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Offshore surface waters of Antarctica are free of microplastics, as revealed by a circum-Antarctic study.

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ABSTRACT

In 2018, during a circumnavigation of Antarctica below 62° S by the sailing boat Katharsis II, the presence of plastics was investigated with surface sampling nets at ten evenly spaced locations (every 36° of longitude). Although fibres that appeared to be plastic (particles up to 2 cm) were found in numbers ranging from 1 particle (0.002 particles per m^3) to 171 particles (1.366 particles per m^3) per station, a Fourier-transform infrared spectroscopy (FT-IR) analysis indicated that these particles were not composed of plastic. The fibres which superficially reminded plastic were composed of silica and are of biological origin most likely generated by phytoplankton (diatoms). Therefore, the offshore Antarctic locations were proven to be free of floating microplastics.

Key words: Antarctic, Southern Ocean, pollution, microplastic, surface waters

Currently, pollution caused by plastics is the focus of media attention. This coverage has very efficiently increased the public's awareness of the problem. There is no doubt that it is time to have a global discussion about the influence of plastics on our ecosystems, as plastics have been discovered in every investigated location. In this century, plastics have been discovered in the most remote marine habitats on the planet, including deep-sea sediments (Tekman et al. 2017) and Arctic ice (Bergmann et al. 2017). With current knowledge, there are still debates about whether plastics have an impact on marine life (see Guzzetti et al. 2018). Plastics were found to be ingested by various organisms, including both invertebrates and vertebrates (e.g., Wright et al 2013, Besseling et al. 2015, Law 2017, Fang et al. 2018, Hernandez-Gonzalez et al. 2018, McGoran et al. 2018). Marine biota were found to be entangled in floating macroplastic products (Barnes et al. 2010, Waluda and Staniland 2013). Tiny fragments of degraded plastics can carry toxins (Guzzetti et al. 2018). As plastics are ingested by organisms from various trophic levels, they might be transferred through food chains (Wright et al 2013, Guzzetti et al. 2018). Therefore, plastics is a quickly emerging problem for humans as a broad pollution issue (Wright et al 2013, Law 2017, Guzzetti et al. 2018).

Antarctic is still considered the most pristine environment on Earth. Humans' impact here is still probably the lowest on the planet, as our density in that area is low and very localized (mostly limited to research bases). In addition, the Antarctic continent, which is surrounded by the Southern Ocean, is isolated from the rest of the world by a convergence zone (a transition between cold Antarctic surface waters and warmer sub-Antarctic water masses), which effectively bars marine life and pollutants exchange from more industrialized areas in lower latitudes (Foster 1984, Chown et al. 2015). One would believe that these factors make the area immune to human impact. Although recent studies indicate that Southern Ocean is not biologically isolated as previously it was believed. It was found that storm-forced surface waves and ocean eddies can enhance oceanographic connectivity between Antarctica and mid-latitudes (Fraser et al. 2018). Since the 1960s, DDT (dichlorodiphenyltrichloroethane) and, later, PCBs (polychlorinated biphenyls) have been found in Antarctica (Risebrough et al. 1976, Bonner 1984). Some pollutants are global in nature, and plastics seem to be one of them. Indeed, plastics are being discovered around the globe, including in the Arctic and Antarctic marine environments (see Lusher et al. 2015, Isobe et al. 2017, Waller et al. 2017 or Kanhai et al. 2018 and the references therein).

In recent years, plastics were not only discovered at locations in Antarctic, such as the Antarctic Peninsula, where the human population is highest and the area is closest to other continents (South America) (see Waller et al. 2017), but also in such remote locations such as in the inner basin of the Ross Sea (Cincinelli et al. 2017, Munari et al. 2017). The highest density of plastics in Antarctic was recorded around the Antarctic Peninsula (Waller et al. 2017), which is most likely due to the effect of the higher sampling effort in the area compared to the rest of the Southern Ocean. However, we cannot rule out that this observation is the effect of higher human activity in that sector.

