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Characterization of plastic debris and association of metals with microplastics in coastline sediment along the Persian Gulf

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A B S T R A C T

This study reports number, size and color distribution, and metal contents of microplastics as well as adherent sediments along the Persian Gulf. Samples were collected from 9 stations in summer 2015 with a sampling time interval of 10 days. Plastic size of 2–5 mm, and ≤0.25 mm with 45 and 33% and white and colorless plastics with 62 and 33% had the highest abundance considering number per m^2, respectively. In general, the majority of collected plastics (79%) were smaller than 5 mm (defined size for microplastics). The mean Al, Fe, Mn, Cd, Cr, Ni, Pb, Cu contents of plastic fragments were 115, 531, 32.2, 0.035, 0.915, 2.03, 4.59, and 3.6 $\mu g\ g^{-1}$, respectively while the mean Al, Fe, Mn, Cd, Cr, Ni, Pb, Cu contents of sediments were 186, 3050, 127, 0.81, 5.01, 14.5, 48.6 and 5.43 $\mu g\ g^{-1}$ respectively. There were significant differences between the abundance of plastic items as well as the all examined metal concentrations of microplastics and sediments at different sampling times. As there is no regular cleanup program in the studied areas, significant differences between plastic items number at different sampling times (with higher plastic items number at the first day of sampling) showed that a large number of plastic items may enter from beaches to the sea and become available to marine organisms.

1. Introduction

Worldwide manufacture of plastics has grown strongly over the last decades from 1.5 million tons per year in the 1950s to 322 million tons per year in 2015 (Plastics Europe, 2016). Plastics are meanwhile amongst the most numerically abundant sort of aquatic debris and beaches (Commission, 2007; Munari et al., 2017; Thompson et al., 2009; Programme, 2005; UNEP, 2008; UNEP, 2009). The accumulation of plastic particles in coastline and aquatic environment is because of the ongoing and intense release of plastic-based materials into the environment (de Sá, Luís and Guilhermino, 2015; Pasternak et al., 2018; Possatto et al., 2011). Despite attempts to clean litter from the aquatic environment and limitations on dumping at sea and along shoreline areas, the amount of plastic debris is still increasing (Thompson et al., 2004; Goldstein et al., 2012). This seems unavoidable because most plastics will not biodegrade, and amounts in the aquatic environment will grow over time (Andrady, 2011). Also, plastic debris may be scattered by ocean currents from densely populated and industrialized regions to even the most remote and unpopulated coastal areas (McDermid and McMullen, 2004; Barnes et al., 2009; Hirai et al., 2011).

Once plastic debris is discarded into marine environments and beaches, it may sorb pollutants including persistent, bioaccumulative and toxic organics as well as metals from the surrounding environment (some up to 100 times that of sediments) (Ashton et al., 2010; Holmes et al., 2012; Ogata et al., 2009; Rochman et al., 2013b; Teuten et al., 2007). Therefore, plastic debris possibly behaves as a stressor to organisms (Rochman et al., 2013b), inflicting both chemical and physical adverse effects on animals upon ingestion. So efforts to manage plastic debris should recognize the complex combination of pollutants linked with this matter.

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There are already many studies that reported the presence of organic contaminants on plastic debris (Ogata et al., 2009; Rios et al., 2010; Hirai et al., 2011; Frias et al., 2010; Van et al., 2012; Karapanagioti et al., 2011; Rios et al., 2007; Ryan et al., 2012) but the presence of metals (adsorbed, adhered, or as additives in the plastic) on plastic debris has only recently been reported (Ashton et al., 2010; Holmes et al., 2012; Nakashima et al., 2012; Holmes et al., 2014; Rochman et al., 2014). Like some organic contaminants such as polybrominated diphenyl ethers (Tanaka et al., 2013), some metals (such as lead) found on plastic debris (Nakashima et al., 2012) originate from the manufacturing process as well as from environmental sorption (Ashton et al., 2010; Holmes et al., 2012). In contrast, it has also been reported that like some organic contaminants such as DDT (Ogata et al., 2009), a number of metals are found on plastic debris only due to environmental sorption (Ashton et al., 2010; Holmes et al., 2012). Chemical components in plastics from manufacturing (Robertson, 1968), degradation and fouling of marine plastic debris through microbial biofilms, and colonization through algae and invertebrates (Holmes et al., 2012; Tien and Chen, 2013) may create active sites for the sorption and/or bioaccumulation of metals. On the other hand, unreacted monomers in the plastics, degradation products, organic pollutants, as well as metals can be leached to the environment (Teuten et al., 2009; Dobaradaran et al., 2017a; Dobaradaran et al., 2017b; Casajuana and Lacorte, 2003). But more research is necessary to fully understand the leaching behavior of pollutants from plastic debris in the marine environment.

