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Geophagy and Microplastic Ingestion

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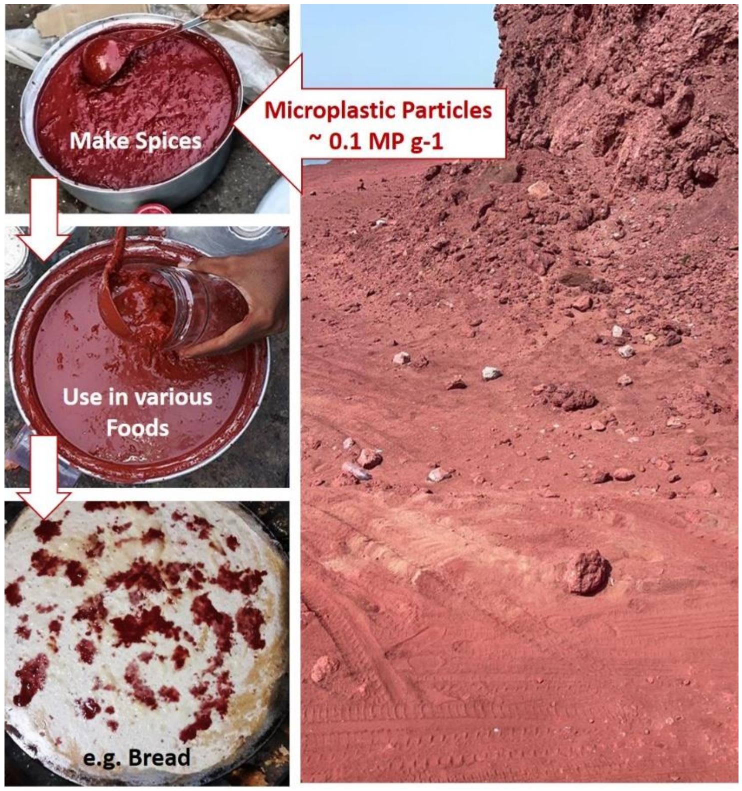
Graphical Abstract



Highlights

- Red soils from Hormoz used to flavour food have been analysed for microplastics.
- Fibres of various polymer types were detected in all samples up to 0.1 MP g^{-1}.
- Geophagy is a route of MP ingestion for humans and animals.
- The significance and impacts of this route require further study.

Abstract

Microplastics (MPs) are ubiquitous and pervasive contaminants whose impacts on human health are unclear but are gaining interest in the scientific literature. Human exposure to MPs may arise through inhalation and ingestion, with research into the latter route focusing on foodstuffs and beverages contaminated from the environment or during processing and preparation. What has not been considered thus far, however, is MP exposure through geophagy, or the cultural, culinary or compulsive ingestion of contaminated soil and dirt. In this study, soils from the island of Hormoz, Iran, and spices prepared from these soils are analysed for MP contamination. Fibres of polyethylene terephthalate, Nylon, polystyrene or polypropylene construction were detected in the soils and in a composite spice derived from packaged products, with the MP concentration greatest in the latter sample (0.1 MP g^{-1}). Although typical consumption of this material results in MP exposure that is lower than that arising from the dietary consumption fish and bottled water, for example, geophagy more generally may represent a more significant means of exposure for humans and animals that deliberately ingest geosolids.

Keywords: microplastics; geophagy; ingestion; pollution; contaminated food; Iran

1. Introduction

Geophagy is the deliberate consumption of natural geosolids, including soil, clay, dirt, ground rock and termite mound earth. The practice is common in many animals, including birds, invertebrates, reptiles and herbivorous and omnivorous mammals, and is believed to control gut pH and protect the gut lining, provide a source of essential trace minerals and detoxify secondary plant metabolites (Lozano, 1998; Engel, 2007). Geophagy is also practiced by many contemporary indigenous humans, perhaps for nutritional or detoxification purposes (Henry and Cring, 2013), while the psychological disorder, pica, may involve the deliberate human consumption of geosolids (Calabrese and Stanek, 1992).

Human geophagy may also arise more indirectly through the use of soils for culinary purposes. On Hormoz (or Hormuz), a small arid island in the Persian Gulf off the coast of Iran (area = 42 km^2; population ~ 6000; Figure 1), red ochre deposits located along the southern coastline and consisting of ferric oxide and smaller quantities of aluminosilicates and carbonates (Alipour et al., 2017), have been employed as a "spice" in the flavouring of food for centuries. Here, soil is mixed with salt and added directly to fish as a marinade or is allowed to settle out of suspensions in water to prepare sauces or make bread.

