

Chemical Behaviour and Biological Effects of Microplastics in China's Coastal Marine Ecosystems

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Abstract—Microplastics have been widely found in China's coastal waters, sediments and marine organisms. This paper reviews studies published mainly between 2020 and 2025 to examine their effects on marine life. It considers not only the presence of microplastics but also how polymer type, particle size and environmental ageing can influence their behaviour and possible toxicity. Weathering can break plastics into smaller particles and change their surface chemistry, affecting their interactions with additives and other pollutants. Studies of plankton, bivalves and fish have reported ingestion, oxidative stress, inflammation and changes in growth or metabolism. However, many of the stronger biological effects have been observed under laboratory conditions. Overall, the evidence shows that marine organisms in China's coastal regions are widely exposed to microplastics and can experience biological effects, but the long-term consequences for populations and marine food webs remain uncertain.

Keywords—Microplastics, China's coastal regions, marine organisms, polymer ageing, ecotoxicity, marine pollution

I. INTRODUCTION

Microplastic pollution in marine environments have become an prominent global environmental issue, posing significant threat to marine ecosystems and biodiversity. The concept of "microplastics" was first proposed by Thompson *et al.* [1] and is generally defined as plastic fragments, fibres, films, or particles with diameters smaller than 5mm. Due to their small size, persistence, and resistance to degradation, microplastics are easily transported and widely distributed in marine environments, making them a long-term pollutant and arousing global concern.

On a global scale, numerous studies have reported the widespread presence of microplastics in marine ecosystems. For example, there are concentration maps of marine microplastics concentration indicating that most areas are with medium concentration, but some areas like South China Sea in Asia, northern waters of Brazil in Africa have very high concentrations of microplastics [2]. More importantly, recent research has shown that microplastics are no longer confined to areas of intense human activity but have been found even in remote polar sea areas, including in water, sediment, sea ice, marine snow, and marine organisms in polar sea areas [3]. This expanding spatial distribution suggests a clear trend that microplastic pollution has shifted from a predominantly regional issue to a global environmental problem, highlighting its growing scale of influence on marine ecosystems.

China's coastal regions are significant for the study of microplastic pollution. As the world's largest producer and consumer of plastics products, China generates substantial quantities of plastic waste each year. Also, China has an

extensive coastline and numerous major river systems which acts as important pathways for land-based plastic waste to enter the marine environment. In addition, study shows that more than 70% of large Chinese cities are located in coastal areas, and coastal development in China plays a leading role in the national economy, accounting for 55% of its GDP [4]. These combined factors contribute to the accumulation of microplastics in China's coastal regions, making them the major spots of microplastic pollution where impacts on marine ecosystems are more direct and potentially more severe.

Microplastic pollution can post great environmental hazards to marine life. Studies suggest that marine organisms that consume microplastics may experience a variety of consequences, such as intestinal tract blockage, inflammation, oxidative stress, hormone disruption, reproductive effects and changes in metabolism and behaviour [5]. Moreover, microplastics can be transferred along marine food chains, accumulating from plankton to fish and further to higher trophic-level organisms such as seabirds. The presence of microplastics in marine life is also potentially linked to human health concerns as humans may be exposed to microplastics through the consumption of seafood and bottled drinking water. There are studies showing that microplastics can induce inflammatory response and disruption of gut bacteria [6] while long-term health effects remain uncertain and require further scientific verification.

This paper examines how microplastics have affected marine life in China's coastal regions between 2020 and 2025. It reviews studies on where microplastics are found, their chemical and physical properties, and their effects on different marine organisms. The paper considers plankton, benthic organisms, fish and other marine animals, as well as differences between coastal regions. It also looks at how factors such as polymer type, particle size, ageing and chemical additives may change the behaviour and possible effects of microplastics. An important part of the discussion is the difference between simply finding microplastics in an organism and showing that they have caused biological harm. Overall, the available evidence shows that marine organisms are widely exposed to microplastics, but their long-term effects on populations and coastal ecosystems are still not fully understood.