The goal of this investigation was to study the potential presence of microplastic particles (particles less than 5 mm in size, as defined by the National Oceanic and Atmospheric Administration [NOAA]) in the surface waters of the Southern Ocean. The study aimed to locate sampling sites around the whole continent, ranging from areas with relatively higher human populations, such as the Antarctic Peninsula (due to research, fishing and tourism), to areas where humans were likely never present or were only sporadically present: offshore open ocean.

This investigation collected samples during the first ever successful human attempt to circumnavigate the Antarctic continent south of the 62nd parallel by sailing boat (Katharsis II). The cruise started on 23.12.2017 in Cape Town, South Africa and finished on 05.04.2018 in Hobart, Australia. Ten sampling locations were selected within the convergent zone between 63° and 69° S (Fig. 1, Table 1). The first station was selected when the boat crossed 63° S, and weather-permitting, evenly distributed samples were taken around the Antarctic continent at approximately every 36° of longitude (Fig. 1, Table 1).

Samples were obtained by using a specifically designed Hydro-Bios net for microplastic sampling with lifting buoys (product no. 438 214). The opening of the net was 70 x 40 cm, and the mesh size was 300 µm. We aimed for 30 minutes of net towing behind the boat at 1 to 2 knots, depending on wind conditions, but everything had to be modified according to the ice, wind and algal bloom conditions. At stations 3, 4 and 6, algal blooms clogged the net; therefore, the net was towed for 10 minutes. The date, time and location of start and end point of the net towing as well as speed of the boat during the sampling were recorded with GPS, enabling the estimation of the water volume sampled by the net. All these data are summarized in Table 1.

All the samples were concentrated on board the boat immediately after sampling by filtering the collected samples through a metal sieve (mesh size of 200 µm) and then by using a metal funnel placed in a glass borax bottle. Although these bottles had plastic leads, they were bright blue, which made any contamination easy to recognize. Therefore we took all possible precautions to avoid self-contamination with plastic. The water samples were preserved in 2% formalin.

All the samples taken in Antarctic were analysed in the laboratory by a single investigator to ensure consistent treatment and no introduction of bias into the analysis. In the laboratory, all the samples were treated with hydrogen peroxide (30% H_2O_2), which is an oxidizing agent that enables the digestion of organic matter with no degradation of plastic polymers (Nuelle et al. 2014). The samples treated with hydrogen peroxide were kept in the oven for 24 hours at 60° C and then left in the bottles for one week at room temperature to ensure the digestion of the largest amount of organic matter. The samples were examined visually by using a stereomicroscope equipped with a fluorescent light, enabling the efficient exclusion of organic particles (Qiu et al. 2016). The microplastic contamination was quantified by counting. Fibres which were found in the samples were measured using an eye piece with graticules (± 0.1 cm) and were classified according to size: (i) 0-0.5 cm, (ii) 0.5-1.0 cm, and (iii) longer than 1 cm.

Laboratory equipment made only of glass and metal was used to ensure the lack of contamination by local sources of plastics. The analysis was performed only when the person analysing the samples was present alone in the laboratory. This procedure was also performed to reduce the probability of the potential contamination of the samples. Additionally, before each Antarctic sample was analysed, a control sample was prepared by using local tap water and all laboratory equipment used in the Antarctic sample analyses. All procedures were performed in the laboratory where the Antarctic samples were analysed. Such an approach was applied to analyse whether the laboratory conditions and the analytic procedures contaminated the samples with plastic particles. During that procedure, no particles of any type were detected.

A Fourier-transform infrared spectroscopy (FT-IR) analysis of the samples was performed with a Frontier FT-IR (PerkinElmer) instrument. The measurements were carried out in an attenuated total reflectance (ATR) configuration with ZnSe cells. The tests were performed at 25 °C in dry air. Particles were identified by comparing the FT-IR absorbance spectra of the microplastics to those in a self-collected, polymer reference library.