In the present study, we hypothesize that the ochre deposits on the island, like soils more commonly, contain microplastics (MPs; Zhang and Liu, 2018; Boots et al., 2019). Accordingly, use of the material for food flavouring may act as a vehicle for the dietary intake of MPs amongst the local population and visiting tourists. More generally, geophagy may represent a means by which MPs are ingested by humans with pica and by a wide variety of animals.

2. Materials and Methods

2.1. Sample collection and microplastic extraction

Five samples of red soil were considered in the study. Four samples (S1 to S4) were collected using a stainless steel trowel from ochre deposits (to a depth of 20 cm) on the south of Hormoz island, while one sample (S5) was purchased from a local trader as a series of pre-packaged spices for cooking purposes (Figure 1).

MPs were extracted and characterized under clean working conditions and with consideration of appropriate controls according to established methods (Abbasi and Turner, 2021). Briefly, about 100 mL of S1 to S4 were transferred to individual glass beakers using a steel spoon and air-dried for 24 h at 25^{o}C in a custom-built cleanroom. Dried samples were passed through a 5-mm stainless steel mesh before being stored in clean glass beakers covered with Al foil. The purchased spices (S5) were already fine and powdery, having been sifted and processed, and a 100 g composite was prepared from different packets in a clean, Al-covered glass jar.

Organic matter was digested in 100-g samples with 200 mL of 30% hydrogen peroxide (Arman Sina, Tehran) for seven days at room temperature and remaining particulate matter was washed using deionized water and dried in a sand bath at 60°C for 2 h. MPs were separated by flotation in a saturated solution of $ZnCl_2$ (Arman Sina, Tehran; density 1.6 – 1.8 g cm^{-3}), with the decanted contents subsequently centrifuged at 4000 rpm and filtered through 2 μm pore size S&S filter papers (blue band, grade 589/3). Filters were air-dried for 48 h at 25^{o}C in a clean room and transferred to Petri dishes for characterization.

2.2. Microplastic identification and characterization

MP were identified and characterized under a Carl-Zeiss binocular microscope at 200-x magnification using a 250 µm steel probe and ImageJ software. Identification was based on shininess, hardness and surface structure, size was scaled according to length, L ($L \leq 100$ µm, $100 < L \leq 250$ µm, $250 < L \leq 500$ µm, $500 < L \leq 1000$ µm, $1000 < L \leq 5000$ µm), colour was categorized as black-grey, yellow-orange, white-transparent, red-pink or blue-green, and shape was classified as fibre, pellet-granule or fragment-flake.

Polymeric composition was determined on 11 MPs from different locations and of different colour and size using a micro-Raman spectrometer (LabRAM HR, Horiba, Japan) with a laser of 785 nm and Raman shift of 400-1800 cm^{-1}.

3. Results and Discussion

The number of MPs in the five 100-g soil samples along with their size distributions are shown in Table 1. Despite the protected and pristine nature of the island, MPs were observed in all samples, with numbers ranging from two in S4 to ten in S5 and totalling 27. All MPs were of a fibrous nature, as exemplified by the microscopic images in Figure 2, with each length category from $\leq$ 100 µm to > 1000 µm represented. The greatest number of MPs observed in the composite derived from packaged spices may arise from the processing of a larger quantity of material into a powdery, palatable form, or material contamination from clothing or other textiles during its manual preparation.

The most abundant colours among the fibres were black-grey (n = 13) and red-pink (n = 9), although it is unclear whether the latter colour is an inherent property of the plastics or surface contamination arising from the ambient red soil. Four polymer types were identified among the 11 microfibers analysed: polyethylene terephthalate (*n* = 5); Nylon (*n* = 3); polystyrene (*n* = 2); polypropylene (*n* = 1); with examples of sample and matched library Raman spectra shown in Figure 3.

