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Occurrence of microplastics in the beach sand of the Chinese inner sea: the Bohai Sea☆

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ABSTRACT

The occurrence of microplastics in the beach sand of the Bohai Sea was investigated for the first time. The Bohai Sea is the largest Chinese inner sea and its coastal region is one of the most densely urbanized and industrialized zones of China. Samples from three costal sites (i.e., Bijianshan, Xingcheng and Dongdaihe) were collected, quantified and identified for microplastic analysis. Effects of sample depth and tourism activity were investigated. Surface samples (2 cm) contained higher microplastic concentrations than deep samples (20 cm). Samples from the bathing beach exhibited higher microplastic concentrations than the non-bathing beach, suggesting the direct contribution of microplastics from tourism activity. Of eight types of microplastics that were found, PEVA (polyethylene vinyl acetate), LDPE (light density polyethylene) and PS (polystyrene) were the largest in abundances. Moreover, the non-plastic items from samples were analyzed and results revealed that the majority abundance of the observed non-plastics were viscose cellulose fibers. Further studies are required to evaluate the environmental hazards of microplastics, especially as they may "act as a contaminant transporter" to the Bohai Sea ecosystem.

1. Introduction

Since the term "microplastic" was first used by Thompson et al. (2004), the occurrence, distribution and transportation of microplastics have attracted extensive concerns (Cole et al., 2011; Hidalgo-Ruz et al., 2012). Due to their microscopic size and various types, examining and understanding their source, transport and adverse impacts on marine wildlife is relatively scarce (Cole et al., 2011) compared to studying the fate and environmental effects of large plastic litter as this has been studied world-widely (Browne et al., 2010; Engler, 2012; Provencher et al., 2014; Reisser et al., 2013). There is still no standard to define microplastic, but the size of 5 mm is a widely accepted criterion to separate microplastics from larger plastic contaminants (Browne et al., 2010). Microplastics have already been detected throughout the entire marine environment, including the open ocean (Cozar et al., 2014), seashore (Turra et al., 2014), estuary (Browne et al., 2010), remote islands (Ivar do Sul et al., 2009) and deep-sea sediment (Van Cauwenberghe et al., 2013). The wide spread distribution and potential toxic effects of microplastics have attracted more attention in recent years. A number of studies under laboratory conditions have demonstrated that, microplastics can be ingested by marine life such as mussels (Browne et al., 2008; von Moos et al., 2012; Wegner et al., 2012), zooplankton (Cole et al., 2013, 2014; Frias et al., 2014) and worms (Browne et al., 2013), and detrimental impacts of microplastic on these animals were uncertain (Wright et al., 2013).

Upon review of sampling schemes for microplastics (Hidalgo-Ruz et al., 2012), it was determined that sampling sediment from coastal beaches would be a cost-effective and efficient approach (Dekiff et al., 2014). Additionally, beach samples could be a good representation of the accumulating result of long-term interfacial interaction between coastal waters and land surface area. These samples, therefore, likely represent a long-term accumulation of microplastics at these sites.

As shown in Fig. 1, the Bohai Sea is a large semi-enclosed inner sea located in the northeast of China. The coastal region surrounding the Bohai Sea is one of the three most densely urbanized and industrialized zones in China (the other two are the Yangtze River Delta and the Pearl River Delta zones). With the rapid

