05 MARINE POLLUTION : SOURCES, QUANTIFICATION AND MITIGATION STRATEGIES

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Introduction

Marine pollution refers to the contamination of the oceans, seas, and coastal waters with harmful or toxic substances, which can adversely impact marine life, ecosystems, human health, and the economy. According to Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), Marine pollution is: *"the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water, and reduction of amenities."*

As marine ecosystems are interconnected and highly sensitive, pollutants can have far-reaching consequences across species and regions. Marine pollution can be classified based on various criteria.

Classification of Marine Pollution

According to the **physicochemical constituents** of the pollutants, they are of the follows. Each of these, interacts with marine ecosystems uniquely and poses distinct risks to marine species and habitats.

i. Organic pollution

- **Biodegradable Organic Matter**: Organic waste from sewage, agricultural runoff, and food processing industries contains biodegradable materials that decompose in water. As they decompose, they consume dissolved oxygen, potentially causing hypoxic or anoxic conditions.
- **Persistent Organic Pollutants (POPs)**: These are toxic chemicals that remain in the environment for long periods, such as pesticides (e.g., DDT), polychlorinated biphenyls (PCBs), and dioxins. POPs are hydrophobic and accumulate in fatty tissues of marine organisms.

ii. Inorganic Pollution

- **Heavy Metals**: Industrial discharges, mining activities, and leaching from waste dumps are the sources of heavy metals in the ocean. Metals like mercury, lead, cadmium, and arsenic are highly toxic and can accumulate in marine organisms.
- **Nutrients**: Nitrogen and phosphorus compounds from fertilizers and wastewater cause nutrient pollution or eutrophication, which triggers excessive algae growth and ultimately depletes oxygen, disrupts ecosystems, and creates dead zones.
- **Acids and Alkalis**: Industrial process discharge acidic or alkaline waste which can alter the pH of seawater, impacting sensitive species and potentially leading to acidification of localized areas.

iii. Suspended Particulate Pollution

- **Sediment runoff**: Soil erosion and construction activities contribute to high levels of sediments entering the oceans. These Suspended particles can cloud the water, reducing sunlight penetration, affecting photosynthetic organisms, and potentially smothering marine habitats like coral reefs.

- **Plastic Particles**: Microplastics and nanoplastics from degraded larger plastic items, are common suspended particulates in the marine environment. They can be ingested by marine life, causing physical and chemical harm.

iv. Thermal Pollution

- **Heat**: Hot water discharged from power plants, industries, and desalination plants raises the temperature of surrounding water. Higher temperatures reduce oxygen solubility, impacting aquatic organisms and ecosystems.

v. Radioactive Pollution

- **Radioactive Isotopes**: Contamination from radioactive isotopes like Cesium-137, Iodine-131, and Strontium-90 can come from nuclear waste dumping, nuclear accidents, and testing. These isotopes emit radiation, which can cause genetic mutations, cancer, and ecological disruptions in marine organisms.

vi. Chemical Pollution

- **Pesticides and Herbicides**: These chemicals enter the marine environment through agricultural runoff and can disrupt endocrine systems in marine species, interfere with physiological function and cause long-term ecological damage.
- **Oil and Hydrocarbons**: Oil spills and hydrocarbon leaks release various toxic compounds (e.g., benzene, toluene, xylene) that coat marine organisms and sea surfaces, blocking light and oxygen. These pollutants can also alter the chemical composition of water and sediments.

vii. Pathogen Pollution

- **Biological Contaminants**: Bacteria, viruses, and protozoa from untreated sewage and wastewater contaminate the coastal waters, which can lead to waterborne diseases in marine organisms and humans.

viii. Noise Pollution

- **Sound Waves**: Sound waves from industrial activities, military exercises, and shipping can disrupt marine animals' communication, orientation, and migration, especially those that that rely on echolocation.

Based on the **physical state** of pollutants—whether they are in solid, liquid, or gaseous form, marine pollution can be classified as follows.

- **Solid Pollution-** e.g. Marine litter, sediments and biodegradable solids
- **Liquid Pollution-**e.g. Oil and hydrocarbon, industrial effluents, agricultural runoff and sewage waste water.
- **Gaseous Pollution-**e.g. Carbon Dioxide (CO_2) Methane (CH_4) and Nitrous Oxide (N_2O), Airborne Pollutants (e.g., Sulfur Dioxide and Nitrogen Oxides).