Concentrations of MPs in Hormoz range from 0.02 to 0.1 per g of sieved soil, with an average of about 0.05 MP g^{-1}. These concentrations are similar to those encountered in remote Tibetan plateau soils reported by Feng et al. (2020) (0.02 to 0.11 MP g^{-1}) but are an order of magnitude lower than concentrations reported in soils from other remote regions (e.g., Scheurer and Bigalke, 2018; Corrandini et al., 2021). The most likely reason for the discrepancy is that the soils on Hormoz are not impacted by MPs carried by river systems (de Villiers, 2019; Jiang et al., 2019). Possible origins of fibrous MP on the island are related to textiles and fabrics worn or used by local people or tourists and/or atmospheric deposition from more regional and distal sources. Given the location of the island, MPs may be transported from more industrialized and urbanized areas to the north via regional air masses (Brahney et al., 2020) and, indirectly, from the ocean to the south via bubble burst ejection and wave action (Allen et al., 2020).

MPs have been detected in a variety of drinks and foodstuffs for human consumption, including tap and bottled waters, milk, fish and shellfish, and salt, with sources attributed to acquisition from the environment as well as contamination during preparation and storage (Mortensen et al., 2021). Given the quantities consumed as part of the human diet and the abiotic nature of its formation, soil from Hormoz is most comparable with table salt, and in particular that derived from rock salt. Yang et al. (2015) detected up to 0.2 MP g^{-1} of rock and well salts purchased in China and, consistent with the present study, the majority of particles were of a fibrous nature ranging from < 100 μm to > 1000 μm in length. The authors suggested that MPs were introduced to deposits from the atmosphere and to material during its collection and packaging. Assuming that the maximum daily consumption of salt by a typical adult (~ 5 g) is similar to the daily intake of soil-derived spices on the island of Hormoz, the annual consumption of MPs by the latter route, at least within the size range considered and detected, is predicted to be about 200. This is considerably lower than the human ingestion of MPs through a broader diet consisting of the consumption of bottled water or seafood, for example (van Cauwenberghe and Janssen, 2014; Oßmann et al., 2018). However, the typical means of cooking with spices are likely to result in burning of MPs and exposure to additional, potentially harmful chemicals (Ghosh, 2016).

More generally, the impacts arising from human and animal MP ingestion are unclear and are the topic of ongoing research and debate (Welle and Franz, 2018; Schwabl et al., 2019; Banerjee and Shelver, 2021; Rahman et al., 2021).

4. Conclusions

Fibrous MPs at concentrations up to 0.1 per g are encountered in iron-rich soils from the island of Hormoz that are used to prepare food and in packaged food derived from these soils. Typical consumption of this material results in MP exposure that is lower than that arising from the dietary consumption fish and bottled water, for example. However, geophagy may represent a more significant means of exposure for specific receptor groups, like individuals suffering from pica and indigenous populations and animals that deliberately ingest soils.

Acknowledgments

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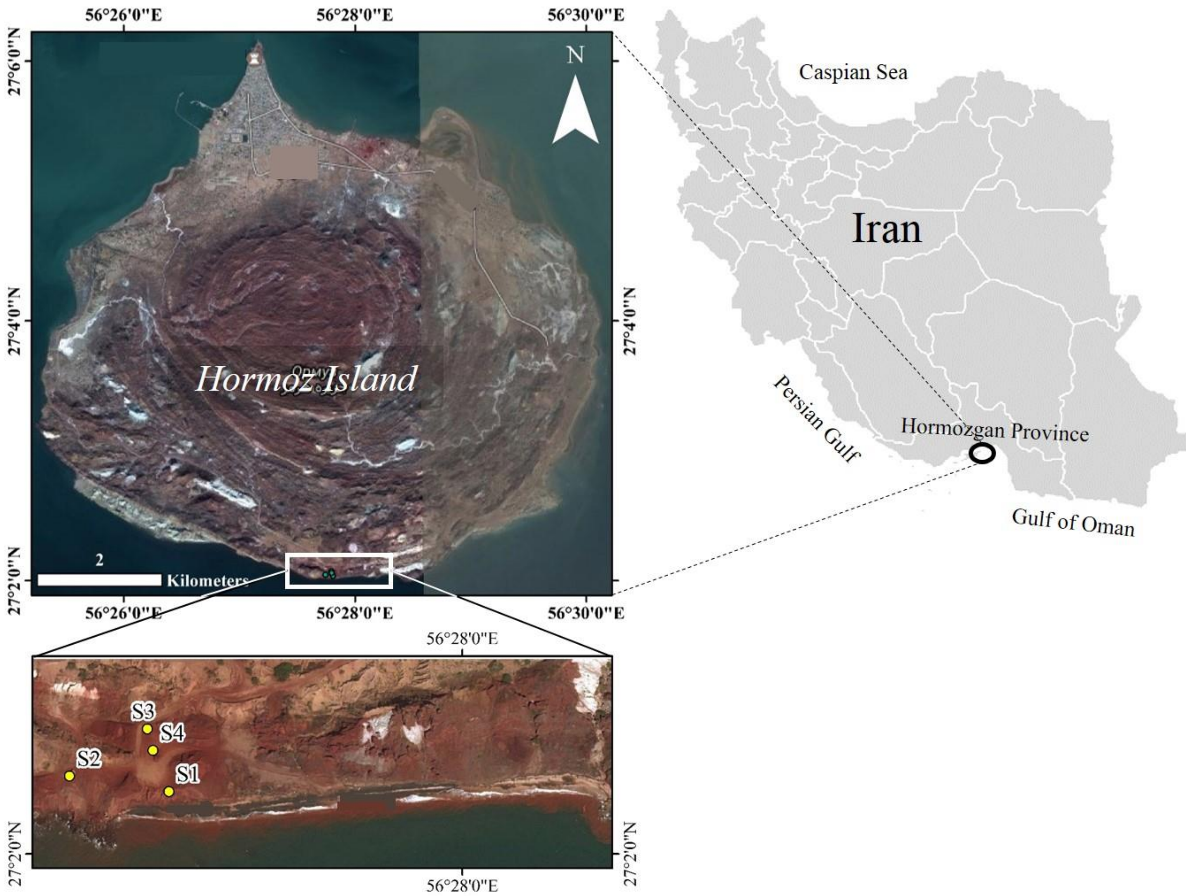


