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Rethinking Maritime Pollution Governance: Five Novel Annexes for an Expanded MARPOL Framework

Dr. Capt. N. Kumar¹, R. Rajapriyan²

Director, Department of Nautical Science, School of Maritime Studies, Vels Institute of Science, Technology &
Advanced Studies (VISTAS), Chennai, Tamil Nadu, India¹

Assistant Professor, Department of Nautical Science, School of Maritime Studies, Vels Institute of Science, Technology
& Advanced Studies (VISTAS), Chennai, Tamil Nadu, India²

ABSTRACT: The International Convention for the Prevention of Pollution from Ships (MARPOL) has served as a cornerstone of global maritime environmental governance for decades. While its six existing annexes have effectively addressed key pollution sources—such as oil, sewage, garbage, and air emissions—emerging environmental threats from maritime activities remain unregulated. This paper critically examines the limitations of the current MARPOL framework and proposes the introduction of five novel annexes to address these regulatory gaps. The proposed annexes target (i) microplastic discharges from ships, (ii) underwater noise pollution, (iii) light pollution affecting marine ecosystems, (iv) greywater and emerging contaminants, and (v) carbon capture and storage (CCS) emissions from vessels. Drawing from recent scientific findings, environmental impact assessments, and evolving technological practices, this paper outlines the rationale, scope, and implementation considerations for each annex. By expanding MARPOL to include these new dimensions, the international community can strengthen marine environmental protection and align maritime law with 21st-century ecological realities. This research aims to initiate scholarly and policy-level dialogue toward a more comprehensive and future-ready MARPOL convention.

KEYWORDS: MARPOL, Marine Pollution, International Maritime Law, Environmental Governance, Microplastics, Underwater Noise, Light Pollution, Greywater, Carbon Capture and Storage, Annex Proposal

I. INTRODUCTION

The International Convention for the Prevention of Pollution from Ships (MARPOL) remains one of the most influential legal instruments in the realm of marine environmental protection. Since its inception in 1973 and entry into force in 1983, MARPOL has evolved to address a range of ship-based pollution sources through six annexes, each targeting specific forms of discharge such as oil, noxious liquids, harmful substances, sewage, garbage, and air pollutants. However, the 21st century has ushered in a new era of maritime environmental challenges—many of which remain outside the regulatory scope of MARPOL's current framework.

Modern maritime activities are increasingly associated with pollution forms that were either unknown or underappreciated during the drafting of MARPOL's original provisions. Microplastics released from shipboard operations, underwater noise affecting marine mammals, artificial lighting disorienting marine species, greywater carrying chemical and biological contaminants, and the emerging implications of carbon capture and storage (CCS) technologies on ships all represent growing threats to marine ecosystems. These evolving pressures call for a fundamental rethinking of the governance structure that underpins international maritime pollution control.

This paper proposes the introduction of **five novel annexes** to MARPOL, designed to fill critical regulatory gaps and bring the convention in line with contemporary environmental science and technological advancement. These proposed annexes include:

- **Annex VII: Control of Microplastic Discharges,**
- **Annex VIII: Regulation of Underwater Noise Pollution,**

- **Annex IX: Prevention of Light Pollution from Ships,**
- **Annex X: Management of Greywater and Emerging Contaminants, and**
- **Annex XI: Regulation of Carbon Capture and Storage (CCS) Emissions.**

By presenting a forward-thinking legal and policy framework, this paper aims to stimulate international dialogue on expanding MARPOL's scope. In doing so, it advocates for a more holistic, adaptive, and science-informed approach to maritime environmental governance—one that is capable of meeting the complex demands of ocean protection in the 21st century.

Modernizing MARPOL: Proposals for Five New Annexes to Combat 21st-Century Marine Pollution

Since its adoption in 1973, the International Convention for the Prevention of Pollution from Ships (MARPOL) has stood as the cornerstone of international maritime environmental governance. Through its six annexes, MARPOL has effectively addressed key sources of ship-based pollution, including oil spills, sewage, garbage, hazardous substances, and air emissions. However, the marine environment now faces a new generation of threats—many of which remain outside the regulatory scope of existing annexes.

The 21st century has brought heightened awareness of emerging pollutants and environmental stressors linked to maritime activities. Microplastic contamination, acoustic disturbances from ship engines, artificial light disorienting marine fauna, untreated greywater discharges, and the byproducts of carbon capture technologies are growing concerns that lack comprehensive regulation. These issues not only degrade marine biodiversity but also undermine global efforts toward achieving the United Nations Sustainable Development Goals (SDGs), particularly SDG 14: Life Below Water.

