Meijer et al. [7] (p. 7), stress the importance of international cooperation and capacity-building to ensure that IoT solutions do not exacerbate existing disparities but instead contribute to more inclusive and effective management frameworks [7].

3.6. Category Four: Integrating Perspectives

The broader implications of plastic pollution research extend beyond technical innovations, demanding an integrated understanding of societal systems, ecological interdependencies, governance structures, and philosophical paradigms. While engineering and monitoring solutions are crucial, the persistence and complexity of plastic pollution also calls for a critical reflection on the values, behaviors, and institutional frameworks that shape human–environment interactions.

In this context, theoretical frameworks serve as interpretive lenses, enabling researchers to unpack the deeper implications of empirical findings. For example, post-phenomenology offers a means of examining how technologies, such as tracking systems, waste infrastructure, and data platforms can mediate human perceptions and actions within environmental systems [55]. This perspective reframes plastic pollution not simply as a technical problem to be solved, but as a socio-technological phenomenon that evolves in tandem with urban life, consumption habits, and environmental governance.

Similarly, ecological materialism draws attention to the active role of matter, in this case, plastic, as a participant in ecological systems. It challenges anthropocentric narratives by recognizing plastic's persistence, mobility, and entanglement with living and non-living systems. This includes marine biota and river sediments [9]. Through this lens, plastic is a pollutant and a material actor that reshapes environments and forces reconsideration of agency, responsibility, and resilience.

This category also foregrounds the interplay between policy and place, emphasizing that effective interventions must be contextually grounded in the cultural, political, and environmental realities of local communities. In Southeast Asia, for example, plastic pollution often intersects with urban inequality, informal economies, and spiritual relationships to rivers and water bodies. As such, regulatory measures could be informed not only by scientific evidence but also by local knowledge, cultural practices, and social dynamics.

The integration of perspectives within this thematic category reinforces the need for interdisciplinary collaboration, bringing together design, sociology, policy, data science, and environmental humanities, to generate responses that are both scalable and sensitive to context. This approach aligns with global calls for systems thinking in sustainability and science, recognizing that the challenges posed by plastic pollution cannot be addressed through isolated or purely technical means.

By synthesizing the diverse strands of empirical and the conceptual, space for theoretical innovation could be made that grounds solutions in the lived realities of the communities most affected by plastic pollution.

3.6.1. Societal and Ecological Contexts

Plastic pollution exerts multifaceted impacts on both human communities and natural ecosystems, producing cascading effects across socio-ecological systems. Urban rivers, in particular, serve as critical connectors between land and sea, and thus represent focal points where these intersecting impacts are most visible. For example, studies in Vietnam have highlighted the ecological consequences of plastic pollution in urban canals. Microplastics, which disrupt aquatic ecosystems, also pose risks to human health through bioaccumulation in the food chain [14]. Fieldwork in these contexts shows that both macro and microplastic contamination are not only environmental hazards but also public health concerns, particularly in areas with limited access to clean water and food security infrastructure [24]. In addition to physical fragmentation, plastics also undergo chemical degradation in aquatic environments. They release hazardous monomers and oligomers. An example of this is polystyrene, which can leach styrene oligomers such as styrene trimer [30]. These compounds are persistent in water systems and are biologically active. Styrene trimer has been shown to metabolize in fish and disrupt cellular processes, including damage to osteoclasts that are critical for bone maintenance and immune response [6,32]. This chemical pathway adds an important dimension to the socio-ecological risks of plastic pollution, especially in regions reliant on freshwater ecosystems for food and livelihood.

The socio-economic implications are equally pronounced, particularly for fishing communities in Southeast Asia. In the Mekong Delta, declining fish stocks and increased operational costs are direct consequences of plastic debris entangling nets and contaminating aquatic habitats [52]. These disruptions to local fisheries illustrate how environmental degradation undermines livelihoods, amplifies existing inequalities, and compromises long-term food system resilience.

Beyond economic losses, plastic pollution manifests as a societal issue with psychological and cultural dimensions. Communities in heavily polluted areas often report feelings of helplessness and disempowerment, which are exacerbated by inadequate governmental responses [24]. This sense of environmental despair has been linked to diminished community wellbeing and reduced civic engagement. Such findings show the importance of community empowerment and participatory approaches to addressing pollution challenges effectively.

Empirical evidence increasingly supports the idea that effective solutions must be rooted in context-sensitive social engagement strategies [4,33]. Programs that incorporate local knowledge, values, and lived experience not only increase intervention uptake but also build long-term environmental stewardship.

