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INTERRELATED THREATS: PLASTIC AND CHEMICAL POLLUTION IN THE OCEANS AND THEIR IMPACT ON AQUATIC FOOD SECURITY

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Abstract

Purpose: This study examines the intertwined threats of plastic and chemical pollution in marine ecosystems and their implications for aquatic food security. Both forms of pollution have become increasingly urgent global concerns, as they threaten biodiversity, ecosystem services, and the safety of seafood consumed by millions of people worldwide. **Design/Methodology/Approach**: A qualitative, descriptive exploratory research design was applied, combining systematic literature review and semi-structured expert interviews. Data were collected from peer-reviewed journal articles indexed in Scopus, technical reports from international organizations (e.g., FAO, UNEP), and policy documents. Thematic analysis was employed to identify patterns, relationships, and emerging issues concerning plastic chemical interactions and their impact on food safety and security. **Findings**: The findings highlight that plastic pollution, particularly microplastics and nanoplastics, causes direct physiological stress to marine organisms and serves as a vector for hazardous chemicals such as persistent organic pollutants (POPs) and heavy metals. Chemical pollutants, especially mercury and pesticides, exhibit bioaccumulative and biomagnifying effects along aquatic food webs. The combined exposure amplifies risks, undermines ecosystem stability, and poses potential health hazards for human consumers. This dual threat jeopardizes both marine biodiversity and global food security. **Practical Implications**: The study emphasizes the urgency of integrated policy responses, including stricter waste management, reduced use of single-use plastics, and stronger regulations on toxic chemicals. It also suggests the need for cross-disciplinary research focusing on realistic co-exposure scenarios, sensitive detection methods for nano microplastics, and risk assessments for seafood safety in diverse socio-ecological contexts. **Originality/Value**: By addressing the synergistic effects of plastic and chemical pollution, this study contributes to filling a critical gap in the discourse on marine environmental risks. It underscores the multidimensional nature of ocean pollution, ecological, socio-economic, and health-related, while providing insights for policymakers, researchers, and practitioners seeking sustainable solutions to safeguard marine ecosystems and aquatic food security.

Keywords: *Marine pollution; Microplastics; Chemical contaminants; Food security; Bioaccumulation; Environmental governance*

Introduction

The ocean is the largest ecological system on earth that provides a wide range of environmental services, from climate regulators, carbon sinks, to the main source of food for billions of people. Marine ecosystems support the sustainability of the aquatic food chain which is the basis of global food security, especially for coastal communities that are highly dependent on marine products as a source of protein (FAO, 2020). However, in recent decades, the ocean has faced tremendous pressure due to human activities, particularly plastic and chemical pollution. These two forms of pollutants not only exacerbate the degradation of marine ecosystems, but also pose a serious threat to aquatic food security (UNEP, 2021).

Plastic pollution has been identified as one of the most pressing environmental problems of the 21st century. Every year millions of tons of plastic enter the ocean through rivers, fishing activities, and poorly managed waste disposal (Jambeck et al., 2015). Plastics that are fragmented into microplastics and nanoplastics have the ability to accumulate in the bodies of marine organisms. These particles can cause physical effects such as blockage of the digestive tract and chemical effects due to the release of harmful additives (Rochman et al., 2016). The accumulation of plastics in the aquatic food chain poses a serious risk, both to marine biodiversity and to the humans who consume it (Galloway et al., 2017).

On the other hand, chemical pollution from pesticides, heavy metals, hydrocarbons, and industrial chemicals also enters the ocean through land runoff, mining activities, and oil spills. These chemicals have toxic, persistent, and bioaccumulative properties that can damage the physiology of marine organisms (García-Galán et al., 2017). Heavy metals such as mercury, for example, can be concentrated in high levels of predatory fish, thereby magnifying the impact of bioaccumulation and biomagnification along the food chain (Zhang et al., 2022). The interaction between chemical pollutants and marine organisms not only reduces species diversity, but also threatens the quality of marine food consumed by humans (Costa et al., 2020).