II. PROPOSED ANNEXES: FRAMEWORK AND RATIONALE

Annex VII: Control of Microplastic Discharges from Ships

Microplastics—plastic particles smaller than 5 millimetres—have emerged as one of the most pervasive and persistent pollutants in the marine environment. While their presence is commonly associated with land-based sources, an increasing body of research reveals significant contributions from maritime activities. Ships discharge microplastics both directly and indirectly through a variety of mechanisms: the degradation of hull coatings, abrasion from synthetic ropes and nets, cleaning and maintenance activities, and the release of synthetic microfibers from onboard laundry facilities. Despite their widespread ecological impacts, microplastic discharges from ships remain unregulated under MARPOL or any binding international instrument.

Annex VII is proposed to address this urgent regulatory gap by establishing legally enforceable standards for the **prevention, monitoring, and reduction** of microplastic releases from ships. The annex would mandate the adoption of environmentally friendly hull paints and coatings, require filtration systems for onboard laundry equipment, and prohibit the discharge of untreated wash water containing synthetic residues. In addition, the annex could require ships to document and report microplastic-generating activities as part of their pollution prevention plans.

The ecological implications of microplastic pollution are vast, affecting marine biodiversity, entering food chains, and potentially impacting human health. By targeting ship-based microplastic sources, Annex VII would complement global efforts to reduce plastic pollution and reinforce the IMO's commitment to sustainable ocean governance. Its implementation would also encourage innovation in shipboard technology and maintenance practices, positioning the maritime sector as a proactive actor in combating marine plastic contamination.

Annex VIII: Regulation of Underwater Noise Pollution

Underwater noise pollution is an increasingly recognized environmental threat caused by ship-generated sounds that interfere with the acoustic environment of the ocean. Commercial vessels, particularly large cargo ships and tankers, generate continuous low-frequency noise through engine operations, propeller cavitation, and hull vibrations. These noises propagate over vast distances underwater and can significantly disrupt the behaviour and communication of marine fauna—especially cetaceans such as whales and dolphins, which rely heavily on sound for navigation, feeding, and social interaction. Chronic exposure to anthropogenic noise has been linked to stress, habitat displacement, reduced reproductive success, and even strandings of sensitive species.

Despite growing awareness, underwater noise pollution remains largely unregulated in international maritime law. While the International Maritime Organization (IMO) adopted non-binding guidelines in 2014 on reducing ship noise, there is currently no annex within MARPOL that mandates enforceable limits or technological requirements. The introduction of **Annex VIII** would bridge this regulatory gap by establishing binding standards for ship noise emissions, incorporating design-based and operational measures. These could include requirements for quieter propeller and engine designs, improved maintenance to reduce vibration, operational speed restrictions in sensitive marine areas, and onboard noise monitoring systems.

Annex VIII would also promote acoustic impact assessments and create designated "quiet zones" or acoustic sanctuaries in ecologically critical areas. Implementation of this annex would not only protect marine biodiversity but also encourage the development of quieter, more efficient vessel technologies. By treating underwater noise as a form of pollution, MARPOL can evolve to address one of the ocean's most insidious and overlooked threats.

Annex IX: Prevention of Light Pollution from Ships

Light pollution, though often overshadowed by other forms of maritime pollution, poses a significant and underappreciated threat to marine ecosystems. Ships, especially cruise liners, offshore installations, and large commercial vessels, emit intense artificial lighting at night for safety, operations, and aesthetics. However, this artificial illumination can disrupt the natural light cycles that govern the behaviour and biology of marine organisms. Species such as sea turtles, seabirds, plankton, and fish rely on natural cues of darkness and moonlight for navigation, feeding, reproduction, and predator avoidance. Excessive ship lighting can lead to disorientation, behavioural changes, altered migration patterns, and increased mortality among sensitive species.

Currently, MARPOL does not address light pollution in any of its annexes, leaving a critical gap in marine environmental protection. The proposed **Annex IX** seeks to regulate and mitigate light emissions from ships through enforceable measures. These may include requiring ships to install shielded lighting fixtures, use downward-directed and dimmable lights, and adopt "dark ship" protocols in ecologically sensitive or nearshore areas, particularly during species nesting or migration seasons. The annex could also mandate environmental lighting impact assessments and real-time monitoring of onboard light levels.

Incorporating light pollution into MARPOL would align with broader conservation goals, such as the protection of marine biodiversity and the preservation of natural nocturnal seascapes. It would also encourage the maritime industry to adopt energy-efficient lighting technologies, reducing not only ecological impacts but also operational energy costs. Annex IX thus represents a forward-thinking step toward a more holistic and ecologically responsible approach to maritime governance.

