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Microplastics in Beaches of the East Frisian Islands Spiekeroog and Kachelotplate

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Abstract Microplastic particles were quantified in beach transects of the East Frisian islands Spiekeroog and Kachelotplate and in two samples from a tidal flat. Both granules and fibres were present while fragments and polystyrene pellets were completely absent. On the Kachelotplate the highest number of granules (496/10 g sediment) was observed at the high water line while on Spiekeroog a sample from the dune area had the highest value (38/10 g sediment). The tidal flat samples hat 36 and 136 granules/10 g sediment with the higher number being associated with a blue mussel bank. Fibres were more homogeneously distributed and did not show any particular enrichment. In comparison with data from the Belgian coast the total numbers are higher which might be related to the exposure situation of the island beaches.

Keywords Microplastics · Wadden Sea · Beach sediment · Marine debris

The occurrence of plastic debris in coastal and open marine environments is extensively documented (Derraik 2002; UNEP 2005, Meith 2009; Ryan et al. 2009). While this macroplastic litter is well characterised in terms of sources and effects on marine biota microplastic, i.e. particles smaller than 5 mm, has received considerably less attention. Although the first report on its presence appeared already some 40 years ago (Carpenter et al. 1972) research on this topic intensified only since the late 1980s (e.g. Arthur et al. 2009; Browne et al. 2011). Besides so-called pre-production pellets, i.e. virgin material used to mould thermosetting plastics, macroplastic may undergo thermal, photochemical, chemical or physical fragmentation and eventually reach the microplastic stage.

Microplastic (MP) is present ubiquitously in beach and subaqueous sediments as well as in suspension (cf. Barnes et al. 2009; Andrady 2011). It can be assumed that some microplastic originates from breakdown and fragmentation of larger macroplastic items (Andrady 2011). On the other hand, Browne et al. (2011) conclude that a large proportion is derived from sewage.

Data for the southern North Sea are so far missing with the exception of the report by Claessens et al. (2011) for Belgian coastal areas. In the present communication data for beach transects on two East Frisian islands of contrasting characteristics are presented.

Materials and Methods

Beach samples were collected on the islands Kachelotplate and Spiekeroog in December 2011 at the locations given in Fig. 1. Two additional samples were taken on the tidal flat Nordland south of Juist, one sample in a blue mussel bank and one at the low water line. About 500 g sediment were removed to a depth of 1 cm and dried at 70°C. 10 g each were treated with 30 % H_2O_2 overnight to remove natural organic debris. Preliminary experiments indicated that this treatment did not affect plastic particles. A pretreatment became necessary as beach sands were found to contain a large number of natural organic material such as higher plant debris and fine-grained peat, particularly on the Kachelotplate. MP particles were then selectively extracted from the sediment by floatation in a zinc chloride solution

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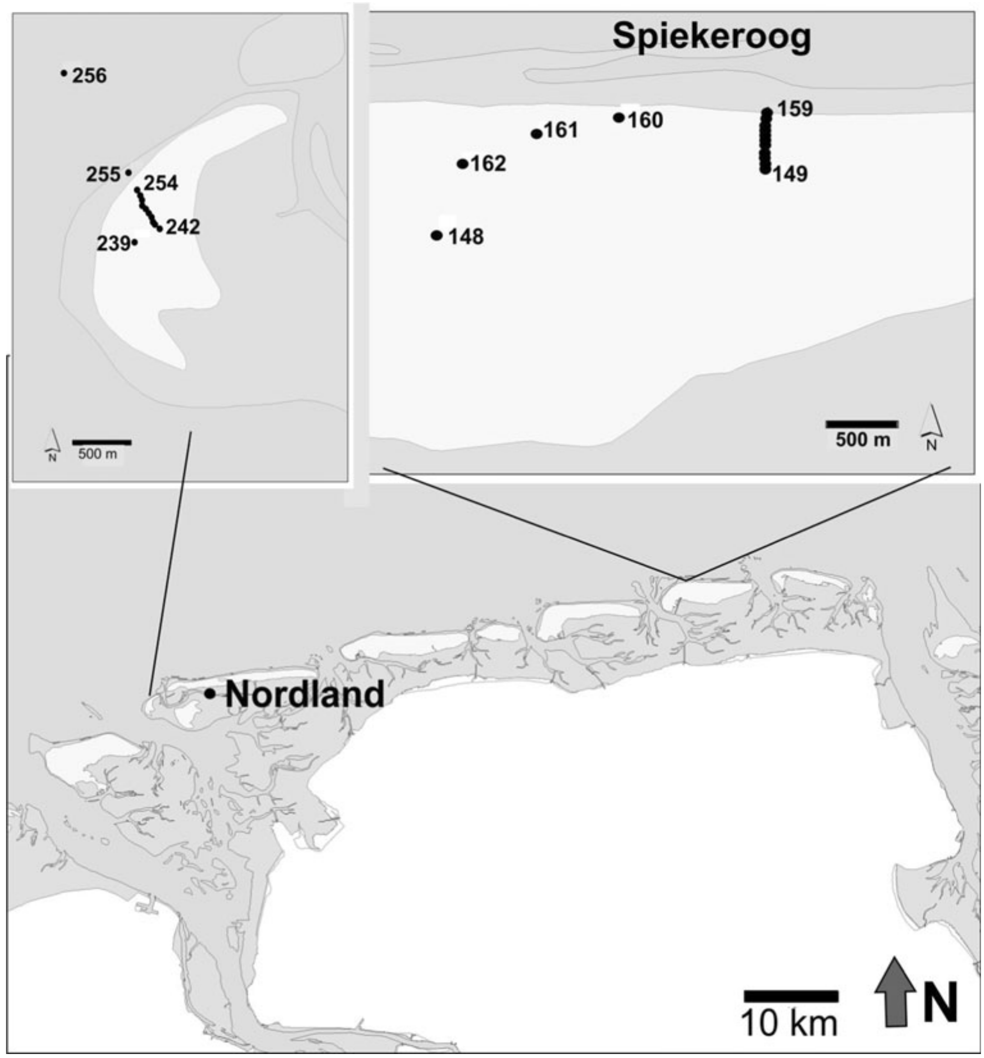


