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A Review of Microplastics in China Marine Waters

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Abstract Microplastics (<5 mm) are ubiquitous in the environment and can pose potential danger to the ecosystem and even human health. As the sink of microplastics, the ocean, especially the densely populated coastal area, has become a hotspot for research on microplastic pollution. In the last decade, the research of marine microplastics has been rapidly increasing in China. This review summarized the microplastic research conducted in China marine waters so far, and introduced the trends and progress of microplastic research in the four seas along the coast of China. We reviewed and compared the current sampling, extraction, and identification methodologies of China's microplastic research. According to the sampling method, the 30 reviewed studies were separated into two categories, trawl sampling and bulk sampling, to summarize relevant data, including abundance, sizes, shapes, colors and polymer types of microplastics. The main results showed that the distribution of microplastics in China's marine environment varied significantly, with offshore mariculture zones and the South China Sea being the most contaminated areas. Transparent, granules (or pellets) and fibers were the most dominant microplastic colors and shapes, and the size of microplastics was influenced significantly by the sampling method. Polyethylene (PE), polypropylene (PP) and polystyrene (PS) were the most common polymer types found in the China Sea, accounting for 49.96%, 29.97%, and 12.38% of the total studies, respectively. Compared with other global data, China's coastal microplastic pollution is at an intermediate level and does not seem to be a major microplastic pollution source.

Key words microplastics; seawater; trawl sampling; bulk sampling; China

1 Introduction

The durability of plastic materials and their great economic benefits have led to the wide use of plastic products. Since the beginning of the 20th century, the use of plastic products has increased approximately 24 times (PlasticsEurope, 2020). As of 2020, global plastic production reached 307 million tons, with China accounting for 32% of the world's total (PlasticsEurope, 2021). However, only about 9% of these plastics are recycled after use, with around 60% being deposited in landfills or discarded in the natural environment (Geyer *et al*., 2017; Fok *et al*., 2019). One plastic bottle can take 400 years or more to break down and some plastic products might take up to thousands of years to completely decompose in landfills (Chamas *et al*., 2020). According to the latest data from the IUCN (International Union for Conservation of Nature), more than 12 million tons of plastics end up in oceans per year (IUCN, 2022). If we maintain the current high use and low recycling rates of plastics, then 12 billion tons of plastic waste is expected to exist in the environment by 2050 (Geyer *et al*., 2017). Plastics in the environment will eventually break into microplastics with a diameter of less than 5 mm through long-term physicochemical processes and biological effects (Thompson *et al*., 2004, 2009). Of concern is the surge in the use of plastic products, especially disposable masks, due to the recent worldwide pandemic of the novel coronavirus (COVID-19) (Mallick *et al*., 2021), which may release the large amounts of microplastics into the environment in the coming years, leading to new environmental problems (Wang *et al*., 2021b).

In the last decade or so, microplastics have been observed in a variety of media including seawater, sediment, atmosphere and freshwater around the world (Allen *et al*., 2019; Koelmans *et al*., 2019; Ahmad *et al*., 2020; Zhang

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et al., 2020b). Compared with bulk plastics, microplastics are hydrophobic with large surface area, making it easier to adsorb organic pollutants or heavy metal pollutants (Lee *et al*., 2014; Li *et al*., 2018; Gao *et al*., 2019). Performance-enhancing additives added during the production process increase the potential environmental impacts of microplastics (Hahladakis *et al*., 2018; Liu *et al*., 2019b). As pollutants carrier, microplastics can be transported by ocean currents and ingested by marine organisms. Persistent organic pollutants adsorbed on the surface of microplastics are more prone to desorption in the digestive environment of low pH, high temperature and intestinal surfactant compared with seawater environment (Bakir *et al*., 2014; Coffin *et al*., 2019). Pollutants on the microplastics can undergo bioaccumulation in organisms and are passed along the trophic levels, increasing the health risks of higher organisms (Barboza *et al*., 2018; Schwabl *et al*., 2019).

As interest in microplastics has increased among researchers and the public, more and more studies have been carried out. Research on microplastics can be traced back as far as 1970s (Carpenter and Smith, 1972). Since 2011, the number of research reports on microplastics has grown exponentially in recent years (Fig.1). The most recent statistics showed that 44 countries have carried out extensive research on microplastics (Ajith *et al*., 2020). The first microplastics research paper in China was published in 2014 (Zhao *et al*., 2014), within 7 years, China's research on microplastics has reached about 30% of the world's (Fig.1). The State Oceanic Administration (SOA) of China have been conducting microplastic observations in the China Seas since 2016. A lot of researchers have also investigated the abundance and distribution of microplastics in the waters of various sea areas in China. However, the sampling, extraction procedures and identification methods used in these studies were different, making it difficult to obtain accurate pollution status of microplastics in the China Seas. The main objectives of this review are: 1) to summarize the current methods used to sample, extract, identify and quantify microplastics in China marine waters, 2) to discuss the presence and distribution of microplastics in China marine waters by categorizing them according to different sampling methods, 3) to analyze the features of microplastics in China's offshore waters, and 4) to make recommendations for further research work on microplastics in the future.

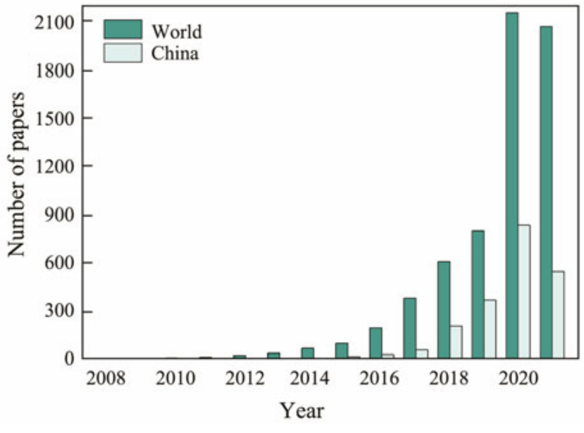

Fig.1 Publications on microplastics research in the world and in China since 2008.

2 Search Terms and Literature Collection

To conduct the statistical analysis over the literature on microplastics in China marine waters, keywords 'microplastic(s), plastic debris, plastic fragments', 'water, seawater', 'Bohai Sea, Yellow Sea, East Sea, South China Sea', 'China' were used separately or in combination in database 'ScienceDirect', 'Pubmed', 'Web of Science' and 'Baidu Scholar' and 'China National Knowledge Infrastructure (CNKI)' for a comprehensive literature search. A total of 30 papers on microplastics investigation published before July 31, 2021 in the seawater along the coast of China were selected. The sampling years in these papers ranged from 2013 to 2019. In addition, the study area (latitude and longitude), sampling method, extraction procedures, identification methods, the range of abundance (average abundance), morphological characteristics (particle size, shape, color, polymer type) and other details were extraction for subsequent analysis (Tables 1 and 2).

