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SHORT COMMUNICATION

Microplastics in the benthic invertebrates from the coastal waters of Kochi, Southeastern Arabian Sea

S. A. Naidu · V. Ranga Rao · K. Ramu

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Abstract This study examined microplastic particles present in the benthic invertebrates *Sternaspis scutata, Magelona cinta* (deposit feeders) and *Tellina* sp. (suspension feeder) from the surface sediments of off-Kochi, southwest coast of India. The microplastic particles and thread-like fibres detected in these organisms were identified to be polystyrene by using DXR Raman microscope. Examination of the microplastic particle in *Sternaspis scutata* by epifluorescent microscopy showed fragmentation marks on the surface suggesting that the microplastic particle was degraded/weathered in nature. The study provides preliminary evidence of the presence of microplastics in benthic fauna from the coastal waters of India. However, further studies are required to understand the sources, distribution, fate and toxicity of the different types of microplastics in benthic invertebrates in order to identify any potential threats to higher trophic level organisms.

Keywords Microplastics · Coastal water · Arabian Sea · Polychaetes · Polystyrene

S. A. Naidu · V. Ranga Rao · K. Ramu (✉)
Integrated Coastal and Marine Area Management-Project Directorate, Ministry of Earth Sciences, NIOT Campus, Chennai, India
e-mail: ramu@icmam.gov.in

Introduction

The pollution of the marine environment by plastic litter from the shallow coastal areas to the open oceans is a global problem and has been well documented (Thompson et al. 2004; Law and Thompson 2014; Ivar do Sul and Costa 2014). Because of the growing demand, usage pattern and production trends of plastics, the improper disposal of the plastic waste will lead to an increase in plastics debris in the oceans (Thompson et al. 2009; Eriksen et al. 2014). The input of microplastics to the oceans from the land can be attributed to the direct introduction with runoff from densely populated or industrialized areas and the subsequent breakdown of plastic litter by physical (wind, waves and currents), chemical (UV radiation) and biological (microbial) degradation (Wright et al. 2013; Ivar do Sul and Costa 2014). Ships and vessels, offshore oil and gas platforms and aquaculture installations are some of the sea-based sources of plastic litter (UNEP 2005). In recent years, several studies have revealed that microplastics are widespread and ubiquitous within the marine environment (Cole et al. 2011; Van Cauwenberghe et al. 2013; Ivar do Sul and Costa 2014).

The most widely used synthetic plastics are low- and high-density polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS) and polyethylene terephthalate (PET) (Andrady and Neal 2009; Hidalgo-Ruz et al. 2012). Typically, the high-density polymer particles sink and accumulate in the sediment, while the low-density polymer particles float at the sea surface. Since microplastics occur in sedimentary habitats and because of their small size, both benthic suspension and deposit feeders may accidentally or selectively ingest sinking and sedimentary microplastics (Bolton and Havenhand 1998; Thompson et al. 2004; Cole et al. 2011; Wright et al. 2013; Van Cauwenberghe et al. 2015). Studies suggest that the hydrophobic pollutants available in the seawater adsorb onto plastic debris under ambient environmental conditions (Thompson et al. 2009; Cole et al. 2011). Thus, the ingestion of microplastics by the lower trophic level organisms has a potential for bioaccumulation of pollutants (Teuten et al. 2009). A number of studies have shown that microplastics can be ingested by marine biota under laboratory conditions (von Moos et al. 2012; Van Cauwenberghe et al. 2015; Ribeiro et al. 2017); however, under in situ conditions the organisms are exposed to microplastics throughout their lifetime as compared to the short experimental periods. The continuous ingestion and accumulation of microplastics by the organisms may have potential toxicological effects.

India is one of the major plastic consumers in the world, with an annual consumption of ~ 5.6 million tonnes (Toxics link 2014). The coastal waters and estuarine systems have been recognized as hotspots for microplastic pollution (Browne et al. 2010; Wright et al. 2013). However, to our knowledge no studies have reported the presence of microplastics in biota from the Indian coastal waters. In the present study, an effort was made to assess the occurrence and type of microplastics in benthic invertebrates from the coastal waters of Kochi, southwest coast of India, which is vulnerable to plastic pollution.

Study area

Kochi with a population of 2.5 million people is the second most urbanized city on the west coast of India, (UN 2016). The Kochi estuarine system connected to the southeastern Arabian Sea by two permanent openings has a number of chemical industries at the upstream region (Balachandran et al. 2006). Further, the prolonged monsoon with an annual rainfall of about 3200 mm results in the wash out of wastes into the network of rivers, streams and finally into the coastal waters of Kochi. In addition, Kochi has an all weather natural port that handles a number of container cargo vessels (Ramzi et al. 2017). Due to the dense population, large riverine discharge, industrial and maritime activities, the coastal waters of Kochi are vulnerable to pollution by plastics.

