IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Microplastics in Sumba waters, East Nusa Tenggara

To cite this article: M R Cordova and U E Hernawan 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **162** 012023

IOP Conf. Series: Earth and Environmental Science **162** (2018) 012023 doi:10.1088/1755-1315/162/1/012023

Microplastics in Sumba waters, East Nusa Tenggara

M R Cordova and U E Hernawan

Research Center for Oceanography, Indonesian Institute of Science (LIPI). JL. Pasir Putih 1, Ancol, Jakarta Utara, Jakarta, 14430, Indonesia

E-mail: muhammad.reza.cordova@lipi.go.id

Abstract. The accumulation of plastic debris in the oceans has been widely recognized as a threat to marine environment. A recent study estimated that Indonesia is one of the biggest sources of plastic wastes in the ocean, but directly-measured abundance data from the seawater in Indonesia is lacking. We documented the abundance and distribution of microplastics (size <5mm) in sub-surface seawaters of Sumba, a pristine region in Indonesia. Water samples were collected from 5 m, 50 m, 100 m, 300 m depth and near the sea bottom. Samples were examined for microplastics using flotation and filtration methods. We found microplastic in all sampling locations, consisting of fibers (45.45%), granules (36.36%) and other plastic form (18.18%). Most of microplastic particles were found at water depths less than 100 m (81.82%), which was the thermocline area. Our finding corroborates the believe that plastics has widely invaded marine environment in different parts of the seas and oceans, including pristine, remote, and unknown areas.

1. Introduction

Plastics are a successful story with regard to their characteristics that make them suitable for a wide variety of products [1]. By 2014 the total plastic production reached 311 million tons [2]. High consumption rate but low recovery rates has driven plastics to be a potential threat to the environment. [3] reported that most of plastic packaging is not recovered, of which 40% goes landfilled and 32% leaks to the environment including marine ecosystem. Plastic pieces that ended up in the environment remain still with very slow degradation (up to 100 years). Recent studies estimated that plastic debris in the ocean are between 7,000 – 250,000 metric tons [4,5]; land based input to the oceans are between 4.8 - 12.7 metric tons; and Indonesia was listed as one of the top sources of land based input [6]. This estimation, however, lacks real abundance data in the ocean since it used mathematical model based on solid waste production, population density and economic status of the countries.

Plastic pollution was initially seen as an aesthetic problem [7,8], however recent studies have shown that marine animals can be negatively affected by the presence of plastics. Threats posed by plastics with large size are obvious, clear environmental risks by physical impairment after swallowing, entanglement [9]. [10] stated that from the 1960s to 1990s, physical impairment caused by plastics had increased almost three times (267 to 693 species). Furthermore, [9] reported that all seabird species (395 species) contained plastics in their digestive systems.

Plastic waste can be degraded by UV thermal oxidation or mechanic processes up to the microscopic size [11,12]. Microplastics (<5mm) are formed by the physical, chemical and biological fragmentation of larger items of plastics. Besides commonly-used plastics, microplastic may originate from cosmetic or fabric, in the form of microbeads [13,14]. The impact of microplastics in the marine environment are not clearly known. Studies in the last decade have indicated potential environmental risks from microplastics, but real consequences are mostly unknown. Microplastics accumulation in gastrointestinal on marine organism has been reported [15–19], but the impact of the accumulation to the organisms are not known. Microplastics could enter the food web by organism ingestion [20], could interference digestive tract function [17], and may act as a carrier for organic material and heavy metals [21–23].

Sumba, located in East Nusa Tenggara, Indonesia, is a pristine region in the outlet of Indonesian Through Flow (ITF) connecting the Pacific Ocean and the Indian Ocean. It is in the southern part of the Wallacea transition zone, where Indo-Malaya and Australasian biogeographic characteristics meet. It has unique marine ecosystems and high biodiversity. This area is an important migration corridor to many marine megafaunas and pelagic fishes. Here, we documented the abundance and distribution of microplastics (size <5mm) in sub-surface seawaters of Sumba.