3.6.2. Policy Implications

Policies targeting plastic pollution must navigate complex trade-offs, balancing environmental objectives with socio-economic realities. Southeast Asia has seen government-led initiatives such as Vietnam's ban on single-use plastics, which successfully raised public awareness. However, without sufficient investment in monitoring systems, institutional coordination, and waste management infrastructure, the practical impact of these initiatives remains limited [56]. These findings highlight a recurring gap between policy design and implementation, which often undermines the effectiveness of legislative measures.

On a global scale, the Basel Convention amendments regulating transboundary plastic waste trade represent an important step toward addressing environmental disaster. By tightening regulations on the international movement of plastic waste, these amendments have placed pressure on high-exporting countries to improve domestic processing capacity. However, they have also led to unintended consequences, such as the proliferation of informal recycling initiatives operating outside regulatory frameworks. This systemic evolution exposes workers to significant health risks while exacerbating environmental degradation in under-resourced regions [3].

This reveals a deeper tension in current governance models, namely, the risk of policy externalities that shift rather than solve pollution burdens. Effective policy interventions must therefore address both systemic and localized challenges, particularly in regions with weak infrastructural support.

3.6.3. Successful Policy Case Studies

Despite challenges, certain policy interventions have achieved measurable success. For example, Malaysia's Extended Producer Responsibility (EPR) program incentivizes manufacturers to bear the costs of plastic waste disposal, resulting in a reported 15% increase in national recycling rates over a three-year period [50]. Similarly, Singapore's integrated waste management system, which combines stringent regulatory enforcement, centralized waste-to-energy infrastructure, and community education campaigns, has consistently achieved recycling rates exceeding 60% [43]. These examples illustrate the value of aligning regulatory frameworks with broader urban development agendas, demonstrating that coordinated, systems-based policy design can yield tangible environmental outcomes.

Comparative perspectives also emphasize the importance of tailoring policies to local contexts. While the European Union's Plastic Strategy has significantly reduced landfill dependency and curtailed plastic waste exports through unified legislative instruments and circular economy incentives, direct replication of such models in Southeast Asia remains challenging. Structural constraints, including the prevalence of informal recycling economies, limited municipal capacity, and variable enforcement capabilities, necessitate a more adaptive and context-sensitive policy approach [24].

These findings reinforce the importance of capacity-building, knowledge transfer, and phased policy implementation in lower-income regions. Designing scalable interventions in diverse settings requires not only policy diffusion but also structural adaptation, where best practices are translated and localized rather than imported wholesale.

3.6.4. Integration of Theoretical Frameworks

Building on the earlier discussion of theoretical perspectives, this section explores how frameworks such as post-phenomenology and ecological materialism are operationalized in plastic pollution research. Rather than framing plastic pollution solely as a technical or ecological issue, these approaches contextualize how technologies mediate human–environment interactions and how materials like plastic exert agency within ecosystems, particularly in relation to emerging digital and sensor-based innovations.

At the same time, integration with established scientific frameworks such as systems ecology, hydrological modeling, and environmental chemistry remains essential [20]. These frameworks provide the empirical grounding necessary for interpreting material flows, assessing pollutant behavior, and modeling ecosystem impacts [14–16]. When used in tandem with more interpretive approaches, they enable a fuller picture, one that combines measurable impacts with social, sensory, and ethical considerations [4].

For example, post-phenomenology can be applied to examine how technologies such as IoT-enabled sensors or drones not only gather data but also shape user experience and environmental perception. Participatory research involving local stakeholders in the deployment and interpretation of these technologies can foster new narratives and promote agency in responding to pollution [55,57].

Ecological materialism supports inquiry into how plastic waste interacts with microbial communities, alters sedimentation, or influences nutrient cycles in urban rivers [9]. For instance, drone-based monitoring systems have been considered as tools for enhancing stakeholder engagement by visualizing pollution hotspots and fostering more informed dialog between communities and policymakers [44]. Similarly, research on plastics in the Saigon River has demonstrated how plastic particles contribute to biofilm formation, influencing water quality, nutrient cycles, and oxygen levels [32].

Taken together, these examples highlight the importance of interdisciplinary theoretical integration. By bringing together scientific frameworks and socially embedded perspectives, future research could deepen both understanding and action on plastic pollution.

3.6.5. Advancing Research and Policy Through Integration

The review reveals a persistent gap between academic research on plastic pollution and its practical application in policymaking. While a significant body of literature explores technological innovations and community-based strategies, few studies provide clear models for translating these findings into integrated policy frameworks [26,31,35]. This fragmentation limits the potential for coordinated evidence-based responses to plastic pollution.