What makes this problem even more complex is the interaction between plastic and chemical pollution. Plastics in the ocean often act as vectors for harmful chemicals by absorbing persistent organic pollutants (POPs) and heavy metals from the aquatic environment (Koelmans et al., 2016). As a result, marine organisms that ingest microplastics are not only exposed to mechanical risks, but also inherent chemical contaminants. Thus, plastic and chemical pollution are not two separate threats, but rather are interrelated and reinforce their negative impact on marine ecosystems (Hermabessiere et al., 2017).

The combined impact of plastic and chemical pollution directly has implications for aquatic food safety. Consumption of polluted fish and marine life has the potential to cause health problems in humans, including neurotoxic problems, endocrine disorders, and carcinogenic risks (Barboza et al., 2018). In addition, the declining quality and quantity of marine products can affect the economic and social stability of coastal communities. Therefore, the issue of marine pollution is not only an ecological problem, but also a multidimensional problem that includes public health, social welfare, and global food security (Prata et al., 2020).

Seeing the complexity of this problem, a holistic research and policy approach is needed to understand and overcome the threat of marine pollution. Research on the linkages between plastic and chemical pollution to the aquatic food chain can provide a scientific basis for more effective mitigation strategies (Lusher et al., 2017). In addition, the integration of international efforts through a global environmental framework is essential to reduce sources of pollution from land and sea (UNEP, 2021). Thus, this study is expected to make a significant contribution to understanding the dynamics of the dual threat of marine pollution and its implications for aquatic food security.

Literature review

Sources, pathways, and dynamics of plastic & chemical pollution in the ocean

The literature suggests that plastic inputs to the oceans come from poor management of land, river flows, fishing activities, and maritime transport; Influential early estimates put millions of tons of plastic into the ocean each year (Jambeck et al., 2015). In the marine environment, plastics are fragmented into microplastics (<5 mm) and nanoplastics, while additives (e.g. BPA, phthalates) can be released into the water column (Hermabessiere et al., 2017). In parallel, chemical pollutants including pesticides, heavy metals, polycyclic aromatic hydrocarbons (PAHs), and persistent organic pollutants (POPs) enter through agricultural runoff, industrial estates, oil spills, and atmospheric deposition (UNEP, 2021). A global review confirms the spatio-temporal co-existence of plastics and chemical contaminants in coastal zones densely populated by human activity (Costa et al., 2020; FAO, 2020).

Microplastics as chemical vectors: evidence of absorption & co-exposure

A number of experimental studies and modelling have shown that plastic particles can absorb (adsorb/sorb) organic contaminants (e.g. PCB, DDT, PBDE) and metals, potentially act as "vehicles" that increase the bioavailability of pollutants for biota (Koelmans et al., 2016). These findings give rise to the concept of *multiple stressor exposure* of organisms that ingest microplastics not only to face physical stressors (abrasion, buildup in the intestines) but also to chemical exposures carried on plastic surfaces and dissolved in water (Galloway et al., 2017). Nevertheless, the intensity of plastic vectorial contribution relative to other chemical exposure pathways (food, water) is still a matter of debate, demanding a realistic mass- and dose-based quantification approach (Koelmans et al., 2016).

Effects on organisms: from sub-cellular responses to fitness

At the organism level, the literature reports a diverse range of responses: oxidative stress, inflammation, endocrine disruption, changes in eating behavior, decreased growth and reproduction in invertebrates, fish, and zooplankton (Barboza et al., 2018; Hermabessiere et al., 2017). For chemical contaminants, heavy metals such as Hg and Cd, as well as pesticides and antibiotics, exhibit toxicity affecting hematology, detoxification enzymes, neurotoxicity, and immunosuppression (García-Galán et al., 2017; Zhang et al., 2022). The effects of co-exposure (plastic + chemical) are potentially synergistic, but cross-species outcomes are still heterogeneous due to differences in particle size, polymer type, additives, environmental concentrations, and test protocols (Costa et al., 2020).

