MICROPLASTIC POLLUTION IN THE DIPOLOG RIVER: ASSESSMENT AND IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT

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Abstract

Microplastic pollution is a critical environmental issue that affects aquatic ecosystems globally. This study investigates the presence, composition, and concentration of microplastics in the Dipolog River, a crucial water resource in Zamboanga del Norte, Philippines. The research utilizes a comprehensive sampling and analytical approach to assess the distribution of microplastics across three distinct sites: Piñan (upstream), Polanco (midstream), and Dipolog City (downstream). The findings reveal significant microplastic contamination, predominantly comprising fibers and fragments of polymers such as polyethylene (PE), polypropylene (PP), and polystyrene (PS). The study highlights the urgent need for sustainable waste management practices and public awareness to mitigate the adverse effects of microplastics on human health and the environment. The research also provides recommendations for policy development, infrastructure enhancement, and further research, contributing valuable baseline data for future studies.

Keywords and phrases: *Microplastic Pollution, Dipolog River, Aquatic Ecosystems, Waste Management, Environmental Policy*

Introduction

Microplastics, defined as plastic particles smaller than 5 mm, have emerged as pervasive contaminants in aquatic environments. These particles originate from various sources, including the degradation of larger plastic debris (secondary microplastics) and the direct release of small plastic particles, such as microbeads in personal care products (primary microplastics) (Auta et al., 2017; Hale et al., 2020). The resilience of these materials, combined with their widespread use, has resulted in their ubiquitous presence in marine and freshwater systems (Rochman et al., 2019). Microplastics pose significant risks to marine life, potentially causing physical harm, chemical toxicity, and the bioaccumulation of pollutants in the food chain.

The Dipolog River, flowing through the Zamboanga del Norte province in the Philippines, is a vital water resource for the local population, supporting domestic, agricultural, and industrial activities. However, the river is increasingly threatened by pollution from various anthropogenic activities, including improper waste disposal and runoff from agricultural lands. This study aims to provide a comprehensive assessment of the microplastic pollution in the Dipolog River, examining the distribution and characteristics of microplastics along different sections of the river. The research seeks to identify potential sources of contamination and propose strategies for sustainable management and mitigation.

Methods

This study employed a descriptive research design, incorporating both quantitative and qualitative methods to assess the presence and characteristics of microplastics in the Dipolog River. Conducted in July 2019, the research involved sampling across three sites representing different environmental conditions: Piñan (upstream), Polanco (midstream), and Dipolog City (downstream). The selection of these sites aimed to capture a comprehensive understanding of microplastic distribution along the river continuum, as the Dipolog River originates from Mt. Malindang in Misamis Occidental and flows through several municipalities before emptying into the Sulu Sea. This river serves as a critical source of water for various uses, making it an essential study area for understanding microplastic pollution.

The sampling sites were chosen based on their geographical location and the degree of human activity, which is expected to influence the concentration and composition of microplastics. Piñan, characterized by a rural area with low population density and limited industrial activities, was expected to have lower levels of microplastic contamination. In contrast, Polanco, a sub-urban area with moderate human activity, including agriculture and small-scale industries, and Dipolog City, an urban area with significant population density and industrial activities, were likely contributing to higher levels of pollution.

Water samples were collected from the surface and water column (up to 3 meters deep) at each site, using stainless steel bottles pre-rinsed with tap and site water to minimize contamination. The collected samples were transported to the laboratory for analysis, where microplastics were isolated using vacuum filtration and particles were visually identified under a stereo microscope at 45× magnification. The identification criteria included size, shape, color, and lack of cellular structure. To confirm the polymer types, a subset of samples underwent Fourier Transform Infrared Spectroscopy (FTIR) analysis, identifying polymers such as PE, PP, and PS among others. The concentration of microplastics was calculated as the number of particles per liter of water, with additional characterization involving categorizing the microplastics by type (fibers, fragments, films) and color (black, blue, transparent, etc.).

Ethical Considerations

Ethical considerations were central to the study's design and implementation. Informed consent was obtained from all participants, ensuring they were fully aware of the study's purpose, procedures, and potential risks. Data confidentiality was strictly maintained, with all identifying information anonymized in the analysis and reporting. The study adhered to the ethical guidelines set forth by the institutional review board and relevant national and international regulations.

Results

The analysis of water samples from the Dipolog River revealed a pervasive presence of microplastics across all three sampling sites, with notable variations in concentration, composition, and physical characteristics. The total microplastic count varied significantly between sites, reflecting the influence of local environmental conditions and human activities. Dipolog City (downstream) recorded the highest concentration of microplastics, with an average of 1,200 particles per liter, while Polanco (midstream) had approximately 800 particles per liter, and Piñan (upstream) exhibited the lowest concentration, with around 400 particles per liter. These findings suggest a gradient of pollution, increasing with proximity to urban and industrial areas.

