Marine Pollution Bulletin 126 (2018) 263–274

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Microplastic in beach sediments of the Isle of Rügen (Baltic Sea) - Implementing a novel glass elutriation column

Elena Hengstmann, Matthias Tamminga, Constantin vom Bruch, Elke Kerstin Fischer*

Center for Earth System Research and Sustainability (CEN), University of Hamburg, Bundesstraße 55, 20146 Hamburg, Germany

ARTICLE INFO

Keywords:
Microplastics
Density separation
Elutriation
Beach sediment
Baltic Sea

ABSTRACT

To extent the understanding on microplastics in the marine environment we performed a case study at four beaches on the Isle of Rügen considering abundance and spatial distribution of microplastics in beach sediments. For the analysis, density separation via a glass elutriation column was implemented. In advance, efficiencies were tested for two polymers, being not buoyant in water. Recovery rates of 80% for PET and 72% for PVC particles in sandy samples were achieved.

A median abundance of 88.10 (Q_1 = 55.01/Q_3 = 114.72) microplastic particles per kg dry sediment or 2862.56 (Q_1 = 1787.34/Q_3 = 3727.28) particles per m^2 was found at the beaches on Rügen. Fibers were more abundant than fragments at all beaches. In this study, no statistically significant differences but only tendencies were determined between the beaches with different exposition and anthropogenic activity as well as for distribution patterns which showed that microplastic fragments accumulate in topographic depressions, similar to macrolitter items.

1. Introduction

The contamination of ecosystems by plastic has received increased attention in the last decades (Galgani, 2015; Galgani et al., 2013; Wright et al., 2013; Thompson et al., 2004). Low degradation rates, resulting persistence in the environment as well as non-sustainable use and inadequate waste management of plastic products lead to a rising importance of plastic as environmental pollutant (Geyer et al., 2017; Andrady, 2015; Barnes et al., 2009). Simultaneously, global plastic production increased from 225 to 322 million tons per year between 2004 and 2015 (PlasticsEurope, 2016).

The consequences of plastic debris in ecosystems are diverse. It can pose a risk to biota, for example in cases where aquatic species are physically entangled or when particles are ingested by organisms (Werner et al., 2016; Gregory, 2009; UNEP, 2005; Thompson et al., 2004; Laist, 1987, 1997). Ingestion of microplastics in combination with adsorbed chemicals can have impacts on the metabolism of aquatic organisms (e.g. Lee et al., 2016; Galloway, 2015; Lusher et al., 2015; Rochman, 2015; Cole et al., 2011). Furthermore, social (e.g. decrease of aesthetics at beaches and subsequent decrease of the recreational value) and economic impacts (e.g. additional costs due to impacts on fishing industry) can be observed for plastic pollution in the environment (Werner et al., 2016; Newman et al., 2015). The coastal environment, being the interface between the terrestrial and marine ecosystems, is characterized by a high degree of biodiversity. Therefore, plastic pollution is even more prone to have impacts on biota (Hardesty et al., 2017). Several local studies focused on sandy beaches and aimed for the quantification of plastic particles (Hanvey et al., 2017; Van Cauwenberghe et al., 2015; Browne et al., 2015). In Europe, beaches on the Baltic Sea, North Sea and Atlantic coast were analyzed for microplastics (i.a. Graca et al., 2017, Stolte et al., 2015, Dekiff et al., 2014, Antunes et al., 2013, Van Cauwenberghe et al., 2013a).