II. LITERATURE REVIEW

A. Sources, Classification and Chemical Properties

1) Primary and secondary microplastics

Marine microplastics come from many different sources and can generally be divided into primary and secondary

microplastics. Primary microplastics are plastics that are originally produced at a very small size, such as industrial pellets and some abrasive particles. In comparison, secondary microplastics are formed when larger plastic products gradually break down into smaller pieces. These larger plastics can include packaging, ropes, fishing nets, tyres and synthetic textiles [7, 8]. Along China's coast, microplastics can enter the marine environment in several ways. Rivers and wastewater can transport plastic particles from inland areas to the sea. At the same time, fishing, aquaculture, shipping and tourism can also release plastics directly into coastal waters. Microplastics may even reach the Bohai and Yellow Seas through atmospheric deposition [9].

The shape and size of microplastics can affect how marine organisms are exposed to them. For example, fibres may become trapped in feeding structures or stay in the digestive tract, while irregular fragments may have rough surfaces or edges. Thin plastic films have a relatively large surface area compared with their mass, and small beads can be easily ingested by some filter-feeding organisms. Particle size is also important. Smaller microplastics can potentially be taken up by a wider range of marine organisms and have a larger surface area relative to their mass. As plastics remain in the environment, ageing and physical breakdown can produce increasingly smaller particles. Some of these

particles may be too small to be collected by the nets commonly used in microplastic surveys. As a result, studies using larger mesh sizes may underestimate the amount of small microplastics present in the marine environment [10, 11].

2) Polymer composition, functional groups and environmental behaviour

Several types of polymers have been commonly found in microplastic studies along the Chinese coast. These include polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polystyrene (PS), polyamide (PA or nylon) and polyvinyl chloride (PVC) [12]. Although they are all plastics, their chemical structures are different, which gives them different physical and chemical properties. For example, differences in density can affect whether a plastic particle is more likely to remain near the water surface or sink into deeper water and sediments. The functional groups present in a polymer can also affect its polarity and how it changes when exposed to the environment. This means that different types of microplastics may behave differently in seawater and may also interact differently with pollutants and marine organisms. The main structural characteristics of these six polymers and their possible environmental effects are summarised in Table 1.

Table 1. Structural features and environmental behaviour of common marine microplastic polymers

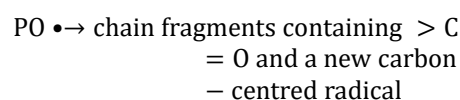
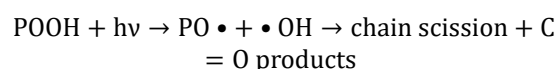
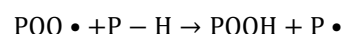
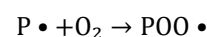
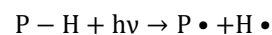
Polymer	Key structural feature	Typical marine behaviour	Chemical relevance
PE	Non-polar $-CH_2-$ backbone	Usually buoyant when clean; common in films and packaging	Hydrophobic surface favours partitioning of non-polar organic chemicals; oxidation adds carbonyl and hydroxyl groups.
PP	Hydrocarbon backbone with $-CH_3$ side groups	Usually buoyant; common in ropes, packaging and fibres	Tertiary carbon atoms make PP relatively susceptible to photo-oxidation and embrittlement.
PS	Aromatic phenyl side groups	May float or remain suspended; often brittle after ageing	Aromatic surface can interact with aromatic pollutants; styrene-related residuals and additives may be relevant.
PET	Ester groups and aromatic rings	Denser than seawater and often associated with fibres or sediments	More polar than PE/PP; ester groups and weathered surfaces influence hydrogen bonding and sorption.
PA	Amide groups	Often present as fishing-net or textile fibres; readily biofouled	Amide groups allow hydrogen bonding and can increase interactions with polar compounds and metals.
PVC	Chlorinated carbon backbone	Dense and more likely to settle	Often contains substantial plasticiser and stabiliser packages; weathering can promote additive release.