Based on the **persistence** of pollutants, which refers to how long they remain in the marine environment before breaking down or being removed. Marine pollution can be classified into the following categories.

i. Persistent Pollutants

- Persistent pollutants are stable, do not degrade easily, and remain in the marine environment for extended periods. They can accumulate in marine organisms and ecosystems, leading to long-

lasting ecological and health impacts. e.g. persistent organic pollutants (POPs), heavy metals, plastics and microplastics, radioactive Substances.

ii Semi-Persistent Pollutants

- Semi-persistent pollutants break down more readily than persistent pollutants but can still remain in the marine environment for moderate periods, often several months or years. They may impact ecosystems over time, especially with repeated or large-scale exposure.e.g. are more degradable than POPs**,** Some Hydrocarbons (components of crude oil, such as polycyclic aromatic hydrocarbons (PAHs), are semi-persistent. While these chemicals break down faster than other pollutants, they can persist in marine waters long enough to affect water quality and harm marine organisms.

iii. Non-Persistent Pollutants

- Non-persistent pollutants break down relatively quickly in the marine environment, typically within days to weeks. Although they may cause immediate harm, they do not tend to accumulate long-term. e.g. are Biodegradable Organic Matter (from sewage or agricultural runoff, including plant material and animal waste) nutrients (Nitrogen and Phosphorus Compounds) from fertilizers and wastewater are non-persistent, thermal Pollution (Heat): Warm water discharged from various sources dissipates quickly once the discharge stops.

Based on the **origin of the pollutants**,marine pollution can be classified into point source pollution and nonpoint source pollution

i.Point Source Pollution:

- This type of pollution comes from identifiable, single sources, such as factories, sewage treatment plants, or oil spills. Because these sources are localized, monitoring, controlling, and regulating them is often easier. For instance, industrial facilities discharging toxic chemicals or sewage treatment plants release treated wastewater. They are generally continuous or happen at specific times, making them more traceable.

ii.Nonpoint Source Pollution:

- Unlike point source pollution, nonpoint source pollution is diffuse and originates from multiple sources hence it is more challenging to control.It usually enters marine environments indirectly, often carried by runoff from rain or snowmelt. Common examples include agricultural runoff containing fertilizers and pesticides, urban runoff from roads and streets, and atmospheric deposition from pollutants like nitrogen oxides.

Sources of pollution

Marine pollution originates from diverse sources, with land-based sources being the significant contributor either through run-off and discharges (via waterways; 44%) or through the atmosphere (33%). Only 12% of all pollution is due to maritime activity and shipping accidents. Dumping of garbage and sewage, and the consequences of offshore drilling and mining make up for the rest (resp. 10% and 1%).

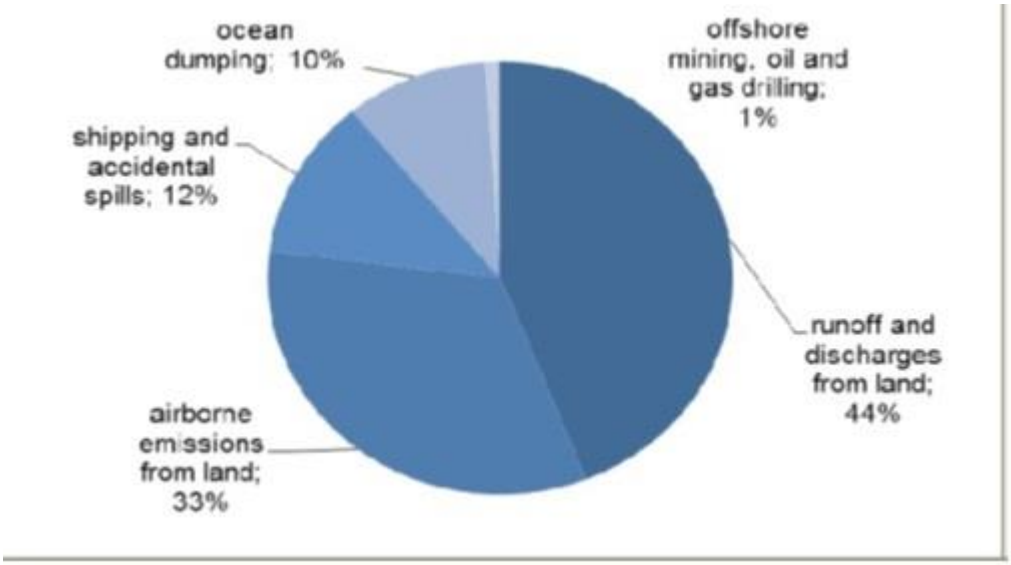

Fig. Sources of marine pollution. (adapted from Potters, 2013)