2. Introduction

2.1. Study area

Sumba is located in East Nusa Tenggara, eastern Indonesia (Figure 1). Sumba waters area is believed to have high marine life, but minimal scientific information. From the perspective of oceanography, this area is also believed to be unique because of the interaction between Indonesian Through Flow (ITF/Arlindo). The presence of four water masses on the western side, north and south of Sumba Island (Northern Pacific Subtropical Water-NPSW, North Pacific Intermediate Water-NPIW, Northern Indian Subtropical Water-NISW and Northern Indian Intermediate Water-NIIW), proves that this area is an outlet of ITF [24–26]. A front near the western tip of Sumba Island potentially trigger an eddy and might be influenced by the South Java Current (SJC) [24–26]. This current is believed to trigger upwelling which is important for fishery resources. In addition, oceanographic process also believed to be important in Sumba region is mixing, that is the mixing of water masses that can occur due to tidal currents, bathymetry, and internal waves.

2.2. Sample collection

Sampling was conducted during the 9th Ekspedisi Widya Nusantara (EWIN IX) in August 2016 using RV Baruna Jaya VIII. Sampling sites are shown in Figure 1. Water samples (10 liters per depth per site) were collected using Rosette Water Sampler at 5 m, 50 m, 100 m, 300 m and near the sea bottom, then were filtered using a sterile Whatman® cellulose nitrate filter papers (diameter 47 mm; pore size 0.45µm). To accelerate filtration process, we used Gast vacuum DOA-P504-BN. All samples in the filter papers were stored at 4±2 °C before analysis in sterile Petri dish and covered with ParaFilm® sealing film. To prevent samples from being contaminated, we wore laboratory latex gloves and eyeglasses for filtering, sorting and counting. All sterile glassware were used and filters were stored in Petri dishes, sealed with Para Film.

2.3. Sample analysis

Microscope Leica M205C was used to examine microplastics particles on the filters. We were using the following characteristics [17,27,28] to identify microplastics, namely (1) particle size ≤ 5mm, (2) homogeneous colour, not shiny or sparkling and no cellular or organic structure, (3) fiber particles are unbranched and not segmented. The microplastics identified were counted and measured. The types of microplastic then were classified as fibers, granule, fragment, and foam; and were categorized to the size of <300µm; 300-500µm; 500-1000µm; >1000µm. We analyzed microplastics with sizes more than 250µm using Fourier Transform Infrared (FT-IR). FT-IR can be used to analyze microplastics samples directly [29]. Polymer analysis was done using Nicolet™ iS5 FT-IR Spectrometer, equipped with a laminated diamond crystal Thermo Scientific™ iD5 attenuated total reflectance (ATR) accessory, and corrected using Omnic^{tm} Software. The instrument was operated based on [30] at a range of 600 and 3800 cm-1, a resolution 8 cm and at a rate of 16 scans per analysis, in single reflection mode. Before we analyzed using FT-IR, all potentially plastic particles were rinsed with ethanol 96%. To prevent samples from airborne contamination, we analyzed all particles based on a report by [31]. Afterwards, we did not quantify the fiber particle of the same polymer type as the lab clothes we have worn. Microplastics concentration are presented as n/m^3 unit (Table 1) to compare with other research result, simple statistical tests were performed on the data collected using Microsoft Excel are presented mean values ± standard deviations (SDs).