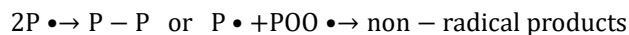
Density alone does not fix a particle's position. Biofilm growth and attachment of minerals or organic matter can increase the effective density of initially buoyant PE and PP, causing them to sink. Conversely, turbulence can resuspend particles from sediments. Polymer type also affects microbial colonisation: experiments with PE, PP and PS in seawater show that biofilm structure changes with both polymer identity and exposure time [13]. Microplastics therefore move dynamically between coastal compartments.

3) Oxidation, fragmentation and ageing in seawater

Marine plastics do not rapidly mineralise to carbon dioxide and water, but they do age. Ultraviolet radiation can excite polymer chromophores or impurities and initiate radical reactions. In the presence of oxygen, polymer radicals form peroxy radicals and hydroperoxides; subsequent chain scission introduces carbonyl, hydroxyl and carboxyl-containing groups. The principal initiation, oxygen-addition and propagation steps are shown below. Waves, sand abrasion and temperature changes then exploit the weakened structure, producing cracks and smaller fragments [14, 15]. This is fragmentation, not necessarily complete biodegradation.

The radical mechanism can be written more explicitly as the following simplified sequence, where P represents a polymer chain. The first reaction may be initiated by ultraviolet light acting on a chromophore or pre-existing defect. Hydroperoxides are unstable and can generate alkoxy and hydroxyl radicals; β -scission of an alkoxy radical then shortens the chain and produces carbonyl-containing end groups [15].





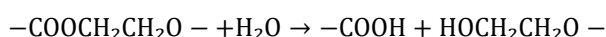
These reactions show that plastics can follow different pathways during ageing. Chain scission breaks the polymer chains into shorter sections, which reduces the average molecular mass and can make the plastic more brittle. In some cases, radicals can also react with each other and form cross-links between polymer chains. Which reaction is more important depends on several factors, including the amount of oxygen available, the structure of the polymer and exposure to different wavelengths of light. Pigments and stabilisers added during plastic production can also affect this process. PP can be particularly sensitive to oxidation because radicals can form at the tertiary carbon in its structure. PE has a different structure because it does not contain the methyl side group found in PP. PS contains phenyl groups, which can stabilise radicals, although oxidation products can still be formed. PET is different again because ester and aromatic groups are already part of its original chemical structure. For this reason, changes in the infrared spectrum of PET cannot be assessed in exactly the same way as PE. The polymer should first be identified before its level of chemical ageing is evaluated.

Secondly, ageing can also change how a microplastic behaves in seawater. As the surface becomes damaged, it often becomes rougher and its surface area may increase. Oxidation can also introduce oxygen-containing groups onto the plastic surface, making it more polar. These changes can affect how other chemicals interact with the microplastic. For example, some metal ions may bind more easily to an aged surface through electrostatic interactions or complex formation. However, the behaviour of organic pollutants is more complicated because it also depends on the polymer, the properties of the pollutant and environmental factors such as biofilms and dissolved organic matter. Ageing does not necessarily mean that a microplastic will adsorb more pollutants or become more toxic. New surface groups may provide additional sites for some chemicals to bind, but ageing may also cause previously adsorbed chemicals to be released or reduce the importance of hydrophobic interactions. The effect can therefore vary between different plastics and pollutants, and should be considered for each polymer-contaminant combination rather than assuming the same behaviour for all microplastics [16, 17].