Several publications highlight the importance of interdisciplinary collaboration but stop short of detailing how such integration occurs in practice. For example, GIS-based spatial analyses have been used to identify pollution hotspots, yet their incorporation into urban planning or regulatory enforcement remains inconsistent [32,35]. Similarly, while community-based monitoring and waste sorting programs show promise at the local level, few are systematically linked to broader municipal or national strategies [14,30].

A number of studies emphasize the need for co-developed interventions involving researchers, policymakers, and local stakeholders. However, these partnerships are often described in aspirational terms rather than presented as established models [3,37,52]. This suggests that while the value of integration is widely recognized, mechanisms to support it, such as shared data platforms, cross-sector task forces, or joint funding streams, are still underdeveloped. The literature also points to challenges in scaling successful interventions. Local innovations often lack the institutional support needed for expansion. These limitations underscore the need for more robust frameworks that align research outputs with policy instruments, enabling long-term, system-wide impact. Although integration between research and policy is widely acknowledged as critical, this review finds limited evidence of sustained or institutionalized mechanisms for achieving it. The patterns emerging across these themes offer insight into current research strengths and gaps, which are further examined in the following section.

4. Discussion

Drawing together the discussion, this section outlines the study's contributions and future research directions. This review synthesizes insights from the evolving landscape of plastic pollution research, underscoring the central role of urban waterways as conduits for plastic waste [8], and the growing integration of scientific [58], technological [18], ecological [12], and social perspectives in tackling this environmental crisis [10,11]. The findings reinforce the need for interdisciplinary approaches, bringing together environmental scientists, engineers, sociologists, and policymakers [22,23], to develop more effective solutions that combine advanced monitoring tools [21], grassroots engagement [26,50], and policy-driven initiatives [12,24].

Urban rivers such as the Saigon River in Vietnam are shown to contribute significantly to plastic waste transfer from land to sea [32,58,59]. Seasonal dynamics particularly during monsoon periods, have a marked effect on plastic flux, as studies by Emmerik et al. and Strady et al. illustrate [8,31]. This variability highlights the limitations of cross-sectional data and the importance of longitudinal approaches capable of capturing temporal shifts in pollution patterns.

Technological innovations have reshaped research on plastic pollution. Multi-sensor monitoring systems, including IoT-enabled sensors [21], satellite imaging [39], and GIS-based tools [40,43], are increasingly supplementing or replacing traditional field sampling. These technologies offer datasets with precise measurements across spatial and temporal scales. The combination of Internet of Things (IoT) devices, machine learning models, and spatial mapping techniques now enables researchers to monitor complex waste pathways more effectively [15,47]. However, the diffusion of these tools remains uneven, with challenges related to affordability, technical capacity, and cross-site comparability persisting in many contexts. An example of these implementation challenges can be seen in the deployment of a GPS-enabled plastic bottle tracker in Vietnam [25]. The device combined a 3DR Pixhawk flight controller, UBlox M6 GPS, MPU6000 accelerometer, magnetometer, barometer, and a 13 dBi monopole antenna. It ran on open-source Ardurover firmware, with remote telemetry facilitated by a 4G dongle connected to a Raspberry Pi Zero. Over a nine-day fieldwork period, the system collected high-resolution GPS and sensor data across 205 km of the Saigon River. Despite its functionality, several technical limitations were encountered, including sensitivity to antenna orientation, limited battery life, inconsistent mobile network coverage, and disruption caused by wake turbulence from commercial river traffic. While analysis using a Hidden Markov Model enabled detailed interpretation of plastic movement states, effect evaluation indicators such as recovery rates and predictive accuracy were difficult to validate due to the lack of baseline data and the variability of river conditions. Comparable implementation difficulties were noted in a wireless river monitoring study conducted in Ghana [18]. There, wireless sensor nodes, using Arduino Uno R3 microcontrollers and XBee Pro wireless communication modules were deployed along the Tar River. Some of these installations were compromised by environmental hazards, including animal interference (notably alligators), harsh weather, and unstable node positioning. These two examples show that while technological innovations offer significant potential for riverine pollution, field-based deployments remain highly susceptible to local environmental conditions and infrastructural constraints. Addressing these issues requires both improved technical design and context-specific implementation strategies. The keyword co-occurrence analysis (Figure 5) highlights research hotspots at the intersection of monitoring technologies, governance, and public engagement [35,56]. It also reveals persistent blind spots, particularly regarding the cultural and community-level implications of pollution. Case studies such as Gampaha Municipality [51] and Can Tho City, Vietnam [52], illustrate the impact of community led waste initiatives. However, scaling these efforts often depends on the extent to which local programs are integrated into wider policy frameworks and supported with sustained resources [38,56,57].