Fig. 1 Location of sampling stations in the Lower Saxonian Wadden Sea

of 1.5 g/cm^3. This density was chosen as most plastic types have specific gravities > 1 (http://www.plasticsusa.com/specgrav2.html). The floating microplastic particles were filtered over 1.2 µm gridded cellulose nitrate filters, rinsed several times with doubly distilled water, air-dried and then counted under a dissecting microscope at up to 80× magnification.

All analyses were done in triplicate. Despite careful and extensive homogenisation of the sediments the data displayed a high variability with relative standard variations ranging from 17.7 % to 124.9 % for granular microplastics and 0 % to 88.2% for fibres (Fig. 2).

Regional Setting

The Kachelotplate is an emerging sandbank island W of Juist (Fig. 1). It shows initial dune formation with vegetation cover (Wehrmann and Tilch 2008). As a result of its exposed position in the Lower Saxonian Wadden Sea the island is strongly affected by storm surges occurring several times per year thus preventing the development of a stable dune belt so far. Macroplastic occurrence on the Kachelotplate has been reported by Liebezeit (2008).

The island of Spiekeroog, on the other hand, is a fully developed dune island and represents a typical barrier island in a mesotidal system (Flemming and Davis 1994). A large belt with vegetated dunes of up to 25 m height is present, partly with little forests in the valleys in between the dunes with alder, birch and oak. During the last 100 years Spiekeroog has developed in easterly direction. The eastern part of the island, the so-called Ostplate, is characterised by salt marshes, in the northern part by large areas of small and young primary dunes and spacious sheets of brackish water. The Ostplate has a length of about 7 km to the east and a width from north to south of about 2.5 km.

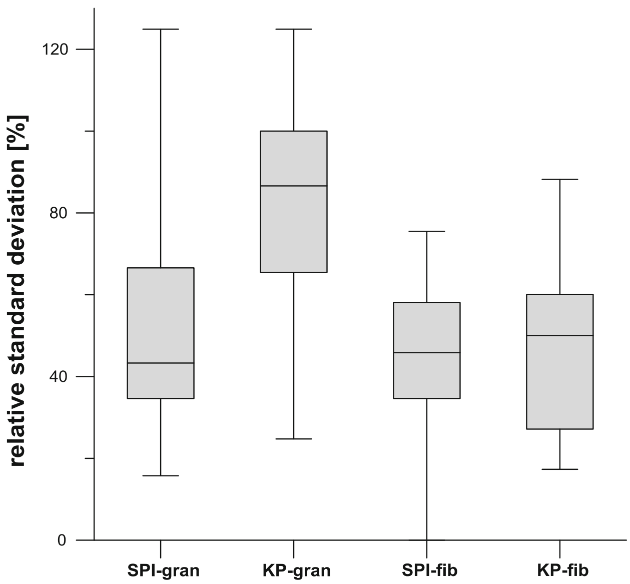


Fig. 2 Relative standard deviations for Spiekeroog (SPI) and Kachelotplate (KP) samples. *Gran* granular microplastics, *fib* fibres, n = 29. *Boxes* encompass the 25 % and 75 % quartiles, *horizontal lines* indicate median values

Results and Discussion

In both settings granular and fibrous microplastic particles were encountered. On the Kachelotplate between 0 and 621 granules/10 g sediment and 1–14 fibres/10 g sediment were found (Figs. 3, 4). The highest numbers of granular MP were encountered at the high water line. This is in line with observations of McDermid and McMullen (2004) who also found the highest number of plastic items here with one order of magnitude difference between high water line and berm samples.