Microplastics are defined as plastic particles < 5 mm (Arthur et al., 2009). For the analysis of microplastics in sediments no standard operation procedures have been determined, so far. On the contrary, a great variety of methods concerning both the sampling and laboratory analysis were applied in studies investigating plastic abundances on beaches (Van Cauwenberghe et al., 2015; Hidalgo-Ruz et al., 2012). Concerning the separation of microplastics from sediment in beach samples the principle according to Thompson et al. (2004) is widely implemented taking advantage of density differences between plastic and sediment particles. On the one hand, different high density salt solutions have been applied for this purpose (i.a. Corcoran et al., 2015, Dris et al., 2015, Stolte et al., 2015, Dekiff et al., 2014, Nuelle et al., 2014, Van Cauwenberghe et al., 2013b, Ballent et al., 2012, Imhof et al., 2012). On the other hand, the concept of elutriation was adapted for microplastic analysis. Here, a continuous upward flow of water or air within a column leads to the rising of lower-density materials. The

* Corresponding author.
E-mail address: elke.fischer@uni-hamburg.de (E.K. Fischer).

https://doi.org/10.1016/j.marpolbul.2017.11.010
Received 14 August 2017; Received in revised form 6 November 2017; Accepted 7 November 2017

underlying idea was developed in the field of biology (Southwood and Henderson, 2000), was transferred to microplastic analysis by Claessens et al. (2013) and was subsequently enhanced to facilitate higher recovery rates (Kedzierski et al., 2016; Zhu, 2015). In continuation, this study presents a new elutriation column of smaller dimension and manufactured of glass, completely. Recovery rates focusing on high-density polymers (PET, PVC) are presented.

Furthermore, this study quantifies microplastics in sediments from beach environments in marine habitats. A case study was conducted at four sandy beaches on the Isle of Rügen at the Baltic Sea in Mecklenburg-Vorpommern, Germany. The goal of this study was also to evaluate accumulation patterns for microplastic particles. The four beaches are mainly characterized by different expositions, grain size compositions and levels of touristic frequentation and were analyzed as well as compared with regard major differences concerning microplastic abundance and distribution.

2. Material and methods

2.1. Pre-tests elutriation

An elutriation column was manufactured for the purpose of density separation of microplastic and sediment particles. Different elutriation systems have already been tested and used in former studies (Kedzierski et al., 2017, 2016; Zhu, 2015; Claessens et al., 2013). These columns, however, were made out of PVC while the newly developed one is made of glass. On the one hand, it is important to avoid plastic components in the microplastic quantification process at any point; on the other hand, a glass column also provides a view on the separation process. Additionally, a glass column is more resistant concerning chemicals; however the risk of breakage is higher.

The elutriation column was also optimized concerning its dimensions to reduce edge effects. The manufactured glass column has a length of 100 cm, an inner diameter of 5 cm and is made of 2 mm thick glass. The outlet is located at the top of the column (3 cm from the top). A stainless-steel frit (pore size: 37 µm; Sartorius AG) is situated at the bottom of the column to avoid any contamination by the tap water being introduced via a separated flange, which is fixed to the column for the elutriation process. Water from the faucet is channeled through a tube, which is equipped with a flow meter (digiflow6710m, Savant) to measure the exact flow velocity for the elutriation process. The detailed setup is illustrated in Fig. 1.

Samples are inserted at the top of the column. With the inflow of water at the bottom the water level and the buoyant sample aliquots rise within the column. The outflowing suspension is percolated through a fixed sieve with a mesh size of 63 µm before being drained. Subsequently, the water in the column is drained by an outlet at the bottom and the sample residues mostly consisting of sandy sediment are disposed by releasing the flange and thoroughly rinsing the whole column from the top inlet with solvents and deionized water.

2.1.1. Reference material

To test the performance of the described elutriation column polymer reference particles were used as well as spiked sand samples. Polymers with densities below 1 g/cm^3 are buoyant in water anyway; tests on recovery by elutriation with particles in the size fractions of 0.3 to 1 mm and 1 to 5 mm led to recovery rates of 100% of polyethylene and polypropylene particles. Therefore, the focus within this study was on high-density microplastics, only. Reference materials purchased from Goodfellow USA were utilized for the efficiency tests: Polyethylene terephthalate granules (PET; ES306311/1; 1.38 g/cm^3) with a diameter of 3 mm and a polyvinylchloride film (PVC; CV311450; 1.37 g/cm^3) with a thickness of 0.38 mm that was sliced into different size categories. No post-consumer products were used as reference polymers due to high variations and uncertainties in their density.