3 Analytical Methodology

3.1 Microplastic Sampling

A review of 30 reported studies on the collection of microplastics in China marine waters revealed two main types of sampling methods, trawl sampling and bulk sampling (Fig.2). Trawl sampling used different types and mesh sizes of trawls, such as manta nets (a mesh size of 330 μm or 333 μm), neuston nets (160 μm, 330 μm or 333 μm), bongo nets (333 μm or 500 μm) and plankton nets (330 μm) to collect the microplastics in the seawater. Generally speaking, trawls were usually lowered to a depth of about 0 – 1 m below the surface of seawater, except for Cai *et al*. (2018) who used bongo phytoplankton trawls with a vertical opening to collect the microplastics in a depth range of 0 – 218 m of water column. Trawling was usually carried out at about 2.0 knots, and the duration did not exceed 30 min. The setting of trawling time and speed is always related to the mesh of the trawl and water conditions. For example, Teng *et al*. (2020) used a manta net at a speed of 5.0 knots for only 10 min to sample the surface water in Laizhou Bay near the coast of Bohai Sea. The volume of seawater flowing through the trawl for each sample is generally calculated in two ways. One is using a digital flow meter installed at the mouth of the trawl to calculate the volume of water flowing through the trawl. Another is to calculate the water volume according to the towing distance obtained with the onboard GPS or knot-meter multiplied by the sampling time, then multiplied by the opening area of the trawl. Since it is difficult to ensure that the trawl is perpendicular to the sea level and it is hard to maintain the water

Table 1 Summary of microplastic studies using trawling sampling method in the marine waters of China [a]

Location	Sampling	Preparation	Identification	Average abundance (items m^{-3})	Size (mm)	Shape	Color	Polymer types	Ref.
Bohai Sea	Manta net 330 µm	0.05 M Fe (II)+30% H_2O_2, 75℃, 30 min	Stereoscopic microscope µ-FTIR	0.33±0.34 Range: 0.01-1.23	0.3-5: 55% 5-25: 38% >25: 7%	Fragment: 46% Line: 24% Film: 22% Foam: 5% Fiber: 3% Pellet＜1%	White: 68% Transparent: 11% Green: 10% Yellow: 6% Others: 5%	PE: 51%, PP: 29%, PS: 16%, PET: 3%, PVC&PU&AN ＜1%	Zhang *et al.*, 2017
Laizhou Bay, Bohai Sea	Manta net 333 µm	30% H_2O_2, 24 h	Stereoscopic microscope µ-FTIR	1.70±1.50 Range: 0.10-6.70	Average: 1660.0 ±1310.4 µm Range: 336.2-4997.7 µm	Fiber: 96.08% Film: 2.44% Fragment &Pellet: 1.48%	Not mentioned	PET: 32.8% CP: 27.8% PP: 14.5% PAN: 9.4% PE: 9.0% PVAc:5.4% Other: 1.1%	Teng *et al.*, 2020
Yellow Sea	Bongo nets 500 µm	Collected samples by hand under a microscope	Stereoscopic microscope µ-FTIR	0.13±0.20 Range: 0-0.81	Average: 3.72±4.70; Range: 0.35-44.99	Fragment: 42% Film: 22% Foam: 19% Fiber: 16%	Not mentioned	PE: 55.93% PP: 32.20% PS: 6.78% Other: 5.07%	Sun *et al.*, 2018
Yellow Sea	Neuston net 333 µm	35% H_2O_2, three weeks	Stereoscopic microscope µ-FTIR	0.33±0.28 Range: 0.117-0.506	Range: 0.05-5	Fiber: 75.4% Others: 24.6%	Colored: 30% Black: 40% Transparent: 20% White:10%	PET, CP, PE, PPA, Fiber, PVC, Alkyd resin, LDPE	Wang *et al.*, 2018
Jiangsu coastal area, South Yellow Sea	Neuston net 330 µm	0.05 M Fe (II)+30% H_2O_2, 24-48 h	Stereoscopic microscope µ-FTIR	0.0998 ± 0.0720 Range: 0.0206-0.2897	<1: 41.87%	Fiber: 46.12% Others: 53.88%	Transparent: 29.10% Blue: 27.19% Green&White: 10.97%	PE:33.99% PP: 21.11% Rayon, PES, PS, Nylon	Wang *et al.*, 2021a
Weihai, Yellow Sea	Plankton net 330 µm	35% H_2O_2, one week	Stereoscopic microscope, FTIR, pyrolysis-mass spectrometry (small particles)	5.90±3.50	>5: 4.4% 1-5: 32.6% 0.3-1: 26.2% <0.3: 36.8%	Fragment: 45.4% Fiber: 28.2%	Transparent: 42.4% White: 31.6%	PE: 41%, PP: 36%, PS: 13%, PET, PVC	Zhang *et al.*, 2021
Yangtze Estuary, East China Sea	Neuston net 333 µm	30% H_2O_2, saturated $ZnCl_2$ solution for density flotation (24 h)	Dissecting microscope	0.167±0.138 Range: 0.030-0.455	>0.5-1:35.4% >1-2.5:29.9% >2.5-5:25.9% >5: 8.8%	Fiber: 83.2% Film: 2.1% Pellet: 14.7%	Transparent: 28.8% Colored: 57.9% White: 2.9% Black: 10.3%	Not mentioned	Zhao *et al.*, 2014
East China Sea	Bongo net 500 µm	Collected samples by hand under a stereomicroscope	Stereoscopic microscope, FTIR	0.31 Range: 0.011-2.198	<500: 6.46% 0.5-5.0: 88.6% >5.0: 5.0%	Foam: 54.8% Fragment: 21.4% Film: 11.8% Line: 8.5% Fiber: 3.6%	White: 71.9% Colored: 18.5% Transparent: 6.9% Black: 2.7%	PE:45.5%, PP:34.6%, other:19.9%	Liu *et al.*, 2018
Hangzhou Bay, East China Sea	Trawl nets 330 µm	10% KOH, 60℃, 24-48 h. saturated NaCl solution for density flotation (24 h)	Stereoscopic microscope, µ-FTIR	0.14±0.12	Average: 1.58±0.99	Pellets: 46.4% Fibers, Fragments, Films	Not mentioned	PE: 52.3% PP: 33.6% Rayon: 4.4% PE&PP: 6.7% Cellulose: 3.0%	Wang *et al.*, 2020
Taiwan Strait, East China Sea	Manta net 330 µm	30% H_2O_2, 24-48 h, saturated NaCl solution for density flotation (24 h)	Stereoscopic microscope, µ-FTIR	0.026 Range: 0.004-0.058	Range: 0.1-5.0	Fragments: 37% Films, Fibers, Pellets	White&Green: 84% Yellow, Blue, Green, Red, Brown, Gray	PE, HDPE, PP, Polyester	Wu *et al.*, 2021

(*to be continued*)

(*continued*)