According to a recent report (Barboza and Gimenez, 2015), from 2004 to 2014 microplastics research has focused on the United States, Western Europe, Oceania, and East Asia. Though there are some reports on the metal contents of sediment (Karbasdehi et al., 2016; Dehghani et al., 2017) and seawater samples in the northern part of the Persian Gulf there is hardly any information available on the occurrence and relevance of microplastics in the Middle East region. For example, in a study the mean concentration levels of metals such as Cd, Co, Cu, Mn, Ni, Pb, and Zn in seawater samples were reported as 0.16, 2.58, 11.53, 5.25, 12.83, 3.04, and 8.58 μg/L respectively (Delshab et al., 2017). There is only one recent report on number (particle/kg of sediment), type and dimensions of plastics along the beaches of the Strait of Hormuz, Persian Gulf (Naji et al., 2017) as well as one report on the number (items/ 200 g dry sediment), shape and color of microplastics (Akhbarizadeh et al., 2017).

So in the present study our aim was (1) to provide for the first time data on the quantity (items m^{-2}), color and size distribution of marine plastics and microplastics in the Bushehr seaport shoreline, and (2) to determine the contents of microplastics and adherent sediments with a variety of metals including trace metals (Cd, Cr, Ni, Pb, and Cu) as well as major metals (Fe, Al, and Mn).

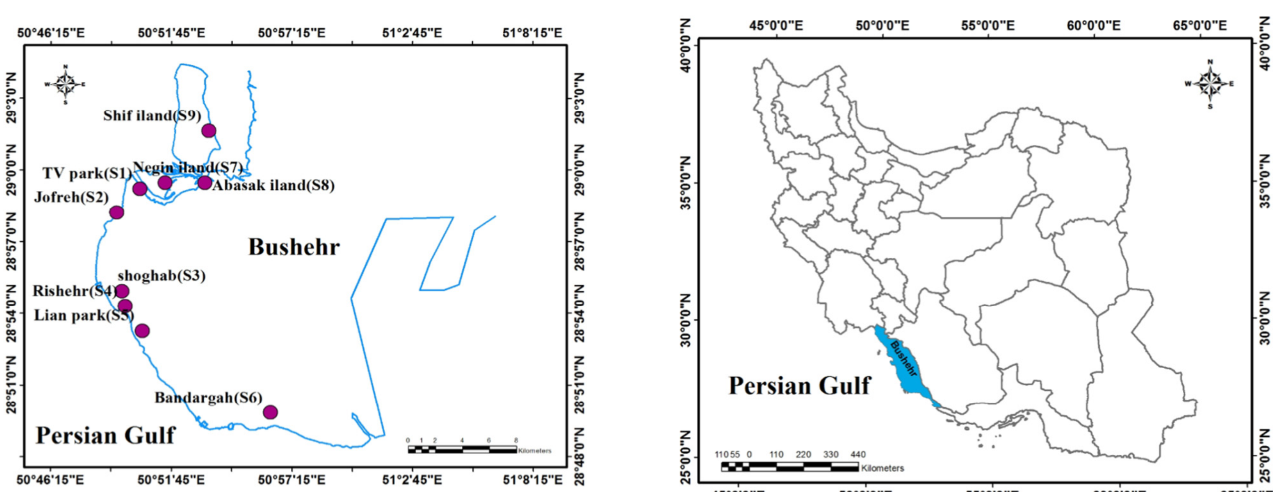
2. Materials and methods

2.1. Study area

To evaluate the occurrence, number, size and color distribution of plastics as well as metal concentration levels of microplastics (size of <5 mm) and sediments, field surveys were conducted at 9 stations along the Persian Gulf in Bushehr in summer 2015. All selected stations have a texture of sand in the surface with grain sizes up to 250 μm. The location of sampling stations and the geographic coordinates are shown in Fig. 1. All sampling stations are close to urban areas.

2.2. Sampling and sample preparation

At every beach examined (S1-S9), sediment samples from the top 10 cm were gathered at the intertidal zone (at high tide) on



Distance (km) between stations	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
S_1	-	2.66	9.21	10.76	12.71	21.36	1.13	4.05	9.57
S_2		-	6.68	8.32	10.30	19.26	2.82	4.38	12.18
S_3			-	2.34	4.30	14.82	9.07	9.62	18.48
S_4				-	2.3	12.38	10.53	10.45	19.79
S_5					-	10.65	12.26	12.03	21.06
S_6						-	20.76	19.04	28.39
S_7							-	2.95	9.46
S_8								-	9.72
S_9									-

Fig. 1. Location and geographic coordinates of sampling points along the northern part of the Persian Gulf in Bushehr coastal areas.