



Centre for Aerospace and Defence Laws

DDE-NALSAR
M.A.(Maritime Laws)

**Emerging Challenges to Marine Pollution and Use of Advanced
Technologies in Combating Marine Pollution with Case Studies**

23 February 2025

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Introduction

With the rapid development of human society, there is an increasing diversity and **geographic spread of substances** being released into the marine environment.

Above threshold values these substances **can have negative effects** on the biological component of these systems and are therefore classified as pollutants

Pollutants can be introduced to marine environments **directly** through human activities, **indirectly** through runoff such as discharges of untreated or partially treated wastewater, and or by exchange with the atmosphere

The **relative contribution of different pollutants** from these pathways **varies substantially** between substances and also spatially and temporally

Research on marine pollution is an important component of marine science, with the number of studies on this topic rapidly increasing through time (Figure 1A).

Most of these studies have been conducted in **shallow nearshore environments** of sheltered estuaries and bays **where human activities are concentrated** whereas **only very few studies have been conducted in open oceans and deep seas**

The research effort is **not evenly distributed** across the globe, with much of the published literature being **produced in China**, followed **closely by the USA** and **various countries in Europe** (Figure 1B).

This reflects the substantial impacts of these nations on the marine environment and their leading role in producing scientific outputs

Alarminglly, recent research on pollution in many developing regions such as **Africa**, Asia, and South America (Figure 1B), has **demonstrated high levels of pharmaceuticals**

Hence, **more research** on marine pollution in these little-studied regions is necessary to gain a greater understanding of the **spatial footprint of anthropogenic activities**.

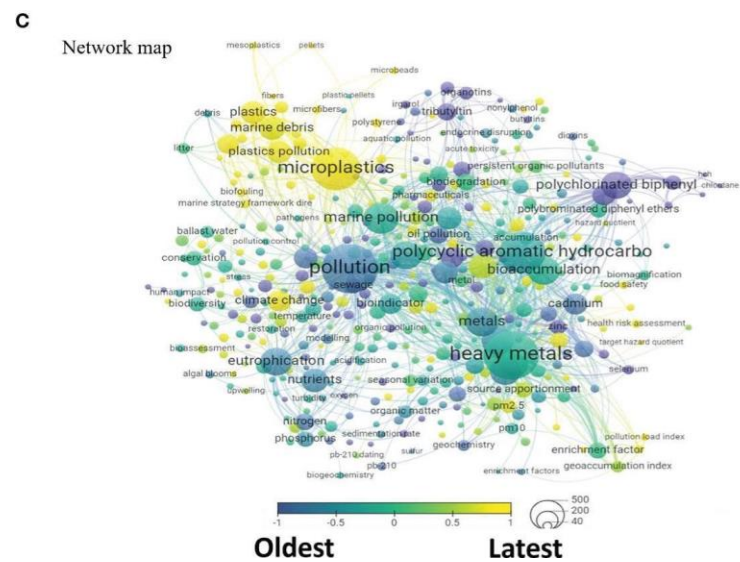
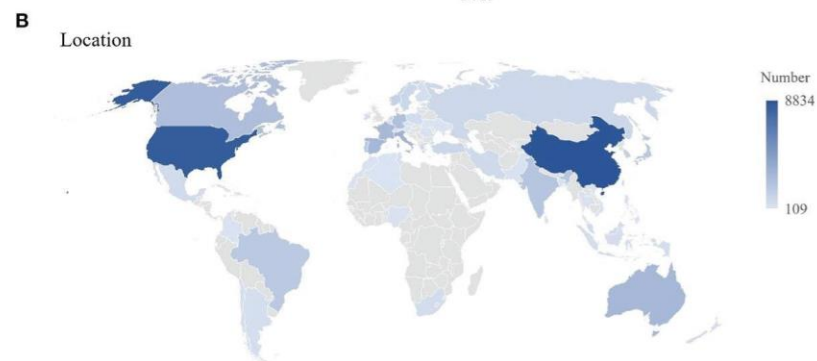
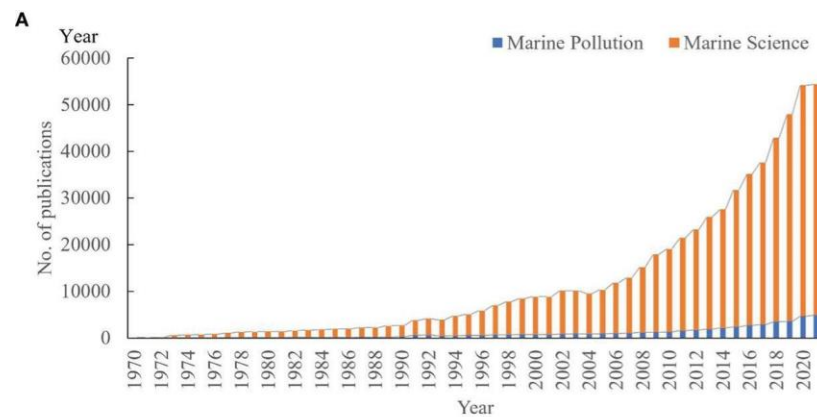