Location	Sampling	Preparation	Identification	Average abundance (items m^{-3})	Size (mm)	Shape	Color	Polymer types	Ref.
South China Sea	Bongo nets 333 μm	30% H_2O_2, saturated NaCl solution for density flotation (24 h)	Stereoscopic microscope, μ-FTIR	0.045±0.093	Range: 0.3-5.0	Not mentioned	Not mentioned	PES, PE, PP-PE copolymers	Cai *et al.*, 2018
Nansha Islands, South China Sea	Neuston net 160 μm	0.05 M Fe (II)+30% H_2O_2	Stereoscopic microscope, μ-FTIR	0.469±0.219 Range: 0.148-0.842	Average: 664±174 μm	Granules, Fibers Fragments, Pellets, Films	Not mentioned	PET, PC, PE, PEA, PA, PS	Wang *et al.*, 2019b
Haikou Bay, northern South China Sea	Neuston net 333 μm	0.05 M Fe (II)+30% H_2O_2, 70℃, 30 min	Ruler, Stereoscopic microscope, μ-FTIR	0.44±0.21 Range: 0.26-0.84	<1: 14.13% 1-1.9: 37.77% 2-2.9: 21.30% 3-3.9: 18.16% 4-4.9: 8.64%	Fiber: 83.12% Foam: 5.79% Line: 5.1% Fragment: 3.83% Films: 2.16%	Black:71.44% Red:12.07% White :7.66% Green :6.67% Others:2.16%	PE:90.32% PS:1.29% PP:2.58% Polyester:2.58% Paint:1.94% Nylon:1.29%	Qi *et al.*, 2020
South China Sea and Western Pacific	Manta net 330 μm	30% H_2O_2, 37℃, 24 h. saturated NaCl solution for density flotation (24 h)	Stereoscopic microscope, μ-FTIR	0.13±0.07 Range:0.05-0.26	Not mentioned	Fragment: 36% Pellet:51% Other: 13%	Colored: 55% Black: 13% Transparent: 5.5% White:32%	PE: 26% PP: 31% PMA: 11%	Liu *et al.*, 2021

Note: ^{a} Locations arranged from the north to the south along China coast.

Table 2 Summary of microplastic studies using bulk sampling method in the marine waters of China ^{b}

Location	Sampling	Preparation	Identification	Average abundance (items L^{-1})	Size (mm)	Shape	Color	Polymer types	Ref
Bohai Sea	CTD 10 L 5 m to the bottom	30% H_2O_2, 120℃, 48 h	Stereoscopic microscope, μ-FTIR	Surface: 2.2±1.4 Range: 0.4-5.2 Column: 4.2±1.8 Range: 1.6-5.0	<1: 35% 1-5: 65%	Fiber: 75.0% Fragment: 24.6% Pellet: 0.4%	White: 54.4% Black: 11.2% Blue: 14.9% Yellow:11.6% Green: 6.0% Other: 1.9%	PE: 40% PP: 30% PS: 30%	Dai *et al.*, 2018
North Yellow Sea	Niskin hydrophore 25 L 30 cm	Fe (II)+ 30% H_2O_2-NaCl solution (1.2 gcm^{-3}) for density flotation	Stereoscopic microscope, μ-FTIR	0.545±0.282	<0.5: 35.7%-83.5% 0.001-1>70%	Film: 58.1 ± 24.9% Fiber: 39.1±22.3% Pellet: 2.1 ± 3.4% Granule:0.6 ± 1.8%	Transparent: 42.9-89.9% Black: 2.4-14.8% Colored: 3.7-50.0% White: 50%	PE:77.8% PP: 11.1% PEA:11.1%	Zhu *et al.*, 2018
Sanggou Bay, Yellow Sea	Bucket 50 L 10 cm	1M NaOH 24 h, 10 min	Stereoscopic microscope, FTIR, SEM	63.6±37.4	0.1-0.5: 36.6% 0.05-0.1: 28.45%	Fiber: 80–89% Pellet, Film, Line, Fragment	Transparent: 84.3%,	PE: 42% PP: 26% PS: 15% PA: 8% PET&PVC: <6%	Wang *et al.*, 2019a
Jiaozhou Bay, Yellow Sea	Stainless-steel hydrophore 50 L <10 cm	Milli-Q water $ZnCl_2$ (1.5 gmL^{-1}) solution for density flotation	Stereoscopic microscope, μ-FTIR	0.046±0.028 0.02-0.12	1.29 ± 0.70 1-1.99: 31.25% 0.5-0.99: 31.25%	Fiber:77.14% Fragment: 22.86%	Blue: 43.75% Black:40.63%	PET: 56.25% PP: 34.38% PE: 3.13% PA: 3.13% PVAC: 3.11%	Zheng *et al.*, 2019
North Yellow Sea	Stainless-steel hydrophore 20 L <10 cm	30% H_2O_2 60℃, 24h	Stereoscopic microscope, Hot point test	4.00	0.005-0.05	Fiber: 40% Fragment: 30% Film: 30%	Transparent: 40% Black: 40% Blue&Red&Green: 20%	PE: 50% PP: 50%	Sui *et al.*, 2020

(*to be continued*)

(*continued*)

Location	Sampling	Preparation	Identification	Average abundance (items L^{-1})	Size (mm)	Shape	Color	Polymer types	Ref
Sanggou Bay, Yellow Sea	Niskin hydrophore 100 L 20 cm	30% H_2O_2 NaCl (1.2 g cm^{-3}) solution for density flotation	Stereoscopic microscope, μ-FTIR	20.06±4.73 Range: 12.68-31.46	<0.5: 48.15%-89.51 %,	Fiber: 20% Film: 30% Pellet: 50%	Transparent: 53.38%-84.48% Black: 1.89%-25.24% Colored: 3.55%-33.72%	PE:37.11% PS, PP, PC, Cellulose	Xia *et al.*, 2021
Three Urban estuaries East China Sea	Teflon pump 20 L 30 cm	An enzymatic digestion protocol	Stereoscopic microscope, μ-FTIR	Minjiang: 1.2458±0.5315 Jiaojiang: 0.9556±0.8487 Oujiang: 0.6800±0.2846	0.5- 10.6 0.5-5.0: >90%	Fibres and granules:>90%	Colored, black, transparent	PP: 51.2% PE: 39.0% PVC: 2.4% PTFE: 7.3%	Zhao *et al.*, 2015
Changjiang Estuary, East China Sea	Pump 100 L 50 cm	30% H_2O_2 50℃, 12 h	Stereoscopic microscope, μ-FTIR	0.231±0.182	<5.0: 90% 0.07-1.0: 68.4% 1.00-5.0: 26.2%	Fiber: 82.8% Fragment :15.1% Film: 2.1%	Colored:76.7% Black:18.2%, Transparent: 5.1%	PE:82.4% PP:9.1% PVC:6.5% Others: <3%	Xu *et al.*, 2018
Yangtze River and East China Sea	Air lift pump 5 L <10 cm	10% KOH 65℃, 24-48 h	Stereoscopic microscope, μ-FTIR	0.90	0.1-1: 57-80%	Fragment: 57% Fiber: 37% Pellet: 2% Film: 4%	Blue&Red: 46-76%	PES: 27.7% Rayon: 14.4% PP: 8.7%	Luo *et al.*, 2019
Estuaries in Shanghai, East China Sea	Stainless steel apparatus 5 L <10 cm	30% H_2O_2 60℃, 48 h	Stereoscopic microscope, FTIR	27.84±11.81 Range:13.53±4.60 -44.93±9.41	0.02-2.535	Granules: 38.04% Fragments: 35.57% Films: 22.52% Fibers: 3.87%	Black: 56.46% Transparent: 17.47% Orange: 8.31% Colored:2.31%	PE: 50% PP: 37.5% PS: 6.25% PC: 6.25%	Zhang *et al.*, 2019
Ma'an Archipelago, Shengsi, East China Sea	Stainless-steel bucket 30 L 0-1 m	0.05 M Fe (II)+30% H_2O_2,	Stereoscopic microscope, μ-FTIR	0.2±0.1-0.6±0.2	0.5-1:48.9 ± 21.9% 0.2-0.5 :21.5 ± 18.5%	Fiber: 70.0 ± 27.0%, Fragment: 21.1 ± 19.8%, Films: 8.9 ± 9.2%	Blue: 62.2 ± 16.0%, Transparent: 11.2 ± 9.6% Red: 10.2 ± 9.5%	PP: 21.9%, PE: 18.8%, 18.8%, PS:9.4%, PA: 6.3%	Zhang *et al.*, 2020a
South China Sea	Pumped 3000 L 0.5 m	200-300 mL Milli-Q water	Stereoscopic microscope, μ-FT-IR	2.569±1.770 Range: 0.300-7.467	0.02-0.30	Not mentioned	Not mentioned	Alkyd resin: 22.5% PCL: 20.9% PEA: 15.5% PS: 14.7% PTFE: 4.7% Others: 21.7%	Cai *et al.*, 2018
Zhubi Reef, Nansha Island, South China Sea	Container 20 L <10 cm	30% H_2O_2 25℃, 24 h	Stereoscopic microscope, micro-Raman	4.933±1.369 Range: 1.400-8.100	<0.05: 82% 0.5-1: 11% 4-5: 7%	Pellet:48% Fiber: 44% Fragment: 6% Film: 2%	Blue: 58% Transparent: 34% Pink: 4% Green: 2%	PP: 25% PA: 18% PS: 16% PVC: 12%	Huang *et al.*, 2019
Maowei Sea, South China Sea	Stainless-steel sampler 5 L <10 cm	10% KOH 40℃, 48-72 h	Stereoscopic microscope, μ-FT-IR	4.5±0.1 Range: 1.2-10.1	<1: 50% 1-5: 50%	Fiber: 80%	White: 88%	PE: 40% PP: 10% Rayon: 40%	Zhu *et al.*, 2019
Maowei Sea, South China Sea	Steel bucket 5 L <10 cm	10% KOH 40℃, 48 h	Stereoscopic microscope, μ-FT-IR	1.47-7.61	1-5: 54.4%	Fiber, Foam	Blue	PET: 60.3% PS: 14.3% PE: 7.0%	Zhu *et al.*, 2021
Xisha Islands, South China Sea	Niskin water sampler 5 L 1 &10- 40 m	10% KOH NaCl (1.2 g cm^{-3}) solution for density flotation	Stereoscopic microscope, μ-FT-IR	1m: 1.0-12.2 10-40 m: 6.1	0.3884 Range: 0.007-4.856 <0.02: 2.4%, 0.02-0.33: 64.8%	Fiber:79.7% Fragment: 13.2% Pellet: 5.2%	Red & Black & Blue: 76.9%	Rayon: 64.8% PET:7.3%	Ding *et al.*, 2019

