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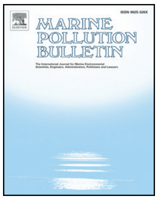

Do microplastic loads reflect the population demographics along the southern African coastline?

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ABSTRACT

Plastic pollution is a major anthropogenic contaminant effecting the marine environment and is often associated with high human population densities and industrial activities. The microplastic (63 to 5000 μm) burden of beach sediment and surf-zone water was investigated at selected sites along the entire length of the South African coastline. It was predicted that samples collected in areas of high population density, would contain a higher microplastic burden than those along coasts that demonstrate very low population densities. With the exception of water column microplastics within Richard's Bay Harbour (413.3 ± 77.53 particles$\cdot$m^{-3}) and Durban Harbour (1200 ± 133.2 particles$\cdot$m^{-3}), there were no significant spatial differences in microplastic loads. This supports the theory that harbours act as a source of microplastics for the surrounding marine environment. Additionally, the absence of any spatial variation highlights the possible long range distribution of microplastic pollutants by large scale ocean currents.

1. Introduction

Plastic debris unintentionally or deliberately discarded may be introduced into the marine environment directly or via indirect sources, for example rivers, storm-water runoff and wind transportation (Fischer et al., 2016). Moreover, in the case of large plastics this reservoir may aid in their fragmentation, as countless items get stranded on shorelines globally and with the cumulative effects of wind and ultraviolet radiation result in the formation of secondary microplastics (Andrady, 2011). Wastewater effluent represents a major additional source of microplastic contamination i.e. microfibers and microbeads (Fendall and Sewell, 2009; Browne et al., 2011; Chang, 2015). Microfibers, also classified as secondary microplastics are released during the washing of synthetic carpets and clothing (Browne et al., 2011), while microbeads a type of primary microplastic enters via the use of many household cosmetic products (Fendall and Sewell, 2009; Chang, 2015). Introduction of these microplastic contaminants are not exclusively via the above mentioned pathways. Nurdles, the precursors for larger plastic items are a major pollutant near areas of high industrial activity, such as harbours, due to accidental loss and spillage during transportation (Gregory, 1996). Additionally, harbours may have a high number of microbeads used in industrial processes, such as air-blasting (Gregory, 1996). Thus, areas with high human population densities and industrial activities may result in an increased microplastic burden entering the marine ecosystem. Furthermore, it has been hypothesised that an area with high microplastic source inputs will result in a higher burden on the surrounding aquatic environment.

Populated coastal zones have been associated with a high microplastic burden due to the occurrence of more point sources such as wastewater treatment plants that are unable to remove a large quantity of microplastic particles, potentially releasing millions of plastic particles into the receiving waterways daily (Murphy et al., 2016). McCormick et al. (2014) found higher microplastic numbers below sewage outfalls when compared to samples collected in the open ocean, stating that treatment facilities are not designed to remove these minute plastic particles. Similar point sources have been identified globally, for example Pearl River in Hong Kong highlighted a major source of microplastic pollutants during seasons of heavy rainfall (Cheung et al., 2016). Romeo et al. (2015) recorded higher microplastic loads associated with areas exhibiting high human activity when compared to various control sites. In Singapore low microplastic concentrations were linked to lower levels of anthropogenic activity (Nor and Obbard, 2014). However, a number of studies contradict this local retention around point sources. Klein et al. (2015) found no significant correlation of microplastic abundance with population density, with sample sites near sewage outfalls not showing a higher abundance of microplastic particles. A study in the Mediterranean investigated the microplastic load near a populated coastal zone and Marine Protected Area (MPA) not finding any distinct differences (Alomar et al., 2016). Comparable results were recorded with Australian cities and remote locations showing similarly high microplastic loads (Reisser et al., 2013). Laglbauer et al.

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(2014) could find no spatial variation between touristic vs. non-touristic beaches. This suggests the potential widespread dispersal of buoyant microplastics through hydrodynamic processes and ocean currents (Claessens et al., 2011). Posing a significant socio-economic threat as inadequate discharge of plastic waste by a country does not only have localised consequences but transboundary effects (Walker et al., 2006). This long range distribution of microplastic pollutants not only cross political, but also ecosystem boundaries with near shore contamination affecting offshore habitats (e.g. deep sea canyons, remote islands and Antarctic communities).

The current wastewater infrastructure in South Africa is poorly managed and unable to keep up with the rapidly growing population (Mema, 2010). Thirty years ago, Brown (1987) stated that only a fraction of sewage in South Africa was treated before discharge. The percentage of wastewater treated has further decreased with increased urbanisation and the poor management of wastewater treatment plants (Mema, 2010). As a result, Jambeck et al. (2015) ranked South Africa as one of the top contributing countries to the problem of mismanaged plastic debris. It is thus necessary to investigate the spatial distribution of microplastics along the South African coastline, in order to determine major source/sink areas. The first study investigating the presence of microplastics along the South African coast was Ryan and Moloney (1990), who used a 2 mm-mesh sieve, resulting in estimates from 491 m^{-1} to 678 m^{-1} for 1984 and 1989 respectively. Subsequently, Nel and Froneman (2015) investigated bays as possible microplastic sinks along the south-eastern coastline, however no inter-beach variation was found. Additionally, Naidoo et al. (2015) highlighted the importance of Durban harbour and adjacent estuaries as microplastic sources contaminating the surrounding marine environment. The aim of this study was to continue investigating the source/sink dynamics on South African beaches, as well as the role of local retention vs. widespread long-range distribution of microplastics. In particular investigating the spatial distribution of microplastics along a gradient of human population density, expanding the entire length of the South African coastline from Cape Vidal in the east to Port Nolloth in the west (Fig. 1).

