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White Tides: The Plastic Nurdles Problem

Galgani Francois [1], Rangel-Buitrago Nelson [2, *]

[1] Unité Ressources marines en Polynésie Francaise, Institut français de recherche pour l'exploitation de la mer (Ifremer), BP 49, Vairao, Tahiti, French Polynesia
[2] Programade Física, Facultad de Ciencias Básicas, Universidad del Atlántico, Barranquilla, Atlántico, Colombia

* Corresponding author : Nelson Rangel-Buitrago, email address : nelsonrangel@mail.uniatlantico.edu.co

Abstract :

The proliferation of plastic pollution, particularly from nurdles (small plastic pellets used in manufacturing), poses significant environmental and ecological risks. Originating with the invention of Bakelite in 1907 and escalating post-World War II with advanced petrochemical technologies, nurdles are the second largest source of primary microplastic pollution globally. Each year an estimated 445,970 tonnes of nurdles enter the environment worldwide. Nurdle spills, such as those along Spain's Galician coast and other global incidents, underline the need for improved spill response, preventive measures, and international regulatory coordination. The environmental impact of nurdles, compared to more visible oil spills, is insidious and long-lasting due to their persistence and widespread dispersion. Current regulations, like the International Maritime Organization's (IMO) guidelines, reveal gaps in enforcement and fail to fully address the long-term consequences of spills. Recent technological innovations and policy interventions aim to mitigate risks, but there's an urgent need for coordinated global action, stricter controls, and investment in biodegradable alternatives to safeguard marine environments and ensure ecological sustainability.

Graphical abstract

A single outstretched hand displays a collection of nurdles, gathered from a square meter of a Caribbean beach, serving as a stark illustration of the raw materials that feed the global plastic product industry. These pellets are emblematic of the widespread issue of plastic pollution—an issue not limited to the Galician coast but resonating across the planet. The proliferation of nurdle pollution is in step with the increase in global plastic production, highlighting the escalating concern over its significant environmental repercussions.

Highlights

► Nurdles cause extensive marine pollution. ► Global nurdle spills highlight transport risks. ► Socioeconomic impact of nurdle spills on coasts. ► Regulations on nurdle spills lack uniformity. ► New strategies emerging for tackling nurdle pollution.

Keywords : Pollution, Plastics, Nurdles, Spills, Management. In

In the Anthropocene epoch, a notable characteristic is the widespread proliferation of plastic pollution. Initially lauded as a revolutionary material for its durability, versatility, and cost-effectiveness, plastic has become an integral part of modern life (Rangel-Buitrago et al., 2022). Its

origins date back to the invention of Bakelite in 1907, marking the beginning of synthetic plastics. The post-World War II period saw a dramatic increase in plastic production, a trend closely linked with advancements in petrochemical technologies and expanding consumer cultures. This escalation, from 2.3 million tons in 1950 to approximately 600 million tons by 2022 (Andrady 2022), highlights plastics' deep integration into various sectors, from packaging to healthcare. However, this growth has had significant environmental consequences. The resistance of plastics to natural degradation processes has led to a considerable environmental crisis. About 8.3 billion metric tons of plastic produced since the 1950s have resulted in approximately 60% being discarded in landfills or the natural environment (UNEP 2021). As these materials break down into microplastics and nanoplastics, they infiltrate terrestrial, freshwater, and marine ecosystems, posing substantial threats to biodiversity and ecosystem integrity (Andrady 2022). Therefore, plastics in the Anthropocene are characterized by their transformative impact on human society and a problematic environmental legacy (Williams and Rangel-Buitrago 2022).

A recent disturbing example of this legacy is the ecological crisis unfolding along Spain's Galician coast. In early December 2023, the Vessel Toconao, lost six containers near Viana do Castelo in Portuguese waters. One container, filled with 25 kg sacks of plastic Nurdles from Bedeko Europe, caused extensive pollution in the marine ecosystem. Carried by strong Atlantic currents, these pellets have affected the Galician Rías Baixas and surrounding regions. The severity became apparent when, by January 4th, an estimated 25 tons of pellets had been spilled, impacting areas from the Vigo estuary to parts of Asturias, including the Rías Baixas and Costa da Morte. Despite the significant ecological threat and unclear official guidelines for pellet collection and toxicity understanding, local communities have demonstrated resilience and commitment by organizing voluntary clean-up efforts along the coast.