On Spiekeroog, on the other hand, the dune sample 148 had 15–58 (mean 38) particles/10 g. As this sampling location is located within the dune belt where a more or less continuous vegetation cover can be found this suggests that MP may be deposited here after atmospheric transport and is trapped by the vegetation cover.

Both tidal flat samples had higher number of granular MP than the beach samples. Here the mussel bank sample showed higher values than the samples taken at the low water line. This might be related to the fact that fine-grained sediments dominate the Nordland area. This could be the result of a microbial biofilm formation on MP particles (e.g. Lobelle and Cunliffe 2011) and subsequent association with inorganic material thereby increasing specific gravity and hence sedimentation potential. While beaches are highly dynamic intertidal flats experience less wave energy and might hence be prone to higher levels of microplastics. Although a relation between grain size and MP content has not been established so far our unpublished data for Jade Bay sediments indicate that fine-grained sediments generally contain higher MP levels.

In contrast to granular MP fibres showed a more homogenous distribution (Fig. 4). Enrichment either at the high water line or in dunes could not be established. Similarly the tidal flat samples did not show increased numbers. These numbers suggests that either fibres are not as numerous as granules in suspension or that they exhibit a different settling behaviour.

Claessens et al. (2011) report a maximum number of 390 particles/kg for harbour sediments and a minimum of 72 particles/kg for a coastal sediment. Excluding the Spiekeroog dune sample, the two Kachelotplate samples at or near the high water line and the two tidal flat samples than the mean granule number of our beach samples is 210/kg

Fig. 3 Mean numbers of granular microplastics at beaches of the Kachelotplate and Spiekeroog. For station locations refer to Fig. 1

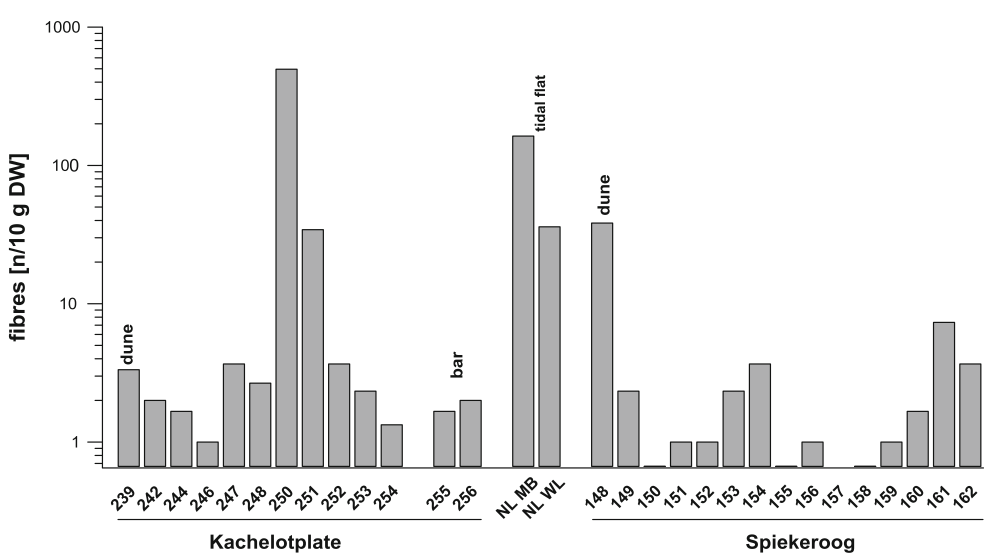
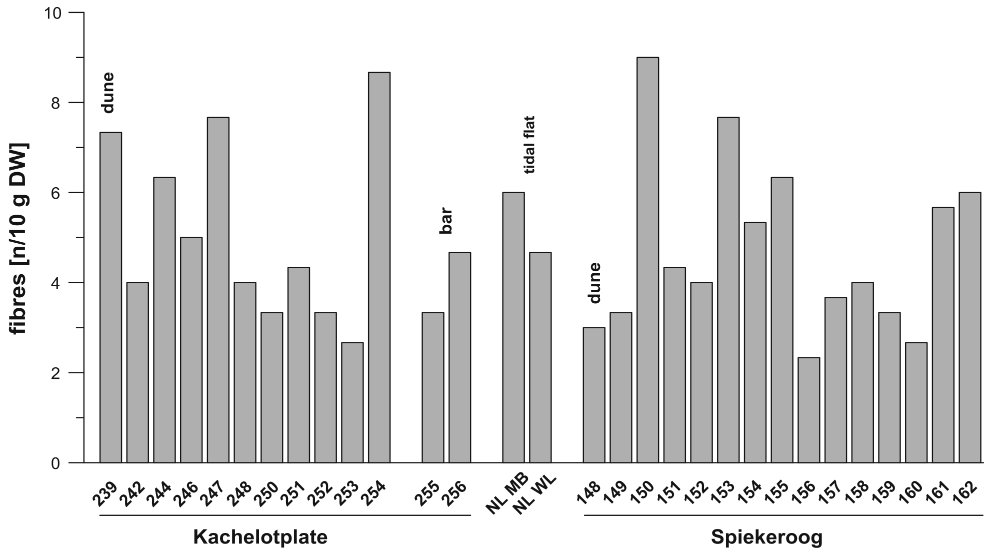


