Science of the Total Environment 613–614 (2018) 530–537

Contents lists available at ScienceDirect

Science of the Total Environment

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

Short Communication

Variation in plastic abundance at different lake beach zones - A case study

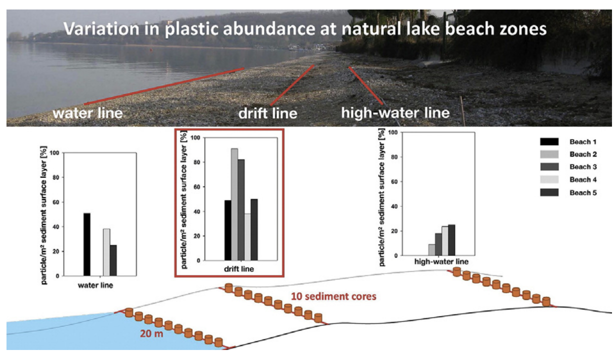
Hannes K. Imhof [a], Alexandra C. Wiesheu [b], Philipp M. Anger [b], Reinhard Niessner [b], Natalia P. Ivleva [b], Christian Laforsch [a,*]

[a] Department of Animal Ecology I and BayCEER, University of Bayreuth, Universitätsstr. 30, 95440 Bayreuth, Germany
[b] Institute of Hydrochemistry (IWC), Chair for Analytical Chemistry and Water Chemistry, Technical University of Munich (TUM), Marchioninistr. 17, 81377 Munich, Germany

HIGHLIGHTS

- Plastic abundance varies at natural lake beach (accumulation) zones.
- Drift line might be an appropriate beach sediment sampling zone for microplastic.
- Sample strategy adaptations are necessary to enable microplastic identification down to 1 μm.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 27 June 2017
Received in revised form 28 August 2017
Accepted 30 August 2017
Available online xxxx

Editor: Jay Gan

Keywords:
Plastic debris
Microplastic
Sediment sampling
Freshwater
Lake
Beach sediment

ABSTRACT

Plastic particles in marine and freshwater environments span from macroscopic to microscopic size classes. Each may have a different impact on individuals, populations and ecosystems, but still the wide variety of methods used in beach sediment sampling inhibit comparisons among studies and therefore hampers a risk assessment. A large portion of the uncertainties is due to differing sampling strategies.

By quantifying the alongshore distribution of macro- and microplastic particles within five beaches of Lake Garda, we aim to shed light on the accumulation behavior of microplastic particles at an exemplary lake which might give indications for potential sampling zones. The identification of plastic at the single particle level with a spatial resolution down to 1 μm was performed by Raman microspectroscopy. Given the time consuming approach we reduced the number of samples in the field but increased the spatial area where a single sample was taken, by utilizing a transect approach in combination with sediment cores (5 cm depth).

The study revealed that, in comparison to the water line and the high-water line, the drift line of all five beaches always contained plastic particles. Since the drift line accumulate particulate matter on a relatively distinct zone, it will enable a comparable sampling of microplastic particles. The applied sampling approach provided a representative method for quantifying microplastic down to 1 μm on a shore consisting of pebbles and sand. Hence, as first step towards a harmonization of beach sediment sampling we suggest to perform sampling at the drift line, although further methodological improvements are still necessary.

1. Introduction

The contamination of the ocean with plastic debris has been characterized as one of the top emerging global issues (UNEP, 2014) since there

* Corresponding author.
E-mail address: christian.laforsch@uni-bayreuth.de (C. Laforsch).

http://dx.doi.org/10.1016/j.scitotenv.2017.08.300
0048-9697/

is a concern that it harms organisms or even humans on different levels (physical harm and chemical toxicity) and has the potential to biomagnify up the food chain (GESAMP, 2015; Vethaak and Leslie, 2016). The majority of the plastic waste is likely to accumulate in the oceans following transport via rivers from terrestrial sources to the ocean (Jambeck et al., 2015). As a result, research has been focused on the implications of plastic debris to the marine environment (e.g. da Costa et al., 2017; Gall and Thompson, 2015; Werner et al., 2016; Wright et al., 2013). In recent years, there has been a shift in research focus from the marine to the limnetic environment which is for example reviewed in: Reifferscheid et al. (2017), Dris et al. (2015), Duis and Coors (2016), Eerkes-Medrano et al. (2015), Ivleva et al. (2017), Wendt-Potthoff et al. (in press). Macroplastic (>5 mm) and microplastic particles (most defined as particles <5 mm) were identified in river surface water and riverine shoreline sediments. Similarly, in lakes macro- and microplastic particles were detected in surface waters and beach sediments. The assessment of sandy beaches is a common measure to examine the contamination of a waterbody with microplastic. Over 80% of the marine studies analyzed beach sediments (Van Cauwenberghe et al., 2015). Therefore, a large body of literature exists about the contamination of beach sediments from the shorelines of the sea, of lakes and streams but also of sub tidal sediments and the deep sea (reviewed in: Dris et al., 2015; Ivleva et al., 2017; Lusher, 2015; Van Cauwenberghe et al., 2015). An advantage of analyzing microplastic in sediments is the lower particle size detection limit, which is only determined by the performed sample preparation and particle identification methods. In contrast, the sampling of surface waters, is often limited to the mesh size of the sampling apparatus (often 300 μm, Hidalgo-Ruz et al., 2012). However, due to a considerable variation of beach sampling approaches among studies, the outcome of current studies has limited comparability. This is true for the marine (for reviews see: Browne et al., 2015; Hidalgo-Ruz et al., 2012; Ivleva et al., 2017; Lusher, 2015; Van Cauwenberghe et al., 2015), but also the limnetic environment (for reviews see: Dris et al., 2015; Duis and Coors, 2016; Eerkes-Medrano et al., 2015; Ivleva et al., 2017; Reifferscheid et al., 2017; Wagner et al., 2014). Next to differences in the performed methods for the quantification of microplastic, from separation, sample processing, identification methods to the analyzed size classes of the particles (Ivleva et al., 2017; Lenz et al., 2015; Löder and Gerdts, 2015), the sampling itself accounts for a large portion of the variation. One reason for the differing sampling methods is a lack of knowledge of particle distribution, accumulation and dispersal on beaches. Mainly because previous studies were driven by the question 'if' and 'how much' microplastic does exist rather than by the examination of the alongshore distribution. In the marine environment some studies tried to assess the intra-beach accumulation patterns of microplastic (e.g. Araújo and Costa, 2007; Heo et al., 2013; Imhof et al., 2017; Moreira et al., 2015; Turra et al., 2014) but only a limited amount of general studies are available for lake beaches (for a complete list see Table S.4 in the Supplementary Information). Giving that available studies are not comparable due to the sampling of different beach zones, the knowledge on microplastic abundance in potential accumulation zones on lake beaches would be a first step towards harmonized sampling approaches. Therefore, the current study aims to improve future monitoring approaches by the examination of microplastic accumulation patterns in lake beach sediments.

