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Occurrence and distribution of microplastics in marine sediments along the Belgian coast

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ABSTRACT

Plastic debris is known to undergo fragmentation at sea, which leads to the formation of microscopic particles of plastic; the so called 'microplastics'. Due to their buoyant and persistent properties, these microplastics have the potential to become widely dispersed in the marine environment through hydrodynamic processes and ocean currents. In this study, the occurrence and distribution of microplastics was investigated in Belgian marine sediments from different locations (coastal harbours, beaches and sublittoral areas).

Particles were found in large numbers in all samples, showing the wide distribution of microplastics in Belgian coastal waters. The highest concentrations were found in the harbours where total microplastic concentrations of up to 390 particles kg^{-1} dry sediment were observed, which is 15–50 times higher than reported maximum concentrations of other, similar study areas.

The depth profile of sediment cores suggested that microplastic concentrations on the beaches reflect the global plastic production increase.

1. Introduction

The global production of plastics was approximately 1.5 million t/y in the 1950's. Currently it is estimated at almost 250 million t/y and it is still increasing by 10% each year (Plastics Europe, 2008). While reliable estimates of the input of produced plastics in the environment cannot be obtained, substantial amounts end up in the marine environment through industrial discharge, littering and terrestrial runoff (Derraik, 2002). This has lead to increasing levels of plastic litter in oceans worldwide.

The occurrence and distribution of large plastic debris in the marine environment is well documented (Derraik, 2002) and the adverse effects of this type of pollution on marine life have been described extensively (e.g. Baird and Hooker, 2000; Bugoni et al., 2001; Carr, 1987; Laist, 1987; Moser and Lee, 1992). However, these larger items eventually undergo fragmentation which leads to the formation of microscopic particulates of plastic (Barnes et al., 2009). These so called 'microplastics' (plastic particulates ⩽1 mm) may become widely distributed in the marine environment through hydrodynamic processes and ocean currents (Ng and Obbard, 2006).

Little is known about the (adverse) effects of microplastics on marine organisms. Recently it has been shown that these particles can be ingested by mussels (*Mytilus edulis*) and can translocate to the tissue and persist there for at least 48 days (Browne et al., 2008). Other organisms (i.e. polychaete worms, barnacles, amphipods and sea cucumbers) have also been found to ingest microplastics during laboratory trials (Graham and Thompson, 2009; Thompson et al., 2004). No significant adverse effects have yet been observed, but this may be due to the short exposure time used in these studies (Browne et al., 2008). Plastic pellets and fragments have also been shown to (1) absorb and transport hydrophobic chemicals including polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and nonylphenols, and (2) transfer these pollutants to organisms (Derraik, 2002; Endo et al., 2005; Rios et al., 2007; Teuten et al., 2007). Even though it was recently suggested that the severity of both these phenomena is low (Zarfl and Matthies, 2010; Gouin et al., 2011), the lack of other studies confirming these suggestions justify the interest in the occurrence and ubiquity of microplastics in the marine environment. Multiple reports are available on environmental concentrations of plastic fragments larger than 1 mm, including pre-production pellets (e.g. Gregory, 1983; McDermid and McMullen, 2004). However, it has recently been argued that only fragments of 1 mm and smaller should be classified as microplastics (Costa et al., 2010). Up until now, only three studies on the

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Table 1
Maximum concentrations of microplastics found in three reported studies on the occurrence and distribution of microplastics. All concentrations are expressed as either mg or number of particles kg^{-1} dry sediment (fourth column).

Country	Location	Maximum concentration	Unit	Reference
India	Ship-breaking yard	89	mg kg^{-1}	Reddy et al., 2006
Singapore	Beach	3	# kg^{-1}	Ng and Obbard, 2006
United Kingdom	Beach[a]	8	# kg^{-1b}	Thompson et al., 2004
United Kingdom	Estuarine[a]	31	# kg^{-1b}	Thompson et al., 2004
United Kingdom	Subtidal[a]	86	# kg^{-1b}	Thompson et al., 2004

[a] Only fibre concentrations were reported.
[b] Original unit (# fibres 50 mL^{-1} sediment) converted using an average sediment density of 1600 kg m^{-3} (Fettweis et al., 2007) and 1.25 as average wet sediment/dry sediment ratio.

occurrence of plastic fragments have included true microplastics (Ng and Obbard, 2006; Reddy et al., 2006; Thompson et al., 2004) (Table 1). Hence, only limited data on the global abundance of microplastics is available at this time.

The aim of this study was to investigate the occurrence and distribution of microplastics in Belgian marine sediments collected in harbours, on beaches and offshore. At two of the beaches, sediment cores were taken to study time trends of microplastic accumulation. The extracted microplastics were grouped into four categories (i.e. fibres, granules, plastic films and spherules), counted and identified using Fourier transform-infrared (FT-IR) spectroscopy. Results were compared with those of other, similar studies and attempts were made to relate the occurrence of microplastics to local human activities.