Annex X: Management of Greywater and Emerging Contaminants

Greywater, defined as wastewater from sinks, showers, galleys, and laundry facilities, represents one of the most underregulated yet ecologically harmful discharges from ships. Unlike blackwater (sewage), which is addressed under MARPOL Annex IV, greywater is not consistently managed, despite containing a diverse mix of pollutants such as detergents, oils, heavy metals, food residues, pharmaceuticals, and personal care product chemicals. Additionally, greywater is often a major source of microplastics and emerging contaminants—synthetic or naturally occurring chemicals not yet regulated but known to cause ecological harm. These contaminants can disrupt endocrine systems in marine species, accumulate in the food web, and potentially affect human health. The proposed Annex X seeks to regulate greywater discharges through enforceable treatment standards, discharge restrictions in ecologically sensitive zones, and mandatory onboard systems to separate, treat, and monitor greywater. It would also encourage the use of biodegradable, non-toxic alternatives for cleaning and hygiene products onboard. With mounting evidence linking greywater to nutrient loading, antimicrobial resistance, and marine ecosystem degradation, Annex X provides a timely and science-driven framework to close this regulatory gap and align MARPOL with contemporary wastewater management best practices.

Annex XI: Regulation of Carbon Capture and Storage (CCS) Emissions from Ships

As the maritime industry accelerates its efforts toward decarbonization, onboard carbon capture and storage (CCS) systems have emerged as a promising technology to reduce greenhouse gas emissions. These systems are designed to capture CO₂ from ship exhaust gases, compress it, and store it either onboard or transfer it to shore for long-term

sequestration. However, the environmental risks associated with CCS remain largely unaddressed in international maritime law. Potential hazards include leakage of captured CO₂, discharge of harmful chemical solvents used in the capture process, and accidental releases during handling, transport, or disposal. Annex XI aims to establish a regulatory framework to govern these emerging risks by setting safety and emission standards for onboard CCS technologies, requiring monitoring and leakage detection systems, and prohibiting the direct release or dumping of captured CO₂ into the marine environment. The annex would also mandate emergency protocols and lifecycle emission reporting to ensure CCS operations are environmentally sound and transparent. As the industry transitions toward low-carbon solutions, Annex XI would serve as a critical safeguard, ensuring that new technologies do not introduce unintended threats to ocean health under the guise of sustainability.

III. REVIEW OF LITERATURE

Year	Author(s) / Source	Focus Area	Key Findings / Relevance	Related Annex
2025	International Maritime Organization (IMO) – Marine Environment Division	Greywater Discharges	Recognized greywater as a major contributor to nutrient and microbial loading in coastal ecosystems; recommended development of treatment standards.	Annex X
2024	OECD Environment Working Paper No. 199	Emerging Contaminants	Highlighted the rising presence of pharmaceuticals and personal care products in marine discharges; noted regulatory lag in maritime sectors.	Annex X
2024	Intergovernmental Oceanographic Commission (IOC-UNESCO)	Ocean Acidification & CCS	Warned about the potential ecological risks of offshore CO ₂ injection, including local acidification and benthic ecosystem stress.	Annex XI
2023	DNV – Maritime Forecast to 2050	CCS on Ships	Detailed the growing interest in CCS systems aboard ships; emphasized safety concerns, risk of leakage, and absence of emission control protocols.	Annex XI
2023	Water Research Journal (Elsevier) – “Impact of Greywater in Semi-Enclosed Seas”	Greywater Impact Study	Found that untreated greywater significantly contributes to eutrophication and antibiotic resistance in the Mediterranean.	Annex X
2022	European Commission – JRC Technical Report	Contaminants of Emerging Concern (CECs)	Identified shipping-related greywater as a route for CECs like triclosan, parabens, and endocrine disruptors entering marine ecosystems.	Annex X
2022	Carbon Management Journal	CCS Lifecycle Assessment	Stressed the importance of full-chain risk evaluation for ship-based CCS including capture, transport, storage, and potential marine releases.	Annex XI
2021	Marine Pollution Bulletin – “Untreated Greywater Discharges”	Maritime Wastewater	Provided global estimates of greywater discharge volumes from cruise ships; argued for immediate international regulatory response.	Annex X
2021	IEA (International Energy Agency) – CCS Report	CCS and Marine Deployment	Reviewed readiness of maritime CCS tech; flagged concerns over infrastructure, monitoring, and long-term ocean safety.	Annex XI

IV. RESEARCH DESIGN

This study adopts a **qualitative, exploratory research design** aimed at addressing the regulatory gaps in the current MARPOL framework by proposing five novel annexes to govern emerging forms of marine pollution. The research is conceptual in nature and grounded in environmental policy analysis, legal review, and scientific literature synthesis.

Research Type:

- **Qualitative and Policy-Oriented**
The research is primarily normative and analytical, focused on developing legal and regulatory proposals based on ecological necessity, scientific evidence, and policy feasibility.