Measurement of pollution

Pollution measurement methods cover a range of scientific techniques to evaluate pollutants in marine and coastal environments:

1. **Water Sampling and Analysis**: Water samples are collected and tested for pollutant concentration using chemical analysis or spectrophotometry, chromatography, and mass spectrometry.
2. **Sediment Core Analysis**: By analyzing seabed sediment cores, scientists assess pollution accumulation over time, revealing historical pollution patterns and trends.
3. **Ecotoxicological Testing**: Bioassays expose aquatic organisms to water or sediment samples in labs to test for toxicity effects on survival, growth, and reproduction.
4. **Half-Life and Bioavailability of Pollutants**: The half-life of pollutants measures their persistence in the environment. Bioavailability indicates how accessible a pollutant is to living organisms. Pollutants undergo various processes in the water, including adsorption, oxidation, and biotransformation.
5. **Biomonitoring of Marine Life**: Pollutants concentrated in organisms, are estimated either directly from water (bioconcentration) or through food chains (biomagnification). Bioaccumulation is measured by the Bio Accumulation Factor (BAF). Indicators such as enzymes in marine animals can detect early pollutant exposure, showing oxidative stress or genetic damage called biomarkers in marine organisms. In addition to that fish and wildlife are monitored for signs of pollution-related deformities, disease, and reproductive or behavioural issues.
6. **Remote Sensing and Satellite Monitoring**: **Satellite Imagery**: Detects pollution markers like algal blooms, oil spills, and sediment plumes through water color and temperature changes. In addition to that aerial drones equipped with cameras, drones monitor pollution sources, especially in inaccessible areas.
7. **Real-Time Sensor Networks and Autonomous Platforms**: Buoys and Underwater Sensors are used for continuously monitor water quality for pollutants, detecting changes in dissolved oxygen, pH, turbidity, and more. Autonomous Underwater Vehicles (AUVs) collect data on pollutants in hazardous or deep areas, mapping pollution distribution.

8. **Citizen Science and Community Reporting**: Citizen data from beach cleanups provide insight into local pollution sources, especially plastic waste. Community members report pollution sightings, complementing scientific data collection.
9. **Computer Modeling and Prediction Tools**: Pollutant Transport Models can **s**imulate pollutant movement and predict future regional levels. Similarly climate and pollution interaction models are used to **e**xamine how climate change might amplify pollution impacts, and aid on mitigation strategies.

These diverse methods collectively provide a comprehensive understanding of pollution sources, trends, impacts, and potential mitigation approaches for marine ecosystems.

Mitigation measures

Marine pollution mitigation aims to prevent pollutants from entering the ocean and address existing contamination through the following key strategies:

- **Plastic and solid waste**: Enforcing bans on single-use plastics, improving waste management, and implementing Extended Producer Responsibility (EPR) policies to promote eco-friendly designs.
- **Chemical Pollution**: Upgrading wastewater treatment, managing agricultural runoff, and enforcing regulations on industrial effluent.
- **Oil Spill** : Enhancing shipping regulations, improving oil spill response, and enforcing safety protocols for offshore drilling.
- **Nutrient Pollution**: It can be controlled by sustainable agriculture, restoring wetlands, and upgrading septic systems to limit nutrient runoff.
- **Clean-Up Initiatives**: Organizing beach clean-ups, deploying ocean-cleanup technologies, and retrieving abandoned fishing gear may be followed to reduce marine debris.
- **Sustainable Fishing Practices**: This can be achieved by regulating harmful fishing gear, establishing Marine Protected Areas (MPAs), and managing fisheries to reduce the ecosystem damage.
- **Carbon Emissions**: This can be regulated by implementing carbon reduction policies and protecting blue carbon ecosystems to combat ocean acidification.
- **International Agreements**: Include treaties like MARPOL, the London Protocol, and the developing Global Plastics Treaty. By supporting these, pollution control standards are achievable.
- **Monitoring and Enforcement**: Management of pollution hotspot is achievable by monitoring systems and enforcing environmental laws.
- **Public Awareness and Education**: Raising awareness, engaging communities in conservation, and educating youth to foster long-term stewardship.

All these above strategies aim to reduce pollution and protect sustainable ocean ecosystems for the future.

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