2. Materials and methods

2.1. Sampling

An overview of the sampling stations is given in Fig. 1. In each of the three harbours, three to four sampling stations were selected to represent inner to outer harbour conditions (Fig. 1). The three studied harbours differ in their main activities: (1) the harbour of Zeebrugge is the largest coastal harbour used mainly by naval and commercial boats (freight ferries, container vessels, large passenger ships), (2) the harbour of Oostende is used by pleasure crafts, fishing boats and passenger ferries, and (3) the harbour of Nieuwpoort mainly by pleasure boats as it hosts the largest yacht harbour of Northern Europe. In each harbour, one station was located in or near the yachting facilities (stations ZB2, OO2 and NP2 respectively) (Fig. 1).

Three sea sampling stations (S1–S3) were selected near the mouths of the three coastal harbours and three additional stations were chosen further off shore (S4–S6) (Fig. 1). Station S4 was located 11 km off shore in the sedimentation zone of the Scheldt river; stations S5 and S6 were both located 21 km off shore. All subtidal stations (i.e. harbour and sea stations) were sampled using a Van Veen grab (70 kg, 0.1 m^2 sampling surface).

Sediment was also collected on three Belgian beaches: two known for sand deposition (Koksijde-Bad and Groenendijk-Bad) and one known for erosion (Knokke-Zoute) (Fig. 1). On each beach, sand was collected at the high watermark, in the middle of the intertidal area and in the subtidal zone, except at Knokke-Zoute, where no samples were taken in the latter zone. To study potential trends in time, sediment cores were taken at Koksijde-Bad and Groenendijk-Bad, where the annual local deposition rate, as derived from coastal line maps (Afdeling Waterwegen Kust, 2000a,b), was approximately 7 and 2 cm, respectively. This allowed sediment layers of roughly 4 years (Koksijde-Bad) and 16 years old (Groenendijk) to be studied. Each core was divided in four equal parts, resulting in sediment layers each representing a time span of 1 year for Koksijde-Bad and 4 years for Groenendijk. The cores were taken at the high water mark and in the intertidal zone.

2.2. Analysis

The microplastics in the sediment samples were extracted using the method of Thompson et al. (2004) with some minor modifications. In short, 3 L of a concentrated saline solution was added to 1 kg of wet sediment and stirred for 2 min. The sediment was then allowed to settle for 1 h before the supernatant was poured through a 38 μm mesh sieve. For each sediment sample this extraction was performed twice and the collected particles (sieve) were examined using a binocular microscope. The particle recovery of the extraction procedure was ascertained by spiking known concentrations of microplastics (of similar dimensions as those encountered in the field) into clean sediment and subjecting it to repeated extractions. Recovery of fibres and granules/spheres was assessed separately for both sandy sediments (more than 50% of the sediment particles >63 μm) and sludge (less than 50% of the sediment particles >63 μm). The resulting particle recoveries (ranging from 68.8% to 97.5% for the different sediment and particle types) were used as correction factors for calculating the microplastic concentrations reported in this paper.

Microplastic particles were categorised into four different types: fibres, granules, plastic films and spherules. Particles of each type were identified by Fourier transform-infrared (FT-IR) spectroscopy using an AutoIMAGE-microscope attached to a Perkin-Elmer Spectrum GX spectrometer equipped with a nitrogen-cooled Mercury cadmium telluride-detector. The spectra were recorded in reflection mode in the spectral range 400–4000 cm^{-1} by co-adding 128 scans at a resolution of 4 cm^{-1}. The aperture was set at 100–100 μm using adjustable knife-edges. As in the studies of Thompson et al. (2004) and Ng and Obbard (2006), the particles were identified by comparing FT-IR absorbance spectra of the microplastics to those in a polymer reference library.

Microplastic concentrations were expressed as number of particles kg^{-1}dry sediment and on a weight basis (mg microplastics kg^{-1} dry sediment) to allow comparison with other studies.

2.3. Statistical analysis

All statistical comparisons were performed using SPSS software (SPSS, 2007). For multiple comparisons, the nonparametric Kruskal–Wallis test was used. If this test indicated significant differences, the nonparametric Mann–Whitney *U* test for pairwise comparisons was used to identify the significantly differing groups (significance level: 0.05).

3. Results

The number of microplastic particles observed at the different sampling stations in the Belgian coastal zone is presented in Table 2. All sediment samples collected in the harbours, on the beaches and sublittorally (BCS) contained microplastics (38 μm–1 mm). The four different types of particles were encountered with the majority (based on numbers) being fibres (59%) and granules (25%), which were both present at all sampling locations. Also plastic films (4%) were observed at all sampling stations with a few