Note: [b] Locations arranged from the north to the south along China coast.

depth, the exact volume of filtered water is difficult to obtain. Some studies tried to solve this problem through computation. For example, Wang *et al.* (2021a) used 95% filtration efficiency to calculate the volume of filtered seawater. In addition to the exact volume of filtered water that affects the abundance of collected microplastics, the mesh size of trawls (usually greater than 300 μm) also limits the collected microplastics, and some small microplastics are likely to be overlooked or underestimated when using trawling to collect microplastics.

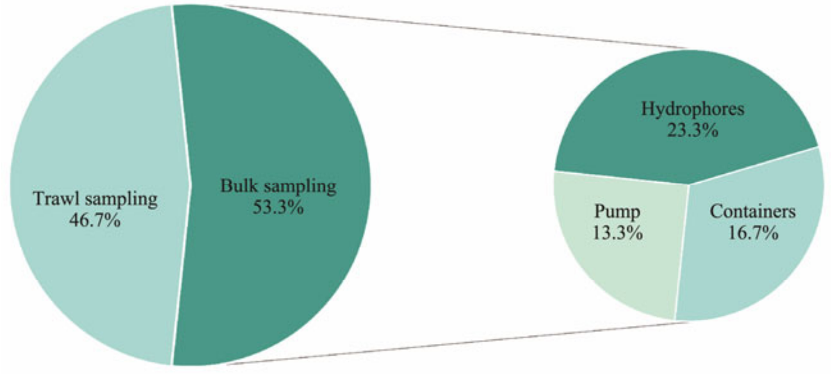

Fig.2 Percentage of sampling methods of microplastic in China marine water.

Bulk sampling is used slightly more often than trawl sampling for microplastic study in China marine water. Pumps, hydrophores and different containers are commonly used for bulk sampling of seawater (Fig.2). Only four studies (13.3%) in the retrieved literature collected seawater by Teflon pumps or air lift pumps, usually at depths between 30–50 cm. Other studies (23.3%) have used hydrophore to collect 5–100 L of seawater sample. Hydrophore can be set at different sampling depths to collect microplastics in the water column with varying volume (Dai *et al.*, 2018; Tekman *et al.*, 2020). Due to the large amount of water sampled by bulk sampling, the water body is usually concentrated and filtered through 20–200 μm mesh sized steel sieve after sampling (Chae *et al.*, 2015; Zheng *et al.*, 2021). Trawling sampling and bulk sampling methods showed different results in terms of morphology and abundance of the final extracted microplastics.

Cai *et al.* (2018) and Zheng *et al.* (2021) conducted a comparison of trawling and bulk sampling methods in the South China Sea and Bohai Bay in the Yellow Sea, respectively. Both studies showed that different sampling methods result in orders of magnitude differences in microplastic abundance. By comparing sampling methods of microplastics in surface seawater, Zheng *et al.* (2021) found that microplastics collected by trawling and bulk sampling also differed in the proportion of polymer types, shapes, and sizes. And the average and median sizes of microplastics collected by trawling were significantly higher than bulk sampling. Besides, Comparing the areas where trawling and bulk sampling were applied, it was found that bulk sampling was usually applied to near shore, such as the bays and islands, and trawling sampling was often applied to open sea areas. One reason might be the bulk sampling requires less complicated sampling tools, a stainless-steel bucket or air pump can be enough, while the trawling sampling requires mutual cooperation of the vessel and multiple crew members to complete the sampling, making it difficult to achieve parallel samples at each sampling site. Another reason might be that bulk sampling is easier to get replicate samples, with 2–3 replicates in almost every study. In addition, the volume of bulk sampling can be measured accurately, which is hard to achieve when using trawling sampling. However, in terms of the volume of filtered water, bulk sampling is several times less than that of trawling, and the representation of the results might be difficult to guarantee. Some studies on microplastics methodology have mentioned that the larger the sampling volume, the more representative and stable the experimental results (Liu *et al.*, 2019a; Li *et al.*, 2020; Sun *et al.*, 2021). But some scholars believed that the trawling sampling can miss small-sized microplastics (Chae *et al.*, 2015; Ryan *et al.*, 2020). There is still no perfect sampling method for comprehensive monitoring of microplastics in the water bodies. It is recommended to use multiple sampling methods to complement each other as much as possible when conditions permit.

