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A quantitative analysis of microplastic pollution along the south-eastern coastline of South Africa

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ABSTRACT

The extent of microplastic pollution (<5 mm) in the southern hemisphere, particularly southern Africa, is largely unknown. This study aimed to evaluate microplastic pollution along the south-eastern coastline of South Africa, looking at whether bays are characterised by higher microplastic densities than open stretches of coastline in both beach sediment and surf-zone water. Microplastic (mean ± standard error) densities in the beach sediment ranged between 688.9 ± 348.2 and 3308 ± 1449 particles·m^{-2}, while those in the water column varied between 257.9 ± 53.36 and 1215 ± 276.7 particles·m^{-3}. With few exceptions there were no significant spatial patterns in either the sediment or water column microplastic densities; with little differences in density between bays and the open coast ($P > 0.05$). These data indicate that the presence of microplastics were not associated with proximity to land-based sources or population density, but rather is governed by water circulation.

1. Introduction

Microplastics are defined as small plastic particles with an upper size limit of 5 mm (GESAMP, 2015). Primary microplastics, such as industrial pellets or nurdles are used as precursors in the manufacturing of larger plastic items (Gregory, 1996; Cole et al., 2011; Hidalgo-Ruz et al., 2012), with accidental losses occurring mainly during their manufacture and transportation stages (Gregory, 1996). Granulated particles called "microbeads" are also classified as primary microplastics, with their incorporation in a number of industrial (air-blasting media) and household (hand-cleaners and facial scrubbers) products (Gregory, 1996). Originating from the fragmentation of larger plastic items are secondary microplastics, the most common source of plastic pollution in the marine environment (Andrady, 2011; Cole et al., 2011; Hidalgo-Ruz et al., 2012). Larger plastic items enter the marine environment and through a combination of photo-degradation and mechanical breakdown from wave action the item fragments into smaller and smaller pieces (Andrady, 2011). Garments and carpeting may break-down during the washing process releasing small microfibres into waterways, eventually entering the marine environment (Browne et al., 2011; Mathalon and Hill, 2014). Determining the sources of these particles is a fundamental step in identifying possible mitigation steps, thus understanding whether they are primary or secondary microplastics is essential (GESAMP, 2015). In addition, identifying whether they originate from either a sea- or land-based source, as well as if they were accidentally or deliberately introduced into the ocean will assist the development of prevention methods.

Originally thought to be inert, Carpenter and Smith (1972) was the first study to identify the presence of biofouling organisms (hydroids and diatoms) associated with industrial pellets collected in the Sargasso Sea. GESAMP (2015) stated that this association between marine organisms and microplastics may have "potential ecological and human health risks". Especially because the size range of these microplastic particles are similar to planktonic organisms residing within the water column, previously not affected by larger marine debris (Barnes et al., 2009; Van Cauwenberghe et al., 2015). These microplastics may become vectors for the transportation of toxic chemicals, originating from either the plastic item (additives, monomers and by-products) or the surrounding marine environment (persistent organic pollutants) (Teuten et al., 2009; GESAMP, 2015). Thus, when ingested by various fauna, there is a potential for toxic compounds to bio-magnify through the food-web (GESAMP, 2015). Although investigations into this have increased dramatically, knowledge is still scarce, including the impact these microplastics may have on human health and food consumption.

The widespread distribution of microplastic pollution has been highlighted in a number of studies (e.g. Browne et al., 2011; Ivar do Sul and Costa, 2014; Law and Thompson, 2014). Including, the Artic (Obbard et al., 2014) to mid-ocean convergence zones, such as the North Atlantic (Carpenter and Smith, 1972; Law et al., 2010) and South Pacific subtropical gyre (Eriksen et al., 2013). However, in South Africa the information on microplastic pollution is limited. Between 1977 and 1978, Ryan (1988) sampled the sea-surface water off the south-western Cape Province; finding a mean particle density of

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3.64 particles·m^{-2}. Samples were comprised of foamed plastics, fragments of manufactured articles, industrial pellets and fibres (Ryan, 1988). A subsequent study conducted at 50 South African beaches during 1984 and again in 1989, found similar results (Ryan and Moloney, 1990). Lamprecht (2013) sampled Milnerton beach in Table Bay and found a mean of 30,900 microplastic particles·m^{-3}. Although, this study was only conducted on one beach, it also considered the vertical profile of microplastic particles, in the sediment, to a depth of 30 cm. The most recent study by Naidoo (2015) along the KwaZulu-Natal coastline found peak concentration values in the sediment of Durban harbour (1789 particles per 1200 mL). It is essential to increase the understanding of microplastic pollution in South Africa, as it was ranked in the top 20 countries with the highest mass of mismanaged plastic debris (Jambeck et al., 2015).

This study, thus, aimed to evaluate the extent of microplastic pollution along the south eastern coastline of South Africa, in particular, looking at whether bays which are considered largely retention systems, are characterised by higher microplastic densities than open stretches of coastline. The distribution, density and composition of microplastic particles collected from both beach sediment and surf-zone water from 21 beaches (12 within bays and 9 along the open coast) across the south-eastern coastline of South Africa was investigated in November 2014.