Sampling methodology

As part of the Ecosystem Modelling Project for the southwest coastal waters of India, five transects with 25 locations orthogonal to the Kochi coast, southeastern Arabian Sea are being monitored seasonally for the benthic macrofauna to understand the linkages between benthic and pelagic environments. In November 2016, benthic macrofauna from two locations was collected for the examination of microplastics as the ingestion of microplastics is of concern and has been recently observed in a wide range of taxa (Fig. 1). The sediment samples were collected with a Van veen grab sampler having a mouth area of 0.1 m^2. The sediment samples were washed through a 0.5-mm mesh sieve, and the collected organisms were fixed and preserved in neutral formalin–Rose Bengal mixture. The sediment samples were also collected for particle size analysis.

Sample processing and identification of microplastics

The sieved benthic macrofauna was examined under a binocular microscope (Lawrence & Mayo), and the targeted benthic invertebrates, polychaetes [*Sternaspis scutata* (5 mm; deposit feeder), *Magelona cinta* (25 mm; deposit feeder)] and bivalve *Tellina* sp. (8 mm; suspension feeder), were separated and used for this study (Fig. 2). For each species, three numbers of organisms were picked and washed by gently shaking in particle free seawater obtained by filtering with 0.22 µm polycarbonate filters (Millipore) in order to remove sediment particles adsorbed onto the surface of the organism. The washed polychaetes *Sternaspis scutata* and *Magelona cinta* were put in a drop of water on an object slide and squeezed firmly with a cover slip. The bivalve *Tellina* sp. was opened with a sharp knife, and the soft tissue was placed on an object slide. Measures were taken to avoid any contamination while handling and processing of the samples. All the dissecting tools were rinsed with Milli-Q water before use.

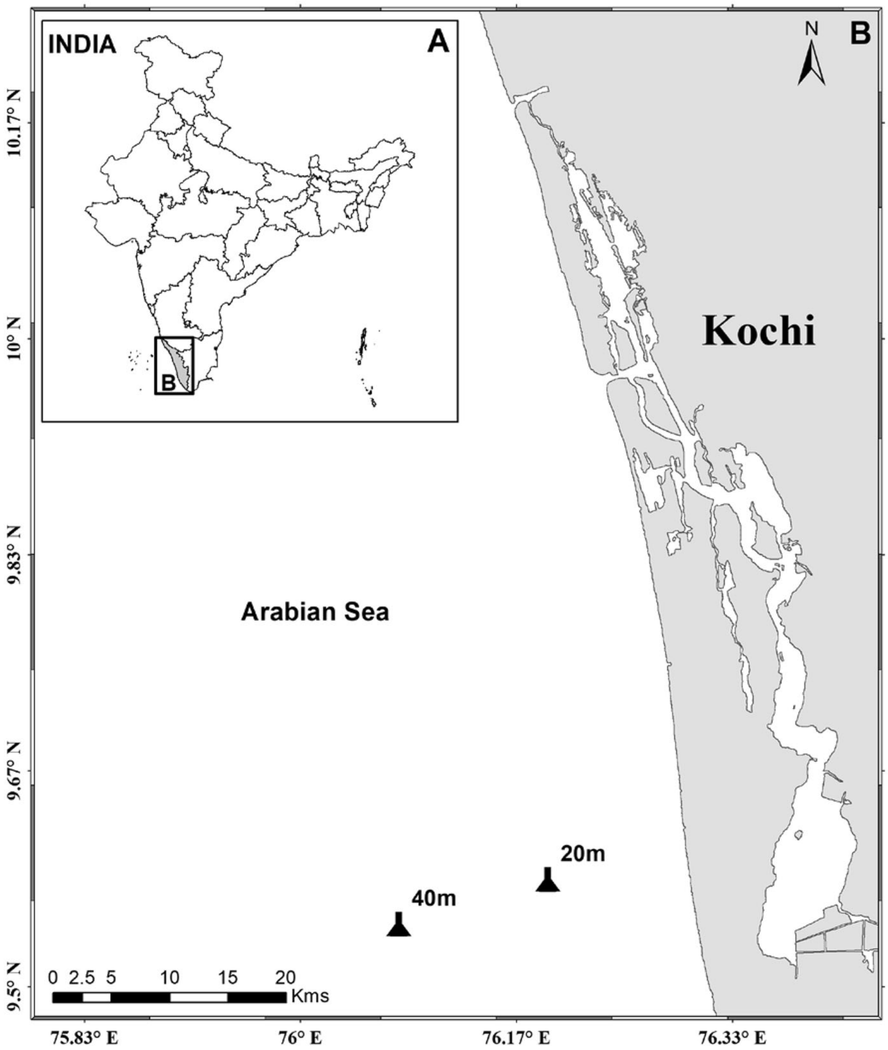

Fig. 1 Sampling locations of the benthic invertebrates in the coastal waters of Kochi, Arabian Sea