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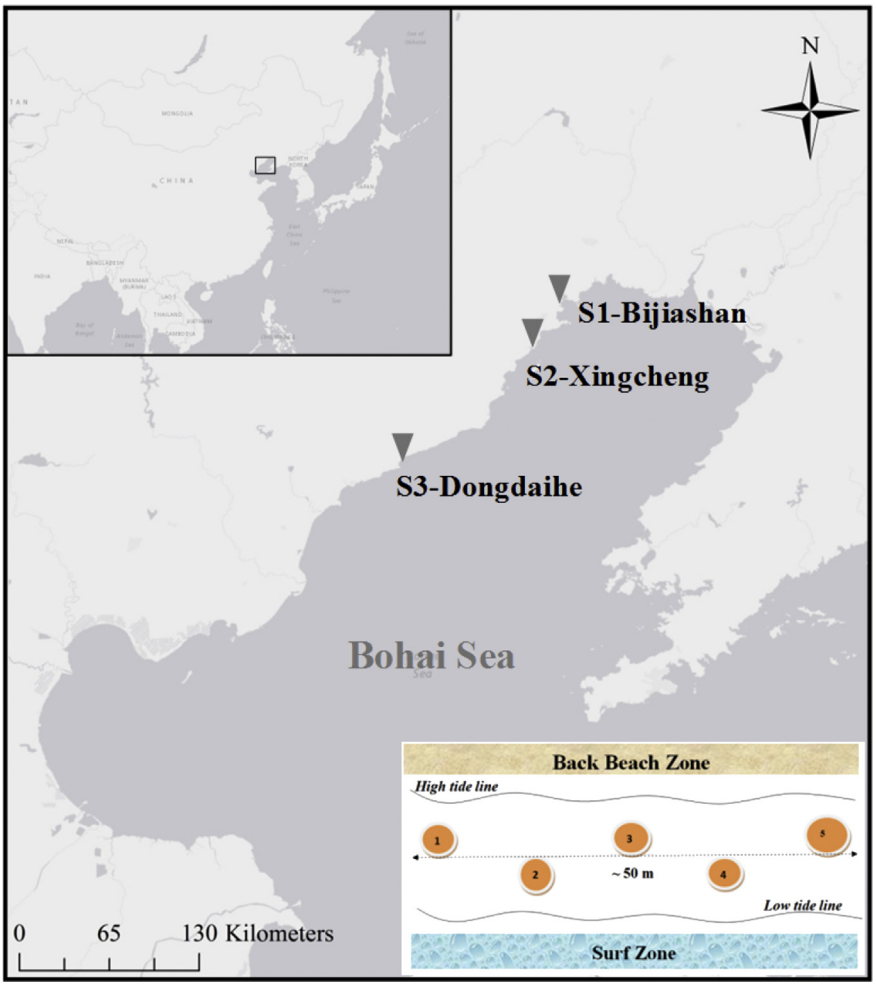

Fig. 1. Map of the studied beach sites in Bohai Sea, China. The inset graph indicates the five replicate samples in each studied beach.

economic growth in the last two decades, the Bohai Sea has encountered huge pollution challenges due to its semi-enclosed nature and the intensive urbanization and industrialization compared to other Chinese coastal regions (Gao et al., 2014). Many kinds of contaminants such as heavy metals (Gao and Chen, 2012; Wu et al., 2014), persistent organic pollutants (POPs) (Zhang et al., 2009) and antibiotics (Zou et al., 2011) in the Bohai Sea have already been reported. Moreover, the oil spilling that occurred in the Bohai Sea (Li et al., 2015b), intensified the present pollution status. There is concern that the Bohai Sea may degrade to a dead sea if no effective protection measures are enforced as soon as possible. More than 40 rivers including the Yellow River, drain into the Bohai Sea. These rivers transfer terrestrial pollutants (Zhang et al., 2009), including microplastics, to the Bohai Sea where they can accumulate.

Few studies of microplastic have been done in China (Li et al., 2015a; Qiu et al., 2015; Zhang et al., 2015; Zhao et al., 2015). Zhao et al. (2014) conducted the first microplastic observation in the Yangtze River estuarine, however, so far no observed data of microplastic' occurrence and chemical composition in the Bohai Sea has been published. It is essential to obtain these data firstly before further assessing the potential environmental risks of microplastic such as toxic and/or contaminant transport effects. In this study, the sand samples collected from three beach sites in the north Bohai Sea were quantified and characterized for microplastic analysis. All these three sites are located in the Liaoning Province, a major base for the Chinese heavy industry. Several large-scale petrochemical and smelter plants are within 50 km of the sampling sites. The main aim of this study is to provide data on the abundance and chemical composition of microplastics in the north Bohai Sea.

2. Materials and methods

2.1. Field sampling collections

The sand samples were collected from three locations in the north Bohai Sea from July 25th to the 27th, 2015. The three locations, i.e., S1-Bijianshan, S2-Xingcheng and S3-Dongdaihe, are all on the coast line of the Liaoning Province of China, which is famous for petrochemical (e.g., production of isopropanol, needle coke and rare earth butadiene rubber, etc.) and equipment manufacturing industries in China. There was no obvious precipitation during the sampling period. In each studied location, samples were collected from two sites, i.e., the non-bathing beach and the bathing beach. The non-bathing beaches are not developed for commercial activity and the human presence was slight. On the other hand, the bathing beach was developed for commercial activity, attracting about 800 thousand tourists in the summer season (June–August). The beach activities of tourists included camping, picnicking and so on. The distance between the two sites in each location was within 1 km.

As shown in the inset of Fig. 1, samples were collected in a 50-