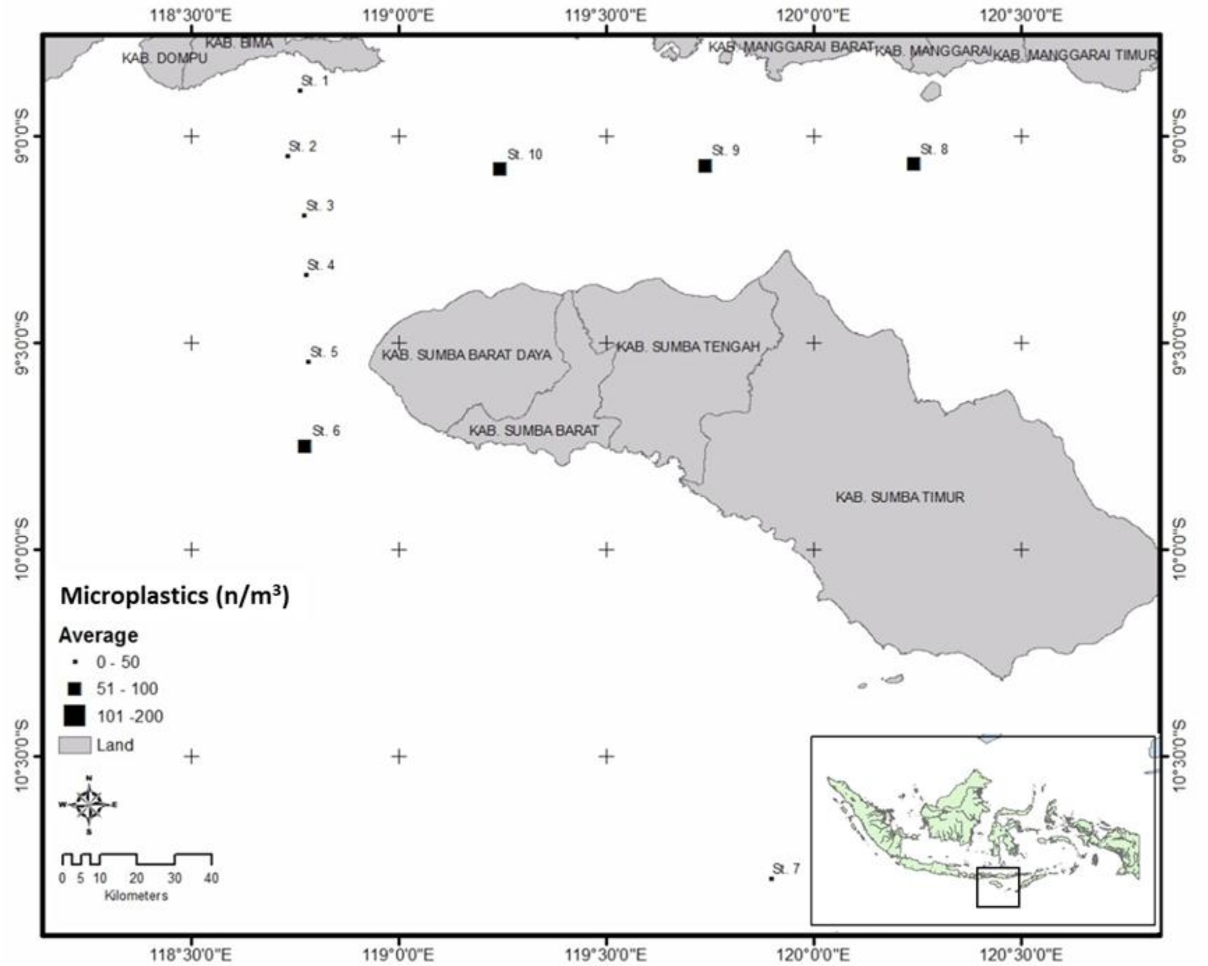

Figure 1. Sampling sites and average abundance of microplastics particles in five different depth (5 m, 50 m, 100 m, 300 m depth and near the sea bottom)

3. Results and discussion

3.1. Study area

Plastic particles were found in all sampling location (10 sampling locations). Average microplastics concentration per station in five different depth were 44 ± 24.59 n/m^3. The highest concentration of microplastics was observed in Sumba Strait (St-8 and St-10). At 5m depth, microplastics particles were found in all sampling locations (Figure 2). However, microplastics was not observed at 100m depth. This might be related to the presence of thermocline zone, ranging from 53m to 144m depth.

