Marine Pollution Bulletin 136 (2018) 464–471

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Microplastic and charred microplastic in the Faafu Atoll, Maldives

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ARTICLE INFO

Keywords:
Microplastic
Char
Atoll
Reef
Maldives

ABSTRACT

Microplastics are recognized as a growing threat for the marine environment that may even affect areas generally considered pristine. In this work we surveyed the microplastic contamination in the Faafu Atoll (Maldives, Indian Ocean) across twelve sampling station, located either inside or outside the reef rim. Sediments and seawater samples were collected. Despite the remoteness of the atoll, the scarce local population and low touristic annual afflux, the detected average abundance were 0.32 ± 0.15 particles/m^3 in the surface water and 22.8 ± 10.5 particles/m^2 in the beach sediments. Polymers identified through Fourier-Transform Infrared spectroscopy were mostly polyethylene, polypropylene, polystyrene, polyvinylchloride, polyethyleneterephtalate, and polyamide. Elastomeric residues and charred microparticles were also found. In particular, the charred microparticles were prevalently located nearby the inhabited island and they might be considered a peculiarity of the area, related to local practice of burning plastic waste at the shoreline.

1. Introduction

Plastic has undoubtedly extraordinary properties: is easy to process, durable, lightweight and it has low production costs. These properties are the reasons of its capillary use across the world and of its exponential production. It has been estimated that the cumulative value of worldwide plastic production has already exceed the 5 billion tons and it is expected to increase to 33 billion tons by 2050 (Plastics Europe, 2016).

A side effect of this mass production is that an enormous quantity of plastic waste ends up into the ocean due to improper disposal (from 4.8 to 12.7 million metric tons each year) and accordingly to anticipated trends, the number will continue to grow (Jambeck et al., 2015). Plastic is just now so abundant that it has been proposed as a new stratigraphic indicator of Anthropocene (Zalasiewicz et al., 2016).

Once introduced into the environment, plastic may persist for decades due to its chemical properties (Barnes et al., 2009; Ivar do Sul and Costa, 2014), and undergo over time to disintegration into smaller fragments under the combined effect mechanical breakdown caused by waves, UV induced photolysis, and biological degradation (Browne et al., 2007; Barnes et al., 2009; Ceccarini et al., 2018).

This process lead to the formation of very tiny particles – called microplastics (smaller than 5 mm) that represent the new challenge of the plastic contamination problem (Eriksen et al., 2013; Lusher et al., 2015): over 92% of all plastic items currently found at sea are microplastic (Moore, 2008). Open ocean water bodies (Cole et al., 2011; Desforges et al., 2014; Hidalgo-Ruz et al., 2012; Lusher et al., 2014), beaches and coastlines (Claessens et al., 2011; Hengstmann et al., 2018; Moore et al., 2002; Zhang et al., 2018), subtropical oceanic gyres (Brach et al., 2018; Ory et al., 2017), polar areas (Lusher et al., 2015; Obbard, 2018), deep ocean sediments (Van Cauwenberghe et al., 2015), and freshwater systems (Eriksen et al., 2013; Vaughan et al., 2017; Wagner and Lambert, 2018) have been already documented to accumulate microplastics.

Microplastic may severely affect marine wildlife. Main problems arise due to ingestion (Gall and Thompson, 2015): microplastic particles are mistaken by food because their size, shape and colour (Schuyler et al., 2014) by the marine fauna as zooplankton and larval fish (Desforges et al., 2015; Sun et al., 2017; Steer et al., 2017), sessile invertebrates (Wright et al., 2013) sea turtles (Camedda et al., 2014) marine birds (Van Franeker et al., 2011) and fish species (Boerger et al., 2010). In addition to direct mechanical effects, i.e. particles may entangle block or abrade feeding appendages and internal organs (Wright et al., 2013), a variety of indirect effects is also observed: harmful substances present as ingredient in the microplastic particles may leach into the digestive tract reducing survival, feeding, immunity or

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https://doi.org/10.1016/j.marpolbul.2018.09.023
Received 25 July 2018; Received in revised form 12 September 2018; Accepted 14 September 2018
0025-326X/

antioxidant capacity (Browne et al., 2007), organic and metal contaminants may be accumulated from surrounding water and found an easy enter inside the organism (Koelmans et al., 2016); a wide range of rafting alien species and microbial communities may found in microplastic a vector to colonize ecosystems (Barnes, 2002; Kirstein et al., 2016).

Although worldwide attention to the marine plastic litter has been grown in the last decades, together with the number of scientific publications devoted to the microplastic topic, knowledge about the abundance, composition and size distribution of plastic debris in areas remote to human civilization is still considered scarce (Thompson et al., 2004; Bergmann et al., 2015; van Sebille et al., 2015). This information is fundamental to support the management of the problem (GESAMP, 2015).

Maldivian coral reef is the seventh largest coral reef system on the globe, with a total surface of 8920 km^2, accounting for 3.13% of the world's reef area (Spalding et al., 2001) and probably accounting for the highest coral cover values in the western Indian Ocean (Goreau et al., 2000). Unfortunately, several threats are contributing to its environmental decline. Some are natural such as coral bleaching, algal overgrowth, invertebrate outbreaks and coral diseases (Montano et al., 2012; Saponari et al., 2018), other are human-related, such as coral mining, pollution, fishing, tourism and land reclamation (Jaleel, 2013).