3.2 Microplastic Sample Preparation

Prior to the identification of microplastics, microplastics need to be extracted and purified from seawater samples in order to improve the efficiency of subsequent inspection and identification. According to the recommended analytical method specification for microplastics published by NOAA in 2015 (Masura *et al.*, 2015), trawl collected samples were firstly filtered through 5.6 mm and 0.3 mm stacked stainless-steel sieves, and solids on the 0.3 mm stainless-steel sieves surface were collected and then digested with 0.05 mol L^{-1} Fe (II) and 30% H_2O_2. Finally, saturated NaCl was added to the digested solid to extract microplastics through density separation. In the reviewed papers, 14 studies (46.7%) collected microplastics by trawling along the coast of China. 12 out of these 14 studies (85.7%) used microplastics extraction process similar to the NOAA standard method, with only a few modifications in the details. In three of these studies, stainless steel sieves with a mesh sized of 2 mm instead of 5.6 mm and 0.3 mm (Wang *et al.*, 2018, 2019b, 2021a) were used in the wet sieving steps. Two other studies employed different protocols from the NOAA's. One study used 10% potassium hydroxide (KOH) instead of 30% H_2O_2 as the digestion solution (Wang *et al.*, 2020). The other studies manually picked up the suspected microplastic fragments, which tended to ignore a large number of microplastics in the small particle size range and fibers, and their experimental results confirmed this suspicion (Sun *et al.*, 2018).

The general strategy for bulk sampling was roughly the same as that for trawl samples to extract microplastics, with only slight differences in the choice of sieves and digestion solution. Briefly, bulk sampling usually used micron-sized sieves in the range of $5-50\,\mu m$ for the sieving process. The digestion solution commonly used included $0.05\,mol\,L^{-1}$ Fe (II) and 30% H_2O_2, 10% KOH, 1 $mol\,L^{-1}$ NaOH or digestive enzymes (Zhao *et al.*, 2015).

Fig.3 Commonly used filter membranes (inner ring) and pore sizes (outer ring) used in the reviewed paper for extracting microplastics.

After digestion and density separation, the final step of the extraction process was often the separation of microplastics from the solution by filtering the flotation solution or the digestion solution onto a filter membrane. Filtration facilitated the concentration of microplastics in solution to reduce subsequent microscopy time. Among the 30 papers reviewed, nylon fiber filter membranes (numbers of studies, $n=6$, 23.1%) and glass fiber filter membranes ($n=6$, 23.1%) were the most commonly used, followed by stainless steel sieves ($n=4$, 15.4%), nitrocellulose filter membranes ($n=3$, 11.5%), mixed fiber filter membranes ($n=2$, 7.7%), and Sartorius filter membranes ($n=2$, 7.7%). Pore sizes and frequencies of usage are as shown in Fig.3 for the frequency of use. As can be seen from the figure, different types of filter membranes include multiple pore sizes, which may also contribute to the difference in the microplastics results.

3.3 Microplastic Identification

Microplastics filtered onto the filter membrane are usually visually identified and quantified before the final amount of microplastics determined after identification. A stereo microscope is used to sort out suspected microplastics and record their morphological characteristics. This approach can greatly save time on identification. Suspected microplastics (which usually represents more than 20% of the total number of suspected microplastics) were identified by Fourier transform infrared spectroscopy (FTIR), such as micro-FTIR (μ-FTIR) and attenuated total reflection FTIR (ATR-FTIR), or Raman. Twenty-eight studies (66.7%) used FTIR or Raman technology to identify microplastics, other identification methods have also been used. Zhao *et al.* (2014) was performed only by visual identification, and Sui *et al.* (2020) performed identification by a hot needle held with tweezers for the identification of polymer types. Since these two studies did not perform final identification of the types of microplastic polymer, they were not included in the statistical analysis in this paper. Worth noticing is that using FTIR or Raman to identify microplastic polymer types is a time-consuming and labor-intensive process, there is an urgent need to find more efficient identification methods for microplastic polymer type identification.

4 Microplastic Pollution Status in the Marine Environment of China

4.1 Microplastic Occurrence and Abundance

Since the abundance of microplastics might be greatly affected by differences in sampling methods, we categorized and summarized the results of microplastic abundance from trawling and bulk seawater samples separately.

The common abundance units for trawling and bulk seawater samples are 'items m^{-3}' and 'items L^{-1}'. For studies using 'items (50 L)$^{-1}$', 'items (20 L)$^{-1}$' or 'items (100 L)$^{-1}$', we converted the microplastic abundance units to 'items m^{-3}' for trawling and 'items L^{-1}' for bulk seawater samples by multiplying the corresponding factors.

Based on available data, microplastic is widespread along the coast of China. The spatial distribution of microplastic abundance is shown in Fig.4. The abundance of microplastics collected using trawling method in China's coastal waters ranged from 0.004 to 3.78 items m^{-3}, with an average abundance of 0.80 ± 1.22 items m^{-3} (Table 1). Based on trawling samples, the most polluted areas included the Laizhou Bay (Teng *et al.*, 2020), the Yellow Sea (Zhang *et al.*, 2021), and the South China Sea (Liu *et al.*, 2021) (Fig.4a). Teng *et al.* (2020) collected 58 surface seawater samples in the semi-enclosed bay of Laizhou Bay to investigate the contamination patterns of microplastics. This study sampled the largest volume of seawater among all the studies. It also highlighted that microplastic distribution was influenced by coastal current dynamics (Teng *et al.*, 2020). Liu *et al.* (2021) in a field study of surface seawater microplastics in the Pacific and South China Sea found that Kuroshio invasion also affected the fate of microplastics to some extent. In addition to the influence of ocean currents and other factors, microplastic pollution can be significantly aggravated by nearshore fishing activities. A microplastic survey conducted by Zhang *et al.* (2021) along the coast of Weihai, a city of fishing center and coastal resort, found that the average abundance of microplastics in the seawater was 5.90 ± 3.50 items m^{-3}, which was the peak of microplastic abundance in China's offshore, and the abundance of microplastics even reached 11.49 items m^{-3} at stations located in the mariculture area.

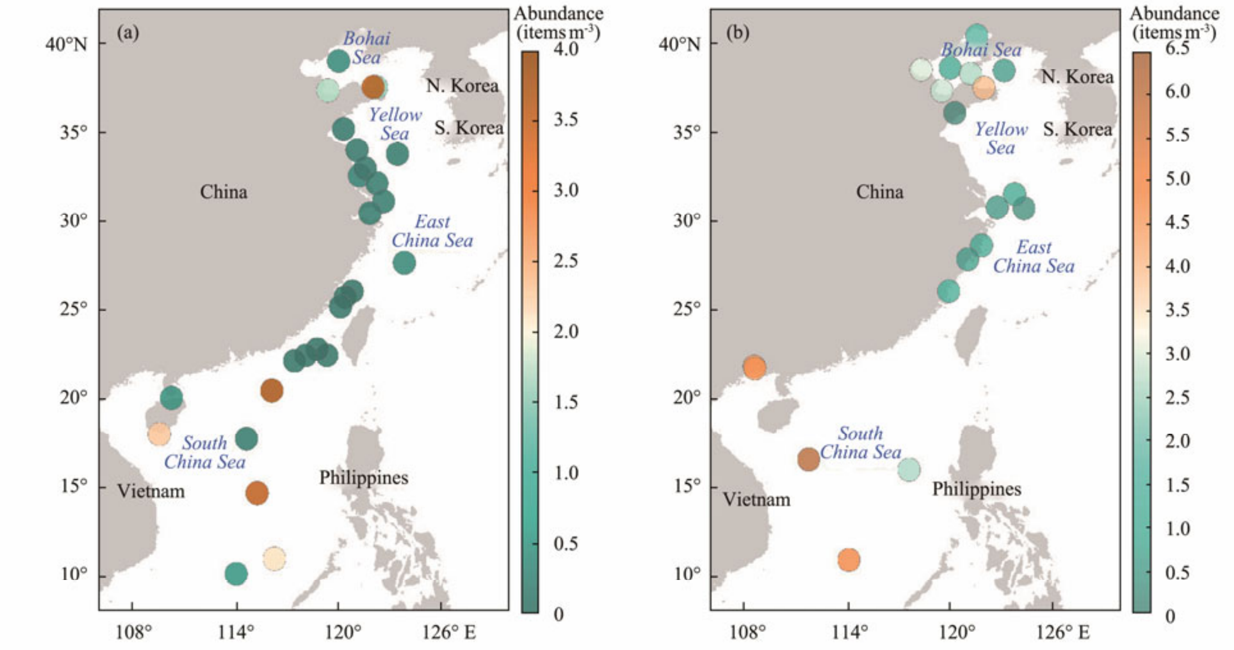

Fig.4 Distribution of microplastic abundance based on (a) trawl samples and (b) bulk water samples of China.