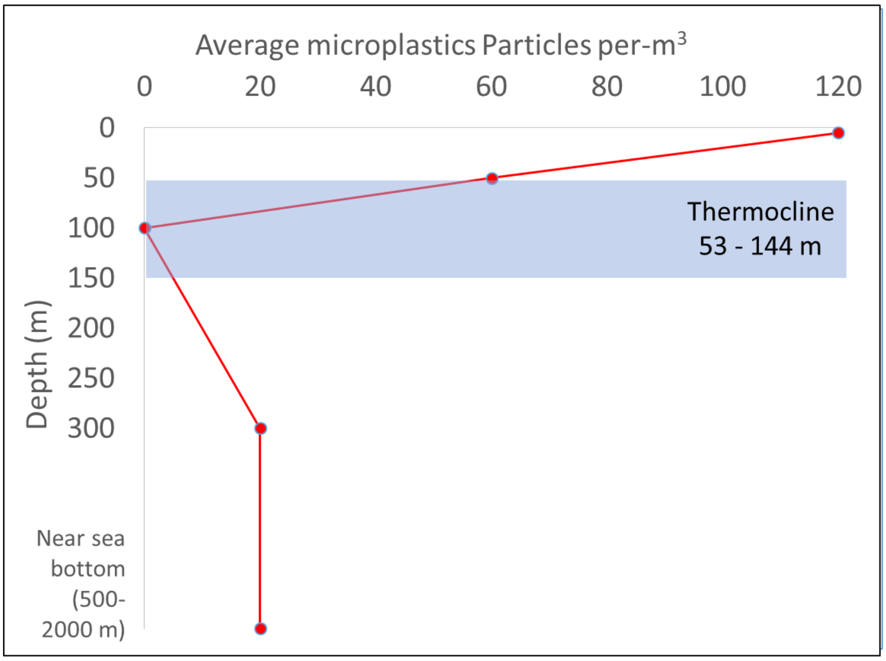

Figure 2. Average of microplastics abundance (n particles/m^3) in all station at five different depth in Sumba Sea

Microplastics abundance at 5m depth was nearly similar with that of the coastal area in Yangtze estuary China [32,33]. The abundance in this area was higher than that of other open oceans, for example North East Atlantic Ocean (2.46 n/m^3; [34]), East China Sea (0-1.44 n/m^3; [33]), and North West Mediterranean (0.116 n/m^3; [35]. The wide variety of microplastic abundance in different oceans might be related with the fact that microplastics tend to be heterogeneously distributed in a water mass [36]. Because Sumba region is one of the ITF outlets [24–26], characterized by four water masses (NPSW, NPIW, NISW, NIIW), we believe that microplastics observed in Sumba might not only come from anthropogenic activities around [28] Sumba, but also from other parts of the oceans in the Pacific.

Table 1. Microplastics occurrence, characteristic and polymer composition

Size	Form			Percentage (%)	Polymer				Percentage (%)
	Fibers	Granule	Other		PE	PS	PA	PP	
<300µm	1	1	0	9.09	1	0	0	0	4.55
300-500µm	3	2	4	40.91	4	2	1	1	36.36
500-1000µm	4	5	0	40.91	5	0	0	4	40.91
>1000µm	2	0	0	9.09	4	0	0	0	18.18
Percentage (%)	45.45	36.36	18.18		63.64	9.09	4.55	22.73	

PE- Polyethylene; PS- Polystyrene; PA- Polyamide; PP- Polypropylene

3.2. Microplastics occurrence, characteristic and polymer composition

We classified microplastics from Sumba into four size categories: <300µm, 300-500µm, 500-1000µm, and >1000µm; and into three forms: fibers, granule, and other type (fragment, foam) (Table 1). In all sampling stations, microplastic size ranges from 280µm to 1120µm. Most of identified microplastics (81.82%) were 300-1000µm in size. Fibers were the most abundant form (45.45%), followed by granule (36.36%) and other type (18.18%). We identified four dominated categories of plastic polymers:

Polyethylene (PE), Polystyrene (PS), Polyamide (PA) and Polypropylene (PP). PE was the most common dominated polymer type, followed by PP, PS, and PA (Table 2).