Chemical ageing is commonly evaluated by Fourier-transform infrared spectroscopy. For PE, oxidation is indicated by growth of a carbonyl band near 1715 cm^{-1} relative to a comparatively stable C-H bending band near 1460 cm^{-1} . An illustrative carbonyl index is shown below, although the exact integration ranges and reference bands vary among polymers and studies.

$$CI = A_{1715}/A_{1460}$$

Reporting the spectrum and calculation method is essential because two studies can obtain different CI values from the same material. PET contains ester groups before ageing, so its spectrum must be interpreted differently. Hydrolysis can cleave an ester linkage at the surface as follows:



In seawater this reaction is generally slow, but photo-oxidation, heat and microbial activity can make damaged regions more accessible.

Fragmentation also changes biological availability. Accelerated ageing of marine PE, PP and PS has produced very large numbers of fragments below $2 \mu\text{m}$, illustrating how one visibly larger item can become a reservoir of micro- and nanoplastics [10]. Smaller particles are more likely to contact gills, cross gut epithelia or enter cells, although field evidence for tissue translocation remains less complete than laboratory evidence.

4) Additive release and interactions with co-existing pollutants

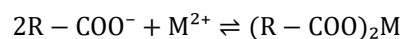
Commercial plastics are formulations, such as plasticisers, antioxidants, ultraviolet stabilisers, pigments, flame retardants and metal-based stabilisers may be physically mixed into the polymer and can migrate as the material ages. Reviews of marine plastics report phthalates, bisphenol A, alkylphenols, brominated flame retardants and antioxidants among chemicals of concern [18, 19]. Leaching depends on molecular size, polymer free volume, temperature, salinity, dissolved organic matter and the degree of weathering. The toxicological effect attributed to a particle may therefore arise partly from its chemical mixture.

Microplastics can also sorb chemicals already present in seawater. Hydrophobic organic pollutants, including polycyclic aromatic hydrocarbons (PAHs), can partition into non-polar polymers, while oxidised groups and biofilms provide binding sites for metal ions. Field-aged plastics generally have more complex surfaces than pristine laboratory beads. Nevertheless, describing microplastics simply as 'vectors' may exaggerate their importance: natural sediments, organic particles and prey can transport much larger chemical masses. Whether a microplastic increases exposure depends on pollutant concentration, sorption and desorption rates, gut conditions and the organism's other exposure pathways [17].

The ability of a microplastic to sorb a chemical can be represented by a distribution coefficient, where C_s is the mass of chemical associated with the plastic and C_w is its dissolved concentration at equilibrium.

$$K_d = C_s/C_w$$

A higher value shows stronger partitioning between the plastic and water, but does not directly indicate greater toxicity. For metals, binding may occur through interactions with oxygen-containing groups on an aged plastic surface. In contrast, PAHs are mainly influenced by hydrophobic interactions, although the behaviour varies between polymers.



where $R-\text{COO}^-$ represents an oxidised carboxylate site and M^{2+} a divalent ion such as Cu^{2+} or Pb^{2+} . Evidence from the Pearl River Estuary shows how ageing can affect this process. Shi *et al.* [20] exposed conventional and biodegradable microplastics to natural conditions for up to 9–12 months. Properties related to plastic ageing explained 51.0% of the variation in metal adsorption, compared with 13.2% for the environmental factors measured in the study. The

biodegradable plastics also adsorbed more Cu, Pb and As than conventional plastics after ageing, although this pattern was not the same for every metal. This suggests that biodegradable plastics should not automatically be assumed to have a lower chemical risk.

Pollutants associated with microplastics may also contribute to biological effects. Studies of marine bivalves exposed to both microplastics and PAHs have reported oxidative stress, lipid peroxidation and DNA damage. Similar studies with metals show that the response can vary with the polymer, metal and exposure level [21, 22]. This makes it important to consider the chemicals associated with microplastics, rather than assessing the particles alone.