Nurdles, or pre-production plastic pellets, the minuscule yet indispensable constituents of the plastic manufacturing industry, are ubiquitous in their application as the foundational material for a vast array of products (Plastics Europe 2022). Measuring less than 5mm, these pellets are synthesized from various polymer types, providing the essential units for the fabrication of a diverse range of plastic goods, encompassing everyday household items to sophisticated medical devices. Their adaptability is a key attribute, with the capacity to be heated, molded, and then reformed, proving vital to the versatility of plastic production processes (Flick 2021). They are classified as primary microplastics, made to be microplastics and used as such, enabling the industry to limit the energy needed to melt plastic during the thermoforming stages, compared with large plastic blocks. Despite their industrial significance, nurdles pose considerable environmental hazards due to their propensity to float and their size, which can lead to inadvertent dispersal in marine environments, exacerbating plastic pollution as exemplified by the recent spill off the Galician coast. Ranking as the second most significant source of primary microplastic pollution globally, an estimated 445,970 tonnes of nurdles are believed to contaminate earth ecosystems annually.

The environmental challenges posed by nurdles extend beyond the Galician coast incident, representing a broader global pattern. For example, in 2012, Hong Kong's shores experienced significant pollution following a container spill of nurdles during Typhoon Vicente. In 2017, Durban, South Africa, saw a catastrophic spill from a shipping container, releasing a deluge of nurdles into the Indian Ocean and affecting distant shores. Sri Lanka faced one of its most severe

environmental disasters in 2021 when the X-Press Pearl cargo ship caught fire, resulting in the spillage of billions of nurdles. Additionally, a 2020 container spill near New Orleans, USA, added to the growing list of nurdle pollution events.

These incidents underscore a critical need for enhanced global cooperation to address the disparities in regulatory frameworks across different jurisdictions. International collaboration is imperative to develop standardized regulations and practices for the handling, transportation, and response to nurdle spills. This approach should aim at establishing global treaties or agreements that mandate unified safety and environmental protection standards, like how the Paris Agreement seeks to unify global efforts against climate change. Such international agreements could ensure consistent application of safety protocols, monitoring, and spill response mechanisms, significantly mitigating the impact of nurdle pollution worldwide. Establishing a global consensus on handling nurdles could also facilitate more effective enforcement of regulations, ensuring that all nations adhere to the same high standards of environmental protection and spill prevention.

The trajectory of nurdle pollution mirrors the growth in global plastic production and the evolving awareness of its environmental impacts. Historically, the production and use of nurdles in the plastic industry have grown exponentially, parallel to the overall increase in plastic manufacturing since the mid-20th century (UNEP 2021; Rangel-Buitrago et al., 2022). This rise in production has inherently increased the risks and frequency of nurdle spills. These spills originate from various sources throughout the plastic cycle, including manufacturing facilities where accidental spillages can occur during handling or transfer. However, a significant portion of nurdle pollution stems from maritime transport, where containers filled with these pellets are at risk of compromise, as evidenced in incidents like Durban and Sri Lanka. Land-based transportation and recycling operations also contribute to nurdle dispersal, often through mishandling or inadequate containment measures.

Nurdle pollution, when compared to oil spills, presents a distinct marine threat (Table 1). While oil spills are visibly impactful, causing immediate harm to marine life and coastlines, nurdles offer a less visible but enduring hazard. Unlike oil, which may dissipate over time, nurdles remain in the environment indefinitely. Their small, buoyant nature allows for extensive dispersion across oceans, complicating cleanup and posing broad ecological risks. Thus, despite the acute damage of oil spills, the persistent and widespread nature of nurdle pollution represents a significant, ongoing challenge to marine ecosystems.