The analytical methods for identification of microplastics in various matrices are still under development. In a review on the analytical methods for microplastics, Shim et al. (2017) suggested the use of Raman spectroscopy for particles less than 20 µm in size. In this study, the prepared specimens were examined using a stereo zoom microscope at 10× and 40× magnification and by the Nikon Upright Fluorescent Microscope (Eclipse 80i). The type of polymer the microplastic particles were made of was identified by the DXR Raman microscope (Thermo Scientific, USA). The operating conditions of the DXR Raman microscope were as follows: excitation wave length 532 nm, laser beam power < 5 mW, grating 900 groves/mm, a 50× long working distance objective and an integration time of 10 s. The resulting spectra were compared with the Aldrich Raman condensed phase library for polymers. The OMNIC Software was used to operate the instrument and for data analysis.

Results and discussion

The epifluorescence microscopy and DXR Raman microscope are well-established techniques for the examination and identification of microplastic particles in biological organisms and sediments (Cole et al. 2013; Imhof et al. 2013; Thompson et al. 2004; Sruthy and Ramasamy 2017). The epifluorescence microscopic examination of the gut content of the sediment

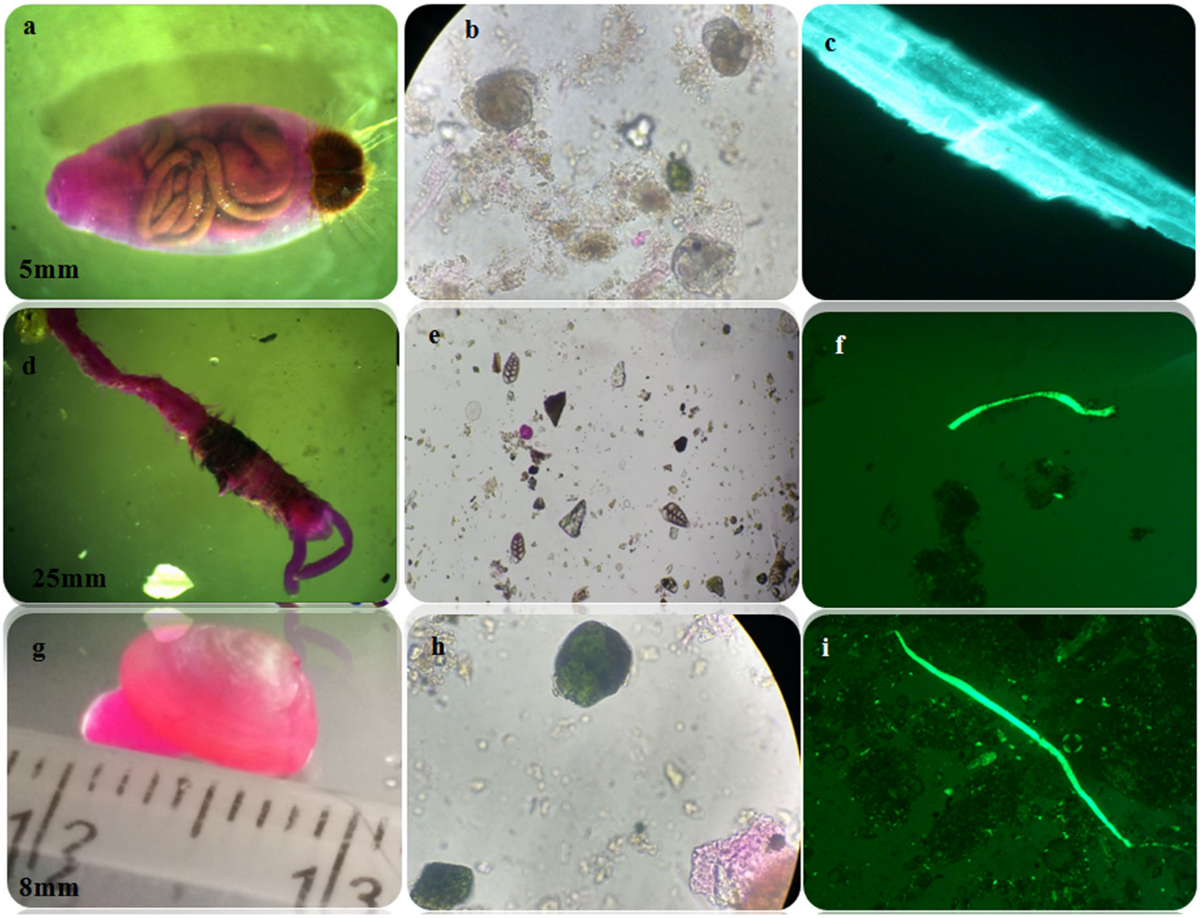

Fig. 2 Microscope images of the benthic invertebrates (**a** Sternaspis scutata; **d** Magelona cinta; **g** Tellina sp.) and corresponding images representing the gut contents (**b** Sternaspis scutata; **e** Magelona cinta; **h** Tellina sp.) and the epifluorescence images of the microplastic particles found in the gut (**c** Sternaspis scutata; **f** Magelona cinta; **i** Tellina sp.)