In bulk seawater samples, the average abundance of microplastics was 2.25 ± 0.56 items L^{-1}, with a range of 0.044 – 6.100 items L^{-1} (Table 2). Two studies on the occurrence of microplastics in the whole water column showed higher abundance of microplastics in the Bohai Sea and the South China Sea (Dai *et al.*, 2018; Ding *et al.*, 2019). In particular, the accumulation of microplastics was the highest at water depths of 5 – 15 m, and the microplastic abundance generally showed a decreasing trend as the water depth increased. Some researchers suggested that the vertical distribution of microplastics in the water column was influenced by the vertical turbulence of the seawater, for example, the surface current velocity in the Bohai Sea was higher than the subsurface and bottom currents. Current can affect the settling rate of microplastics (Dai *et al.*, 2018). Also, the polymer type of microplastics and the biological contamination formed due to surface properties may affect the depth distribution of microplastics by changing their density (Harrison *et al.*, 2018; Zhou *et al.*, 2018). Consistent with the distribution of microplastics in trawling sampling, mariculture zones were still the most polluted areas of microplastics, such as Sanggou Bay in the Yellow Sea (Xia *et al.*, 2021) and Maowei Sea in the South China Sea (Zhu *et al.*, 2019; Zhu *et al.*, 2021). The highest abundance of microplastics was found in Sanggou Bay, the largest mariculture bay of China, with an abundance of 20.06 ± 4.73 items L^{-1}, of which 62.76% of the microplastics were contributed by the plastic waste generated from mariculture (Xia *et al.*, 2021).

Comparing the distribution of microplastic abundance collected using trawling method (Fig.4a) with those collected using bulk sampling method (Fig.4b), it was found that the abundance of microplastics collected by the two sampling methods had at least one order of magnitude difference, but the general distribution trend was basically the same along the coastal of China. The highest microplastic abundance was found in Bohai Bay, nearshore aquaculture areas and the South China Sea regardless of the sampling method (Fig.4). However, different results were observed on microplastic abundance near Reefs, which is located in the southernmost part of the South China Sea. The microplastic abundance using trawling method showed significantly lower values (Wang *et al.*, 2019b), while the microplastic abundance using the bulk method in the nearby area remained high (Huang *et al.*, 2019). This may be related to the use of a trawl with a160 μm mesh (all other studies had a mesh of ≥300 μm). It is usually assumed that the smaller the mesh of trawls used, the more microplastics to be captured. In practice, trawls with too small a mesh are highly prone to be clogged and thus the volume of water passing through the trawl was correspondingly reduced, which will sequentially lower the level of sample representation. Therefore, the standardization and unifying of sampling methods is necessary in microplastic research.

4.2 Microplastic Features

4.2.1 Size

The size of microplastics is a very important parameter in the research of microplastics, and is a key factor in determining whether microplastics can be ingested by organisms (Imhof *et al.*, 2012). The size of microplastics in the literature is generally divided into small microplastics (1 – 1000 μm) and large microplastics (1000 – 5000 μm) (Imhof *et al.*, 2012). Due to the limitation of the mesh size, microplastics collected in trawling samples were mainly large plastics (1000–5000 μm). For example, in the Laizhou Bay (Teng *et al.*, 2020), Yellow Sea (Sun *et al.*, 2018) and Hangzhou Bay (Wang *et al.*, 2020), the average size of microplastics in the seawater collected by trawling was (1660.0 ± 1310.4) μm, (3720.0 ± 4700.0) μm and (1580.0 ± 990.0) μm, respectively. In the Jiangsu coastal area, microplastics with a diameter of above 1.0 mm represented the largest fraction in the seawater samples, accounting for 58.13% (Wang *et al.*, 2021a). The coastal area is the closest to the source of plastic contamination, where the discharged microplastics have not been physically broken therefore retain their original size. This phenomenon was also observed in Haikou Bay in the northern South China Sea, where only 14.13% of the under 1 mm microplastics were detected in the seawater samples (Qi *et al.*, 2020). Different from the trawling samples, small microplastics (1 – 1000 μm) dominated the size of microplastics in the bulk sampling studies. Microplastics under 1.0 mm in the surface seawater sampled at a 30 cm water depth by Niskin hydrophore in the North Yellow Sea accounted for more than 70%. As microplastic size increased, the microplastic abundance showed a decreasing trend (Zhu *et al.*, 2018). In the Yangtze River, the largest river in China, 57%–80% of microplastics in the seawater samples collected using pumps installed onboard was in the size range of 100–1000 μm (Luo *et al.*, 2019). Since onboard pump usually was equipped with strainers at the inlet and outlet to avoid clogging by particulate and colloidal impurities in the seawater, the method might lead to a reduction in the size and shape of the collected microplastics (Zheng *et al.*, 2020). Summarizing the three pump sampling studies, nearly 70% of the microplastics were fibers with size of 70–1000 μm (Zhao *et al.*, 2015; Xu *et al.*, 2018; Luo *et al.*, 2019). Therefore, in studies targeting microplastic size, it is necessary to consider the difference in results caused by the mesh size of sampling tools in different sampling methods.

4.2.2 Shape

Microplastics come in various shapes in China marine water samples, with fibers, fragments, pellets or granules, foams, and films being the five common shapes. Among the 28 studies, granules (or pellets), fibers and fragments were the dominant shapes of microplastics in China marine water, and more than half of the studies indicated that granules (or pellets) and fibers (60.37%) were the representative shapes of microplastics (Fig.5a). Fibers usually originated from synthetic textiles and mariculture fishing gear (Browne *et al.*, 2011), while particles may also originate from secondary microplastics produced by breaking large plastics, or from man-made industrial primary microplastic products, such as particles in daily chemical products (Wang *et al.*, 2019b).

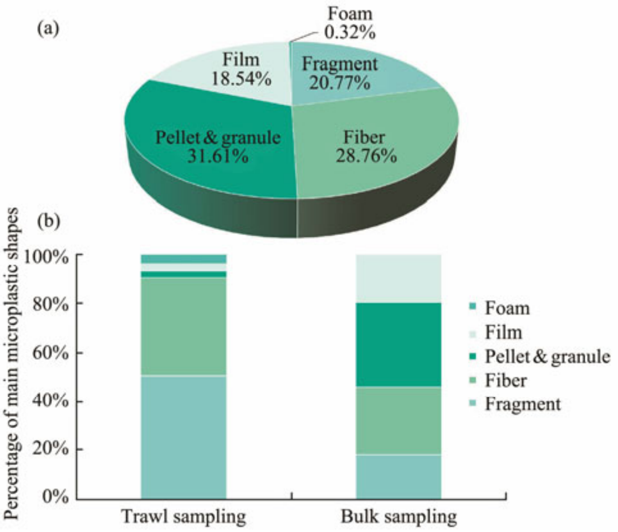

Fig.5 Percentage of main microplastic shapes (a) and microplastic shapes using trawling and bulk sampling methods (b) in the reviewed studies.

