Marine Pollution Bulletin xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Microplastics elutriation from sandy sediments: A granulometric approach

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ARTICLE INFO

Article history:
Received 24 January 2016
Received in revised form 18 March 2016
Accepted 18 March 2016
Available online xxxx

Keywords:
Microplastics
Extraction techniques
Elutriation
Sandy sediments
Granulometric classification

ABSTRACT

Although relatively easy to extract in the marine environment, microplastics are very difficult to recover when they are trapped in sediments. The elutriation column is one of the best tools currently available for extracting plastics from sediment, but with a high sand recovery yield. This study aims to address the following questions: (*i*) is it possible to use a sedimentological approach to limit the sand recovery? (*ii*) does the extraction velocity of the sand and plastic particles vary according to density and granulometry? (*iii*) what is the relative recovery efficiency obtained for dense polymer particles mixed with marine sand? Based on a new granulometric classification, different plastic particle-size fractions are defined. Their extraction velocities are experimentally determined on particles of sediment and different plastics (PA, PVC). The particle recovery experiments indicate that it is possible to extract >90% of dense plastic particles in cases of negligible sand recovery.

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1. Introduction

Due to their physical and chemical properties, plastics are commonly used in a large range of industrial products. In connection with demand, the production of plastics has greatly increased during the second half of the 20th century (PasticsEurope, 2013). Plastic particle pollution of the marine environment appeared along with this increase in production (Carpenter and Smith, 1972). In 2010, it is estimated that between 4.8 and 12.7 million tons of plastics entered the oceans (Jambeck et al., 2015).

Plastics are generally considered as inert materials. However, additives, which are molecules added to the plastic to modify its properties, can become leached into the marine environment (Cadogan et Howick, 2000 in Nerland et al., 2014). Some of these additives (e.g. bisphenol A; triclosan; hydrazine) are known to be hazardous (Hansen et al., 2012). Furthermore, when dispersed into a polluted environment, plastics can adsorb other pollutants (Frias et al., 2010). An increasing number of studies reports the presence of contaminants such as metals (Ashton et al., 2010; Holmes et al., 2012, 2014), endocrine disruptors (Browne et al., 2013; Rochman et al., 2013, 2014) or persistent organic pollutants (e.g. Bakir et al., 2014; Rios et al., 2007; Van et al., 2012) on microplastic particles. Because of their small dimensions, microplastics can be ingested by marine organisms (Lusher et al., 2013; Setälä et al., 2014; Van Cauwenberghe et al., 2015a) and the pollutants can be desorbed (Avio et al., 2015; Colabuono et al., 2010; de Sá et al., 2015). In this way, some pollutants can enter the food chain. The impact of microplastic ingestion has been tested in a large range of organisms such as *Arenicola marina* (Van Cauwenberghe et al., 2015a), *Mytilus sp.* (Browne et al., 2008; von Moos et al., 2012) and *Carcinus maenas* (Farrell and Nelson, 2013), and numerous effects have been demonstrated that are due to this ingestion, such as: (*i*) accumulation (Setälä et al., 2014; von Moos et al., 2012); (*ii*) translocation (Farrell and Nelson, 2013); (*iii*) inflammatory response (von Moos et al., 2012); (*iv*) reduction in available energy (Watts et al., 2015); (*v*) developmental defects (Della Torre et al., 2014 *in* Van Cauwenberghe et al., 2015a,b).

Plastics are the most common type of debris found on beaches (Nerland et al., 2014), and some studies show that marine sediments are contaminated by dense microplastics (i.e. ≥ 1035 $kg\cdot m^{-3}$) (Claessens et al., 2011; Thompson et al., 2004; Vianello et al., 2013). These dense microplastics are available for uptake by benthic organisms (Van Cauwenberghe et al., 2015b). Thus, several cases of plastic ingestion by commercially important benthic crustaceans are known (Van Cauwenberghe and Janssen, 2014). Through the proliferation of microplastic particles, there is an increasing risk that humans will be indirectly exposed to marine pollutants (De Witte et al., 2014; Van Cauwenberghe and Janssen, 2014). Consequently, the evaluation of contamination of marine sediments by microplastics is a major issue.

In most studies, microplastics are recovered using dense media such as NaCl solutions (Hidalgo-Ruz et al., 2012). Unfortunately, these saline solutions do not extract microplastics denser than 1200 $kg\cdot m^{-3}$ (Claessens et al., 2013). Other solutions, such as NaI or $ZnCl_2$, allow high recovery yields. However, these solutions are very expensive and cannot be applied when there are significant volumes of sediment to

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http://dx.doi.org/10.1016/j.marpolbul.2016.03.041
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Please cite this article as: Kedzierski, M., et al., Microplastics elutriation from sandy sediments: A granulometric approach, Marine Pollution Bulletin (2016), http://dx.doi.org/10.1016/j.marpolbul.2016.03.041

be treated (Claessens et al., 2013; Nuelle et al., 2014). Due to this recurrent difficulty, some methods have been proposed that are generally based on the differences in migration velocity between sand and plastic particles in a flowing fluid medium (Claessens et al., 2013; Nuelle et al., 2014; Zhu, 2015). The elutriation column developed by Claessens et al. (2013) allows high recovery yields of dense microplastics. This method is inexpensive and allows elutriation on significant volumes of sediment. However, for the extraction velocity of microplastics, the sand recovery yield is high. Some methodological approaches currently used in sedimentology may help to enhance the elutriation process and limit the sand extraction. In the present study, we aim to determine: (i) if splitting the sample into different size classes can improve the elutriation process (ii) the variation of extraction velocity of the sand (mainly quartz particles) and plastics (PA, PVC) according to their density and size class (iii) the relative recovery yield of a dense polymer (PVC) extracted from marine sand.

