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Amount and distribution of neustonic micro-plastic off the western Sardinian coast (Central-Western Mediterranean Sea)

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A B S T R A C T

A plethora of different sampling methodologies has been used to document the presence of micro-plastic fragments in sea water. European Marine Strategy suggests to improve standard techniques to make future data comparable. We use Manta Trawl sampling technique to quantify abundance and distribution of micro-plastic fragments in Sardinian Sea (Western Mediterranean), and their relation with phthalates and organoclorine in the neustonic habitat. Our results highlight a quite high average plastic abundance value (0.15 items/m^3), comparable to the levels detected in other areas of the Mediterranean. "Site" is the only factor that significantly explains the differences observed in micro-plastic densities. Contaminant levels show high spatial and temporal variation. In every station, HCB is the contaminant with the lowest concentration while PCBs shows the highest levels. This work, in line with Marine Strategy directives, represents a preliminary study for the analysis of plastic impact on marine environment of Sardinia.

1. Introduction

Plastics are synthetic organic compounds, derived from the polymerization of monomers extracted from oil or gas (Rios et al., 2007). In the last fifty years, since these materials started to be utilized, their presence in the marine environment has grown rapidly with the consequence that nowadays 40–80% of debris in the marine environment are plastic (Barnes et al., 2009; Cole et al., 2011).

The sources of plastic debris in marine environment may be either land (e.g. domestic objects) or marine-based (e.g. nylon nets and other fishing industry residual) (Andrady, 2011; Derraik, 2002; Goldberg, 1997; Gregory, 2009) and the highest levels of plastic pollution are usually found nearby heavy urbanized areas (Derraik, 2002). The distribution and abundance of plastic debris are strongly influenced by hydrodynamics and show high spatial variability in both the open ocean and shoreline waters (Barnes et al., 2009; Browne et al., 2010).

Oceanic currents lead to high dispersion patterns (Law et al., 2010; Martinez et al., 2009; Maximenko et al., 2012), which in turn permit plastic materials to reach remote areas, like islands or polar regions, distant from sources of pollution (Barnes et al., 2009; Derraik, 2002; Gregory, 2009; Zarlf and Matthies, 2010).

In the marine environment plastic material requires several centuries, or even thousands of years, to degrade (Arthur et al., 2009; Barnes et al., 2009; Derraik, 2002; Goldberg, 1997; Gorman, 1993; Hansen, 1990; Moore, 2008; O'Brine and Thompson, 2010; UNESCO, 1994; Zarlf et al., 2011). Debris items are usually subdivided into different size categories: mega-debris (>10 cm); macro-debris (2–10 cm); meso-debris (2 cm–5 mm)

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and micro-debris (<5 mm) (Barnes et al., 2009). Micro-plastic particles are largely represented by plastic items, such as scrubbers and industrial pellets, that serve as precursors for manufactured plastic products (primary sources). A great amount of marine micro-particles is also constituted by fragments and fibres, derived from the breakdown of larger plastic products (secondary sources) (Hidalgo-Ruz et al., 2012). Plastic micro-fragments are accumulating on the sea surface, especially within the neustonic habitat, and several publications report increasing concentrations in oceans and seas (Collignon et al., 2012; Doyle et al., 2011; Fossi et al., 2012; Law et al., 2010; Moore et al., 2001; Ryan et al., 2009).

Plastic pollution was initially seen as a merely aesthetic problem (Galgani et al., 2013; Gregory, 2009), but many studies over the past decades show how several marine animals are negatively affected by the presence of plastic (Boerger et al., 2010; Derraik, 2002; Galgani et al., 2013), mainly by entanglement and ingestion (Gregory, 2009; Laist, 1997; Thompson et al., 2009; Van Franeker et al., 2011).

The consequence of plastic ingestion could be the release and absorptions of plastic additives such as phthalates, used to enhance plastic performance. Phthalates have been related to a wide range of adverse health effects in several animals. Certain phthalates, such as DEHP (di-(2-ethylhexyl)phthalate) and its metabolite MEHP (mono-(2-ethylhexyl) phthalate), are reproductive toxicants, mainly disturbing the reproductive system (Foster et al., 2000). Plastic material can also adsorb toxic chemicals present at low concentrations in the water column, in particular persistent organic pollutant (POPs) such as HCB, PCBs, DDTs (Rios et al., 2007; Teuten et al., 2009) which can be released and absorbed by the organism after the ingestion. All these chemical pollutants, acting as endocrine disruptors, can potentially affect organisms and populations viability (Caserta et al., 2013; Fossi et al., 2007).