FIGURE 1 The total number of studies:

(A) on marine pollution and marine science by year;

(B) by country (with more than 100 results); and

(C) a network map showing the **most research topics in marine pollution** during 1970 to 2021 based on keyword searches in the search engine Web of Science. The search for studies on “marine pollution” and “marine science” was conducted on 23rd August 2021. A total of 39,550 research articles on “marine pollution” and 568,755 on “marine science” were identified.

Traditionally, research on marine pollution has **focused** on studying how the **release of hazardous or waste substances** in particular **heavy metals and nutrients affects individual organisms**

More recently, however, research on marine pollution has highlighted how the **input and spread of other substances including debris, microplastics, antibiotics and persistent organic pollutants (POPs)**, antibiotics can influence populations, assemblages and ecosystems (Figure 1C).

The range of topics suggests the **definition for marine pollution should be expanded** to include the individual and interactive impacts of these substances with other forms of pollution from energy transfer (e.g., heat, noise and light) and artificial structures (e.g., sea cages, oil rigs, coastal infrastructure) or from the construction of marine artificial structures (e.g., sea cages, oil rigs, coastal infrastructure).

Nutrient Enrichment

High nitrogen and phosphorus concentrations are common sources of pollution in the marine environment, with inputs derived from various point and diffuse sources.

Resultant eutrophication has many undesirable ecological effects, for example phytoplankton blooms and/or shifts toward noxious cyanobacteria, replacement of ecosystem engineers including kelps and scleractinian corals with structurally less complex foliose or turf-algae and increases in the occurrence and severity of marine diseases.

Most devastatingly, nutrient pollution has been linked to low levels of dissolved oxygen in marine environments, or hypoxia conditions which create large areas devoid of macrofauna, due to emigration or mortality, leading to the creation of dead zones.

Understanding the impacts of nutrients, through time and across multiple locations and marine habitats remains an ongoing challenge in marine science.

Heavy Metals

Heavy metals (the group of metals and metalloids of relatively **high atomic mass**, that can **cause toxicity problems**) are primarily brought into marine environments through **industrial, urban runoff** and **shipping activities**, where they disperse into the water column or are incorporated into sediments.

Some metals such as **Fe**, Zn and Cu play vital roles in marine organism's metabolism and only become toxic at **high concentrations**. Other metals, including **Hg**, Pb, Cd and Cr are detrimental to marine organisms even at **low concentrations**.

As pollutants, heavy metals have known effects on the **physiological and individual performance** of **seaweeds and invertebrates with knock on effects on fishes**.

In **sheltered locations**, heavy metals are particularly hazardous pollutants in the marine environment because they **do not degrade and can bioaccumulate** through the food chain with potential detrimental effects to human health *via* consumption of contaminated seafood.

Rare earth elements (e.g. lanthanides and + yttrium) and **nanoparticles** of Ag, **ZnO** and TiO have also been increasingly detected in the marine environment. However, the **extent and impact** of these rare elements and nanoparticles on marine organisms and ecosystems have **yet to be determined**.

Persistent Organic Pollutants

POPs are a broad range of **organic chemicals** that are persistent, **bio accumulative and toxic** substances in the environment and include some **polycyclic aromatic hydrocarbons** (PAHs).