B. Distribution in China's Coastal Regions

1) Bohai Sea and Yellow Sea

The Bohai Sea is a semi-enclosed sea connected to the Yellow Sea through the Bohai Strait. Its relatively limited water exchange means that plastics entering from rivers, coastal cities, ports, fisheries and aquaculture can remain in the area for longer periods. Microplastics have been widely found in its sediments. Zhao *et al.* [23], for example, reported an average of 171.8 items kg⁻¹ dry sediment in the Bohai Sea, compared with 123.6 items kg⁻¹ in the northern Yellow Sea.

Microplastics have also been found in marine organisms from this region. Zhao *et al.* [24] detected them in about 91.9% of the molluscs examined, with an average of 3.30 ± 2.04 items per individual or 1.04 ± 0.74 items g⁻¹ wet weight. These results show that exposure among molluscs is common. However, the presence of particles does not necessarily show that they have caused biological harm, as the study did not establish a direct relationship between microplastic concentration and biological effects.

In the Yellow Sea, microplastic distribution is affected by river inputs, coastal development, aquaculture and ocean currents. The southern Yellow Sea is also influenced by the densely populated coast around Jiangsu and the Yangtze River region. However, results from different studies can be difficult to compare because sampling and identification methods vary. Sun *et al.* [25], using ATR-FTIR and micro-Raman analysis, also showed that factors such as particle size, shape and polymer composition need to be considered alongside particle abundance.

Particle size is particularly important when comparing studies. Zhou *et al.* [11] reported an average concentration of $6,890 \pm 5,720$ items m⁻³ in water samples from the South Yellow Sea and East China Sea. Most of these were very small particles, with those below 100 µm averaging 6,567 items m⁻³. Such values cannot be directly compared with studies using manta nets, which generally collect much larger particles. This suggests that reported concentrations can change considerably depending on the sampling method and the range of particle sizes included.

2) East China Sea and South China Sea

The East China Sea receives microplastics from rivers, cities and aquaculture activities. In Xiangshan Bay, microplastics have been found in surface water, sediments and marine organisms. Chen *et al.* [26] found similarities between particles in sediment and those found in organisms living within the sediment, suggesting that habitat can influence exposure.

Microplastic pollution has also been reported along the coasts of Guangdong and Hainan and in the Pearl River Estuary. Its distribution varies between locations because of differences in river inputs, urban activity, tourism, fisheries and coastal currents [27, 28]. The Pearl River Estuary is particularly useful for studying how microplastics change after entering the marine environment. Shi *et al.* [20] found that long-term exposure under estuarine conditions changed the surfaces of both conventional and biodegradable plastics and affected their ability to adsorb metals.

C. Effects on Marine Organisms

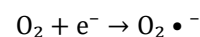
1) Plankton and primary production

Plankton are an important part of marine food webs and can easily come into contact with small microplastic particles. In phytoplankton, particles may attach to the cell surface and reduce the amount of light available for photosynthesis. Chemicals released from plastics may also affect cell membranes and normal cell activity. Experiments have reported changes in growth and chlorophyll levels after microplastic exposure [29, 30]. Zooplankton can ingest microplastics when feeding, which may reduce their food intake and affect the energy available for growth and reproduction [31]. However, changes in natural plankton populations are influenced by many other factors, including temperature, nutrients and predation. It is therefore difficult to link changes in field populations to microplastics alone.

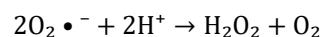
2) Benthic organisms and bivalves

Benthic organisms live close to the seabed, where microplastics can accumulate in sediments. Molluscs, crustaceans and marine worms may therefore be exposed through contact with sediment or through feeding. Bivalves are often studied because they continuously filter seawater and can take up suspended microplastics. They are also important in Chinese aquaculture and are commonly consumed as seafood. Studies from the Bohai Sea and other coastal areas of China have found microplastics in bivalves, while laboratory experiments have reported effects such as oxidative stress, immune responses and changes in energy reserves [24, 32].