The environmental and ecological ramifications of nurdle pollution in marine ecosystems are profound and multifaceted. A primary concern is the ingestion of nurdles by marine wildlife. Due to their small size and resemblance to fish eggs or other natural prey, a variety of marine organisms, from small fish to large mammals, often consume nurdles (Stubbins et al., 2021; Williams and Rangel-Buitrago 2022). This ingestion can lead to internal injuries or blockages, and potentially, the leaching of toxins into these creatures' bodies, given the nurdles' chemical composition (Nam et al., 2021). This issue extends beyond individual organisms, as these pollutants enter and ascend the marine food chain, ultimately posing risks to higher trophic levels, including human consumers (Gregory 2009). Furthermore, the persistence of PET plastics, from which most nurdles are made, presents a long-term threat to marine habitats. PET's durability and resistance to degradation mean

that once nurdles enter an ecosystem, they can persist for centuries, continuously posing a threat to biodiversity and habitat health (Pacchioni 2022).

Nurdle spills also have significant socioeconomic consequences, particularly affecting coastal communities whose livelihoods and economies are closely linked to marine environment health. The fishing industry, crucial to many coastal regions, is especially susceptible to nurdle pollution repercussions (Royal Society Te Apārangi 2019). Spills can lead to fish stock contamination, either through direct ingestion of nurdles by marine life or through bioaccumulation of associated toxins. This contamination poses human health risks, potentially leading to fishing activity restrictions or bans, resulting in substantial economic losses for local fishing communities (Geyer 2020). Additionally, nurdles' presence on beaches and in coastal waters can severely impact tourism, another vital economic sector for many coastal areas (Williams and Rangel-Buitrago 2022). The visual pollution from accumulated nurdles, along with the associated environmental damage, can deter tourists, thereby affecting tourism-dependent businesses.

The economic impact of nurdle spills extends beyond immediate local industry effects, with cleanup operations being costly and protracted. The challenge of collecting and removing widely dispersed, small nurdles contrasts with the sometimes-quicker containment of oil spills. Additionally, the extensive environmental remediation needed to counteract nurdle pollution's ecosystem effects increases the financial strain. These costs affect governments, environmental agencies, and local communities and industries through the indirect costs of ecological damage. Consequently, nurdle spills pose a critical socioeconomic challenge, necessitating sustained and comprehensive mitigation efforts.

Technology is perhaps the principal management tool used for addressing nurdle pollution (Rudolph et al., 2017). However, the response tools and methodologies currently in use exhibit significant limitations, necessitating advancements to enhance their effectiveness and efficiency (Williams and Rangel-Buitrago 2022). Conventional approaches, including physical collection methods such as fine mesh nets and vacuum systems, are instrumental in remediation efforts but fall short in addressing the complexity and scale of nurdle pollution (Schmaltz et al., 2020). These tools, while effective in localized areas, struggle to cope with the widespread dispersion of nurdles across vast marine environments. This challenge is compounded by the pellets' buoyant nature and the variable conditions of marine settings (Forsberg et al., 2020). The limitations are not solely operational but also encompass logistical challenges of deployment, especially in remote or difficult-to-reach areas, and the significant labor and time requirements for cleanup operations, which often rely on community volunteer efforts.

Moreover, technological interventions, such as drones and remote sensing for spill detection and assessment, represent a promising avenue for rapid response and monitoring (Goncalves et al., 2022). However, these technologies are still in their early stages regarding widespread application for nurdle pollution. The effectiveness of these advanced tools is often hampered by the lack of integration with comprehensive spill response strategies and the absence of global standards for their deployment. The need for significant advancements is evident not only in the development of more efficient and scalable collection tools but also in their integration with predictive modeling and real-time monitoring systems. Such advancements could enable proactive responses, targeting nurdle spills before they disperse widely, thereby mitigating the environmental impact.

Beyond conventional response tools and emerging technologies, several other innovative approaches aim to tackle the issue of nurdle pollution more effectively. Bio-remediation techniques and the development of advanced materials present innovative approaches to mitigating the environmental impact of plastic nurdle pollution (EU 2023). Research in bioremediation focuses on harnessing the potential of microorganisms or enzymes, specifically bacteria or fungi, capable of degrading various polymers such as polyethylene and polypropylene into non-harmful substances. While these methods are currently experimental, they hold promise for the sustainable management of nurdle pollution.

Concurrently, the development of materials with a high affinity for plastics, including oil-absorbent polymers and magnetic nanoparticles with specialized binders, aims to improve the efficacy of nurdle capture (Pacchioni 2022). These materials could be integrated into booms and barriers designed to effectively retain nurdles while allowing water to flow through, thereby enhancing the efficiency of cleanup operations in affected aquatic environments. The adoption of such materials faces challenges related to cost, performance, and the readiness of the plastic manufacturing industry to transition to new materials.