Based on different sampling methods, the dominant shapes of the microplastics detected in the study were significantly different (Fig.5b). In trawling samples, fragments were the dominant shapes accounting for 50.47% and 39.80% respectively. In bulk water samples, granules (or pellets) and fibers were the dominant shapes accounting for 34.18% and 27.78%, respectively. The estuary of the sea is the place with the most fibers. In 2015, Zhang *et al*. investigated the microplastics in the three estuaries of the Minjiang, Jiaojiang and Oujiang Rivers and found that fibers exceeded 90%. The same results were found in the Yangtze Estuary, where fibers accounted for 82.80% of the total (Xu *et al*., 2018). Even in the sparsely populated Xisha Islands in the South China Sea, the percentage of fiber microplastics reached 79.70% (Ding *et al*., 2019). In summary, fibers have become the predominant form of microplastics in the ocean.

4.2.3 Color

The color of some plastics increases the likelihood of predation by marine organisms (Botterell *et al*., 2019). Of the 28 studies reviewed, six studies (21.4%) lacked color-related data. Microplastic color is usually obtained visually by experimenters relying on a stereomicroscope, and there is subjective variability in color discrimination. A variety of colors were reported in the reviewed studies, including transparent, white, blue, black, red, green, yellow, brown, gray, pink, and orange (Tables 1 and 2). According to the percentage of microplastic colors reported in the reviewed studies, transparent, white, blue, colored, and black were the five main colors (Fig.6). In the China marine water, the main microplastic color was transparent, accounting for 67.03%. Light-colored microplastics were frequently detected in the open oceans, for example, 82% – 89% of floating plastics in the South Atlantic were light-colored (Ryan *et al*., 1987) and 72% of light-colored plastics in the North Pacific (Day *et al*., 1985). Light-colored plastic products in daily life, such as transparent disposables and fishing line, may be the source of light-colored microplastics, and colored plastics can easily fade to white or transparent microplastics through seawater immersion and sunlight radiation (Xu *et al*., 2020; Yang *et al*., 2021). Thus, further identification of the possible sources of microplastics requires identification of polymer types, and color analysis can only be used as an supplementary parameter.

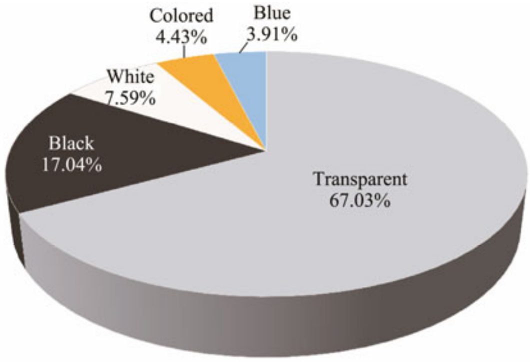

Fig.6 Percentage of main microplastic color detected in the reviewed studies.

4.2.4 Polymer type

The identification of polymer types is important for tracing the source of microplastics. Fig.7 showed the percentage of the major microplastic polymer types detected in the reviewed studies. As can be seen from the figure, PE, PP and PS were the dominant microplastic polymer types found in the marine environment in China. PE and PP, as common food packaging material for daily and fishery products, are the two polymer types with the highest global plastic demand, while PS accounts for 6.10% of global demand (PlasticsEurope, 2021), Haikou Bay, located in Haikou City, has the highest PE detection rate of 90.32% due to coastal commercial and human activities (Qi *et al*., 2020). While in the mariculture zone, most of the microplastic fibers and fragments were identified as PE and PP, mainly from fishing nets and ropes. Polystyrene (PS) is also commonly detected in the seawater due to the frequent use of foam floats in mariculture zones (Zhang *et al*., 2021). In addition to these common polymer types, in the South China Sea, the most detected polymer type by Cai *et al*. (2018) was alkyd resin, accounting for 22.50%. Notably, alkyd resin is an important raw material for antifouling coatings for ships, and this is the first report of resinous plastics in addition to common polymer types in the offshore China. And in fact, Song *et al*. (2014) highlighted that alkyd resin should be considered as an important source of marine microplastics. What can also be found from the compiled data is that a wide variety of marine plastic polymers can be found when a spectrometer was used to identify the polymer types of microplastics.

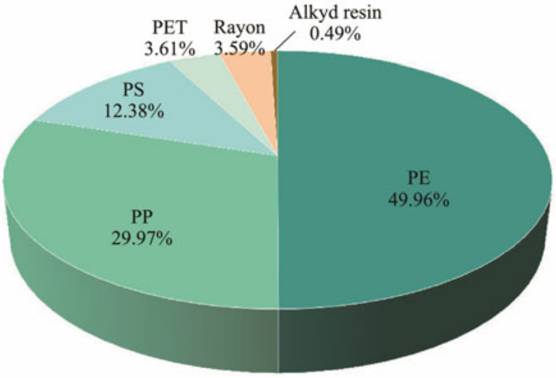

Fig.7 Percentage of main microplastic polymer type detected in the reviewed studies.

4.3 Comparison of Microplastic Pollution with Other Areas in the World

Due to the lack of standardized methods, it is usually difficult to compare the level of microplastic pollution in the seawater from various regions in the world. The coastal region is most frequently approached by human activities, since nearly half of the world's population live in coastal areas (The Center for International Earth Science Information Network/CIESIN, 2018) (CIESIN, 2018). To compare the level of microplastic pollution in the coastal waters of China with the rest of the world, we chose 14 and 9 previous studies that had collected data using trawling sampling and bulk sampling respectively (Table 3). In trawling samples, Guanabara Bay in southeastern Brazil (Olivatto *et al*., 2019) and Geoje Island on the southern coast of South Korea (Song *et al*., 2014), which are located in the semi-enclosed bay, had significantly higher microplastic abundance in the seawater (0.004–3.590 items m^{-3}). Both Guanabara Bay and Geoje Island are not only world-renowned tourist destinations, but also the place affected by various sources of environmental pollutants. Industrial wastewater is continuously discharged into the vicinity of Guanabara Bay, and Geoje Island is the second most visited island in South Korea, with a well-developed fishery and shipbuilding industry. In contrast, microplastic abundance in the Sardinia Sea of Italy, was closest to that in Chinese Seas. The study area in Sardinia is a marine protected area for Mediterranean marine mammals, and researchers believe the area is subject to extremely high levels of human pressure (Fossi *et al*., 2012). Affected by human activities, the distribution of microplastics in the offshore is generally higher than that in the open ocean (Jambeck *et al*., 2015; van Sebille *et al*., 2015). We found that the abundance of microplastics in most of the global seas was in the same order of magnitude but slightly lower than that in Chinese seas, except for the western Pacific ((0.06 ± 0.03) items m^{-3}) and the Antarctic Peninsula ((0.013 ± 0.005) items m^{-3}), where the abundance of microplastics was significantly lower than that in Chinese waters ((0.8 ± 1.22) items m^{-3}) by one order of magnitude.