Generally, the whole methodology followed that described in Nuelle at al. (2014), Qiu et al. (2016), and Prata et al. (2019).

In total, 3147.7 m^3 of surface water was filtered by the deployed net at the ten sampling sites (Table 1). Within this water volume, 488 transparent fibres that appeared to be plastic were recorded (Table 2). Fibres were present at all ten investigated locations (Table 2). The fibres glowed during the examination with fluorescent light, which suggested that they were made of plastic. Although this methodology enables the exclusion of organic particles, Fourier-transform infrared spectroscopy (FT-IR) analysis confirmed that these particles were not plastic fibres. All together 107 particles were randomly selected from the samples and analysed with FT-IR. The fibres that often exceeded the defined microplastic size (above 5 mm) ranged from 1 particles (0.002 particles per m^3) to 171 particles (1.366 particles per m^3) per station with overall mean concentration for all the stations 48.8 ± 62.81 (standard deviation) (0.262 ± 0.435 particles per m^3) (Table 2). Detailed analysis of obtained FT-IR spectrum of the fibres indicated organic origin (silica) of these (Fig. 2). And as comparison of the FT-IR spectrum with literature source shows (Camargo et al. 2016) these fibres originate from planktonic algae – diatoms which could generate those types of structures. Therefore fibre density and size from station to station probably exhibits local abundance of these organisms during period of our sampling.

Based on the obtained results, as sampling sites were rather evenly spread around the Antarctic continent (Fig. 1, Table 1), we can assume that microplastics might still be absent in the offshore marine system of Antarctica, at least at the locations covered by this study. Even the area around the Antarctic Peninsula, which has the most tourist boat traffic, the highest density of research bases (Hansom and Gordon 1998) and is potentially the area most polluted with all types of plastic, had no traces of microplastic in the samples. Yet we had just one sampling station next to Antarctic Peninsula (station no 7) therefore more intense sampling effort is needed to confirm whether surface offshore waters are free of microplastic,

Our results are surprising, as each previous investigation of the Southern Ocean recorded the presence of microplastics. The locations where microplastics were recorded in the Southern Ocean range from along the Antarctic Peninsula to remote locations in the Ross Sea as well as the open waters of the Southern Ocean (see Cincinelli et al. 2017, Isobe et al. 2017, Munaria et al. 2017, Waller et al. 2017, Reed et al. 2018). Even a study by Isobe et al. (2017), which included sampling the open waters of the Southern Ocean with a similar methodology to ours (i.e., a surface net and a comparable volume of water sampled), recorded the presence of plastics. At locations below 60° S, Isobe et al. (2017) recorded concentrations of particles ranging from 0.046 to 0.099 particles per m^3 at selected locations. Generally, those values are rather low compared with the amount of microplastics found elsewhere in the world ocean, especially in marine zones close to more industrialized areas (see Wright et al 2013, Isobe et al. 2017 and the references therein). Currently, plastics in Antarctica, especially microplastics, are mostly concentrated close to locations with direct, intense human activities (e.g., the Antarctic Peninsula) (Waller et al. 2017). Therefore more investigations are needed to recognize scale of this pollution in the Southern Ocean. Additionally, this study indicates that materials that visually appear to be plastic must be analysed with specialized equipment (e.g., FT-IR) before drawing final conclusions concerning the composition of the material.

The sampling took place during the successful, first-ever circumnavigation of the Antarctic continent below 62° S by sailing boat. This study is an example of a positive citizen-science activity that can generate valuable data.

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Author contributions

PK conceived of and designed the study and analysed the data. PK, MK, TG, HL, MB, MT, IK, RK and WM collected samples. LW performed the Fourier-transform infrared spectroscopy (FT-IR) analysis. The paper was written by PK and LW and was approved by all authors: PK, MK, TG, HL, MB, MT, IK, RK and WM.

Conflicts of interest

The authors express no conflicts of interest, neither direct nor indirect, in the publication of this manuscript. All funding sources have been referenced in the manuscript.