deposit feeding polychaetes *Sternaspis scutata* (Fig. 2a) and *Magelona cinta* (Fig. 2d) and suspension feeding bivalve *Tellina* sp (Fig. 2g) showed the presence of fluorescent particles and fibres (Fig. 2c, f, i). This could be due to the ingestion of particles present in the water column by the suspension feeding bivalve *Tellina* sp. and from the sediments by the deposit feeding polychaetes *Magelona cinta* and *Sternaspis scutata*. The size, shape, density, colour and abundance of the microplastic particles make them available to a wide range of biological organisms (Kach and Ward 2008; Moore 2008; Wright et al. 2013). Due to the non-selective feeding habit of polychaetes, they ingest microplastics present in the sediment along with organic matter (Thompson et al. 2004; Browne et al. 2013; Wright et al. 2013). The uptake of microplastics by bivalves has been observed in laboratory experiments (Thompson et al. 2004; Browne et al. 2008; von Moos et al. 2012) and in the natural populations (Murray and Cowie 2011; Van Cauwenberghe et al. 2015).

DXR Raman microscope was used to identify the polymer composition of the blue fluorescent particle found in *Sternaspis scutata* (Fig. 2c) and green fluorescent fibres found in *Magelona cinta* and *Tellina* sp. (Fig. 2f, i). The comparison of the measured Raman spectra with the Raman spectral library revealed 67 and 98% matching with polymer polystyrene for the blue fluorescent particle (Fig. 3a) and the green fluorescent fibres (Fig. 3b), respectively. Polystyrene is one of the most widely used plastics and commonly identified microplastic litter in marine habitats across the globe. The bioavailability of microplastics is dependent on the density of the plastic

