Marine Pollution Bulletin 133 (2018) 9–17

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Microplastics elutriation system
Part B: Insight of the next generation

Mikaël Kedzierski[a,*], Véronique Le Tilly[a], Patrick Bourseau[a,b], Guy César[c], Olivier Sire[a], Stéphane Bruzaud[a,*]

[a] Université Bretagne Sud, IRDL, UMR CNRS 6027, 56100 Lorient, France
[b] Université de Nantes, GEPEA, UMR CNRS 6144, 44602 Saint-Nazaire, France
[c] SERPBIO, Université Bretagne-Sud, 56321 Lorient, France

ARTICLE INFO

Keywords:
Microplastics
Extraction techniques
Sand
Elutriation
Numerical modeling
Elutriation system design

ABSTRACT

Elutriation is an efficient process for extracting microplastics. The development of a numerical model has shown the need for optimizing aspects of the design of the actual elutriation protocol as well as the dimensioning of the column to increase its efficiency. The study aims to propose new dimensioning data and protocol elements for designing an efficient column. Using a numerical model, the filling velocity was calculated as a function of the size and the density of the particles to prevent sand suspension. The sieving protocol was adapted to increase the density limit for the extraction of plastic particles from 1460 to > 1800 $kg{\cdot}m^{-3}$. The durations of the elutriation and the column height were calculated to improve the control of the particle suspension. These results contribute to the development of the next generation of elutriation system and will accelerate the study of plasticome in the context of sandy sediments.

1. Introduction

Since 1950, the plastic production has increase exponentially (PlasticsEurope, 2013) and simultaneously the plastic pollution has increased in natural environments. Thus, plastics are the most common waste found on many beaches (Bouwman et al., 2016; Nerland et al., 2014; Rosevelt et al., 2013; Topçu et al., 2013). The survey of plastics in sediments implies innovative methods particularly for the smallest range of size, which are generally called microplastics. In particular, the identification of the chemical nature of these microplastics is a major issue. Some of these methods are very fast but destructive such as thermal degradation (Dümichen et al., 2015; Dümichen et al., 2017). Others, such as Raman spectrophotometry (Frère et al., 2016; Lenz et al., 2015) or IR spectrophotometry (Harrison et al., 2012; Lorenz, 2014; Primpke et al., 2017) are time consuming but preserve samples for further analyses. This second class of techniques generally involves a pre-treatment stage of sand-plastic separation. Among plastic extraction techniques, the most common is based on saturated sodium chloride solution (Qiu et al., 2016; Thompson et al., 2004). However, the relatively low density achieved by this solution (1200 $kg{\cdot}m^{-3}$) is not high enough to extract all the microplastics present in sand (Claessens et al., 2013; Imhof et al., 2012; Kedzierski et al., 2017b; Nuelle et al., 2014). This method biases our vision of the "plasticome" (*i.e.* all the plastic particles present in a particular environmental compartment (air, water, soil, organisms), in a limited area and for a given period of time) (Kedzierski et al., 2017b). Other denser solutions can alternatively be used, such as zinc chloride (Imhof et al., 2012; Liebezeit and Dubaish, 2012), sodium polytungstate (Corcoran et al., 2009; Corcoran et al., 2015) or sodium iodide (Claessens et al., 2013; Dekiff et al., 2014; Kedzierski et al., 2017b) to ensure highly efficient extraction of plastics. However, these salts are very expensive and toxic. To reduce these costs, different protocols based on two steps of separation have been proposed. These techniques are generally based on a first step of concentration of microplastics followed by an extraction step by flotation at the surface of a dense solution. Two main methods were proposed: the elutriation column (Claessens et al., 2013) and the Air-Induced Overflow (AIO) method (Nuelle et al., 2014). For these two methodologies, the use of a dynamic method based on liquid flow to extract microplastics requires a perfect process control. This prerequisite is especially important in order to compare the results of these methods which are currently spreading in the scientific community (Hengstmann et al., 2018; Naji et al., 2017; Wessel et al., 2016). Elutriation was first developed in the second half of the 20th century in order to extract living organisms from sand (Southwood and Henderson, 2000). More recently, the elutriation process has demonstrated its ability to extract microplastics from sand (Claessens et al.,

* Corresponding authors.
E-mail addresses: mikael.kedzierski@univ-ubs.fr (M. Kedzierski), stephane.bruzaud@univ-ubs.fr (S. Bruzaud).

https://doi.org/10.1016/j.marpolbul.2018.05.011
Received 3 January 2018; Received in revised form 7 May 2018; Accepted 8 May 2018
0025-326X/ © 2018 Published by Elsevier Ltd.

2013; Kedzierski et al., 2016; Zhu, 2015). However, the extraction of microplastics is more complex than that of living organisms and involves calculating velocity of the fluid as a function of the particle and fluid properties (Kedzierski et al., 2016). To facilitate the determination of this velocity, a numerical model of the elutriation process, based on hydrodynamic equations, been developed and the results were compared to experimental extraction data (Kedzierski et al., 2017a). This numerical model has demonstrated its ability to determine the most adapted fluid velocity to a given particle class. Thus, the calculated velocities correspond to an extraction of 90% of the microplastics for < 10% of sand. This numerical model also revealed some limitations related to protocols and dimensioning choices or our early elutriation system. The maximum theoretical density of plastic for which a plastic can be elutriated without significant sand contamination, is slightly too low to ensure a good extraction of all medium dense plastics. Another critical element is related to the filling velocity of the column before elutriation. During filling, a particle suspension event may occur if the fluid velocity is too high. This can have a significant impact on the elutriation process. This filling velocity must be precisely controlled but there is no information on the optimal water velocity which must be, at the same time, high enough to fill the column as quickly as possible and low enough to prevent the particle suspension. Calculating this velocity range is necessary. Finally, the numerical model showed that using a constant particle velocity is not the best way to calculate the optimal fluid velocity, and it was suggested that the water velocity should be adapted to the size class of the particle. However, these protocol changes also involve changes in column size and duration of the process. In addition, applying a numerical model of the elutriation implies deep knowledge on certain data such as the maximum density of microplastics in the contaminated sand sample or the dimension of the particles that are most likely not known *a priori*. The main purpose of the study is to propose new information on the elutriation column dimension and protocol elements to design an elutriation system that allows efficient elutriation. In particular, we aim to determine: *i*) whether it is possible to increase the density limit up to 1800 kg·m^{-3} *ii*) to adapt the fluid velocity as a function of the particle properties and finally, *iii*) defining consecutive adaptations concerning column height and the elutriation procedure.