Policy-oriented findings [13,17,22,35], reinforce the importance of national and international coordination. Instruments such as the Basel Convention amendments and Vietnam's plastic reduction laws illustrate growing regulatory awareness, yet the literature points to gaps in enforcement and data-sharing capacity. The heatmap analysis further reveals imbalances in how SDG targets are addressed, showing stronger ties to SDG 14 Life Below Water, but weaker engagement with SDG 6 Clean Water and SDG 15 Life on Land. These patterns reflect a continued emphasis on marine pollution at the expense of inland waterways and terrestrial leakage, indicating room for broader alignment across sustainability targets. Malaysia's Extended Producer Responsibility program, cited for its measurable improvements in recycling outcomes, shows the potential of policy frameworks when backed by enforcement and public involvement [50].

Geographical representation remains uneven. While the literature has many case studies from Southeast Asia and parts of Europe, other regions, particularly sub-Saharan Africa and South America, remain underexplored (Figure 3). The concentration of studies in Southeast Asia reflects both the severity of pollution and the availability of funding and institutional partnerships in countries such as Vietnam and Indonesia. This geographic skew limits the ability to draw general conclusions about global patterns and interventions. In addition, while urban river systems in large cities such as Ho Chi Minh City and Can Tho, both located in the greater Mekong River delta, are relatively well documented, there is far less research on waterways in medium sized cities, rural communities and informal settlements. These environments may face unique waste management challenges and social contexts that differ from major urban centers. As such, caution should be exercised when generalizing findings from large cities to other localities, and future research could expand its coverage to include more diverse and underrepresented areas.

Another major constraint is the fragmentation of data and research outputs. The review identifies a tendency toward isolated, short-term studies with limited collaboration between institutions and countries [46]. This siloed model weakens cumulative learning and hinders policy integration. Several studies call for open-access, real-time data infrastructures to support information sharing, enhance coordination, and enable timely interventions [15]. Establishing such systems remains an important next step in the evolution of the field.

Theoretical contributions, including post-phenomenology [55] and ecological materialism [9], offer tools for re-framing plastic waste as both a material and social actor. These perspectives help explain how human-technology relations and material agency shape environmental outcomes [57]. While not widely applied in current empirical studies, these frameworks invite engagement with the cultural and behavioral dimensions of pollution and present opportunities for deeper integration in future work [38]. This review highlights the need for sustained, interdisciplinary, and contextually grounded research on plastic pollution. Bridging geographic and methodological gaps, while strengthening collaboration across sectors, will be key to developing solutions that are effective, scalable, and just. Technological innovation, global cooperation, and deeper social engagement must work in concert if we are to move beyond incremental improvements and toward structural change in how plastic waste is monitored, managed, and ultimately prevented.

5. Conclusions

This scoping review has provided a synthesis of the current state of plastic pollution research, particularly in the context of urban waterways and technological innovations for mitigation. By integrating insights from interdisciplinary studies, this paper highlights the critical role of urban rivers as conduits of plastic waste, underscoring their significance for marine ecosystems, local communities, and policy development.

Key findings indicate that while technological advancements, such as IoT-enabled plastic tracking, multi-sensor monitoring, and GIS-based mapping, have enhanced our capacity to assess and address pollution, questions around affordability, access, and long-term implementation remain unresolved. Community-led interventions, decentralized waste management models, and circular economy approaches have shown success at the local level, but broader adoption depends on stronger policy alignment and cultural acceptance.

The review also highlights the value of interpretive frameworks that explore the entanglement of plastic with human and ecological systems. While not yet mainstream in environmental science, such approaches can offer alternative perspectives for analyzing and designing interventions.

Despite progress, key limitations persist, including a lack of long-term ecological studies, insufficient attention to behavioral and social drivers, and geographic imbalances in research efforts. Addressing these challenges will require a commitment **to** longitudinal research, interdisciplinary collaboration, and greater inclusivity across regions and research communities.

This research directly informs the development of plastic tracking technologies, positioning them not only as tools for environmental monitoring but also as platforms for stakeholder engagement and policy experimentation. By promoting integrated strategies that combine empirical research, technological innovation, and community participation, future work could make a meaningful contribution to addressing plastic pollution, both locally and globally, in alignment with sustainable development goals.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su17157009/s1, File S1: R Workflow and Code Overview.