They are a relatively diverse group of pollutants derived from multiple sources. For example, PAHs are mainly derived from activities related to the **petrochemical industry, combustion, and oil spills**.

These chemicals have an **extremely long half-life** in the marine environment and have been found from coastal beaches to the deepest ocean trenches.

POPs **accumulate in the tissues of marine flora and fauna**, where they may cause damage, with effects exacerbated *via* bioaccumulation and biomagnification in marine food webs.

There is increasing scientific interest in the presence of newly identified POPs in the marine environment such as **perfluoroalkyl and polyfluoroalkyl substances**, polychlorinated naphthalenes, **flame retardants** and paraffins.

Often the use of these emerging compounds has not regulated and their effects on the surrounding marine environment are **still being investigated**.

Plastic Debris

Inefficient land-based waste management and human negligence have led anthropogenic litter entering and accumulating in the marine environment. Plastic litter is omnipresent **across polar regions** to the equator and persistent in the marine environment both in the water column and sediments.

More than 200 species, including marine megafauna such as seabirds, cetaceans, pinnipeds, and sea turtles, are negatively affected by large plastic debris through entanglement or ingestion.

The smaller particle size may pose greater risk, as the particles can be ingested by a wider range of invertebrate and vertebrate species, enter the food chain and transfer across different trophic levels.

Recent research has demonstrated that **microplastics** (plastic particles between 1 μm and 5 mm) can have physical, chemical, and biological impacts on organisms either directly or indirectly through associated additives (plasticisers) and adsorbed chemical contaminants.

Adverse effects include physical damages such as obstructions, abrasions and inflammation and physiological alterations such as decreased food consumption, weight loss, decreased growth rate and fecundity and energy depletion.

Despite growing research interest, the **broader ecological effects** of macro-, micro- and nano plastic debris in different marine compartments and ecosystem **remain largely unexplored**. Also, the role of different biological processes in affecting the dynamics and fate of these particles necessitates further study.

Artificial Structures

Urbanisation of coastal areas, and growth in the blue economy have resulted in the proliferation of artificial structures (e.g. breakwaters, reefs, sewage/storm water outflows and offshore platforms etc) in the marine environment.

Artificial structures are not traditionally considered a pollutant, but they are included in the broader definition of pollution established by this special issue.

Artificial structures include contamination associated with the **discharge of toxins and nutrients** and **increased noise and light pollution**.

These structures frequently **destroy and fragment natural habitats** but also provide novel surfaces for colonising marine organisms.

Artificial structures can facilitate the establishment and spread of non-native species and in some cases form ecological traps which reduce organism fitness and reduce ecological connectivity by acting as physical barriers to the movement of organisms within and among habitats.

Effects of Multiple Pollutants and Secondary Feedback Loops

Given the **broad connectivity of the marine environment**, there is the general assumption that various forms of marine pollution will be in **some way interactive**.

As the diversity of pollutants in the marine environment increases, so does the **complexity of interactions**. Thus, our ability to interpret and manage such complex and interacting impacts should be enhanced as well.

Complex interactions occur between mixtures of chemicals but also between artificial infrastructure, nutrients, and other sources of pollution.

Although studies on the effect of multiple pollutants and secondary or indirect pathways are complex, their outcomes are more realistic and aligned with management actions.

The **current challenge** is to **establish a framework** to **assess the effects of multiple pollutants that is realistic** and can be used to **guide management decisions**.

This is partly constrained by the lack of research on multiple pollutants in urban marine and estuarine environments.

On a global scale, research has focused over the last 10 years on understanding the effects of individual sources of pollutants, occasionally two pollutants but rarely more.

Climate change, although not a source of pollution, is also **stressor** that can influence the effects of pollution and should also be considered a component in the context of multiple stressors and marine pollution research.

The effects of multiple pollutants are commonly categorised as:

1. Additive,
2. Antagonistic, or
3. Synergistic.

Additive effects are those where the combined effect is equal to the sum of their individual effects, antagonistic effects occur when the interactions between stressors result in a lesser combined effect and synergistic effects result in an amplification of effects.

The effects of marine pollutants can accumulate over time or occur at different frequencies and intensities making the overall impacts difficult to predict.