2. Material and methods

2.1. Elutriation system and process

The purpose of the elutriation system is to effectively separate sand and plastic particles. This system consists of four main parts (Kedzierski et al., 2016): (*i*) the storage and filtration system; (*ii*) the injection and flow control system; (*iii*) the elutriation column (1,86 m high); (*iv*) the water temperature control system. The particles are introduced at the bottom of the empty elutriation column. After the column filling with fresh water through the bed of particles, water is injected at a controlled velocity from the bottom of the column. The lightest particles are carried up the column while the heaviest remain at the bottom. Intermediate mass particles can be suspended at intermediate heights, generally from a few centimeters to a few tens of centimeters, without being transported out of the elutriation column. This part of the sample is called a fluidized bed of particles. In the case of a microplastic extraction, the transported particles should be only made up of microplastics while the sand grains should not be suspended in the column. The behavior of the particles, and consequently the efficiency of the elutriation, depends on the respective terminal falling velocities of the plastic and sand particles. This terminal falling velocity can be defined as the velocity of the particle sedimentation in an infinitely diluted medium (when the particle fall without being slowed by other suspended particles). If the terminal falling velocity of the smallest sand particles is higher than that of the coarser microplastics, then the sand-plastic separation is efficient. In this particular case, the fluid velocity of the water can be precisely adjusted in order to extract all microplastics without any sand particle elutriation. The terminal falling velocity of a particle depends on its density and size (assuming that the particles are roughly spherical). In order to separate particles according to their density, particle size variability must be reduced. Using a sieve column several particle subsamples with smaller size classes can be isolated from the initial sample. In the classic protocol, the sieve column consists of six sieves: 2 mm, 1 mm, 500 µm, 250 µm, 125 µm and 63 µm (Kedzierski et al., 2016). The non-passing fractions of each sieve constitute the different particle size classes, which are then elutriated. The separate elutriation of the different particle size classes is more efficient than if the whole sample were elutriated all at once (Kedzierski et al., 2016).

The elutriation system can be used for two different purposes. Concerning the first one, the elutriation system is used to experimentally determine the optimal fluid velocity required to extract a particle. This type of experiment is particularly sensitive to particle suspension during column filling because this phenomenon artificially increases the extraction efficiency of particles (Kedzierski et al., 2017a). For the second one, the microplastics are extracted from a contaminated sample from the determined optimal fluid velocities. This second protocol is less sensitive to particle suspension during column filling (Kedzierski et al., 2017a). Therefore, the filling velocity of the column must be calculated according to the purpose of the elutriation column.

2.2. Hypothesis and parameters

2.2.1. Constraints

To propose a realistic protocol and a column dimensioning which allows elutriation of microplastics in the size class [63–2000] µm and a density range of [1000–1800] kg·m^{-3} from sandy sediments, some constraints need to be formulated (Fig. 1). First of all, the column height ($H_{c'}$) must be between 0.10 and 2.0 m in order to be easy to handle. Secondly, the duration of the elutriation should be neither too short, to facilitate the handling of the elutriation system, nor too long, for practical reasons. Consequently, the range [60–600] s was proposed. If these two conditions cannot be achieved at the same time, a compromise can be reached by proposing two different elutriation columns. Then, the elutriation process must effectively separate sand and plastic particles. This means that the smallest sand and the coarser plastic particles will be separated as far as possible. Finally, particle suspension must be controlled, both during the column filling step, to avoid any future bias in the measurements (Kedzierski et al., 2017a), and during elutriation, to prevent sand extraction or trapping of microplastics in the sand (Claessens et al., 2013; Nuelle et al., 2014).

2.2.2. Hypothesis

Dimensioning calculations involve a set of hypothesis. The first is that the particles (sand grains and microplastics) are spherical. It is also assumed that there is no specific electrical interaction between the particles. Third, the edge effect is negligible. Last, the values of the generic parameters (particle size and density) are close to reality (see Section 2.2.3).

2.2.3. Generic parameters

Particle density (ρ_p; kg·m^{-3}) is an important parameter needed in model calculations. The density of plastics varies in a large range from 10 kg·m^{-3} (expanded polystyrene) to 2330 kg·m^{-3} (silicones) (Kedzierski et al., 2017b). To extract all the microplastics present in a sand sample, it is necessary to know the maximum density value of the microplastics present in the sample, which is rarely the case. To fill this gap, two generic densities were selected for calculation according to the upper limits of medium dense plastics (MDP; ρ_p^{mdp}; 1500 kg·m^{-3}) and dense plastics (DP; ρ_p^{dp}; 1800 kg·m^{-3}) (Kedzierski et al., 2017b). These two densities correspond to respectively 70–75 and 98% of the plastics produced in Europe. In a real case, a choice must be made between

Download English Version:

https://daneshyari.com/en/article/8870819

Download Persian Version:

https://daneshyari.com/article/8870819

Daneshyari.com