2. Methods and materials

Sediment and water samples were collected, during November 2014, along the south-eastern coastline of South Africa. The research area extended approximately 480 km from Cannon Rocks (33°44.849′ S 26°33.186′E) in the east to Danabaai (34°20.58′S 22°04.529′E; Fig. 1). Within and including the above mentioned sites, 21 beaches were sampled of which 12 were situated in major bays, i.e. Algoa Bay, Jeffrey's Bay, Plettenberg Bay and Mossel Bay (Fig. 1). The remainder nine sites were situated on the open stretch of coastline between the bays (Fig. 1). All sampling procedures done in this study followed the approaches highlighted in the review by Hidalgo-Ruz et al. (2012).

Triplicate beach sediment samples were collected, at each site, from the most recently deposited flotsam at the high-tide line. Bulk samples were made up of the top 5 cm of beach sediment. Samples were subsequently stored in individual ziplock bags and transported back to the laboratory where a sub-sample of 1200 ml was removed. This sub-sample was placed in a pre-rinsed 5 L glass beaker containing saturated saline solution and stirred vigorously allowing the less dense microplastic particles to float to the surface. The supernatant was then sieved through a 65 μm mesh. This density-separation process was repeated five consecutive times, in order to maximise recovery. In addition, triplicate water samples were collected in the surf-zone where the water level was approximately 45 cm in depth. Water was filtered using a WP-2 type net with 80 μm mesh size and a 155 mm hoop diameter for 10 m filtering 188.692 L water for each sampling event. Samples were fixed with 5% formalin and transported back to the laboratory. A Bestscope dissecting microscope, with magnification ranging from 8 to 50×, was used to visually sort the volume-reduced samples of both sediment and water, allowing all possible microplastic particles to be extracted. Extracted microplastic particles were separated into fragments and microfibres, with the latter grouped according to colour (i.e. blue/black, red, yellow and green; Dekiff et al., 2014).

Post-sampling contamination was controlled for by eliminating major sources of in-lab contamination. Distilled water was used to clean the equipment between each sample extraction, additionally the

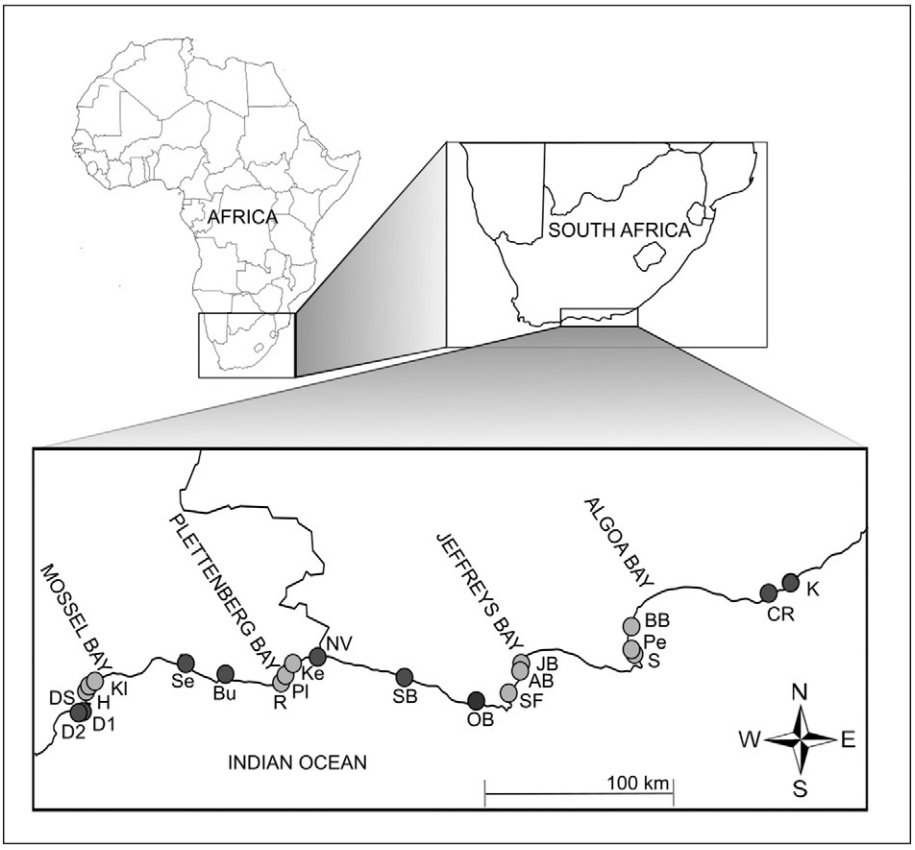

Fig. 1. Map showing the geographical position of the study area within both South Africa and Africa. Highlighting the position of the 21 sample sites namely: K = Kenton; CR = Cannon Rocks; BB = Bluewater Bay; Pe = Port Elizebeth Main beach; S = Summerstrand; JB = Jeffrey's Bay; AB = Aston Bay; SF = St Francis; OB = Oyster Bay; SB = Skuitbaai; NV = Nature's Valley; Ke = Keubooms; Pl = Plettenberg Bay; R = Robberg; Bu = Buffel's Bay; Se = Sedgefield; Kl = Kleinbrak; H = Hartenbos; DS = Diaz Strand; D1 = Danabaai 1 and D2 = Danabaai 2.