Table 3 Comparison of microplastic abundance with reported data from seawaters around the world oceans

Area	Abundance	Mesh size (μm)	Sampling method	Reference
Trawl sampling (items m^{-3})				
South Pacific	0.28	335	Manta trawl	Bakir *et al*., 2020
Western Pacific	0.06 ± 0.03	330	Manta trawl	Liu *et al*., 2021
Western North Atlantic Ocean	0–1.16	335	Neuston net	Law and Thompson, 2014
Eastern Indian Ocean	0.34 ± 0.80	330	Manta trawl	Li *et al*., 2021
Antarctic Peninsula	0.013 ± 0.005	300	Neuston net	Jones-Williams *et al*., 2020
Arctic Ocean	0.34 ± 0.31	333	Manta trawl	Lusher *et al*., 2015
Chukchi Sea, Arctic	0.13 ± 0.11	330	Manta net	Mu *et al*., 2019
Guanabara Bay, Brazil	1.4–21.3	335	Neuston net	Olivatto *et al*., 2019
Geoje Island, South Korea	0.4–54.4	330	Manta trawl	Song *et al*., 2014
Bay of Brest, France	0.24 ± 0.35	335	Manta trawl	Frere *et al*., 2017
Incheon/Kyeonggi, South Korea	0.19 ± 0.14	330	Zooplankton trawl net	Chae *et al*., 2015
Northwest Mediterranean	0.116	333	Manta trawl	Collignon *et al*., 2012
Western Mediterranean	0.15	500	Manta trawl	de Lucia *et al*., 2014
Sardinia Sea, Italy	0.62 ± 2.00	200	WP2 standard net	Fossi *et al*., 2012
Bulk sampling (items L^{-1})				
Northeastern Pacific	2.08 ± 2.19	62.5	Pump	Desforges *et al*., 2014
Nordic Seas	1.19 ± 0.28	50	Pump	Jiang *et al*., 2020
Malaysia	2.112 ± 0.104	20	Pump	Taha *et al*., 2021
Arctic	0.161 ± 0.293		CTD hydrophore	Tekman *et al*., 2020
Southern Atlantic Ocean	1.75–3.30	20	Metal bucket	Ryan *et al*., 2020
Kyeonggi Bay, South Korea	1.602 ± 1.274	20	Plastic bucket	Chae *et al*., 2015
Southern coast of South Korea	1.143 ± 3.353	50	Plastic bucket	Song *et al*., 2014
Gulf of Thailand	9.97	125	Bucket	Vibhatabandhu and Srithongout, 2021
Southeastern coast of South Korea	0.59–1.30	50	Hand beaker	Kang *et al*., 2015
Kuantan Port, Malaysia	0.13–0.69	20	Steel sampler	Khalik *et al*., 2018
Indonesia	0.38–0.61	0.45	Sterile HDPE bottle	Cordova *et al*., 2019

In bulk water samples, due to the diversity of sampling tools, the same type of sampling method is selected for comparison when comparing abundance. For example, the abundance of microplastics detected in the Northeast Pacific (Desforges *et al*., 2014), the Nordic Sea (Jiang *et al*., 2020), and Malaysia (Taha *et al*., 2021) by using onboard pumps were all higher than the mean abundance of microplastics sampled using pumps in the East China Sea estuary ((0.79 ± 0.46) items L^{-1}) (Zhao *et al*., 2015; Xu *et al*., 2018; Luo *et al*., 2019), but were an order of magnitude higher than those in the South China Sea ((2.569 ± 1.770) items L^{-1}) (Cai *et al*., 2018). Using containers such as water hydrophore or buckets in the South Atlantic Ocean (Ryan *et al*., 2020), as well as the areas adjacent to China in Kyeonggi Bay (Chae *et al*., 2015), the Southern coast of South Korea (Song *et al*., 2014), the Gulf of Thailand (Vibhatabandhu and Srithongout, 2022) were essentially in the same order of magnitude as the microplastic abundance using container sampling in the China marine waters ((2.44 ± 0.58) items L^{-1}) (Huang *et al*., 2019; Wang *et al*., 2019a; Zhang *et al*., 2019; Zhang *et al*., 2020a; Zhu *et al*., 2021). Compared with other studies in marginal seas, such as the southeastern coast of South Korea (Kang *et al*., 2015), Malaysia (Khalik *et al*., 2018) and Indonesia (Cor- dova *et al*., 2019) was consistent with the range of microplastic abundance in offshore China (0.044 – 6.100 items L^{-1}). Overall, microplastic pollution in the China marine waters was at a moderate level based on both trawling and bulk seawater samples.

5 Summary and Trends for Future Studies

Available researches have shown that microplastics are ubiquitous in China's offshore aquatic environment system, and microplastic pollution problem was most severe in the aquaculture areas located of the Yellow Sea and in the South China Sea. Considering sampling methods in the seawater environment can bring significant differences to the reported microplastic results, this review separated the microplastics research reported in China's seas into two categories based on different sampling methods, trawl sampling and bulk sampling, for critical review and comparison. We found that on average most of the microplastics reported were larger than 1 mm when using trawling methods and smaller than 1 mm when using bulk sampling method. Microplastic pollution along the coast of China is roughly at a medium level compared with other areas in the world. This result corrects the opinion that the coastal water of China is heavily polluted. We also found that offshore aquaculture may be the main cause of the high abundance of microplastics in the coastal waters of China. Furthermore, the dominant microplastic morphology (transparent lines and fragments) and polymer types (PE and PET) are also correlated with the plastics used in aquaculture.

One aspect we did not discuss in detail is we only separated the studies by trawling or bulk sampling methods. We did not consider the differences in mesh sizes of the trawling method nor the difference in the membrane pore sizes of bulk sampling methods. The difference in the mesh size or the membrane pore size contributes greatly to the reported microplastic abundance data. In addition, μ-FT-IR and μ-Raman are probably the most widely used methods. There are also Pyrolysis GC-MS, hot needle, staining and other methods. Since none of the currently employed identification methods is perfect and each method has its own pros and cons, we need to be aware of the discrepancies these methods might bring into the reported results. Finally, the polymer identification coverage (what percentage of the suspected microplastics were identified) is another factor that can affect the reported data. We have no enough information to consider this in our comparison.

Although microplastic research in China has attracted increasing attention and is a hot topic in environmental research in recent years, many scientific questions remain unanswered. The main issues and future research trend should include, but not limited to, the following:

1) The lack of standardized methods for microplastics research makes it difficult to establish direct comparisons between China and most of the countries. Sampling and extraction methods for both domestic and international microplastic investigations awaits standardization. Similarly, the reporting rule of microplastic size ranges and quantification units need to be established as well.

2) In order to better assess the risk of microplastics, it is necessary to combine multiple media, including the seawater, sediment, biota and air in the marine environment to better study the source-sink mechanism of microplastics using standardized protocols.

3) In addition to the toxicity of microplastics themselves, there is a need to better understand the toxic effects of plastic additives and accompanying contaminants, as well as the transfer of toxicity caused by plastic additives and adhering contaminants in the food chain.

4) Though the microplastic pollution level in China coastal water is currently not at an alarming level, we still need to take necessary measures to control this pollution. Since aquaculture seems to be an important pollution source, some counter measures to minimize aquaculture plastic pollution should be considered.

Acknowledgements

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