A wide variety of approaches, such as selective, bulk and volume-reduced techniques, have been used to identify and quantify micro-plastics. The Manta Trawl, a modified neustonic net with buoyant wings to keep the net aperture at the sea and air interface, is the most commonly used equipment for sea surface micro-litter analysis based on a volume-reduced methodology (Hidalgo-Ruz et al., 2012). The hood deflects wave crests into the submerged net, therefore capturing a measurable volume of micro-debris at the sea surface.

The European Commission (EC) released the Marine Strategy Framework Directive (MSFD/2008/56/EC) which indicates the major contaminant issues related to marine environments and prioritizes the topics to be investigated in order to reach a Good Environmental Status (GES). Considering the increasing abundance of plastic debris in the sea, the EC chose “Marine Litter” as one of the 11 environmental descriptors on the basis of which the marine environmental status is to be estimated. The Marine Strategy describes GES as the condition when “*Properties and quantities of marine litter do not cause harm to the coastal and marine environment*” (Galgani et al., 2010). Nevertheless, a standard methodology for the analysis of micro-plastic abundance, distribution and potential effects on organisms has not been published yet. A standard methodology must be developed and agreed upon before monitoring and mitigation activities can be initiated to support the EU MSFD requirements.

The main goal of this work was to investigate, for the first time, the distribution of neustonic micro-plastics in the area nearby the Gulf of Oristano (Sardinia), developing an integrated analytical approach. Levels of phthalates and POPs were also estimated, in order to determine if there is a correlation between these contaminants and micro-plastics density.

2. Material and methods

2.1. Study area

This study was carried out in the Gulf of Oristano and in an off-shore site nearby, in the western sector of Sardinia (Central-Western Mediterranean Sea) (Fig. 1). The Gulf of Oristano is a semi-enclosed basin connected to the Sardinian Sea through a 9 km long opening delimited by Cape San Marco on the north and Cape Frasca on the south. Two large lagoon systems are present: the Cabras Lagoon on the northern part of the basin and the Marceddì lagoon on the southern part. Both lagoon systems discharge their water into the gulf through their respective inlets. Another water input-point from the surrounding mainland is the Tirso’s river mouth located near the industrial harbour of Oristano city. The typical wind patterns are the Mistral from north-west (NW), the Libeccio from south-west (SW) and the Sirocco from south-east (SE). The Mistral can be considered the main wind force acting in the area. The study area is included in the Algerian Basin, that presents strongly different dynamics mainly constituted by anticyclonic eddies (Olita et al., 2013).

2.2. Sampling technique

Thirty samples of neuston-plankton were collected using a Manta Trawl lined by a 500 μm mesh net. Manta Trawl sampled the top 50 cm of the sea surface at an average speed of 2 knots for 20 min. The sampling activities were conducted only with Mistral blowing conditions, when wind velocity was maximum 8 knots, in order to avoid the mixing of plastic particles in the water column (Kukulka et al., 2012). The Manta Trawl was always towed against the wind. No data are available for current’s conditions at the time of sampling at a small spatial scale. The volume of filtered seawater (m^3) was evaluated by a flow meter (MF315, *OceanTest Equipment, Inc.*). Samplings were conducted in 4 coastal sites (Mal di Ventre – MDV, Caletta – CAL, Marceddì – MAR, Tirso – TIR, Fig. 1) within 12 nautical miles (Nm) in consecutive days at the beginning of July 2012 and July 2013. Off-shore samples (i.e. 20 Nm out) were also collected on the 20th July 2013, during “Minerva” sampling survey (MIN). The off-shore samples were collected in the morning (MIN D) and during the night (MIN N) of the same day. For the estimation of the micro-plastic density, three replicates were collected for every site and for every temporal sampling. In one of the three replicates, the plastic component was removed and the remaining part was used for the estimation of phthalates and organochlorine levels: for each site, samples were filtered by a 500 μm mesh net, stored in liquid nitrogen and then analysed for contaminants.

2.3. Micro-plastic evaluation

For every sample, plastic items were separated from plankton and other organic matter, sorted and measured under a binocular stereoscope (*AxioCam ERc5s for image analysis, Carl Zeiss MicroImaging GmbH, Germany. www.zeiss.de/axiocam*), and only micro-materials (less than 5 mm) were considered. Plastic items density was expressed as items/m^3.

2.4. Phthalates analysis

Di-(2-ethylhexyl) phthalate (DEHP) is the most abundant phthalate in the environment. In both invertebrates and vertebrates, DEHP is rapidly metabolized in the form of its primary metabolite, MEHP (mono-(2-ethylhexyl) phthalate), which can be used as a marker of exposure to DEHP (Barron et al., 1989). DEHP