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Editorial: Biodegradation of emerging marine contaminants

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Editorial on the Research Topic
Biodegradation of emerging marine contaminants

Emerging marine environmental contaminants such as polycyclic aromatic hydrocarbons (PAHs), cyclic peptide toxins, and plastics/microplastics are widely spread in the marine environment. Use of plastics has caused a growing environmental problem in all industrial aspects due to the difficult biodegradation of mostly synthetic plastics, such as polyethylene, polystyrene, polypropylene, and polyethylene terephthalate, which remain in the environment for hundreds of years. These environmental problems became critical because of the massive disposal of plastic waste, which negatively affects rivers and oceans' ecosystems and marine life. Additionally, petrochemicals and PAHs are known toxic and carcinogenic pollutants produced due to the incomplete combustion of carbonaceous materials (combustion of coal, oil, or natural gas burning, and waste incineration). PAHs are usually present in the atmosphere in the gas phase or associated with particles such as microplastics. PAHs tend to associate with particles rather than dissolve in water because of their hydrophobic nature. Particles, such as polystyrene, adsorb PAHs from the surrounding environment and can be easily ingested by marine vertebrates and invertebrates.

The objective of this Research Topic is to understand the role of microorganisms and their products in the degradation of marine contaminants such as PAHs, cyclic peptide toxins, and plastics/microplastics in order to fill the research gaps and update the readers with the recent investigations in this field. Studies involved in this Research Topic include methods from enzymatic biotechnology, metagenomics, and experiments focusing on the degradation, uptake, and accumulation of the contaminants.

Spills of crude oil and gas condensate can result in long-term changes to the productivity and diversity of benthic microbial communities. Such incidents of hydrocarbon pollution can disrupt nutrient balances, impacting geochemical processes (such as denitrification and nitrogen fixation) and thus altering the nutrient environment for both heterotrophic bacteria and autotrophic microorganisms in benthic ecosystems. The identification of hydrocarbon-degrading bacteria, such as *Methylophaga* and

Alcanivorax, show the resilience of benthic ecosystems and their capacity to adapt to contamination. Despite heterotrophic bacterial populations and diversity appearing stable for months after a spill, their productivity levels may surge quickly, indicating that tracking their activity can be a valuable method for assessing pollution from crude oil or gas condensate. Evaluating microbial activity can be enhanced through various molecular (omics) and biochemical (for example, assessing denitrification and nitrogen fixation) analysis methods, which help in understanding the metabolic capabilities and actual breakdown of macromolecules (Kababu et al.).

Sirsoe methanicola is a polychaete worm living on the surface of a methane hydrate in deep-sea oil platform sediments in the Gulf of Mexico and inhabits methane clathrate deposits in the ocean. Metagenome analysis revealed that *S. methanicola* has 42 homologous proteins with the cytochrome P450 superfamily that could be putatively involved in PAHs metabolism (Lim et al.). An indigenous eukaryotic microalgal strain isolated from Daya Bay, *Rhinomonas reticulata* S6A, was able to degrade the alkylbenzene compounds, n-propylbenzene and isopropylbenzene, which have been of concern due to recent C9 aromatics spills in Quangang District, Fujian Province. Alkylbenzene compounds are widely used as a substitute component of jet fuel and diesel oil due to their moderate molecular weight and chain length (Du et al.). Microcystins (MCs) are another emerging marine contaminant commonly produced by harmful cyanobacterial blooms and pose an increasing global threat to human health and ecosystems. Cyclic MCs are degraded to linearized MCs by opening the peptide bond between 3-amino-9-methoxy-2,6,8-trimethyl-10-phenyl-4,6-decadienoic acid (Adda) and arginine using MlrA enzyme. The linearized MCs are further degraded by cleaving the peptide bond between alanine and leucine to produce the tetrapeptide compound using MlrB enzyme. Tetrapeptide compounds are then degraded by the MlrC enzyme to produce Adda. A comprehensive enzymatic mechanism for linearized MCs biodegradation by MlrB was revealed with both computer simulation and experimental verification (Teng et al.).

A year-long study at a Danish marina demonstrated that biofilms and minerals quickly accumulated on surfaces made of polystyrene and polyethylene, becoming noticeable within just three months. The study found that the microbial communities forming on these plastic surfaces were different from those in the nearby natural environments, suggesting the creation of a novel Plastisphere. These microorganisms could produce enzymes for plastic biodegradation and cycle various elements, such as silicon dioxide, iron and manganese oxides, at the plastic surface, introducing biogeochemically active sites (Dodhia et al.). Future work on the mechanisms and interactions driven by this biogeochemically complex surface is still needed. The widespread of microplastics in oceans raised concerns about their impact on marine ecosystems due to the ingestion of microplastics orally by animals. A recent study in this Research Topic has found that microplastic ingestion by deep-sea and coastal mussels can happen through their gills. It found that specific gill cells internalize microplastics via phagocytosis. Using microscopy analysis, researchers confirmed that microplastics were encapsulated within membrane-bound vacuoles. The study conducted by Ikuta et al., highlights the urgent need for further investigation into the effects of microplastic contamination on marine life and human health, particularly focusing on species with body surface exposure to plastics. Nowadays, enzyme engineering plays a vital role in the degradation of marine contaminants. A multigene fusion strategy was introduced for developing a novel hydrophobic cell surface display (HCSD) system in *Escherichia coli* (*E. coli*) for PET degradation by fusing PETase enzyme with hydrophobin HFBII (small, cysteine-rich proteins produced by filamentous fungi) and FadL. FadL is an anchor peptide rich in β-structures, exists in the outer membrane-bound fatty acid transporter of *E. coli*, and it can cross the outer membrane multiple times to form fatty acid-specific channels. The developed system enhanced the interaction between *E. coli* cells and PET surface and accelerated PET bottle biodegradation (Jia et al.).

Author contributions

NS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. LV: Writing – review & editing. JX: Writing – review & editing.

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Conflict of interest

Author JX was employed by company Sinopec Research Institute of Petroleum Processing.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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