A recent review identified synergistic or antagonistic interactions for specific chemical combinations **were not consistent** and often did not exceed the magnitude of the effect predicted by an additive model.

Another option for understanding the effects of multiple pollutants is to consider the severity of the impact based on the magnitude of the interactive effects.

The **magnitude of the effect** could be measured by the extent of the deviation from the expected additive model or other null models depending on the stressor mode of action or species sensitivities. For example, an antagonistic interaction is predicted for nutrients and metal contamination whereby the effects of the individual pollutants are greater than the interactive effects. This type of interactive effect has been shown to occur in coastal marine microbial communities.

However, the direction and magnitude of the antagonistic interactive effect can change at higher levels of biological organisation. This approach is useful as it can identify different magnitudes of the additive, antagonistic or synergistic interactive effects, and potentially more flexible to multiple sources and definitions of marine pollution.

Approaches to Monitoring Marine Pollution

The **development of novel techniques and methods** is critical for **monitoring the impacts of marine pollutants**. Studies on the effects of emerging and multiple pollutants often require innovative models, equipment, or methods to detect impacts.

Environmental Risk Assessment

Conventional quantitative **environmental risk assessment** (ERA) focuses on **characterising the exposure and effect** of a specific chemical substances in the environment, **with their ratio used to estimate risk**.

In the marine environment, however, organisms are simultaneously **exposed to a cocktail** of various anthropogenic chemicals. This discrepancy between the real environment and ERA presents a challenge for monitoring and management.

Recent studies have developed **more complicated ERA frameworks** such as (1) **summing up the toxicity thresholds** derived from the species sensitivity distribution based on either the concentration addition or independent action models and (2) **deriving the mixture toxicity** for each species separately based on the mode of action before fitting species sensitivity distribution and deriving the overall toxicity threshold. However, none of methods consider the potential non-additive interactions among the environmental pollutants.

Therefore, **future ERAs** probably **require a case-by-case assessments** of the interactions between chemicals and other sources of pollution by trained specialists, instead of using standard protocols for risk assessments.

Molecular Approaches and eDNA

Metabolomics, proteomics, and transcriptomics are, high-throughput technologies that are used for **environmental genomics and eDNA monitoring**. These approaches can be used to detect **individual-level responses, populations changes, and occasionally community- level effects of pollution**.

More recently, novel applications that **combine multiple molecular approaches** to detect the effects of pollution on ecosystem functioning have emerged. For example, using metabolomics combined with metabarcoding to detect the effects of pollution on microbial community function. Despite the broad knowledge and potential use of molecular approaches to detect impacts that align with management goals, **barriers adopting them in routine monitoring and pollution assessments remain**.

[Metabolomics is the scientific study of chemical processes involving metabolites, which are the small molecule substrates, intermediates, and products of cell metabolism;

Proteomics is the large-scale study of proteomes, which are the entire sets of proteins produced in an organism, system, or biological context;

Transcriptomics is the study of the transcriptome, which is the complete set of RNA transcripts, including coding and non-coding RNA, in a cell, tissue, or organism]

Unmanned Platforms

Mooring, satellites, and vehicles have great potential to measure the effects of marine pollutants over a wide range of spatial and temporal scales, and is **difficult to assess in environments including open oceans and deeper waters**.

However, much of the research on developing and testing sensors has been **targeted to specific pollutant types and terrestrial settings** (e.g. detection of litter along beaches).

In water, the application of these newly developing technologies is often **limited to specific locations and depths**, and subject to biofouling and maritime growth, which can influence the measurement outcomes.

Further development of sensor technologies and subsequent reductions in costs, will allow these platforms to become increasingly important monitoring tools in marine environments.

Artificial Intelligence/Machine Learning

Machine learning, a subset of artificial intelligence, refers to the ability of machines to learn and understand relationships between inputs and outputs from a full set of representative training samples.

Monitoring approaches that use machine learning to monitor marine pollution are still **relatively conceptual**, although it is a field of research where progress is being made very quickly.

There have been **successful applications** in the context of **oil spill detection**, benthic monitoring [marine fish farming] and monitoring of fish populations while machine learning has been incorporated widely into bioinformatics associated with molecular approaches.

There is clear application where **monitoring techniques generate thousands of images or video, or where large data sets are produced**.