Figure 1: Locations of the soil samples taken from Hormoz Island. Note that one sample (S5) was purchased from a local trader as a series of pre-packaged spices for cooking purposes.

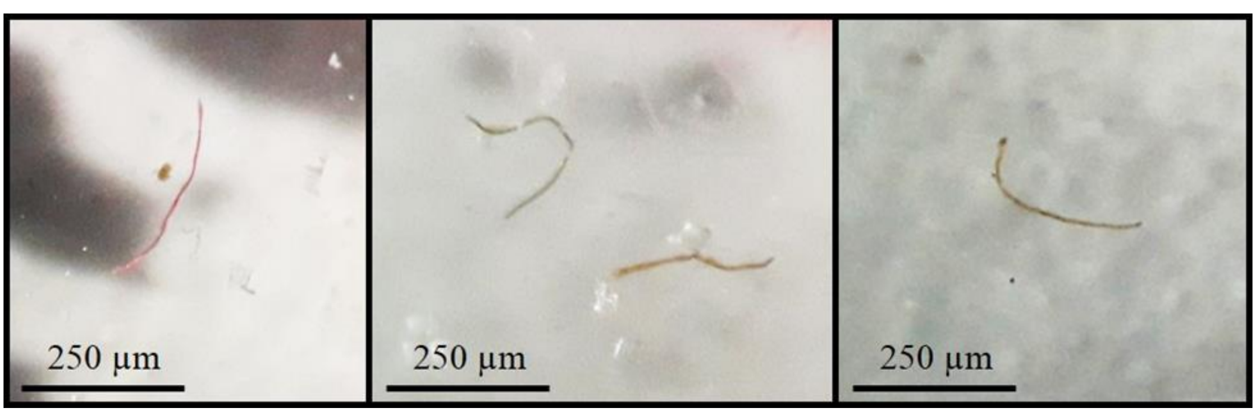
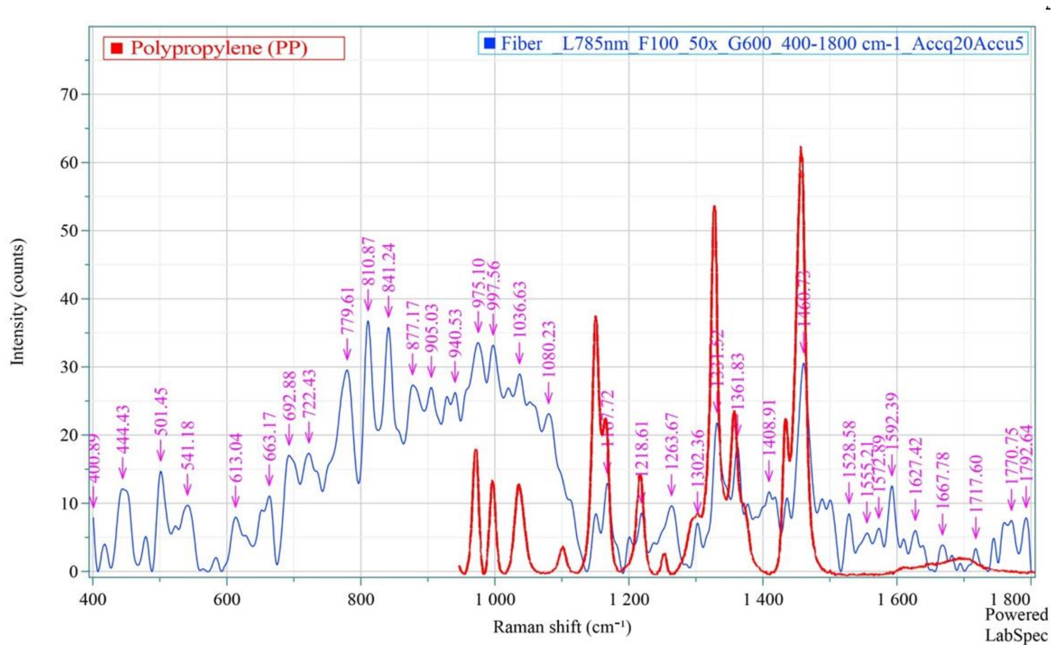