The microplastic contamination in the Maldivian area and the possible impact on the coral reef ecosystem has been still scarcely investigated (Barnes, 2004, Browne et al., 2011; van Sebille et al., 2015; Imhof et al., 2017). Considering that the Republic of Maldives is constituted by a human population of about 300 thousands located in an archipelago of about 1200 islands, and it is now facing a rapid economic growth, scientific investigation is needed in order to plan sustainable development policies and efficient waste management practice.

Under this light, in this study we surveyed the level of microplastic contamination along the Faafu Atoll, a complex of 23 inhabited and uninhabited islands with a total of about 3000 locals, that is far about 140 km from the capital city Malè and 720.000 km from India, the closest country. For the best of our knowledge, this is the first on field investigation regarding its microplastic contamination.

2. Materials and methods

2.1. Sampling location

The study was conducted during May 2018 in Faafu Atoll, Republic of Maldives (Fig. 1). This atoll is approximately 31 km long and 24 km wide and is subjected to two main oceanic stream/current: one toward southwest-northeast from May to November, and another in opposite direction from December to April (Montano et al., 2012). Twelve different sampling sites (Table 1), among those accessible in two side of the atoll, and showing heterogeneous characteristics in terms of reef morphology and exposure were selected (Fig. 1): inner reefs (code = MD1, MD2, BD1, BD2, DD, WA, CA and MMA) and outer reefs (code = NY, BY and FY). The inner reef sites were mainly characterized by lagoon, patches reef or lagoon facing sides of the atoll rim. The inner reef habitat is often subject to high and fluctuating water temperatures, intense UV light, high salinity and potentially desiccation as a result of low tides and exposure. Some sites exhibited typical low-energy reef feature with a luxuriant growth of coral and gentle slopes to all sides, while others were characterized by shallow patchy lagoon reefs or by steep reef walls. Inner reefs, being adjacent to land, are also the areas of reef most affected by land based pollutants and sedimentation. By contrast, the external, ocean-facing side of the atoll rim is naturally characterized by strong and intense hydrodynamic conditions, with higher exposition to water motion, deeper water, lower coral coverage and practically no human activities.

Operations were carried out by using the Marine Research and High Education Center (MaRHE) as logistic station and marine laboratories facility (Supplementary, Fig. S2). This center is placed on Magoodhoo Island (3°4′49.08″N, 72°57′57.19″E), a scarcely habited island (approximately 850 people) that measures 900 × 450 m and is located on the south-east part of the atoll rim. All the sampling activities were documented photographically by using a Canon X7 camera and geographically using a Garmin map64s GPS. Precipitation, wind and tidal cycles data were recorded for each sampling day and for the previous 6 days. During the sampling activities the maximum tidal range recorded on the atoll was 1.1 m. Winds were in general of moderate intensity (6–21 kn) and constant direction (S, SW) accordingly to the summer Monsoon starting season (called "*Halhangu*" in Dhevi, Maldivian language). More detailed information is available in the Supporting information.

2.2. Beach sediments sampling procedure

Plastic abundance in beach sediments was assessed by collecting particles at the high tide drift line approximately 1 h after the afternoon high tide. Sampling of mesoplastic (5–25 mm) and large microplastic (1–5 mm) was performed visually by using a grid of 1 m × 1 m: the grid was positioned at the intersection of the drift line and the line coming from the water perpendicularly to the shoreline; all the potential plastic particles identified by "naked" eyes inside the grid were collected from the sand using forceps, stored in aluminum foil and transferred to the laboratory for further examination. Six replicated samples were collected for each beach.

For invisible microplastic (< 1 mm) we adopted a different procedure. In this case a 50 cm × 50 cm grid was used for collecting the upper surface layer (approx. 1 cm) of the sampling area through a small stainless steel shovel. A fraction of the resulting sediment sample was then weighed (approximately 250 g), dried for 24 h at 60 °C and sorted by size using a set of stainless steel laboratory sieves with 5 mm, 1 mm, 500 μm, 250 μm, 150 μm and 50 μm mesh size (RETSCH GmbH, Germany). Each size sorted fraction was then examined.

2.3. Surface seawater sampling procedure

Microplastic sampling from seawater was conducted aboard the research vessel of Mahre Center by using a neuston tow-net having 200 μm mesh and a conical design with a 35 cm diameter opening and 1 m length. The sampling activities were conducted only with South wind conditions and when wind speed was maximum 10 kn, in order to avoid the mixing of plastic particles in the water column. The net was always towed against the wind and outside of the ship's wake. The top 50 cm of the sea surface were sampled at an average speed of 2 kn for 15 min. Each transect was replicated three times. After sampling, the contents were washed from the outside of the net with a seawater hose into glass sample jars and covered aluminum foil-lined lids. Collected jars were then transported to the laboratory for microplastic examination.

2.4. Microplastic identification

For every sample, potential plastic particles were separated from organic matter, sorted and categorized under a stereo microscope (Leica S9E, Leica Microsystems GmbH, Germany) up to 40× magnification. Mesoplastic and large microplastic were analyzed directly. Not visible microplastic (1 mm–50 μm) were previous submitted to a two-step density separation with a 1.2 g/cm^3 density saturated sodium chloride (NaCl) and a 1.8 g/cm^3 density sodium iodide (NaI) solution, accordingly to literature method (Nuelle et al., 2013). The supernatant was in this case transferred to a glass filtration apparatus and concentrated onto anodisc filters (47 mm, Whatman, Freiburg, Germany). In the case of plankton rich seawater samples an enzymatic digestion (Proteinase-K treatment) of the naturally occurring organic material was performed in