Author Contributions: Conceptualization, P.C., D.C., A.M., K.H.D., A.N.P.H., L.F.R. and K.T.D.; methodology, P.C., D.C. and A.M.; software, P.C.; validation, P.C. and D.C.; data curation, P.C.; writing—original draft preparation, P.C., D.C. and A.M.; writing—review and editing, P.C., D.C., A.M., K.H.D., A.N.P.H., L.F.R. and K.T.D.; visualization, P.C., D.C., A.M. and A.N.P.H.; funding acquisition, A.M. and P.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Auckland University of Technology grant number R1267910.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Hoque, A.; Mohiuddin, M.; Su, Z. Effects of industrial operations on socio-environmental and public health degradation: Evidence from a least developing country (ldc). *Sustainability* **2018**, *10*, 3948. [CrossRef]
2. Bank, M.S.; Swarzenski, P.W.; Duarte, C.M.; Rillig, M.C.; Koelmans, A.A.; Metian, M.; Wright, S.; Provencher, J.F.; Sanden, M.; Jordaan, A.; et al. Global plastic pollution observation system to aid policy. *Environ. Sci. Technol.* **2021**, *55*, 7770–7775. [CrossRef]
3. Hira, A.; Pacini, H.; Attafuah-Wadee, K.; Vivas-Eugui, D.; Saltzberg, M.; Yeoh, T.N. Plastic waste mitigation strategies: A review of lessons from developing countries. *J. Dev. Soc.* **2022**, *38*, 336–359. [CrossRef]
4. McCormick, A.R.; Hoellein, T.J. Anthropogenic litter is abundant, diverse, and mobile in urban rivers: Insights from cross-ecosystem analyses using ecosystem and community ecology tools. *Limnol. Oceanogr.* **2016**, *61*, 1718–1734. [CrossRef]
5. Kotsiuba, I.; Herasymchuk, O.; Shamrai, V.; Lukianova, V.; Anpilova, Y.; Rybak, O.; Lefter, I. A strategic analysis of the prerequisites for the implementation of waste management at the regional level. *Ecol. Eng. Environ. Technol.* **2023**, *24*, 55–66. [CrossRef]