Food chains & biomagnification: implications for food security

Strong evidence suggests the bioaccumulation of Hg and increased methylmercury at high trophic levels, particularly predatory fish, is directly relevant to consumers (Zhang et al., 2022). For microplastics, findings in commercial biota (fish, bivalves, crustaceans) are quite consistent, with variability by habitat and post-harvest handling practices (Lusher et al., 2017; Barboza et al., 2018). Although the contribution of the chemical burden of plastic particles compared to other dietary sources is still being studied, the literature indicates the potential for cross-trophic transfer and *trophic dilution* or *magnification* depending on the nature of the contaminant (Galloway et al., 2017). A key aspect for food safety is the final concentration of chemical residues in human tissues as well as real daily intake (FAO, 2020).

Human health risks & socio-economic dimension

The initial risk assessment highlights the possible impacts to the nervous (methylmercury), endocrine, cardiometabolic systems, and carcinogenic risks of chronic exposure to mixed contaminants through the consumption of seafood (Barboza et al., 2018; Prata et al., 2020). On the other hand, the degradation of the quality of fish/shellfish stocks can decrease economic value, hit coastal livelihoods, and increase nutritional vulnerability, especially in communities that depend on marine protein (FAO, 2020). The global assessment report emphasizes that marine pollution is a cross-sectoral food security issue that requires upstream-downstream governance: from reducing pollution sources, improving waste infrastructure, to standardizing food safety (UNEP, 2021).

Mitigation, governance, and knowledge gaps

Mitigation efforts include policies to reduce single-use plastics, circular design (ecodesign, substitutes for harmful additives), better waste treatment, and *best management practices* in agriculture and industry to reduce chemical runoff (UNEP, 2021). On the science side, the urgent need includes: (i) standardized quantification methods for nanos or microplastics in biotic & food matrices; (ii) co-exposure studies with realistic environmental and dietary scenarios; (iii) determination of dose-response relationships in key commercial species; (iv) *consumer exposure assessment* based on local dietary habits; and (v) evaluation of the cost-benefits of pollution reduction policies on food safety outcomes (Koelmans et al., 2016; Costa et al., 2020; Lusher et al., 2017). Closing these gaps is important for formulating effective and measurable interventions.

Research Methods

This study uses a qualitative approach with a descriptive-exploratory design to deeply understand the phenomenon of plastic and chemical pollution in the ocean and its implications for aquatic food safety. The qualitative approach was chosen because environmental and food issues are complex, contextual, and involve multidimensional interactions between ecology, social, and policy. In line with the views of Creswell and Poth (2018) and Silverman (2020), qualitative methods allow researchers to comprehensively explore stakeholders' experiences, narratives, and perceptions, resulting in richer insights than just quantitative data.

Data collection is carried out through in-depth literature review of scientific articles, international organization reports (FAO, UNEP), policy documents, and relevant research results obtained from reputable databases such as Scopus, ScienceDirect, and Emerald. In addition, semi-structured interviews with marine environmental experts, academics, as well as fisheries and public health practitioners were conducted to gain a field perspective. The purposive sampling technique is used to select key informants who have direct experience in marine pollution or aquatic food management issues (Patton, 2015). This approach is in accordance with the principles of qualitative research that emphasizes the depth of information rather than the number of samples (Flick, 2018).

Data analysis was carried out using thematic analysis methods to identify patterns, categories, and themes that emerged from the data (Nowell et al., 2017). This process includes the stages of data reduction, organization, and interpretation based on the conceptual framework of the research. The validity and reliability of the results were maintained through triangulation of sources (literature, interviews, and institutional reports) and *peer debriefing* with academics in the field of environment and food (Vaismoradi et al., 2013). By adopting this qualitative analysis strategy, the study seeks to present a comprehensive mapping of the relationship between plastic and chemical pollution, its impact on marine ecosystems, and its implications for aquatic food security.

Results and discussion

Plastic pollution as a real threat

The results of a literature analysis show that plastic pollution, particularly microplastics, has been detected in almost all of the world's marine ecosystems, including in commercial organisms such as fish, shellfish, and crustaceans. Global studies estimate that more than 150 million tons of plastic have accumulated in the ocean, with an additional 4.8–12.7 million tons each year (Jambeck et al., 2015). Microplastics are found in marine biota tissues, potentially causing physiological effects such as indigestion, oxidative stress, and inflammation (Barboza et al., 2018). This fact confirms that plastic is not just a waste problem, but also a direct threat to the health of marine ecosystems and food chains.