In parallel, the application of Environmental DNA (eDNA) monitoring and the engagement of citizen science and mobile technology offer complementary strategies for understanding and mitigating the effects of nurdles on marine biodiversity and facilitating community-driven cleanup efforts. eDNA technology provides a novel method for assessing the ecological impact of nurdles by detecting the DNA left by organisms in their environment, thus informing targeted conservation strategies (Rourke et al., 2021). Furthermore, citizen science initiatives and mobile applications empower individuals to contribute to the monitoring and cleanup of nurdle pollution, leveraging community action and data collection to support environmental management (Tunnell 2020). Additionally, the advancement of automated robotic systems equipped for nurdle recovery introduces a technological solution to enhance spill response capabilities, particularly in challenging or hazardous locations, offering a more efficient, continuous, and safer alternative to traditional cleanup methods. These technological and policy measures suggest a comprehensive approach to both immediate spill management and long-term prevention and impact mitigation (Rangel-Buitrago et al., 2022).

The governance of plastic nurdle transportation and accidental spillage operates within a matrix of international and national regulations. However, these frameworks often reveal significant gaps and challenges in enforcement. Internationally, regulations such as the International Maritime Organization's (IMO) International Convention for the Prevention of Pollution from Ships (MARPOL) set broad guidelines for preventing ship-based pollution, including cargo such as plastic pellets. However, enforcing these regulations often falls to individual countries, leading to variability in implementation and effectiveness.

At the national level, some countries have developed specific regulations and guidelines to manage and mitigate risks associated with nurdle spills. For example, the United States employs the Clean Water Act and the National Contingency Plan, outlining responses to pollution incidents in navigable waters. Within the Regional Sea convention OSPAR, and Following a series of stakeholder discussions, a recommendation on a pellet loss certification scheme was drafted and approved in 2021 (OSPAR 2021). Guidelines to support the implementation of the

Recommendation and help create coherence in national approaches to the implementation of external certification schemes were also adopted in 2021 (OSPAR 2021).

Despite existing regulatory frameworks, notable gaps persist in the regulatory landscape regarding nurdle pollution. A significant issue is the lack of uniformity in regulations across different countries, leading to inconsistencies in spill response and prevention measures. Another challenge is enforcing existing regulations, especially in international waters where jurisdictional complexities arise. Additionally, current regulations tend to focus more on response than prevention, lacking specific measures for secure packaging, handling, and transportation of nurdles to minimize spill risks. The small size and ubiquity of nurdles also present unique challenges in monitoring and enforcement, as spills can occur unnoticed and have widespread impacts before any response is initiated.

Amending MARPOL Annex V to explicitly include provisions for the management of plastic pellets could significantly mitigate the risk of environmental pollution from ship-based sources. By categorizing nurdles as a distinct type of cargo, with specific containment and management requirements, the potential for loss overboard can be minimized. Introducing specialized requirements for the packaging, labeling, and stowage of cargo containers carrying nurdles, such as mandatory overpacking or the use of containers with enhanced sealing features, and the stipulation that such containers be stowed in less vulnerable locations on a vessel, could further reduce the likelihood of spills. Additionally, the implementation of a mandate for the immediate reporting of any nurdle losses to maritime authorities under MARPOL would enhance response efficiency and facilitate coordinated cleanup efforts, thereby improving the overall management of nurdle spill incidents.

Further strengthening of port state control measures to include inspections ensuring the secure stowage and handling of nurdles, alongside the development of a standardized global response and cleanup protocol for nurdle spills, would ensure consistent and effective actions across international waters. Enhancing training and awareness programs for ship crews and port personnel on best practices for handling nurdles, coupled with international collaboration and research into sustainable materials and innovative spill prevention technologies, could significantly bolster efforts to prevent nurdle pollution. These measures, fostered under the MARPOL framework, would not only address the immediate challenges posed by nurdle spills but also contribute to the long-term sustainability of marine environments by reducing the frequency and impact of such incidents.