Based on these elements, the elutriation process will be improved and made easier to apply regardless of the column characteristics.

2. Materials and methods

2.1. Elutriation system

The elutriation column separates particles according to their terminal falling velocities which depend on their respective density, size and form. In the case of plastic particles extracted from a sediment, two different columns have been previously developed (Claessens et al., 2013; Zhu, 2015). Building on the initial concept proposed by Claessens and colleagues, we have designed an innovative elutriation system that includes (Fig. 1): (*i*) an injection and flow control system; (*ii*) an elutriation column; (*iii*) a storage and filtration system; (*iv*) a water temperature control.

The elutriation system uses water to extract particles. To avoid overconsumption of water, the elutriation system operates as a closed circuit. The storage and filtration system comprises two superimposed polypropylene tanks. Between these tanks, a 32 μm mesh sieve prevents contamination of the reservoir tank by very fine elutriated particles (32–63 μm). The water flow is monitored and controlled by two flowmeters connected in parallel. The elutriation column is 1.86 m high and has an internal diameter of 106 mm. Water is injected at the bottom of the column. The microparticles are pulled upward and extracted at the top of the column. They are finally captured by the 63 μm mesh sieve. To avoid changes in particle dynamics due to density or viscosity modifications (Richardson et al., 2008), the water temperature is maintained constant at 20 °C throughout the elutriation system using a Minichiller thermostat.

2.2. Tested particles

The marine sand used for these experiments is mostly composed of grains of quartz with a density is 2650 $kg \cdot m^{-3}$, a value close to that measured for the sediment particles making up the sand (i.e. 2631 ± 103 $kg \cdot m^{-3}$; Lorient, France). The experiments were carried out on two different plastic powders purchased from industrial producers: polyamide (PA6) and poly(vinylchloride) (PVC). PA is a thermoplastic polymer, with an average density of 1070 to 1080 $kg \cdot m^{-3}$ (Nuelle

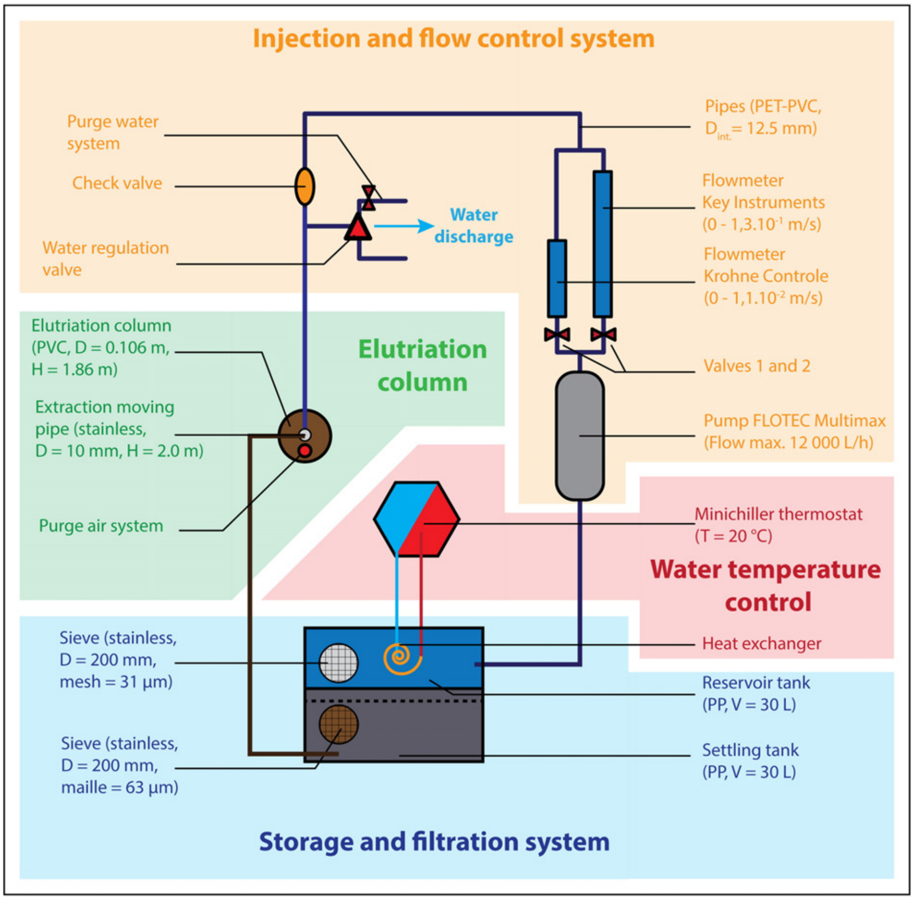

Fig. 1. Schematic diagram of the elutriation system.

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