Chemical pollution and bioaccumulation

Chemical pollutants, especially heavy metals such as mercury, cadmium, and lead, as well as pesticides and hydrocarbons, also show alarming levels of contamination. Heavy metals can accumulate in high-level predatory fish such as tuna and sharks through biomagnification processes (Zhang et al., 2022). This has direct implications for human health, as regular consumption of contaminated fish can trigger neurotoxicity, endocrine disorders, and an increased risk of cancer (Costa et al., 2020). The combination of persistent nature and chemical toxicity makes this pollution difficult to address without decisive policy intervention.

Plastics and chemical interactions as dual threats

Another significant finding is the interaction between plastics and harmful chemicals. Microplastics can act as vectors for persistent organic pollutants (POPs), pesticides, and heavy metals, thereby increasing toxic exposure to marine organisms (Koelmans et al., 2016). Experimental studies show that organisms that ingest microplastics are exposed to not only mechanical risks, but also chemical risks inherent in plastic surfaces (Hermabessiere et al., 2017). This dual threat worsens the condition of marine ecosystems and increases the complexity of pollution management.

Implications for aquatic food security

The accumulation of plastic and chemical pollutants in marine organisms has serious consequences for aquatic food safety. The results of the study showed the presence of microplastics in fish and shellfish traded in the international market (Lusher et al., 2017). Meanwhile, heavy metal contamination in fish consumption has long been a global issue that threatens consumer health, especially in areas with high levels of seafood consumption (Galloway et al., 2017). This condition confirms that the degradation of marine food quality due to pollution can weaken food security and have an impact on the socio-economic stability of coastal communities.

Global mitigation and policy directions

These findings confirm the need for a more comprehensive mitigation strategy. Interventions on pollution sources, such as reducing single-use plastics, improving waste management systems, and controlling the use of hazardous chemicals, are top priorities (UNEP, 2021). In addition, international cooperation in the *framework of pollution governance* must be strengthened to reduce the burden of pollution across countries. Further research needs to be directed towards understanding the mechanisms of co-exposure, long-term health impacts on humans, as well as the development of more sensitive pollutant detection technologies. Thus, collective efforts can be directed not only at the protection of marine ecosystems, but also at securing the aquatic food supply chain.

Conclusion

This study confirms that plastic and chemical pollution in the ocean is a dual threat that is interrelated and has a serious impact on the sustainability of marine ecosystems. Plastics, particularly microplastics and nanoplastics, not only cause mechanical disturbances in marine organisms, but also serve as vectors for harmful chemical pollutants. Meanwhile, chemical pollutants such as heavy metals and pesticides exacerbate conditions with their toxicity and bioaccumulation properties.

The interaction of the two creates new complexities in pollution exposure for marine life. Organisms that consume plastic face not only physical risks, but also inherent chemical contamination. This has an impact on the stability of the aquatic food chain and raises the potential for biomagnification to the level of peak consumers, including humans. Thus, this issue is not only ecological, but also touches on the dimensions of public health and food security.

Overall, these findings suggest that the degradation of marine food quality due to plastic and chemical pollution can undermine global food security. If not addressed immediately, these conditions have the potential to pose multidimensional risks: biodiversity loss, weakened livelihoods of coastal communities, and increased public health burdens. Therefore, the problem of marine pollution should be seen as a cross-sectoral crisis that requires international collaboration.

Suggestion

Based on the results of the research, there is a need for a stricter policy in controlling pollution sources, both from land and sea. The government, together with the private sector and the community, must strengthen waste management, limit the use of single-use plastics, and tighten regulations on the use of hazardous chemicals. In addition, it is important to strengthen the monitoring system for the quality of water and marine food so that it can detect potential health risks early. From the academic side, further research needs to focus on the mechanisms of co-exposure of plastic and chemical pollution to marine organisms with more realistic environmental scenarios. The development of more sensitive detection methods, especially for nanoplastics and complex chemical pollutants, is also urgent. Cross-disciplinary collaboration between environmental scientists, health experts, and policymakers will be key to designing effective interventions, to ensure the sustainability of marine ecosystems and future aquatic food security.