With ongoing improvement and development in computing and technology, there is clear potential for progress in this space.

Solutions for Marine Pollutions

Reducing marine pollution is a global challenge that needs to be addressed for the health of the oceans and the maintenance of its ecosystem goods and services.

Solutions to reduce marine pollution at local scales can be applied singularly or in combination and include

- 1) detection and prevention;
- 2) sustainable management; and
- 3) habitat restoration and reconciliation.

A combined approach may be more appropriate given the broadening definition of marine pollution and the complexity of interactions.

More research in this area is needed to address the complex interactions between marine pollutants and the global nature of impacts.

Case Study 1: Nutrient Pollution

Chesapeake Bay [largest estuary in USA] is an example of where the combined approach of scientific monitoring, sustainable management, and targeted habitat restoration has successfully been implemented to restore estuarine health.

Concerns about the loss of large areas of submerged aquatic vegetation (SAV) within the estuary during the 1970s and 80's, resulted in development of a key goals and comprehensive scientific monitoring program for monitoring changes in water quality through time.

Local management measures which included reduction of land-based nonpoint sources, improved design of watersheds, technological implementation of sewage treatment plants and restoration of the SAV area in the Bay were applied by multiple agencies to reduce the amount of nutrients and sediments entering and concentrating in the Bay.

A scientific monitoring program developed and reported on in an “Annual Ecological Report Card” (AERC) that provides quantitative measurements of (1) water quality through chlorophyll-*a*, dissolved oxygen, and Secchi depth assessments (2) biological measures of phytoplankton diversity and abundance and (3) quantifies the area of SAV which are combined to determine performance-driven numeric grades of the ecosystem health (Bay Health Index).

The AERC is important for communicating the results of the monitoring to decision-makers and stakeholders.

Through time, the AERC has been used to document substantial improvements in water quality and recovery of tens of thousands of hectares of SAV in the estuarine with flow on benefits for biodiversity and other ecosystems services.

Case Study 2: Plastic Debris

Globally marine plastic pollution has become a significant environmental concern for multiple stakeholder groups.

Effective solutions to reduce marine plastic debris are still under development at international level, but focus on combining detection, prevention and sustainable management using **four main categories**:

1. Source prevention based on the 3R rule (i.e. **reuse, reduce and recycle**) and accompanied by land-based management actions to prevent plastic debris to enter the marine environment;
2. Removal based on the environmental monitoring of the marine debris followed by local initiatives at both at institutional and citizenship for plastic clean-up;
3. Regulative and sustainable management frameworks developing and implementing regulations for production of single use plastics, litter disposal, reuse and recycling;
4. Educational which covers campaigns to raise societal awareness and economic/incentive approaches.

The beaches of Cijin, Kaohsiung (Taiwan) have demonstrated that the reduction, reuse and recycling of plastics in terrestrial environments can abate the transfer of these pollutants into marine environments.

In 2001, plastic constituted the 21.1% of household waste.

In 2002, TEPA developed the Plastic Restriction Policy under the Waste Disposal Act which prohibited the use of plastic shopping bags and disposable plastic tableware in all government agencies and public facilities.

Through time, the quantity of shoppers using recyclable shopping bags increased considerably, resulting in a substantial reduction of plastic waste. In 2002 and 2005, Taiwan implemented the Resource Recycling Act (RRA) and the Compulsory Trash-sorting Policy (CTP) which required the use of recycling bins in all public places and encouraged users to sort their waste.

An economic penalty of 1200–6000 NT was applied for unsorted trash.

These policies reduced the waste disposal rate from 2001 to 2010, by 50% (from 0.9 to 0.48 kg per capita).

Over ten years, the development and implementation of a stricter waste-management programs and associated policies has successfully reduced the amount of plastic debris on the surrounding beaches by approximately 20%.

Case Study 3: Artificial Structures

Coastal artificial structures are typically built to protect infrastructure and assets but can have negative impacts on natural intertidal habitats.

The artificial structures in [Caress Bush Park, NSW, Australia](#) represent a key example of where [sustainable management or habitat restoration](#) solutions have been applied during construction to allow natural processes and tidal inundation to occur.

The development contains a mixture of habitats, rock pools, crevices, mudflats for colonising mangroves and planted saltmarshes.