Figure 2: Examples of fibrous MPs retrieved from the soil samples and viewed under a binocular microscope.



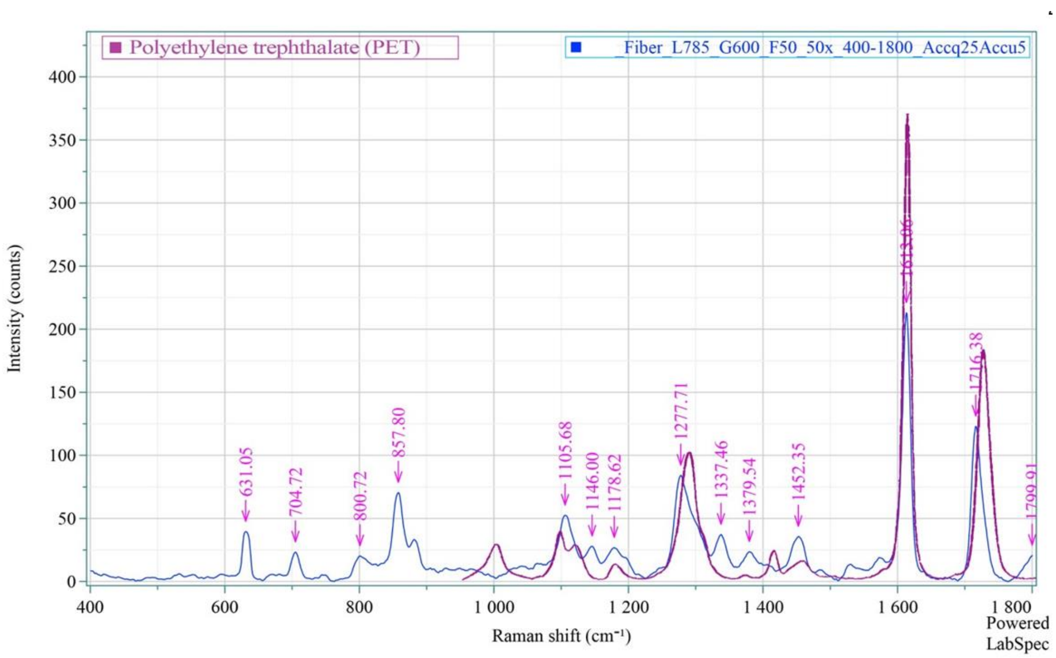


Figure 3: Raman spectra for two MP fibres along with matched library spectra.

Table 1: Number of MPs and their length distributions in the five soil samples.

Length, μm	S1	S2	S3	S4	S5	total
$L \leq 100$	0	1	0	0	3	4
$100 \leq L < 250$	2	1	3	1	2	9
$250 \leq L < 500$	1	2	1	1	3	8
$500 \leq L < 1000$	0	0	0	0	1	1
$1000 \leq L < 5000$	1	3	0	0	1	5
total	4	7	4	2	10	27