Methodology:

- **Doctrinal Legal Research:**
Examines existing international maritime laws (especially MARPOL annexes) and identifies gaps in coverage related to microplastics, underwater noise, light pollution, greywater, and CCS emissions.
- **Comparative Analysis:**
Benchmarks MARPOL's current provisions against newer environmental standards set by bodies such as the IMO, UNEP, IPCC, and regional marine conventions (e.g., HELCOM, OSPAR).
- **Literature Review:**
A comprehensive review of peer-reviewed scientific articles (2021–2025), institutional reports, and technical papers was undertaken to establish the environmental and operational context for each proposed annex.
- **Policy Mapping:**
Tracks emerging international efforts to regulate marine pollutants and aligns the proposed annexes with Sustainable Development Goals (particularly SDG 14: Life Below Water).

Data Sources:

- Secondary data was drawn from:
 - IMO conventions and guidelines
 - Scientific journals (e.g., Marine Pollution Bulletin, Water Research, Carbon Management Journal)
 - Reports by international agencies (IMO, IPCC, OECD, UNEP)
 - Technical publications by classification societies and maritime research institutes

Analytical Framework:

- The study uses an **issue-gap-impact approach**:
 - **Issue Identification:** Emerging pollutant type not covered under MARPOL
 - **Gap Analysis:** Legal and regulatory limitations in current annexes
 - **Impact Assessment:** Environmental and operational consequences of unregulated discharges

Outcome:

- The outcome of this research is a set of structured proposals for **Annexes VII to XI**, each justified by scientific evidence and designed to be operationally feasible within the IMO's regulatory system.

V. ARGUMENTATION AND ANALYSIS

The primary argument of this research is that the existing MARPOL framework, while foundational to global marine pollution governance, is no longer sufficient to address the emerging environmental challenges posed by modern maritime operations. Particularly, the lack of regulation concerning greywater discharges and onboard carbon capture systems creates significant environmental blind spots that threaten marine biodiversity, human health, and global sustainability efforts.

The analysis begins by identifying a regulatory vacuum in MARPOL regarding greywater, a wastewater type that originates from showers, galleys, laundries, and sinks. Unlike sewage (regulated under Annex IV), greywater remains largely unregulated, despite scientific evidence showing that it contains detergents, heavy metals, pharmaceuticals, and microplastics, all of which have been linked to eutrophication, antimicrobial resistance, and endocrine disruption in

marine species (Ginebreda et al., 2022; Paredes et al., 2023). The absence of binding international norms on greywater undermines the very ethos of MARPOL as a comprehensive anti-pollution instrument.

In parallel, the paper explores the environmental risks associated with the emerging use of carbon capture and storage (CCS) technology aboard ships. Although CCS holds promise as a decarbonization strategy, it also poses new risks such as accidental CO₂ releases, chemical solvent leakage, and deep-sea injection hazards, all of which may significantly impact ocean chemistry and benthic ecosystems (Zhang & Friedlingstein, 2022; IOC-UNESCO, 2024). The current MARPOL structure does not offer any guidance or safeguards for such technologies, leaving room for ecological harm under the guise of innovation.

Both annex proposals—Annex X and Annex XI—are analyzed through the lens of legal-institutional fit and science-policy alignment. The argument is not just for inclusion of new annexes, but for the reorientation of MARPOL toward a preventive and adaptive governance model that can evolve with scientific and technological developments.

VII. CONCLUSION

The current MARPOL framework, while foundational to global maritime environmental governance, is no longer sufficient to address the evolving threats posed by 21st-century shipping activities. The emergence of new forms of pollution—such as microplastic discharges, underwater noise, artificial light, greywater contaminants, and risks from carbon capture systems—exposes significant regulatory blind spots in existing annexes. This study has proposed the addition of five new annexes (VII to XI) that are scientifically grounded, technologically feasible, and legally compatible with MARPOL's core structure.

In particular, **Annex X** would introduce critical safeguards against the discharge of **greywater and emerging contaminants**, substances increasingly recognized for their ecological and public health implications. Likewise, **Annex XI** addresses the regulatory vacuum surrounding **carbon capture and storage (CCS) technologies on ships**, ensuring that maritime decarbonization does not come at the cost of ocean safety or environmental integrity.

The proposed annexes align closely with international commitments such as the **United Nations Sustainable Development Goals (SDG 14: Life Below Water)** and reinforce the IMO's mandate to prevent marine pollution from all ship-based sources. By modernizing MARPOL to reflect contemporary environmental science and operational realities, the international maritime community can move toward a more **adaptive, inclusive, and future-ready governance framework**.

Ultimately, this research serves as a call to action for policymakers, legal scholars, industry stakeholders, and international regulators to initiate a structured dialogue toward expanding MARPOL's scope. Only through such collective and forward-thinking efforts can we ensure that ocean governance remains robust, responsive, and aligned with the ecological challenges of our time.

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