Fig. 4 Mean numbers of microplastic fibres at beaches of the Kachelotplate and Spiekeroog. For station locations refer to Fig. 1



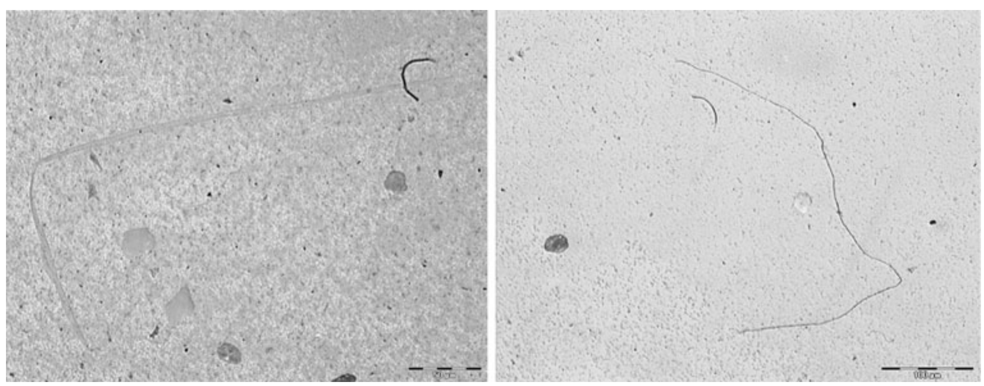


Fig. 5 Examples of microplastic from *left*: Kachelotplate (*scale bar* 50 µm) and right: Spiekeroog (*scale bar* 100 µm)

while a mean value of 461 fibres/kg was found. These higher numbers compared to the situation in Belgium might be due to the fact that there are differences in exposure and sedimentation/burial of MP material.

Typical examples of MP material encountered are given in Fig. 5. Granular and fibrous microplastic were the only types found, fragments were completely absent. As these have been reported from Belgian beaches (Claessens et al. 2011) this absence is particularly noteworthy; the more as plastic foils were encountered frequently during macrolitter surveys. Recalculation of the data given by Liebezeit (2008, 2011) for the Kachelotplate gives a total of 913 foil items including plastic bags out of a total of 3,145 macroplastic pieces counted from May 2007 to February 2011 in 29 surveys. Thus, although the potential for the presence of fragments is given their total absence remains enigmatic at present. Polystyrene pellets also frequently reported (e.g. Claessens et al. 2011) were similarly absent. This might be due to the fact that polystyrene macrodebris was observed extremely rarely in the Kachelotplate litter surveys.

Table 1 Plastic in commercial shower gels and peelings

Product	Weight %	Type
1	0.07	ACR Co
2	0.01	ACR Co
3	1.84	PE
4	1.24	B/E Co
5	1.12	PE
6	2.44	PE
7	4.74	PE

ACR Co acrylate copolymer, *PE* polyethylene, *B/E Co* butylene/ethylene copolymer

The overwhelming majority of granular material was <100 µm in size indicating that pre-production pellets do not contribute to a large extent to loading of the beaches investigated. It can rather be assumed that cosmetics-derived MP is the major source of this type of material in the Lower Saxonian Wadden Sea. Based on our data (Table 1) and those from the literature (e.g. Zitko and

Hanlon 1991; Gregory 1996; Fendall and Sewell 2009) it can be safely assumed that due to the considerable content of MP especially in peelings and the fact that this material passes sewage treatment plants this constitutes a potentially large source for coastal waters. It should also be noted that even water-soluble acrylate copolymers leave an identifiable residue, albeit at a low content (Table 1).

Similarly MP fibres may also originate from discharges of sewage treatment plants (Habib et al. 1998; Browne et al. 2011) besides being derived from rope fragmentation (e.g. Thompson et al. 2004). Interestingly, fibres have also been identified in soils to which sewage sludge had been added as fertilizer up to 15 years after the actual application (Zubris and Richards 2005). This sheds some light on the degradability of microplastics in the natural environment.

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