This simultaneously protects public land from flooding and erosion and improves native biodiversity and habitat connectivity.

This approach to habitat restoration also has the potential to restore other ecosystem services (e.g. nutrient cycling and carbon sequestration), while developing relationships with the community through educational and recreational engagement.

Conclusions and Suggestions

Maritime transport is the backbone of the increasingly globalized economy and the international trade system. However, greenhouse gases and other emissions from vessels and related activities in maritime trade have caused significant environmental impacts, especially in coastal areas.

As the **functions undertaken by ports** have expanded significantly from just the handling of ships and cargo to the pursuit of a wide range of interests, local pollution as well as climate change aggravated by greenhouse gas emissions from the port area is now receiving more attention. Yet it remains difficult to harmonize economic activities and environmental considerations both in seaborne trade and within the port.

The studies indicate that the **shipping industry is responsible** for large quantities of pollutants being discharged into the ocean. Being one of the worlds' most polluting sectors, the increase in marine transport in huge magnitudes in these days also increase ship pollution substantially. The major environmental pollutions from ships are due to ship engine which pollute air, oil spill pollution, Ballast Water Pollution, noise pollutions, solid waste pollution, plastic pollution and even physical damage to the marine animals.

Sulfur emission from ship engine combustion accounts for ~250k deaths and ~6.4M childhood asthma cases annually.

The most staggering statistic of all is that just 16 of the world's largest ships can produce as much lung-clogging sulphur pollution **as all the world's cars.**

Because of their colossal engines, each as heavy as a small ship, these super-vessels **use as much fuel as small power stations.**

But, unlike power stations or cars, they can burn the **cheapest, filthiest, high-sulphur fuel: the thick residues left behind in refineries** after the lighter liquids have been taken.

The stuff nobody on land is allowed to use.

This pollution could kill as many as a million more people in the coming decade – even though a simple change in the rules could stop it.

There are now an **estimated around 100,000 ships on the seas**, and the fleet is growing fast as goods are ferried in vast quantities from Asian industrial powerhouses to consumers in Europe and North America.

Till the end of last decade IMO rules allowed ships to burn fuel containing up to 4.5 per cent sulphur. That is 4,500 times more than is allowed in car fuel in the European Union.

The **sulphur comes out of ship funnels as tiny particles**, and it is these that get deep into lungs.

The largest ships can each emit as much as 5,000 tons of sulphur in a year – the same as 50 million typical cars, each emitting an average of 100 grams of sulphur a year. With an estimated 800 million cars driving around the planet, that means 16 super-ships can emit as much sulphur as the world fleet of cars.

With the growing evidence of significant contribution to global sulphur inventories (estimated to be 13% of total SO_x emissions annually) by the ships, the **IMO proposed new global standards to limit sulphur (S) in fuel oil**.

These standards will reduce sulphate aerosols and provide health benefits to exposed populations. On the other hand sulphate reduction may also directly and indirectly affect atmospheric light scattering and absorption properties, and thereby may increase net forcing effects that contribute to climate change.

But this effect balances by the other green house gases emitted by ships.

Every year ships are belching out almost one billion tons of carbon dioxide. Ships are as big a contributor to global warming as aircraft – but have had much less attention from environmentalists about this aspect.

Another major environmental pollution in the ocean is from **plastic**. There is a bit of plastic everywhere, in our wallets, on our dining tables and kitchens, in our cars and buses and in our phones and offices.

It is nearly impossible to imagine a world without plastics. From its beginning in 1950, global plastic production has increased dramatically from 2 million tonnes to 380 million tonnes in 2015. Its sheer convenience lightweight and durable has made this man-made material ubiquitous in every sphere of human existence.

We almost always take the suffocation warning on plastic bags and packages seriously, keeping plastic packaging out of reach of babies and children. But we have not been as mindful with the planet. Of the 8.3 billion tonnes of plastic produced in the last 70 years, 6.3 billion tonnes have been discarded.

Every year, nearly 13 million tonnes of plastic waste are added to oceans which pollute the ocean water and becoming the threat of many marine animals. Given their durability, plastics do not decompose easily. “A plastic bottle takes between 450-1000 years to decompose,” often plastic bottles travels thousands of kilometer and beached some remote islands.