In a first study on the subalpine Lake Garda (Italy) we observed a high spatial variation of microplastic abundance (February 2011, Imhof et al., 2013). This was confirmed by a second more comprehensive assessment in March 2012 quantifying particles down to 1 μm with a mean abundance of 75 ± 134 microplastic particles/m^2 (Imhof et al., 2016). In contrast to both previous publications we focus in this study solely on the spatial intra-beach variation at Lake Garda and quantified the abundance of microplastic particles in three zones, which can be easily identified (high-water line, drift line, water line). Two of them, the high-water line and the drift line are natural accumulation zones of organic material.

It was hypothesized that the highest number of plastic particles would be located in zones showing the highest accumulation of organic material, such as at the first significant drift line from the water line (e.g. Hidalgo-Ruz and Thiel, 2013; Moreira et al., 2015) and at the high-water line as it might accumulate particles from a larger time-period (e.g. Heo et al., 2013). Furthermore, we assume that there would be less plastic particles at the water line where less organic material is found.

2. Materials & methods

The sampling of the beach sediment was performed at Lake Garda in March 2012. Particle extraction, sample processing as well as the particle identification is already described in detail in Imhof et al. (2016) and we therefore focus on the sampling procedure here.

2.1. Sediment collection

Sediment was collected at five beaches along the coastline of Lake Garda in order to include different beach morphologies (slope, sediment grain size, etc.) and different exposition to wind and waves (Fig. 1). Two beaches (4 and 5) were located at the border of the shallow eastern basin (depth 50 m) and two beaches (1 and 2) at the border of the deeper western basin (350 m). The fifth and last was in the northern part (3) which is bordered by steep mountain walls and therefore exposed to wind and currents from the south (Fig. 1), whereas the beaches in the southern part are located in rather flat terrain. A particular important property is the location of two of the beaches (2 & 5) in natural trapping zones of pollutants (Imhof et al., 2016; Lovato and Pecenik, 2012). The width of the beaches varied between 100 and 1000 m (average: 600 m, Table S.1).

To compare the particle abundance within the five beaches, sampling was performed at three different sample zones within the littoral. We sampled (Fig. 1): (i) the high-water line, defined as the line marking the highest visible water level by deposited organic debris, flotsam or sand, probably created by storm events. (ii) The drift line, defined as the first substantial area which accumulated sand, natural and anthropogenic debris from the water line to the high-water line), commonly sampled in freshwater (Dris et al., 2015; Eerkes-Medrano et al., 2015) but also marine studies (Hidalgo-Ruz et al., 2012) and (iii) the current water line.

The sampling strategy was designed to enable sample processing (MPSS, Imhof et al., 2012) and particle identification by Raman microspectroscopy down to 1 μm (Imhof et al., 2016; Käppler et al., 2016) both being time-consuming approaches. Hence, a trade-off was necessary between the number of samples and the spatial extension of the sample area. Given the time consuming approach we reduced the number of samples but increased the spatial area where a single sample was taken. The sample area used resembles approximately the area in frequently used quadrat sampling (0.25 × 0.25 m or 0.3 × 0.3 m, for reviews see: Browne et al., 2015; GESAMP, 2015; Hanvey et al., 2017; Hidalgo-Ruz et al., 2012; Van Cauwenberghe et al., 2015) with the exception that the area was split into 10 sections (sediment cores) to increase the spatial extent of a single sample. The use of sediment cores for microplastic abundance estimates was recently suggested by Fisner et al. (2017). This was performed, in order to provide a more representative cross-section of the beach at each location. For a comparison of the spatial extent of quadrat sampling and the performed combination of transect and sediment core sampling see Fig. 2.

In each of the above mentioned sampling zones longitudinal transects of 20 m were sampled parallel to the water line resulting in 15 sediment samples in total (5 beaches × 3 transect lines). Within each transect 10 sediment cores of the sediment surface layer were taken in equal distance (10 cm diameter and 5 cm in depth). The 10 cores from one transect were combined and transferred into one sampling container resulting in 4–6 L of sediment per beach covering a surface of 0.08 m^2 (Fig. 2). Core sampling was performed by driving a stainless