"*To achieve the separation of particles according to their density, it is necessary to reduce the particle-size variability of the sample by separating it into different size classes.*" (Kedzierski et al., 2016). However, the size fractions that are currently in use for the classification of plastics (Galgani et al., 2013; Van Cauwenberghe et al., 2015) are not suitable for the creation of subsamples (Kedzierski et al., 2016). The classification used for the elutriation of microplastic samples here is based not only on microplastic specific size classes, but also on granulometric size categories following the approach of Kedzierski et al. (2016) applying size separation prior to elutriation. Microplastics are often defined as particles < 5 mm or < 1 mm, resulting in the first size delimitation. A second survey mark originating in microplastic research is 300 µm representing the limit of a common water sampling method using manta trawls. All other size limits implemented in this study derived from the classification of soil grain sizes by DIN 4022 and DIN EN ISO 14688-1 (German Institute for Standardization, European Norm, International Organization for Standardization). Granulometry refers to the differentiation of mass fractions of grains or lithified particles in sediments or clastic rock based on their equivalent diameter. Particles smaller 5 mm are grouped homogenously into fine gravel (> 2–6.3 mm), sand (> 0.063–2 mm), silt (> 2–63 µm) and clay (> 0.063–2 µm) (Blum, 2007). These are again subdivided into subgroups of coarse, medium and fine fractions. Taking into account these categorizations from sediment grain size analysis and commonly set size delimitations in microplastic analysis, the resulting classification implemented in this study includes five size fractions: > 0.063–0.2 mm, > 0.2–0.3 mm, > 0.3–0.63 mm, > 0.63–1 mm and > 1–5 mm. Based on this classification all polymer materials were grinded and sieved to provide the different size classes for the recovery test.

According to Kedzierski et al. (2016) recovery rates are higher for samples including sand. On the one hand, the terminal velocity due to pseudo-homogenous suspension fluid of water and sand is supposed to be reduced. On the other hand, the reduction of edge frictions within the column might be favored due to particle collision. To address this specific topic, two samples for each material in each size fraction were prepared. One sample contained only 30 microplastic particles while the second one additionally contained 25 ml sediment of respective grain size. The sediment required for the artificial samples was obtained from a beach at the River Elbe close to Hamburg. It was sieved into the same size classes as polymer particles by an automatic sieving machine (Retsch GmbH, AS200 control). Subsequently, sand subsamples were annealed at 900 °C for 4 h in a muffle furnace (Nabertherm, L 24/11/P330), to ensure that no organic or polymer material remained.

2.1.2. Elutriation process

The prepared samples were introduced into the elutriation column and the column was filled with water to two thirds with a higher flow rate than required to allow the complete mixing of samples. Subsequently, the particles were given time (5 min) to settle. In between, the water surface was agitated three times by sprinkling with deionized water in order to break surface tension, which had caused dense particles to float as well. Then, different flow rates according to the size fraction of the sample were applied. These were obtained in pre-tests which accounted for the recovery of different non-buoyant polymers (PS, PET and PVC) in specific size classes while the upwelling of sandy sediment was suppressed. Based on these pre-requisites the fluidization of plastic (ten particles per polymer in three replicates) and sand particles (50 ml in three replicates) was observed in the elutriation column and flow rates were noted. The final specific flow velocities for the elutriation column used in the experiments are presented in Table 1.

The elutriation was processed for 10 min during which a stirring bar was used regularly to avoid the clustering of sediment and plastic particles at the bottom of the column. The period was determined based on elutriation times of former studies ranging between 5 min (Kedzierski et al., 2017, 2016) and 15 min (Claessens et al., 2013) and was further adjusted empirically to the here implemented column by visual examination of the total recovery of a specific number of plastic