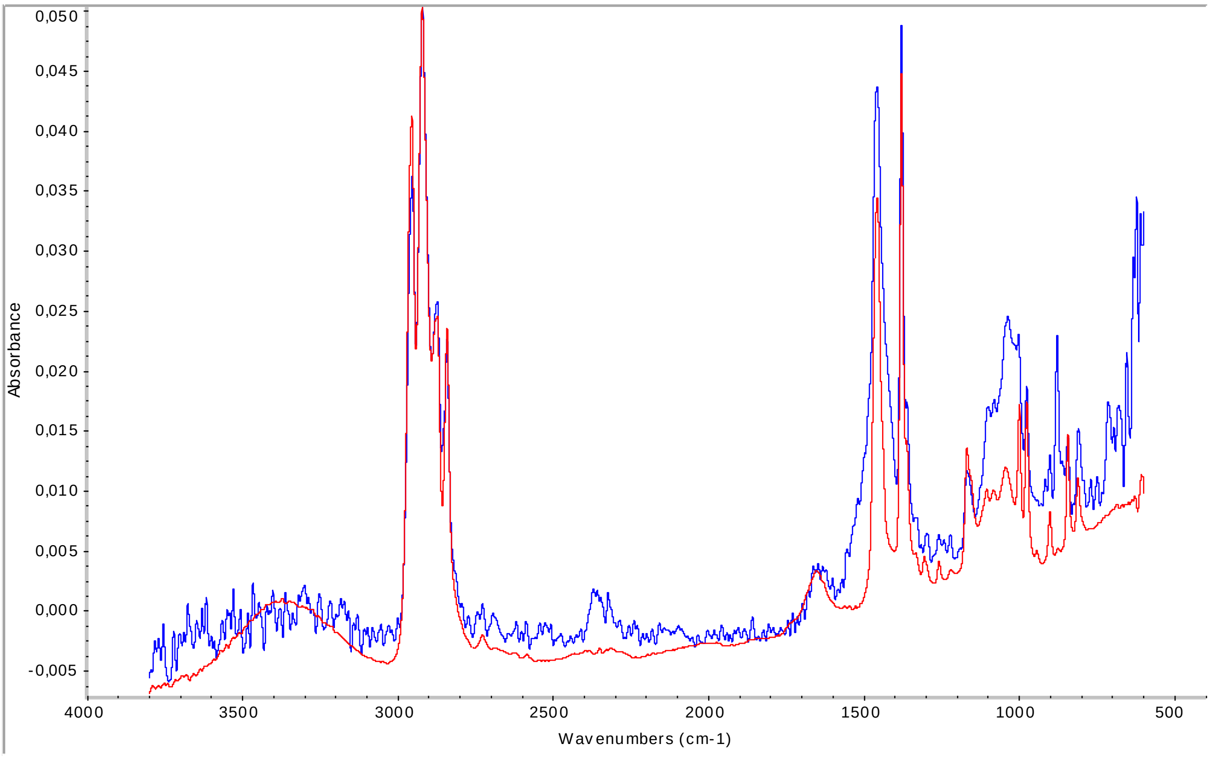

Figure 3. Example of comparison of the spectrum of polypropylene polymer standard from Thermo-scientific (red) and a spectrum obtained from the measurement of a dominated polypropylene fragment particle found in Sumba waters (blue) by ATR-based FTIR spectroscopy

Figure 3 shows examples of the polymers found, which dominated with Polypropylene (PP). From fragment particle sample, prominent presence peak at wavenumber 2950 cm^{-1}, 2916 cm^{-1}, 2837 cm^{-1} and 2868 cm^{-1}. Similar observation by [37] for PP samples indicated peak at 2951 cm^{-1}, 2911 cm^{-1} and 2844 cm^{-1} indicating an asymmetrical type of vibration (v_a-CH_2) [38]. Those were similar displayed vibration bands of polymer standard at 2950 cm^{-1}, 2917 cm^{-1}, 2869 cm^{-1} and 2837 cm^{-1}. In this study, fragment particle found in Sumba waters and polypropylene polymer standard (Figure 3) showed an absorption band at 1375 cm^{-1} and at 1454 cm^{-1}. Spectrum of PP showed symmetrical deformation vibrations (δs–CH_3) at 1372 cm^{-1} and asymmetrical deformation vibrations (δa-CH_3) at 1458 cm−1[37,38].

Size of microplastics could determine the potential impact to the organisms [28]. Smaller size increase the possibility of microplastics ingested by the organisms [33,39]. This situation may pose potential negative impacts to various marine megafauna and important pelagic fishes. Microplastics with size <1000 µm frequently founded on marine organism digestive tract [16,18,19,40], suggesting that marine organisms likely mistake microplastics as their food [41]. Microplastics could disrupt digestive tract function [17] and could also act as a vector for organic and heavy metal pollutants [21–23,42,43]. The most common form was fiber microplastics, similar to the findings by [28,33,44,45]. Fibrous plastic particles in Sumba might derive from fishing nets and rope materials; granule comes from hard plastics and granulated cleaner [45]. Based on FTIR analysis, most polymers identified were dominated polyethylene, followed by dominated polypropylene and dominated polystyrene. The primary use of polyethylene is packaging materials, e.g. food and beverage containers, geomembrane plastic bags and film. Polypropylene is widely used in food and beverage containers, clothing industry, ropes, and re-usable containers [46–48]. Surprisingly, polyamide fiber was also found in Sumba. This fiber might derived from fishing nets and rope material [49,50]. Despite the fact that plastics are newly developed materials (early nineteen centuries made), our finding, that microplastics was found in seawater of Sumba at all surveyed depth, indicated that plastic has invaded marine areas, including pristine areas. It confirms the common believe that plastic waste has spread widely to different parts of the seas and oceans, including remote and unknown areas [51].