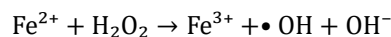
At cellular level, oxidative stress occurs when reactive oxygen species formation exceeds antioxidant defence. Electron leakage or surface-associated redox reactions may first reduce oxygen to superoxide:



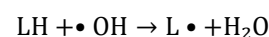
Superoxide dismutase can then convert superoxide into hydrogen peroxide:



In the presence of redox-active iron, the Fenton reaction produces a highly reactive hydroxyl radical:



Hydroxyl radicals can abstract hydrogen from membrane lipids and initiate lipid peroxidation:



This process can generate aldehydes such as malondialdehyde. Increased ROS, lipid-peroxidation products and lysosomal destabilisation therefore form a chemically coherent mechanism, but they remain stress biomarkers.

Lin *et al.* [33] studied 51 farmed oysters from 18 sites along the Chinese coast using laser direct infrared imaging. In oysters from the Bohai Sea, they found an average of 13.62 ± 2.02 microplastic items g^{-1} . They also estimated that consumers could take in about 2.14 ± 0.26 items kg^{-1} body weight day^{-1} through oyster consumption. These results provide useful evidence of exposure, but they do not show that this level of intake is harmful to humans. The possible effects would also depend on factors such as particle size, polymer type and chemicals associated with the plastics.

Ageing may also change the effects of microplastics. Chelomin *et al.* [34] compared pristine and UV-aged polystyrene using mussel cells. The aged particles caused greater changes in cellular activity and more damage to lysosomal membranes and DNA. Since the polymer remained the same, the results suggest that changes caused by UV exposure contributed to the stronger effects. However, this was a controlled experiment, so the results cannot be directly applied to all naturally aged plastics or marine environments.

3) Fish

Fish can take in microplastics from the surrounding water or through their food. Larger particles usually remain in the digestive system, while smaller particles may have a greater chance of interacting with tissues. Laboratory studies have reported inflammation, oxidative stress and changes in metabolism or development after exposure to microplastics

[35]. However, the amount found in fish can vary with habitat, diet and the ability to remove particles from the body. This makes it difficult to predict exposure from the age or size of a fish alone.

III. DISCUSSION

A. The Degree of Influence and Biological Differences of Microplastics

Finding microplastics in marine organisms does not necessarily mean that they have caused serious ecological harm. Studies show that exposure is widespread in China's coastal waters, with microplastics found in plankton and fish. There is also evidence of effects such as oxidative stress, inflammation, reduced feeding and changes in metabolism. However, most of these effects are observed at the level of individual organisms. Evidence that microplastics have directly caused population decline or major ecosystem changes in China's coastal waters is still limited. Therefore, microplastics have clearly affected marine life through widespread exposure and physiological stress, but the longer-term effects on populations and ecosystems remain uncertain [12, 31, 35].

The level of exposure also differs between organisms. Plankton can take up small particles from the surrounding water, while bivalves are regularly exposed through filter feeding. Fish may take in microplastics directly from water or through their food. These differences make it difficult to use a single microplastic concentration to represent the risk to all marine organisms [24, 31, 35]. Table 2 summarises the main exposure pathways, reported biological effects and limitations of the current evidence.

Table 2. Comparison of microplastic exposure and effects across marine organism groups

Group	Main exposure	Most supported effects	Strength and limitation of evidence
Phytoplankton and zooplankton	Surface contact, passive uptake and feeding	Altered photosynthesis or feeding; oxidative stress; reduced energy acquisition	Strong laboratory evidence; field effects confounded by nutrients, temperature and predation.
Bivalves and benthos	Filter-feeding and sediment ingestion	Gut and gill exposure; oxidative and immune responses; possible reproductive effects	Good exposure evidence from China; fewer long-term population studies.
Fish	Water, gills, sediment and contaminated prey	Inflammation, metabolic and behavioural changes, especially in experiments	Effects depend on life stage and dose; tissue translocation and field relevance remain uncertain.
Higher predators	Direct ingestion and trophic transfer	Physical injury from larger plastics; chronic chemical exposure is plausible	Difficult attribution because sample sizes are small and many other stressors act simultaneously.