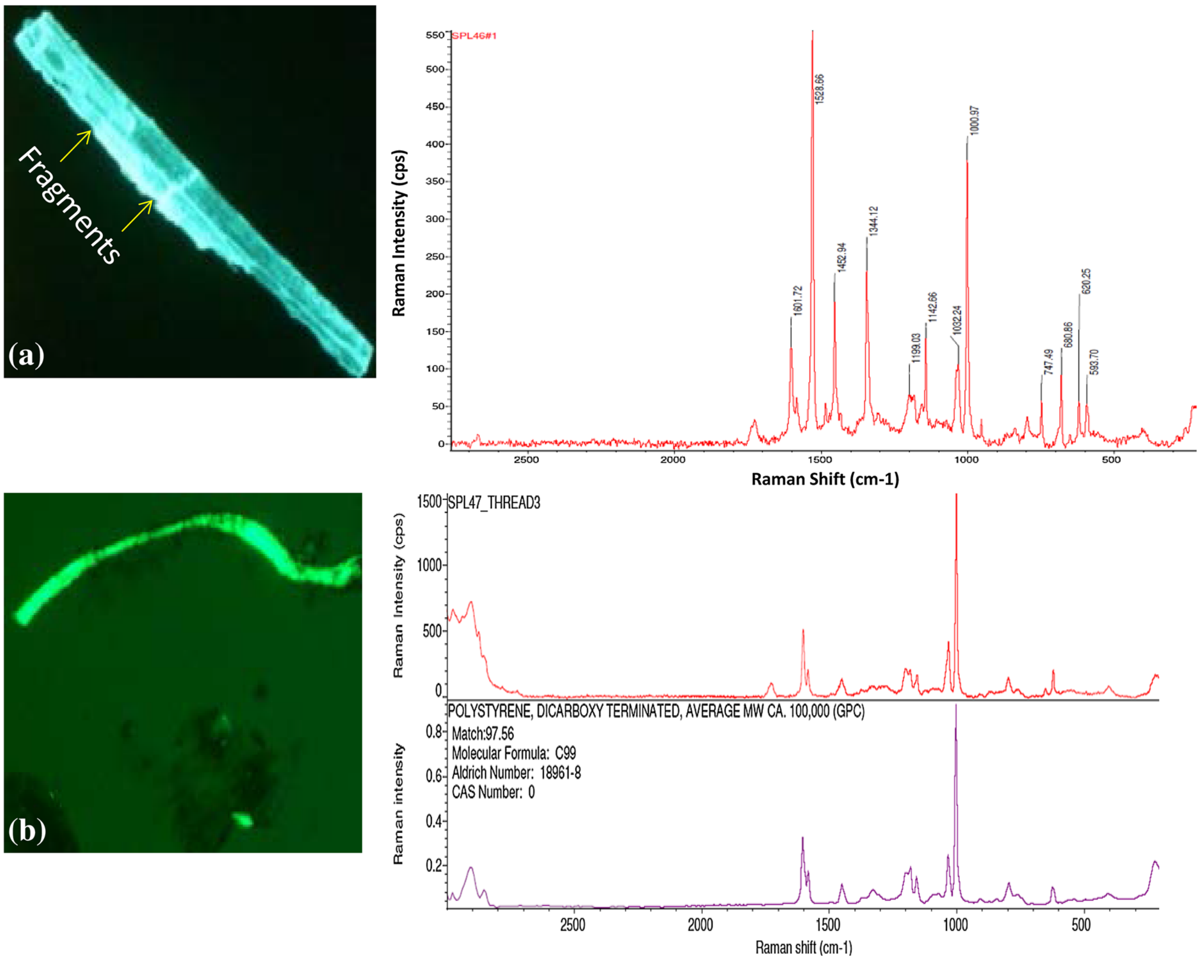

Fig. 3 Identification of the microplastics using DXR Raman microscope. **a** The Raman spectra of the microplastic particle in the gut of deposit feeding polychaete Sternaspis scutata and **b** The Raman spectra of the fibrous microplastic particle in the gut of suspension feeding bivalve Tellina sp. and the Raman spectra for the polymer polystyrene

particle. Polystyrene with a density of 1.04 (Andrady 2017) may readily sink and accumulate in deeper waters making it available to benthic suspension and deposit feeders. In the marine environment, the plastic particles are exposed to a variety of conditions which may alter the original polymer composition (Lenz et al. 2015), which may explain 67% matching of the Raman spectra for the blue fluorescent particle with that of polystyrene. Further, the blue microplastic particle was found to be in a degraded state as evidenced by the cracks and fragmentation on the surface of the particle (Fig. 2c).

There are several studies reporting that the effluents from wastewater treatment plants could be a major contributor of microplastics to the aquatic environments as these effluents contain plastic in the form of synthetic fibres (Browne et al. 2011; Magnusson and Norén 2014; Napper and Thompson 2016). Fibrous microplastics are commonly encountered in the marine environment (Wright et al. 2013). The study site is in close vicinity to one of the most urbanized and populated cities of India, and therefore the disposal of plastics along the shorelines, effluent discharge, shipping and fishing activities could be some of the potential sources of microplastics in the benthic organisms investigated. The breakdown of the plastic litter into smaller size particles and their subsequent ingestion by aquatic organisms can eventually reach the higher trophic levels through food chain (Green 2016; Murray and Cowie 2011).

Conclusion

With rising plastic production and per-capita consumption of plastics, it is obvious that plastic litter will be an environmental issue and aquatic organisms would be exposed to microplastics. The benthic invertebrates that include the suspension and deposit feeders are likely to ingest the microplastics present in the water column and in sediments because of their non-selective feeding behaviour. Consequently, the predation on these benthic invertebrates by the higher trophic organisms may be a pathway for the transfer of microplastics along the food chain. However, studies on the accumulation rates and the residence time of microplastics in these organisms are needed to make sure about the transfer of microplastics across the food webs. This study demonstrated for the first time the presence of microplastics in benthic polychaetes and bivalves from the surface sediments of the southwest coast of India. The pollution by microplastics is relatively a new issue, and further comprehensive scientific investigations are needed to address the levels, sources, distribution and fate of the different type of plastic polymers in the marine environment and their effect on aquatic organisms as they have a potential to endanger animal and human health.

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