6. Geyer, R.; Jambeck, J.; Law, K.L. Production, use, and fate of all plastics ever made. *Sci. Adv.* **2017**, *3*, e1700782. [CrossRef] [PubMed]
7. Meijer, L.J.; Van Emmerik, T.; Van der Ent, R.; Schmidt, C.; Lebreton, L. More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean. *Sci. Adv.* **2021**, *7*, eaaz5803. [CrossRef]
8. Emmerik, T.V.; Schwarz, A. Plastic debris in rivers. *WIREs Water* **2019**, *7*, e1398. [CrossRef]
9. Nukusheva, A.; Rustembekova, D.; Abdizhami, A.; Au, T.; Kozhantayeva, Z. Regulatory obstacles in municipal solid waste management in Kazakhstan in comparison with the EU. *Sustainability* **2023**, *15*, 1034. [CrossRef]
10. Schuyler, Q.; Wilcox, C.; Townsend, K.A.; Wedemeyer-Strombel, K.R.; Balazs, G.H.; Sebille, E.V.; Hardesty, B.D. Risk analysis reveals global hotspots for marine debris ingestion by sea turtles. *Glob. Change Biol.* **2016**, *22*, 567–576. [CrossRef]
11. Blettler, M.C.M.; Abrial, E.; Khan, F.R.; Sivri, N.; Espínola, L.A. Freshwater plastic pollution: Recognizing research biases and identifying knowledge gaps. *Water Res.* **2018**, *143*, 416–424. [CrossRef]
12. Murphy, E.L.; Bernard, M.; Iacona, G.; Borrelle, S.B.; Barnes, M.; McGivern, A.; Emmanuel, J.; Gerber, L.R. A decision framework for estimating the cost of marine plastic pollution interventions. *Conserv. Biol.* **2021**, *36*, e13827. [CrossRef]
13. Calcar, C.V.; Emmerik, T.V. Abundance of plastic debris across European and Asian rivers. *Environ. Res. Lett.* **2019**, *14*, 124051. [CrossRef]
14. Nguyen, N.T.; Nhon, N.T.T.; Hai, H.T.N.; Thien, N.D.; Hiền, T.T. Characteristics of microplastics and their affiliated PAHS in surface water in Ho Chi Minh City, Vietnam. *Polymers* **2022**, *14*, 2450. [CrossRef] [PubMed]
15. van Emmerik, T.; de Lange, S.; Frings, R.; Schreyers, L.; Aalderink, H.; Leusink, J.; Begemann, F.; Hamers, E.; Hauk, R.; Janssens, N.; et al. Hydrology as a driver of floating river plastic transport. *Earth's Future* **2022**, *10*, e2022EF002811. [CrossRef]
16. Ng, C.H.; Mistoh, M.A.; Teo, S.H.; Galassi, A.; Ibrahim, A.; Sipaut, C.S.; Foo, J.; Seay, J.; Taufiq-Yap, Y.H.; Janaun, J. Plastic waste and microplastic issues in Southeast Asia. *Front. Environ. Sci.* **2023**, *11*, 1142071. [CrossRef]
17. Ferronato, N.; Maalouf, A.; Mertenat, A.; Saini, A.; Khanal, A.; Copertaro, B.; Yeo, D.; Jalalipour, H.; Veuthey, J.R.; Ulloa-Murillo, L.M.; et al. A review of plastic waste circular actions in seven developing countries to achieve sustainable development goals. *Waste Manag. Res. J. Sustain. Circ. Econ.* **2023**, *42*, 436–458. [CrossRef]
18. Adu-Manu, K.S.; Katsriku, F.A.; Abdulai, J.; Engmann, F. Smart river monitoring using wireless sensor networks. *Wirel. Commun. Mob. Comput.* **2020**, *2020*, 1–19. [CrossRef]
19. Zhou, J.; Qi, G.; Liu, C. A chaotic parallel artificial fish swarm algorithm for water quality monitoring sensor networks 3d coverage optimization. *J. Sens.* **2021**, *2021*, 5529527. [CrossRef]
20. Emmerik, T.V.; Kirschke, S.; Schreyers, L.; Nath, S.; Schmidt, C.; Wendt-Potthoff, K. Estimating plastic pollution levels in rivers through harmonized monitoring strategies. *Res. Sq.* 2023, *Preprint*. [CrossRef]
21. Wu, F.; Rüdiger, C.; Redouté, J.; Yuce, M.R. A wearable multi-sensor iot network system for environmental monitoring. In *Advances in Body Area Networks*; Internet of Things; Fortino, G., Wang, Z., Eds.; Springer: Cham, Switzerland, 2019. [CrossRef]
22. Debrah, J.K.; Vidal, D.G.; Dinis, M.A.P. Innovative use of plastic for a clean and sustainable environmental management: Learning cases from Ghana, Africa. *Urban Sci.* **2021**, *5*, 12. [CrossRef]
23. Basuki, T.M.; Indrawati, D.R.; Nugroho, H.Y.S.H.; Pramono, I.B.; Setiawan, O.; Nugroho, N.P.; Nada, F.M.H.; Nandini, R.; Savitri, E.; Adi, R.N.; et al. Water pollution of some major rivers in Indonesia: The status, institution, regulation, and recommendation for its mitigation. *Pol. J. Environ. Stud.* **2024**, *33*, 3515–3530. [CrossRef]
24. Phelan, A.; Ross, H.; Setianto, N.A.; Fielding, K.S.; Pradipta, L. Ocean plastic crisis—Mental models of plastic pollution from remote Indonesian coastal communities. *PLoS ONE* **2020**, *15*, e0236149. [CrossRef] [PubMed]
25. Cleveland, P.; Morrison, A. Sông Sài Gòn: Extreme Plastic Pollution Pathways in Riparian Waterways. *Sensors* **2025**, *25*, 937. [CrossRef] [PubMed]
26. Syberg, K.; Palmqvist, A.; Khan, F.R.; Strand, J.; Vollertsen, J.; Clausen, L.P.W.; Feld, L.; Hartmann, N.B.; Oturai, N.; Møller, S.; et al. A nationwide assessment of plastic pollution in the Danish realm using citizen science. *Sci. Rep.* **2020**, *10*, 17773. [CrossRef] [PubMed]
27. Issifu, I.; Sumaila, U.R. A review of the production, recycling and management of marine plastic pollution. *J. Mar. Sci. Eng.* **2020**, *8*, 945. [CrossRef]
28. Kirk, E.A.; Popattanachai, N.; Barnes, R.A.; van der Marel, E.R. (Eds.) *Research Handbook on Plastics Regulation*; Edward Elgar Publishing: Cheltenham, UK, 2024. [CrossRef]
29. Maruf, M.; Chang, Y.; Yang, L. Managing institutional interlinkages for the protection of marine environment in the east Asian seas region and beyond: The case of marine plastic pollution. *Ocean. Coast. Manag.* **2024**, *255*, 107232. [CrossRef]
30. Lahens, L.; Strady, E.; Kieu-Le, T.-C.; Dris, R.; Boukerma, K.; Rinnert, E.; Gasperi, J.; Tassin, B. Macroplastic and microplastic contamination assessment of a tropical river (Saigon River, Vietnam) transversed by a developing megacity. *Environ. Pollut.* **2018**, *236*, 661–671. [CrossRef]
31. Strady, E.; Kieu-le, T.; Truong, T.; Nguyen, P.; Pham, N.; Inamura, Y. Riverine microplastic pollution in Vietnam: A review of current scientific knowledge and legal policies. *Appl. Environ. Res.* **2023**, *45*, 251188. [CrossRef]