B. Release and Toxicity of Additives in Microplastics

Microplastics may affect marine organisms not only through the particles themselves, but also through chemicals released from the plastic. Many commercial plastics contain additives such as plasticisers, flame retardants, antioxidants, UV stabilisers and pigments. Because some of these chemicals are not chemically bonded to the polymer, they can gradually move out of the plastic and enter seawater or biological fluids. For example, phthalates and bisphenol A have been associated with endocrine effects, while some flame retardants and UV stabilisers may also have harmful biological effects. This means that some effects linked to microplastics may actually result from a combination of the particle and the chemicals released from it [18, 19, 36].

The amount of an additive released depends on the type of

chemical, the polymer and the surrounding environment. Smaller molecules can generally move through the polymer more easily, while the structure of the plastic may slow this process. Environmental ageing can also change the rate of release. As plastics become cracked and fragmented, a larger surface area is exposed to seawater, allowing some additives to escape more easily. Temperature and other conditions in seawater can further influence this process. Therefore, newly produced and aged microplastics may not release the same amount of chemicals, which makes their environmental effects more difficult to predict [14, 19, 36].

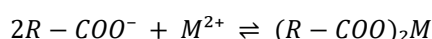
A simplified representation of this reversible partitioning is:



This equilibrium is useful conceptually but does not imply that all additives reach harmful concentrations. Environmental risk depends on the initial additive loading, the mass of plastic present, the rate and extent of release, dilution and degradation in seawater, and uptake by organisms. This distinction is important for China's aquaculture bays and estuaries, where plastic gear, wastewater inputs and long water-residence times may occur together.

C. Composite Effects of Microplastics with Heavy Metals and Organic Pollutants

Once microplastics enter coastal waters, they do not remain chemically isolated but may interact with metals and organic pollutants already present in the surrounding environment. Microplastics can also interact with chemicals already present in coastal water. Fresh PE and PP are relatively non-polar, but weathering introduces carbonyl, hydroxyl and carboxyl groups and increases roughness and porosity. These changes create sites for electrostatic attraction, surface complexation and ion exchange with metals. A simplified carboxylate complexation reaction can be written as:



Here, M^{2+} may represent Cd^{2+} , Pb^{2+} or Cu^{2+} . In the Pearl River Estuary, Shi *et al.* [20] found that environmental ageing changed the capacity of conventional and biodegradable microplastics to adsorb heavy metals, demonstrating that polymer type and surface history matter as much as particle abundance. Biofilms add extracellular polymeric substances with further oxygen- and nitrogen-containing binding sites, but they may also block the original polymer surface. Metal loading must therefore be measured [17, 20].

Hydrophobic organic pollutants, including polycyclic aromatic hydrocarbons (PAHs), can partition from seawater into non-polar polymer domains. Their apparent association with particles is commonly described by a distribution coefficient:

$$K_d = C_s / C_w$$

where C_s is the concentration associated with the solid particle and C_w is the dissolved concentration. A high K_d indicates strong partitioning, but it does not by itself prove that the particle increases toxicity. Microplastics may deliver a concentrated contaminant to the gut if desorption occurs under digestive conditions; alternatively, strong sorption may reduce the freely dissolved fraction and lower immediate uptake from water. Sun *et al.* [21] reported altered haematic responses when a marine bivalve was co-exposed to polystyrene microplastics and a mixture of 16 PAHs, while studies of PVC and cadmium in mussels have identified interactive molecular responses [22]. These findings support the possibility of additive, synergistic or antagonistic effects, but the direction of interaction depends on dose, exposure sequence, polymer ageing and the physiology of the organism.