Moreover, current regulatory frameworks rarely account for the long-term environmental and socioeconomic impacts of nurdle spills. They often lack provisions for comprehensive post-spill environmental monitoring, recovery, and compensation, crucial for addressing the full scope of impacts on affected communities and ecosystems. This gap underscores the need for more holistic and proactive regulatory approaches, encompassing not just spill response but also prevention, monitoring, and long-term impact assessment. For example, as the price of plastic is particularly low, and container losses mainly affect the highest containers onboard, a ban on top-loading plastic containers on container ships could have a much more limited risk and associated cost for the environment.

The "Pellet Watch" program exemplifies international cooperation aimed at monitoring the distribution and ecological impact of plastic pellets in global marine environments. This initiative has been instrumental in global monitoring efforts, systematically documenting the concentrations of persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs), dichloro-diphenyl-trichloroethane (DDT), and hexachlorocyclohexanes (HCHs) in plastic pellets collected from beaches worldwide. This initiative has highlighted significant regional variations in POP concentrations, indicative of differing industrial activities, waste management practices, and environmental regulations. It has also identified temporal trends that underscore the effectiveness of international treaties, like the Stockholm Convention, in mitigating the global impact of these hazardous substances (Ogata et al., 2009). Pellet Watch has underscored the connectivity between terrestrial, marine, and atmospheric systems in the transport and fate of persistent pollutants. The program has significantly contributed to educational efforts and policymaking, informing strategies to curb plastic pollution and POP emissions.

Nurdle pollution in marine environments represents a critical ecological issue demanding swift, collective action from multiple stakeholders. The persistent nature of nurdle pollution, with its global incidents, highlights the need for a unified response involving governments, industries, environmental groups, and communities. This pollution not only impacts marine life and ecosystems but also has significant socioeconomic effects on coastal areas dependent on fishing and tourism. Urgent measures are required to improve international and national regulations, advance spill recovery technologies, and enforce stricter protocols for plastic pellet handling and transport. Additionally, shifting towards biodegradable alternatives is vital for long-term environmental health. Addressing this issue is a shared responsibility, necessitating collaborative efforts to protect marine ecosystems from nurdle pollution. Immediate, coordinated actions are essential to tackle this widespread environmental challenge.

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REFERENCES

Andrady, A., 2022. Plastics and the Ocean: Origin, Characterization, Fate, and Impacts. John Wiley & Sons, Inc.

EU, 2023. Questions and Answers on Measures to reduce microplastic pollution from plastic pellets. European Commission.

Flick, E., 2021. Plastics Additives, Volume 1: An Industry Guide. Elsevier.

Forsberg, P.L., Sous, D., Stocchino, A., Chemin, R., 2020. Behaviour of plastic litter in nearshore waters: First insights from wind and wave laboratory experiments. Mar. Pollut. Bull., 153, 111023.

Geyer, R., 2020. Production, use, and fate of synthetic polymers. In Plastic Waste and Recycling: Environmental Impact, Societal Issues, Prevention, and Solutions, pp. 13-32.

Goncalves, G., Andriolo, U., Goncalvez, L., Sobral, P., Bessa, F., 2022. Beach litter survey by drones: Mini-review and discussion of a potential standardization. Env Poll. 315, 120370.

Gregory, M., 2009. Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philos. Trans. R. Soc. Lond. Ser. B Biol. Sci. 364 (1526), 2013–2025.

Nam, K.B., Kim, M., Hong, M.J., Kwon, Y., 2021. Plastic debris ingestion by seabirds on the korean peninsula. Mar. Pollut. Bull. 166, 112240.

OSPAR, 2021. Recommendation 2021/06 on the reduction of plastic pellet loss into the marine environment. OSPAR.

Pacchioni, G., 2022. Stereochemistry affords control of polymers' properties. Nature Reviews Materials. 7, 82.

Plastics Europe, 2022. Plastics — The Facts. Plastics Europe.

Rangel-Buitrago, N., Neal, W., Galgani, F., 2022. Plastics in the Anthropocene: A multifaceted approach to marine pollution management. Mar. Pollut. Bull. 194, 115359.

Rangel-Buitrago, N., Neal, W., Williams, A., 2022. The Plasticene: Time and Rocks. Mar. Pollut. Bull. 185, 114358.

Royal Society Te Apārangi, 2019. Evidence Summary on Plastics in the Environment. Royal Society Te Apārangi.