In response to global concerns about marine pollution, the International Marine Organization (IMO) in 1973 adopted the International Convention for the Prevention of Pollution from Ships, known as MARPOL 73/78, which has been amended by the Protocols of 1978 and 1997.

MARPOL, primary international regime aimed at preventing and minimizing accidental pollution and pollution from routine operations on board ships entered into force in 1983.

The study of marine pollution has traditionally focused on understanding the detrimental effects of human wastes and hazardous substances on living resources, human health, and activities, at various spatial and temporal scales. More recently, studies have also considered the **input of energy including heat, light, and noise**, and changing environmental conditions (e.g. acidification), as sources of pollution.

Apart from direct discharges from untreated and partially treated sewage, inputs of pollutants can also be transferred into the marine environment indirectly through surface runoff, freshwater inputs, and atmospheric processes. However, research on marine pollution is rapidly expanding, this special issue highlights, new and emerging types of marine pollution, the complexity of their interactions, and approaches for monitoring.

Suggestions

In the ocean because of **sun and wave energy**, the **plastics tend to break down** into smaller particles, called **microplastics** of grain size lower than 5 mm.

Microplastics also enter the aquatic environments directly from a variety of sources, including cosmetics, clothing, and industrial processes.

Microplastics are a cause for concern because their size range overlaps with the preferred particle size ingested by the animals at the base of the aquatic food webs.

Marine microplastic is known to accumulate harmful chemicals on its surface and often ingested by fishes, turtles and birds that mistaken those as food.

Many of the birds and turtles often entangle into the larger debris. Polyethylene (PE) and Polypropylene (PP) is the abundant polymer types found on the marine/beach litter around the coast of India.

In addition to macro/microplastic debris, tar ball deposition along the west coast of India during the southwest monsoon is another environmental issue.

While reports and data on plastic accumulation are available for other oceans, the same is almost nonexistent for the Indian seas.

Understanding importance of **mapping marine microplastic density** is essential for the sustainability of ecosystems.

In order to substantially reduce marine litter and microplastics, it **is essential to develop national and regional policy/action plan and evolve appropriate programmes to tackle the menace of **marine litter**.**

In the entire South Asia Seas (SAS) region, data and/or information about the marine litter (especially microplastics) is limited. It is towards this end; the South Asia Co-operative Environment Programme (SACEP) has attempted to develop a data base for marine litter and microplastics management in the SAS region and has initiated the preparation of a Regional Action Plan on Marine Litter.

The Ministry of Earth Sciences (MoES), Government of India (GoI) through its National Centre for Coastal Research (NCCR) Chennai, has been entrusted to prepare a Country Report on Marine Litter in India. IMO should take initiative to introduce an act by which each state should have this kind of report.

Recent study shows **cleaner marine fuels** will reduce ship-related premature mortality and morbidity by 34 and 54%, respectively. Complying with low-sulphur limits for marine fuels will reduce ship air pollution and attributable health impacts substantially.

Prior to cleaner ship fuels, ship-related health impacts include ~400,000 premature deaths from lung cancer and cardiovascular disease and ~ 14 million childhood asthma cases annually. Reduced PM2.5 from marine engine combustion mitigates ship-related premature mortality and morbidity by 34 and 54%, respectively.

Despite these reductions, low-sulphur marine fuels will still account for ~250,000 deaths and ~6.4 millions childhood asthma cases annually. Lower sulphur fuels also reduce radiative cooling from ship aerosols by ~80%, equating to a ~3% increase in current estimates of total anthropogenic forcing. Therefore, stronger international shipping policies may need to achieve climate and health targets by jointly reducing greenhouse gases and air pollution.

The natural environment is undergoing a dramatic transformation due to global warming. The result is **melting of Arctic ice** and continuous decrease of ice covered area every year as evidenced by satellite observations since 1980.

Such a change may create many new opportunities for maritime transport by increased commercial shipping, tourism, and the extraction and transportation of natural resources.

However, all these activities carry the risk of environmental pollution, such as oil spills in ecologically sensitive areas, and these prevent the Arctic from achieving its full potential.

IMO needs to impose strict regulation in order to keep the biodiversity of this region to be preserve.