The microplastics identified in the samples were categorized into three primary types: fibers, fragments, and films. Fibers were the most prevalent, accounting for approximately 60% of the total microplastics observed. These fibers, predominantly black, blue, and transparent, are likely derived from synthetic textiles, indicating that domestic laundry activities and untreated wastewater discharges are significant sources. The presence of fibers aligns with findings from other studies in similar river systems, which also report a dominance of fibrous microplastics (Browne et al., 2011; Dris et al., 2016).

Fragments constituted around 30% of the microplastics and were mainly composed of polyethylene (PE) and polypropylene (PP). These fragments, often irregularly shaped and varying in size, are attributed to the breakdown of larger plastic debris, such as packaging materials, bottles, and containers. The presence of PS fragments, although less common, points to the disposal of foam-based products like disposable cutlery and insulation materials. Films, representing 10% of the microplastics, were primarily found in the downstream area, suggesting contributions from plastic bags and packaging films, which are commonly used in urban areas.

In terms of size distribution, the majority of microplastics were within the range of 10.1 µm to 50.0 µm. This size range is critical as smaller particles are more likely to be ingested by aquatic organisms, leading to potential bioaccumulation and biomagnification through the food chain. The prevalence of smaller-sized microplastics also indicates advanced degradation of plastic debris, likely facilitated by environmental factors such as UV radiation, mechanical abrasion, and microbial activity.

Further analysis using Fourier Transform Infrared Spectroscopy (FTIR) confirmed the polymer composition of the microplastics. PE and PP were the dominant polymers, consistent with their widespread use in consumer products and packaging. The detection of PS and occasional polyvinyl chloride (PVC) particles underscores the diverse sources of plastic pollution, including industrial processes and consumer waste. The presence of these polymers is particularly concerning due to their potential to adsorb and transport toxic chemicals, thereby posing additional risks to aquatic life and human health.

The spatial distribution of microplastics in the Dipolog River also revealed important insights. The higher concentrations observed in the downstream area (Dipolog City) correlate with higher population density and industrial activities, highlighting the significant impact of urbanization on microplastic pollution. The midstream area (Polanco), with its agricultural activities and moderate urbanization, showed intermediate levels of pollution, indicating that both rural and urban activities contribute to the microplastic load. The upstream area (Piñan), relatively less affected by direct human activities, exhibited the lowest concentration of microplastics, suggesting that natural processes and limited human interference result in lower levels of contamination.

Overall, the results indicate that microplastic pollution in the Dipolog River is a complex issue influenced by various factors, including population density, industrial activity, waste management practices, and natural environmental conditions. The findings provide a critical baseline for understanding the extent of microplastic contamination in the river and underscore the need for targeted interventions to mitigate the impact of this emerging pollutant. The comprehensive data on microplastic types, sizes, and polymer composition will be invaluable for future monitoring and research efforts aimed at addressing microplastic pollution in freshwater systems.

Discussion

The presence of microplastics in aquatic environments has become a critical global concern, with significant implications for ecosystems, human health, and socio-economic systems. The findings from the Dipolog River align with global trends, indicating widespread contamination by microplastics. This section will discuss the implications of these findings, compare them with other studies, and explore potential policy and practice implications, as well as limitations of the study.

The observed microplastic pollution in the Dipolog River, characterized predominantly by fibers and fragments, mirrors findings from various global studies. For instance, similar contamination patterns were reported in the Yangtze River, where fibers constituted the majority of microplastic particles, highlighting the significant contribution of synthetic textiles to microplastic pollution (Xiong et al., 2018). Likewise, studies in European rivers, such as the Thames and the Danube, identified fibers as a prevalent type of microplastic, suggesting that wastewater effluents and urban runoff are major pathways for microplastics entering aquatic systems (Murphy et al., 2016; Lechner et al., 2014).

The identification of polymers such as polyethylene (PE), polypropylene (PP), and polystyrene (PS) is consistent with findings from other studies, indicating these materials' widespread use and subsequent contribution to pollution. For example, a study in the Great Lakes region of North America also reported high concentrations of these polymers, reflecting their prevalence in packaging materials and consumer products (Eriksen et al., 2013). These similarities suggest a commonality in the sources and types of microplastic pollution across diverse geographic regions, emphasizing the global nature of this issue.

The pervasive presence of microplastics in the Dipolog River and their potential ecological and health impacts necessitate urgent policy and practical interventions. First, there is a critical need for comprehensive waste management policies that include regulations on plastic production, use, and disposal. Implementing extended producer responsibility (EPR) schemes can hold manufacturers accountable for the entire lifecycle of their products, encouraging the design of more sustainable and less harmful materials (Lau et al., 2020).

Additionally, improving infrastructure for wastewater treatment is essential. Many existing facilities are not equipped to filter out microplastics, allowing these particles to enter water bodies. Upgrading these systems to include advanced filtration technologies, such as membrane bioreactors and granular activated carbon, can significantly reduce microplastic emissions (Magnusson et al., 2016).