4. Conclusion

Our study reports that microplastics were found in all sampling locations, in the form of fibers (45.45%), granules (36.36%) and other form (18.18%). Most of the microplastic particles (81.82%) were found at water depths less than 100m, which were thermocline area. However, no microplastics was observed at 100m depth. Most of identified microplastics (81.82%) were in 300-1000µm in size. Dominated plastics polymers identified were polyethylene, followed by polypropylene, polystyrene, and polyamide. Further studies are planned to examine microplastic distribution in the region where ITF presence and to investigate the potential impact of microplastics in that area.

Acknowledgement
This study was part of Ekspedisi Widya Nusantara IX (EWIN-IX) funded by DIPA LIPI from the Government of Indonesia. We would like to thank the support from all the crews of RV. Baruna Jaya VIII during the EWIN-IX cruise. We also thank to Mr. Sumijo Hadi Riyono for the sample collection.

5. References

[1] Derraik J G B 2002 The pollution of the marine environment by plastic debris: A review *Mar. Pollut. Bull.* **44** 842–52
[2] PlasticsEurope 2015 Plastics - the facts 2014/2015: An analysis of European plastics production, demand and waste data *PlasticsEurope* 1–34
[3] Ellen MacArthur Foundation 2016 The New Plastics Economy: Rethinking the future of plastics *Ellen MacArthur Found.* 120
[4] Cozar A, Echevarria F, Gonzalez-Gordillo J I, Irigoien X, Ubeda B, Hernandez-Leon S, Palma .A T, Navarro S, Garcia-de-Lomas J, Ruiz A, Fernandez-de-Puelles M L and Duarte C M .2014 Plastic debris in the open ocean *Proc. Natl. Acad. Sci.* **111** 10239–44
[5] Eriksen M, Lebreton L C M, Carson H S, Thiel M, Moore C J, Borerro J C, Galgani F, Ryan P G and Reisser J 2014 Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic. Pieces Weighing over 250,000 Tons Afloat at Sea *PLoS One* **9**
[6] Jambeck J R, Geyer R, Wilcox C, Siegler T R, Perryman M, Andrady A, Narayan R and Law K L 2015 Plastic waste inputs from land into the ocean *Science* **347** 768–71
[7] Galgani F, Hanke G, Werner S and De Vrees L 2013 Marine litter within the European Marine Strategy Framework Directive *ICES J. Mar. Sci.* **70** 1055–64
[8] Gregory M R 2009 Environmental implications of plastic debris in marine settings entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* **364** 2013–25
[9] Gall S C and Thompson R C 2015 The impact of debris on marine life *Mar. Pollut. Bull.* **92** 170–9
[10] Laist D 1997 *Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records.* (New York, Springer) chapter 3 pp 99-139
[11] Andrady A L 2011 Microplastics in the marine environment *Mar. Pollut. Bull.* **62** 1596–605
[12] Wagner M, Scherer C, Alvarez-Muñoz D, Brennholt N, Bourrain X, Buchinger S, Fries E, Grosbois C, Klasmeier J, Marti T, Rodriguez-Mozaz S, Urbatzka R, Vethaak a, Winther Nielsen M and Reifferscheid G 2014 Microplastics in freshwater ecosystems: what we know and what we need to know *Environ. Sci. Eur.* **26** 12
[13] Fendall L S and Sewell M A 2009 Contributing to marine pollution by washing your face:

Microplastics in facial cleansers *Mar. Pollut. Bull.* **58** 1225–8
[14] Browne M A, Crump P, Niven S J, Teuten E, Tonkin A, Galloway T and Thompson R 2011 Accumulation of microplastic on shorelines woldwide: Sources and sinks *Environ. Sci. Technol.* **45** 9175–9
[15] Betts K 2008 Why small plastic particles may pose a big problem in the oceans *Environ. Sci. Technol.* **42** 8996
[16] Farrell P and Nelson K 2013 Trophic level transfer of microplastic: Mytilus edulis (L.) to Carcinus maenas (L.). *Environ. Pollut.* **177** 1–3
[17] Cole M, Lindeque P, Fileman E, Halsband C, Goodhead R, Moger J and Galloway T S 2013 Microplastic ingestion by zooplankton *Environ. Sci. Technol.* **47** 6646–55
[18] Browne M A, Dissanayake A, Galloway T S, Lowe D M and Thompson R C 2008 Ingested microscopic plastic translocates to the circulatory system of the mussel, Mytilus edulis (L.) *Environ. Sci. Technol.* **42** 5026–31
[19] Van Cauwenberghe L and Janssen C R 2014 Microplastics in bivalves cultured for human consumption *Environ. Pollut.* **193** 65–70
[20] Peng J, Wang J and Cai L 2017 Current understanding of microplastics in the environment: Occurrence, fate, risks, and what we should do *Integr. Environ. Assess. Manag.* **13** 476–82
[21] Teuten E L, Saquing J M, Knappe D R U, Barlaz M A, Jonsson S, Björn A, Rowland S J, Thompson R C, Galloway T S, Yamashita R, Ochi D, Watanuki Y, Moore C, Viet P H, Tana T S, Prudente M, Boonyatumanond R, Zakaria M P, Akkhavong K, Ogata Y, Hirai H, Iwasa S, Mizukawa K, Hagino Y, Imamura A, Saha M and Takada H 2009 Transport and release of chemicals from plastics to the environment and to wildlife. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* **364** 2027–45
[22] Rochman C M, Hentschel B T and The S J 2014 Long-term sorption of metals is similar among plastic types: Implications for plastic debris in aquatic environments *PLoS One* **9**
[23] Brennecke D, Duarte B, Paiva F, Caçador I and Canning-Clode J 2016 Microplastics as vector for heavy metal contamination from the marine environment *Estuar. Coast. Shelf Sci.* **178** 189–95
[24] Gordon A L 2005 Oceanography of the Indonesian Seas and Their Throughflow *Oceanography* **18** 14–27
[25] Pranowo W S, Kuswardhani A R T D, Kepel T L, Kadarwati U R, Makarim S and Husri S 2005 *Ekspedisi INSTANT 2003-2005 Menguak Arus Lintas Indonesia* ed A Supangat, I S Brodjonegoro, A G Ilahude, I Jaya and T R Adi (Jakarta, Indonesia: Pusat Riset Wilayah Laut & Sumberdaya Non-hayati, Badan Riset Kelautan dan Perikanan, Departemen Kelautan & Perikanan)
[26] McCreary J P, Miyama T, Furue R, Jensen T, Kang H W, Bang B and Qu T 2007 Interactions between the Indonesian Throughflow and circulations in the Indian and Pacific Oceans *Prog. Oceanogr.* **75** 70–114
[27] Hidalgo-Ruz V, Gutow L, Thompson R C and Thiel M 2012 Microplastics in the Marine Environment: A Review of the Methods Used for Identification and Quantification *Environ. Sci. Technol.* **46** 3060–75
[28] Mohamed Nor N H and Obbard J P 2014 Microplastics in Singapore's coastal mangrove ecosystems *Mar. Pollut. Bull.* **79** 278–83
[29] Käppler A, Windrich F, Löder M G J, Malanin M, Fischer D, Labrenz M, Eichhorn K J and Voit B 2015 Identification of microplastics by FTIR and Raman microscopy: a novel silicon filter substrate opens the important spectral range below 1300 cm(-1) for FTIR transmission measurements *Anal. Bioanal. Chem.* **407** 6791–801
[30] Löder M G J and Gerdts G 2015 Methodology used for the detection and identification of microplastics-a critical appraisal *Marine Anthropogenic Litter* pp 201–27
[31] Nuelle M-T, Dekiff J H, Remy D and Fries E 2014 A new analytical approach for monitoring microplastics in marine sediments *Environ. Pollut.* **184** 161–9