Rourke, M., Fowler, A., Hughes, J., Broadhurst, M., DiBattista, J., Fielder, S., Wilkes, J., Furlan,E., 2021. Environmental DNA (eDNA) as a tool for assessing fish biomass: A review of approaches and future considerations for resource surveys. Env DNA. 4 (1), 9-33.

Rudolph, N., Kiesel, R., Aumnate, C., 2017. Understanding Plastics Recycling: Economic, Ecological, and Technical Aspects of Plastic Waste Handling. Elsevier.

Schmaltz, E., Melvin, E., Diana, Z., Gunady, E., Rittschof, D., Somarelli, J., Virdin, J., Dunphy-Daly, M., 2020. Plastic pollution solutions: emerging technologies to prevent and collect marine plastic pollution. Environ Int. 144, 106067.

Stubbins, A., Lavender, K., Muñoz, S., Biachi, T., Zhu, L., 2021. Plastics in the Earth system. Science 373(6550), 51-55.

Tunnell, J., Dunning, K., Scheef, L., Swanson, K., 2020. Measuring plastic pellet (nurdle) abundance on shorelines throughout the Gulf of Mexico using citizen scientists: Establishing a platform for policy-relevant research. Mar Poll Bull. 151, 110794

UNEP, 2021. Drowning in Plastics – Marine Litter and Plastic Waste Vital Graphics. United Nations Environment Programme.

Williams, A.T., Rangel-Buitrago, N., 2022. The past, present, and future of plastic pollution. Mar Poll Bull. 176, 113429.

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Figure 1. A sandy beach on the Caribbean coast of Colombia exhibits a marked accumulation of microplastics, characterized predominantly by fragments and nurdles. This scene starkly exemplifies the primary components of the global plastic manufacturing industry that ultimately find their way to coastal regions around the world. Such nurdles are indicative of the pervasive problem of plastic pollution, a concern not confined to the Galician coast but echoing globally. The surge in nurdle pollution parallels the rise in worldwide plastic production, underscoring the growing alarm over its considerable environmental impacts.

Table 1. Comparative Analysis of Nurdle Pollution and Oil Spills. The table presents a comparison between nurdle pollution and oil spills, highlighting key aspects where these environmental phenomena converge and diverge.

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Feature	Nurdle Spills ("White Tides")	Oil Spills
Material	Plastic pellets (nurdles) used in the manufacturing of plastic products.	Crude or refined petroleum products.
Visibility	Less visible, especially in water, due to their small size and transparency.	Highly visible slicks on the water surface, making detection and initial assessment more straightforward.
Persistence	Extremely durable and can persist in the environment for hundreds to thousands of years without significant degradation.	Variable; some components may evaporate or biodegrade relatively quickly, while heavier fractions can persist for extended periods.
Environmental Impact	Physical ingestion by marine organisms leading to potential blockages, toxicity, and disruption of feeding behaviors. Microplastics can also absorb and concentrate toxic chemicals.	Toxicity to marine life, coating of marine and shorebird feathers impairing mobility and insulation, and oxygen depletion in aquatic environments.
Economic Impact	Affects local economies by impacting fisheries, tourism, and potentially human health through the food chain. Cleanup efforts are labor-intensive and costly.	Has immediate and visible impacts on tourism, fisheries, and marine industries. Cleanup costs can be substantial, alongside long-term economic damage.
Cleanup Challenges	Difficult to recover due to their small size, buoyancy, and widespread dispersion. Cleanup efforts often rely on manual collection and community involvement.	Cleanup techniques are more developed but can be costly and damaging to the environment. Methods include skimming, dispersants, and in-situ burning.
Regulatory and Policy Framework	Emerging focus, with initiatives like the OSPAR recommendation on pellet loss and Operation Clean Sweep aiming to reduce spill incidents. Enforcement and global consistency remain challenges.	More established regulatory frameworks under the International Maritime Organization (IMO) and national regulations. Response protocols and liability mechanisms are better defined.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Highlights

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- Global nurdle spills highlight transport risks.
- Socioeconomic impact of nurdle spills on coasts.
- Regulations on nurdle spills lack uniformity.
- New strategies emerging for tackling nurdle pollution.