Public awareness campaigns are equally important. Educating the public about the sources and impacts of microplastics can lead to more responsible consumer behavior, such as reducing the use of single-use plastics and participating in proper waste disposal and recycling initiatives. Furthermore, community-based initiatives, such as river clean-up programs and plastic waste collection drives, can engage local populations in addressing this issue (Hartley et al., 2018).

International cooperation is also crucial. Microplastic pollution is a transboundary issue, as evidenced by studies showing plastic debris traveling across oceans and accumulating in regions far from the source (Lebreton et al., 2018). International treaties and agreements, such as the Basel Convention and the proposed global treaty on plastic pollution, can provide frameworks for cooperative action and the harmonization of regulations.

Potential Limitations of the Study

While this study provides valuable insights into the microplastic pollution in the Dipolog River, several limitations must be acknowledged. One limitation is the scope of the sampling period, which was limited to a specific timeframe (July 2019). Microplastic concentrations can vary seasonally due to changes in water flow, weather conditions, and human activities. A more extended study period, encompassing different seasons, would provide a more comprehensive understanding of microplastic pollution dynamics.

Another limitation is the focus on surface water samples. While this method effectively captures floating microplastics, it may overlook particles that settle on the riverbed or are suspended in deeper water layers. Future studies should include sediment sampling and water column profiling to capture a broader range of microplastic distribution.

The study also relied heavily on visual identification and FTIR analysis for polymer identification. While these methods are widely used, they may not detect all types of microplastics, particularly those smaller than 10 µm, which require more sophisticated analytical techniques, such as Raman spectroscopy or pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) (Prata et al., 2019).

Finally, the study did not assess the potential chemical contaminants associated with microplastics. These particles can adsorb toxic substances from the environment, such as heavy metals and persistent organic pollutants (POPs), which can pose additional risks to aquatic life and human health. Future research should explore the chemical interactions between microplastics and contaminants to better understand the full scope of their impact.

Conclusions

This research provides a detailed assessment of microplastic pollution in the Dipolog River, offering valuable baseline data for future studies. The findings highlight the significant presence of microplastics, predominantly fibers, and fragments, with a notable concentration in urban areas. The study emphasizes the urgent need for targeted interventions to address microplastic pollution, including policy development, infrastructure improvements, and public engagement. The results also underscore the potential risks to human health and the environment, necessitating immediate and coordinated action.

Based on the study's findings, several specific recommendations are proposed to address microplastic pollution in the Dipolog River, focusing on immediate and localized actions:

Local governments and environmental agencies should enforce stringent regulations on plastic waste management. Policies should include restrictions on single-use plastics, incentives for using biodegradable materials, and extended producer responsibility (EPR) schemes to ensure manufacturers are accountable for their products' entire lifecycle.

Investment in modern waste treatment infrastructure, including recycling facilities and advanced wastewater treatment plants, is crucial. These facilities should be equipped to handle microplastic filtration and prevent their release into water bodies.

Public education campaigns should focus on the impacts of microplastics and the importance of reducing plastic use. Community involvement in clean-up drives and waste management initiatives should be encouraged to foster a collective effort in addressing this issue.

Continued research is necessary to understand the long-term effects of microplastics and to develop effective removal techniques. Long-term monitoring programs should track microplastic concentrations and assess the effectiveness of implemented measures.

Engaging stakeholders, including local communities, industries, and NGOs, is essential for developing and implementing effective strategies. Collaborative efforts can lead to innovative solutions and shared responsibilities in mitigating microplastic pollution.

By focusing on these specific and immediate interventions within the context of the Dipolog River, the study can significantly contribute to reducing microplastic pollution and protecting the local aquatic ecosystem. This approach will ensure that the recommendations are practical and directly applicable, avoiding broader contexts that may dilute the immediate impact of these strategies.

By implementing these targeted strategies, the Dipolog River can serve as a model for effective microplastic pollution management in the region. These efforts align with Sustainable Development Goals (SDGs) by promoting clean water and sanitation (SDG 6), ensuring sustainable consumption and production patterns (SDG 12), and protecting life below water (SDG 14). Emphasizing these specific strategies within the immediate context will foster a healthier and more sustainable environment for the local community and beyond.

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Disclosure: Use of AI Tools

In compliance with Threshold's guidelines for the ethical use of artificial intelligence (AI) and automated tools in academic research, the authors disclose the use of OpenAI's ChatGPT for enhancing the quality and clarity of the manuscript. ChatGPT was utilized to assist in refining the language, structure, and formatting of the text, ensuring a high level of academic rigor and coherence. The authors confirm that all data analysis, critical interpretations, and conclusions presented in this manuscript were conducted independently by the research team. The AI tool was employed strictly for editorial assistance and did not influence the scientific content or ethical considerations of the study. All intellectual contributions from the AI tool are in accordance with the authors' original intentions and have been reviewed and approved by all co-authors. The use of ChatGPT complies with Threshold's ethical standards and guidelines for transparent reporting of AI involvement in research. The authors remain fully responsible for the integrity and accuracy of the content presented in this paper.

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