[32] Zhang K, Gong W, Lv J, Xiong X and Wu C 2015 Accumulation of floating microplastics behind the Three Gorges Dam *Environ. Pollut.* **204** 117–23
[33] Zhao S, Zhu L, Wang T and Li D 2014 Suspended microplastics in the surface water of the Yangtze Estuary System, China: First observations on occurrence, distribution *Mar. Pollut. Bull.* **86** 562–8
[34] Lusher A L, Burke A, O'Connor I and Officer R 2014 Microplastic pollution in the Northeast Atlantic Ocean: Validated and opportunistic sampling *Mar. Pollut. Bull.* **88** 325–33
[35] Collignon A, Hecq J H, Glagani F, Voisin P, Collard F and Goffart A 2012 Neustonic microplastic and zooplankton in the North Western Mediterranean Sea *Mar. Pollut. Bull.* **64** 861–4
[36] Dubaish F and Liebezeit G 2013 Suspended microplastics and black carbon particles in the Jade system, southern North Sea *Water. Air. Soil Pollut.* **224**
[37] Syakti A D, Bouhroum R, Hidayati N V, Koenawan C J, Boulkamh A, Sulistyo I, Lebarillier S, Akhlus S, Doumenq P and Wong-Wah-Chung P 2017 Beach macro-litter monitoring and floating microplastic in a coastal area of Indonesia *Mar. Pollut. Bull.* **122** 217–25
[38] Fotopoulou K N and Karapanagioti H K 2015 Surface properties of beached plastics *Environ. Sci. Pollut. Res.* **22** 11022–32
[39] Moore C J, Moore S L, Leecaster M K and Weisberg S B 2001 A comparison of plastic and plankton in the North Pacific Central Gyre *Mar. Pollut. Bull.* **42** 1297–300
[40] Foekema E M, De Gruijter C, Mergia M T, van Franeker J A, Murk A J and Koelmans A a 2013 Plastic in North Sea Fish *Environ. Sci. Technol.* **47** 8818–24
[41] Van Cauwenberghe L, Claessens M, Vandegehuchte M and Janssen C 2012 *Occurrence of microplastics in Mytilus edulis and Arenicola marina collected along the French-Belgian-Dutch coast* (Ghent)
[42] Hirai H, Takada H, Ogata Y, Yamashita R, Mizukawa K, Saha M, Kwan C, Moore C, Gray H, Laursen D, Zettler E R, Farrington J W, Reddy C M, Peacock E E and Ward M W 2011 Organic micropollutants in marine plastics debris from the open ocean and remote and urban beaches *Mar. Pollut. Bull.* **62** 1683–92
[43] Rios L M, Moore C and Jones P R 2007 Persistent organic pollutants carried by synthetic polymers in the ocean environment *Mar. Pollut. Bull.* **54** 1230–7
[44] Wright S L, Thompson R C and Galloway T S 2013 The physical impacts of microplastics on marine organisms: A review *Environ. Pollut.*
[45] Claessens M, Meester S De, Landuyt L Van, Clerck K De and Janssen C R 2011 Occurrence and distribution of microplastics in marine sediments along the Belgian coast *Mar. Pollut. Bull.* **62** 2199–204
[46] Miller R C 1990 Polypropylene *Mod. Plast.* **67** 84,86
[47] Arutchelvi J, Sudhakar M, Arkatkar A, Doble M, Bhaduri S and Uppara P V 2008 Biodegradation of polyethylene and polypropylene *Indian J. Biotechnol.* **7** 9–22
[48] Allahvaisi S 2012 Polypropylene in the industry of Food Packaging *Polypropylene* pp 1–20
[49] Thompson R C, Olsen Y, Mitchell R P, Davis A, Rowland S J, John A W G, McGonigle D and Russell A E 2004 Lost at sea: where is all the plastic? *Science* **304** 838
[50] Dekiff J H, Remy D, Klasmeier J and Fries E 2014 Occurrence and spatial distribution of microplastics in sediments from Norderney *Environ. Pollut.* **186** 248–56
[51] Van Cauwenberghe L, Vanreusel A, Mees J and Janssen C R 2013 Microplastic pollution in deep-sea sediments *Environ. Pollut.*