South Africa has four coastal provinces namely; KwaZulu-Natal, Eastern Cape, Western Cape and Northern Cape (Fig. 1). A distinct east-west gradient in population density in the different provinces is evident with KwaZulu-Natal on the east coast having the highest population density (10,267,300 people) and the Northern Cape on the west coast being the most sparsely populated (1,145,861 people). The City of Cape Town Metropolitan Municipality, eThekwini Metropolitan Municipality and Nelson Mandela Bay Metropolitan Municipality are considered major coastal industrial areas (Fig. 1). Higher microplastic loads were expected at sites located along the east coast and low microplastic burden along the west coast, with the exception of locally high pollution near the city of Cape Town.

2. Material and methods

The relatively pristine 2954 km coastline of South Africa can broadly be divided into three coastal regions, the east, south and west coasts (Branch et al., 2010). The east and south coasts of South Africa are dominated by the warm easterly flowing Agulhas Current, which comprises Subtropical Zone surface and South-Indian gyre waters. The cool Benguela Current flows northwards up the west coast cooling the Atlantic Ocean (Branch et al., 2010). In January 2016, sediment and water samples were collected at thirteen sandy beaches and three harbours spanning the entire coastline (Fig. 1). In total, six sites were occupied along the east coast, four along the south coast and six along the west coast (Fig. 1).

All sampling procedures performed in this study have been adapted from the approaches highlighted in the review by Hidalgo-Ruz et al. (2012). A single replicate was taken from 1) the most recent flotsam deposited at the high-tide line, 2) the waterline and 3) a spot equal distance between the two. This resulted in triplicate sediment samples

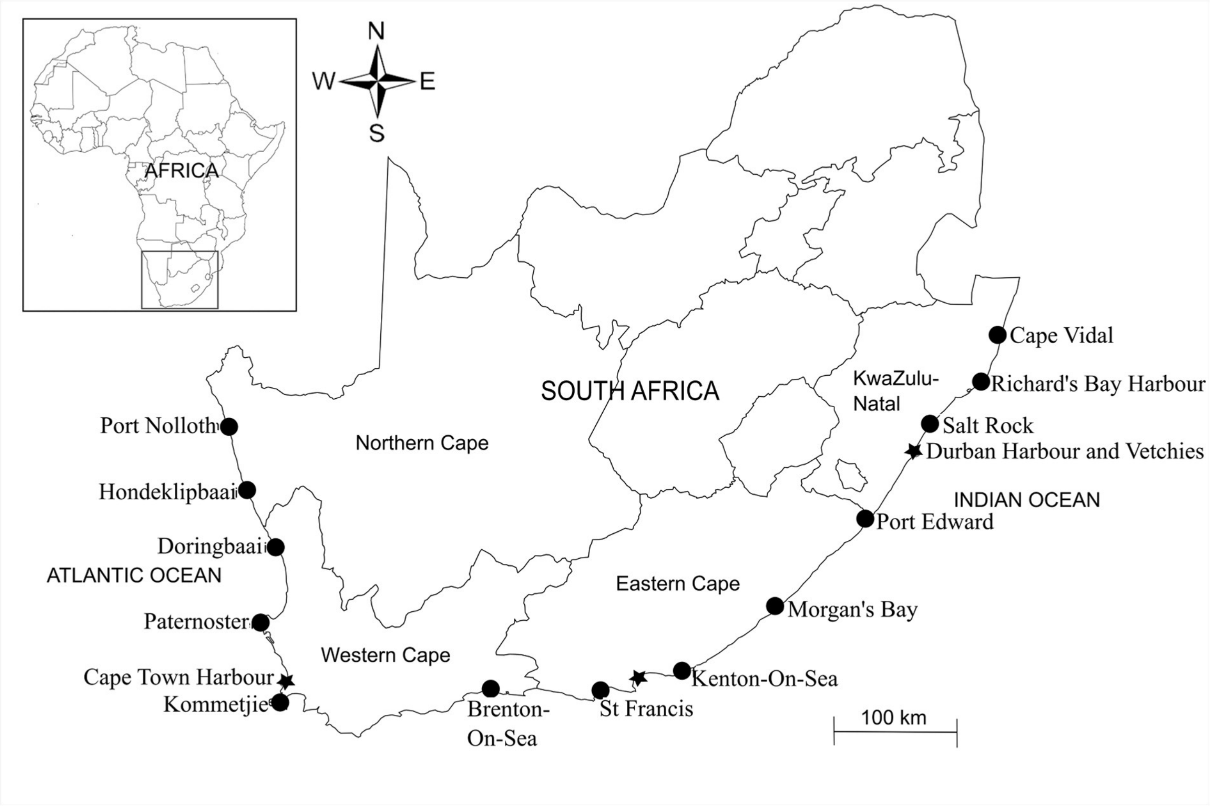

Fig. 1. Map highlighting the geographical position of each sample site (black dot), both sandy beaches and harbours within South Africa, as well as indicating major municipal areas (black star).

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