32. Khuyen, V.T.K.; Le, D.V.; Le, H.A.; Fischer, A.; Dornack, C. Assessing microplastic prevalence and dispersion from Saigon urban canals via Can Gio mangrove reserve to east sea by Raman scattering microscopy. *Microplastics* **2022**, *1*, 536–553. [CrossRef]
33. Phan, T.T.T.; Nguyen, V.V.; Nguyen, H.T.T.; Lee, C. Integrating citizens' importance-performance aspects into sustainable plastic waste management in Danang, Vietnam. *Sustainability* **2022**, *14*, 10324. [CrossRef]
34. Morrison, A.; Lukaszewicz, S. A Perspective on Conservation Technologies for Endangered Marine Birds. *Insights Vet. Sci.* **2023**, *7*, 10–14. [CrossRef]
35. Nguyen, T.; Watanabe, T. Autonomous motivation for the successful implementation of waste management policy: An examination using an adapted institutional analysis and development framework in Thua Thien Hue, Vietnam. *Sustainability* **2020**, *12*, 2724. [CrossRef]
36. Wang, Q.; Zhang, M.; Li, R. The COVID-19 pandemic reshapes the plastic pollution research—A comparative analysis of plastic pollution research before and during the pandemic. *Environ. Res.* **2022**, *208*, 112634. [CrossRef] [PubMed]
37. Cowan, E.; Tiller, R. What shall we do with a sea of plastics? a systematic literature review on how to pave the road toward a global comprehensive plastic governance agreement. *Front. Mar. Sci.* **2021**, *8*, 798534. [CrossRef]
38. MacDonald, A.; Allen, D.; Williams, L.; Flowers, P.; Walker, T.R. People, plastic, and behaviour change—A comment on drivers of plastic pollution, barriers to change and targeted behaviour change interventions. *Environ. Sci. Adv.* **2023**, *2*, 551–557. [CrossRef]
39. Sakti, A.D.; Rinasti, A.N.; Agustina, E.; Diastomo, H.; Muhammad, F.; Anna, Z.; Wikantika, K. Multi-scenario model of plastic waste accumulation potential in Indonesia using integrated remote sensing, statistic and socio-demographic data. *ISPRS Int. J. Geo-Inf.* **2021**, *10*, 481. [CrossRef]
40. Duncan, E.M.; Davies, A.; Brooks, A.; Chowdhury, G.W.; Godley, B.J.; Jambeck, J.; Maddalene, T.; Napper, I.; Nelms, S.E.; Rackstraw, C.; et al. Message in a bottle: Open source technology to track the movement of plastic pollution. *PLoS ONE* **2020**, *15*, e0242459. [CrossRef]
41. Winterstetter, A.; Grodent, M.; Kini, V.; Ragaert, K.; Vrancken, K.C. A review of technological solutions to prevent or reduce marine plastic litter in developing countries. *Sustainability* **2021**, *13*, 4894. [CrossRef]
42. Tasseron, P.; Begemann, F.; Joosse, N.; Ploeg, M.V.d.; Driel, J.V.; Emmerik, T.V. Urban water systems as entry points for river plastic pollution. *Res. Sq.* 2022, *Preprint*. [CrossRef]
43. Mukonza, S.S.; Chiang, J. Satellite sensors as an emerging technique for monitoring macro- and microplastics in aquatic ecosystems. *Water Emerg. Contam. Nanoplastics* **2022**, *1*, 17. [CrossRef]
44. Emmerik, T.V.; Strady, E.; Kieu-Le, T.; Nguyen, L.B.; Gratiot, N. Seasonality of riverine macroplastic transport. *Sci. Rep.* **2019**, *9*, 13549. [CrossRef]
45. Draz, U.; Ali, T.; Ahmad Zafar, N.; Saeed Alwadie, A.; Irfan, M.; Yasin, S.; Ali, A.; Khan Khattak, M.A. Energy efficient watchman based flooding algorithm for iot-enabled underwater wireless sensor and actor networks. *ETRI J.* **2021**, *43*, 414–426. [CrossRef]