References

Barboza, L. G. A., Vethaak, A. D., Lavorante, B. R. B. O., Lundebye, A. K., & Guilhermino, L. (2018). Marine microplastic debris: An emerging issue for food security, food safety and human health. *Marine Pollution Bulletin, 133*, 336–348. https://doi.org/10.1016/j.marpolbul.2018.05.047

Costa, J. P., Santos, P. S. M., Duarte, A. C., & Rocha-Santos, T. (2020). (Nano)plastics in the environment – Sources, fates and effects. *Science of The Total Environment, 709*, 136189. https://doi.org/10.1016/j.scitotenv.2019.136189

FAO. (2020). *The State of World Fisheries and Aquaculture 2020*. Rome: Food and Agriculture Organization of the United Nations.

Galloway, T. S., Cole, M., & Lewis, C. (2017). Interactions of microplastic debris throughout the marine ecosystem. *Nature Ecology & Evolution, 1*(5), 0116. https://doi.org/10.1038/s41559-017-0116

García-Galán, M. J., Garrido, T., Fraile, J., Ginebreda, A., & Barceló, D. (2017). Simultaneous occurrence of pesticides and antibiotics in river sediments and aquatic biota. *Chemosphere, 178*, 267–277. https://doi.org/10.1016/j.chemosphere.2017.03.051

Hermabessiere, L., Dehaut, A., Paul-Pont, I., Lacroix, C., Jezequel, R., Soudant, P., & Duflos, G. (2017). Occurrence and effects of plastic additives on marine environments and organisms: A review. *Chemosphere, 182*, 781–793. https://doi.org/10.1016/j.chemosphere.2017.05.096

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., ... & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science, 347*(6223), 768–771. https://doi.org/10.1126/science.1260352

Koelmans, A. A., Bakir, A., Burton, G. A., & Janssen, C. R. (2016). Microplastic as a vector for chemicals in the aquatic environment: Critical review and model-supported reinterpretation of empirical studies. *Environmental Science & Technology, 50*(7), 3315–3326. https://doi.org/10.1021/acs.est.5b06069

Lusher, A. L., Hollman, P. C., & Mendoza-Hill, J. J. (2017). Microplastics in fisheries and aquaculture: Status of knowledge on their occurrence and implications for aquatic organisms and food safety. *FAO Technical Paper 615*. Food and Agriculture Organization of the United Nations.

Prata, J. C., da Costa, J. P., Lopes, I., Duarte, A. C., & Rocha-Santos, T. (2020). Environmental exposure to microplastics: An overview on possible human health effects. *Science of The Total Environment, 702*, 134455. https://doi.org/10.1016/j.scitotenv.2019.134455

UNEP. (2021). *From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution*. United Nations Environment Programme.

Zhang, Y., Gao, T., Kang, S., Sillanpää, M., & Vogt, R. D. (2022). Mercury in fish and human health: A review. *Science of The Total Environment, 833*, 155134. https://doi.org/10.1016/j.scitotenv.2022.155134

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). Thousand Oaks, CA: SAGE Publications.

Flick, U. (2018). *An introduction to qualitative research* (6th ed.). London: SAGE Publications.

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods, 16*(1), 1–13. https://doi.org/10.1177/1609406917733847

Patton, M. Q. (2015). *Qualitative research and evaluation methods* (4th ed.). Thousand Oaks, CA: SAGE Publications.

Silverman, D. (2020). *Qualitative research* (5th ed.). London: SAGE Publications.

Vaismoradi, M., Turunen, H., & Bondas, T. (2013). Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing & Health Sciences, 15*(3), 398–405. https://doi.org/10.1111/nhs.12048

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). Thousand Oaks, CA: SAGE Publications