D. Physicochemical Properties Shape Biological Effects

Microplastics do not affect all marine organisms in the same way. Their effects depend on both the properties of the particles and the biology of the organisms exposed to them. Plankton and filter-feeding bivalves, for example, are more likely to come into contact with small particles suspended in water. Fibres may become trapped in feeding structures or remain in the digestive system, while very small particles may be more easily taken up by tissues. Bivalves are particularly important in Chinese coastal areas because they continuously filter seawater and are widely used in aquaculture. However, some particles can also be rejected as pseudofaeces, which reduces the amount retained in their bodies. Fish can be exposed through water, sediment or contaminated prey. Microplastics and associated chemicals may also move between organisms through feeding, although there is currently stronger evidence for trophic transfer than for consistent biomagnification [31, 33, 35].

The location of microplastics in the marine environment also affects which organisms are exposed. Low-density plastics such as PE and PP are more likely to remain near the surface at first, whereas denser polymers such as PET and PVC are more likely to occur in sediments. However, this can change as plastics age. Biofilm growth and attached minerals may cause lighter particles to sink, while disturbance of sediments can return particles to the water. Ageing can also change the surface chemistry of plastics and affect their interaction with metals and organic pollutants. In addition, some chemical additives can leach from the plastic itself [13, 15, 17].

For these reasons, toxicity cannot be explained by polymer type alone. Particle size, shape and ageing can all change exposure, while different organisms may take up and process the same particles differently. Risk assessment should therefore consider both the characteristics of microplastics and the species being exposed, as well as chemicals associated with the particles.

E. Management Priorities for China's Coastal Regions

China's Action Plan for Plastic Pollution Control during the Fourteenth Five-Year Plan focuses on reducing plastic use, improving recycling and waste disposal, and cleaning up plastic pollution in rivers and coastal areas [37]. These measures may reduce the formation of secondary microplastics. However, smaller and less visible sources also need attention, including industrial pellets, textile fibres, tyre-wear particles and plastics used in fishing and aquaculture. Controlling these materials before they enter the sea is likely to be easier than removing them once they have spread through coastal waters.

Monitoring is also important. Simply counting microplastic particles does not provide enough information about their possible environmental effects. Studies should also consider particle size, shape, polymer type and the extent of ageing. FTIR and Raman spectroscopy can help identify the polymers more reliably. Sampling sediments and marine organisms such as bivalves, as well as surface water, would also give a better picture of where microplastics accumulate. In more polluted areas, microplastics could be studied together with additives, metals and organic pollutants. China's draft Technical Specifications for Marine

Microplastics Monitoring may help to make sampling and analysis more consistent, although biological effects and associated pollutants are also important for assessing environmental risk [12, 38].

Replacing conventional plastics with biodegradable materials is not always a complete solution. Their degradation depends on environmental conditions, and they may still break into smaller pieces or release chemical additives. Management should therefore consider how plastic products are produced, used and disposed of, rather than focusing only on the type of material. Different coastal regions may also require different approaches because areas such as the Bohai Sea, major river estuaries, ports and aquaculture zones have different sources of plastic pollution and environmental conditions.

IV. CONCLUSION

Studies from 2020 to 2025 show that microplastics are widespread in China's coastal waters, sediments and marine organisms. Their effects are not limited to physical ingestion. The type of polymer and its chemical properties can influence where particles accumulate and how they interact with marine organisms. Ageing can also break plastics into smaller particles, change their surface chemistry and affect the release or adsorption of other chemicals. There is clear evidence that marine organisms are exposed to microplastics, while laboratory studies have reported effects such as oxidative stress, inflammation and changes in feeding or metabolism. However, it is less certain whether these effects lead to long-term changes in populations or marine food webs under natural conditions. Differences in sampling methods and experimental conditions also make studies difficult to compare. Overall, microplastics have affected marine life in China's coastal regions, particularly at the individual-organism level, but the full ecological impact is still uncertain. Future studies should use more consistent methods and pay greater attention to small and weathered particles, additives and other pollutants under realistic environmental conditions.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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