46. Vriend, P.; Roebroek, C.T.J.; Emmerik, T.V. Same but different: A framework to design and compare riverbank plastic monitoring strategies. *Front. Water* **2020**, *2*, 563791. [CrossRef]
47. Jaikumar, P.; Vandaele, R.; Ojha, V.K. Transfer learning for instance segmentation of waste bottles using mask R-CNN algorithm. In *International Conference on Intelligent Systems Design and Applications*; Springer International Publishing: Cham, Switzerland, 2020; pp. 140–149. [CrossRef]
48. Malthus, T.J.; Ohmsen, R.; Woerd, H.v.d. An evaluation of citizen science smartphone apps for inland water quality assessment. *Remote Sens.* **2020**, *12*, 1578. [CrossRef]
49. Liu, C.-S.; Chen, X.-T.; Shih, W.-Y.; Lin, C.-C.; Yen, J.-H.; Huang, C.-J.; Yen, Y.-T. Smart water quality monitoring technology for fish farms using cellphone camera sensor. *Sens. Mater.* **2023**, *35*, 3019. [CrossRef]
50. Gacutan, J.; Oliver, J.L.; Tait, H.; Praphotjanaporn, T.; Milligan, B. Exploring how citizen science projects measuring beach plastic debris can support un sustainable development goals. *Citiz. Sci. Theory Pract.* **2023**, *8*, 40. [CrossRef]
51. Hapuarachchi, H.A.D.T. Community participation in municipal solid waste management: Special reference to Gampaha municipality. *Int. J. Sci. Res. Arch.* **2024**, *11*, 1153–1158. [CrossRef]
52. Thanh, N.T.; Van Toan, P.; Van Ty, T.; Lavane, K.; Minh, H.V.T.; Van Duy, D.; Kumar, P.; Tantray, F.A.; Meraj, G. Assessment and sustainable management strategies for plastic waste in Can Tho City, Vietnam: A circular economy approach. *Water* **2024**, *16*, 951. [CrossRef]
53. Emmerik, T.V.; Schreyers, L.; Mellink, Y.; Sok, T.; Arias, M.E. Large variation in Mekong River plastic transport between wet and dry season. *Front. Environ. Sci.* **2023**, *11*, 1173946. [CrossRef]
54. Hong, S.; Lee, J.Y.; Gandla, S.; Park, J.; Cho, H.; Kim, S. Resistive water sensors based on pedot:pss-g-pegme copolymer and laser treatment for water ingress monitoring systems. *ACS Sens.* **2019**, *4*, 3291–3297. [CrossRef] [PubMed]
55. Broers, V.; Scharrenburg, M.V.; Fredrix, L.; Lataster, J.; Löhr, A.; Jacobs, N. Individual and situational determinants of plastic waste sorting: An experience sampling method study protocol. *BMC Psychol.* **2021**, *9*, 92. [CrossRef]
56. Khuc, Q.V.; Dang, T.; Tran, M.; Nguyen, D.T.; Nguyen, T.; Pham, P.; Tran, T. Household-Level Strategies to Tackle Plastic Waste Pollution in a Transitional Country. *Urban Sci.* **2023**, *7*, 20. [CrossRef]

57. Zhang, O.; Takaffoli, M.; Ertz, M.; Addar, W. Environmental impact assessment of plastic waste management scenarios in the Canadian context. *Environments* **2023**, *10*, 213. [CrossRef]
58. Haberstroh, C.; Arias, M.E.; Yin, Z.; Wang, M.C. Effects of urban hydrology on plastic transport in a subtropical river. *ACS EST Water* **2021**, *1*, 1714–1727. [CrossRef]
59. Giang, N.B.; Tuan, T.N.; Tin, H.C.; Chung, D.T.; Ni, T.N.K.; Binh, N.H.; Nhung, D.T.; Tuan, L.C.; Son, T.M.; Khuyen, N.T.B. Current plastic waste status and its leakage at Tam Giang–Cau Hai lagoon system in central Vietnam. *Urban Sci.* **2023**, *7*, 89. [CrossRef]