Author declaration

All authors have approved the submission of this manuscript, which is an original work conducted by all the authors and has not been published prior to its submission. It is not under consideration by any other publishers.

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Fig. 1. Schematic view of the expedition route of the sailing boat Katharsis II with the location of sampling sites (for detailed coordinates, see Table 1), map sourced and modified from https://data.aad.gov.au.

Fig 2. Chemical and optical characterization of fibres sampled during this study (black line) and phytoplankton group Bacillariophyta - diatoms (grey line) obtained from literature (Camargo et al. 2016). Spectrum obtained with use of a Fourier-transform infrared spectroscopy in an attenuated total reflectance.

Table 1. Sampling locations with detailed timing information, the coordinates of the starting and ending points of the net deployment and the volume of samples (n/a – data not available due to a GPS malfunction).

Table 2. Quantitative fibre spectrum sizes found at each sampling location. Fibres within the size class “longer than 1 cm” never exceeded 2 cm (n/a – data not available due to a GPS malfunction, for details on the sampling sites see Fig. 1 and Table 1).

Table 1

Station no	**Date of sampling**	**Latitude**	**Longtitude**	**Time (local)**	**Volume of water filtered by sampling net [m^3]**
1	10.01.2018	start: 63° 27' 31.0'' S end: 63° 27' 35.7'' S	start: 82° 47' 08.2'' E end: 82° 49' 05.1'' E	16:25 16:57	448.0
2	21.01.2018	start: 63° 49' 22.8'' S end: 63° 49' 28.6'' S	start: 118° 43' 05.5'' E end: 118° 44' 48.1'' E	08:28 08:58	392.0
3	28.01.2018	start: 65° 32' 30.9'' S end: 65° 31' 33.7'' S	start: 155° 28' 50.8'' E end: 155° 28' 48.6'' E	05:27 05:42	504.0
4	03.02.2018	start: 68° 42' 45.9'' S end: 68° 42' 49.3'' S	start: 171° 48' 40.0'' W end: 171° 48' 05.7'' W	16:42 16:53	111.4
5	08.02.2018	start: n.a. end: 69° 45' 25.7'' S	start: n.a. 133° 09' 18.4'' W	15:30 16:00	n.a.
6	14.02.2018	start: 67° 17' 44.9'' S end: 67° 17' 57.5'' S	start: 98° 21' 17.7'' W end: 98° 20' 59.3'' W	05:29 05:41	125.2
7	23.02.2018	start: 63° 23' 42.2'' S end: 63° 23' 35.5'' S	start: 60° 53' 56.4'' W end: 60° 52' 20.6'' W	04:23 04:54	364.0
8	02.03.2018	start: 65° 39' 07.2'' S end: 65° 38' 47.7'' S	start: 24° 05' 59.8'' W end: 24° 05' 07.7'' W	03:20 03:50	251.2
9	08.03.2018	start: 67° 47' 48.2'' S end: 67° 48' 33.8'' S	start: 11° 15' 18.4'' E end: 11° 16' 18.1'' E	16:34 17:05	448.0
10	17.03.2018	start: 63° 42' 21.7'' S end: 63° 41' 57.1'' S	start: 46° 49' 42.3'' E end: 46° 51' 41.4'' E	04:29 05:03	504.0

Table 2

Station no	Fibres < 0.5 cm (per m^3)	Fibres 0.5 - 1.0 cm (per m^3)	Fibres > 1.0 cm (per m^3)
1	1 (0.002)		
2		74 (0.188)	5 (0.012)
3	1 (0.001)		2 (0.003)
4	6 (0.053)		
5		19 (n.a.)	1 (n.a.)
6		171 (1.366)	
7			1 (0.002)
8		162 (0.645)	
9		14 (0.031)	2 (0.004)
10	19 (0.037)	10 (0.019)	
Total number of fibres (per m^3)	27 (0.091)	450 (2.249)	11 (0.021)

Figure 1
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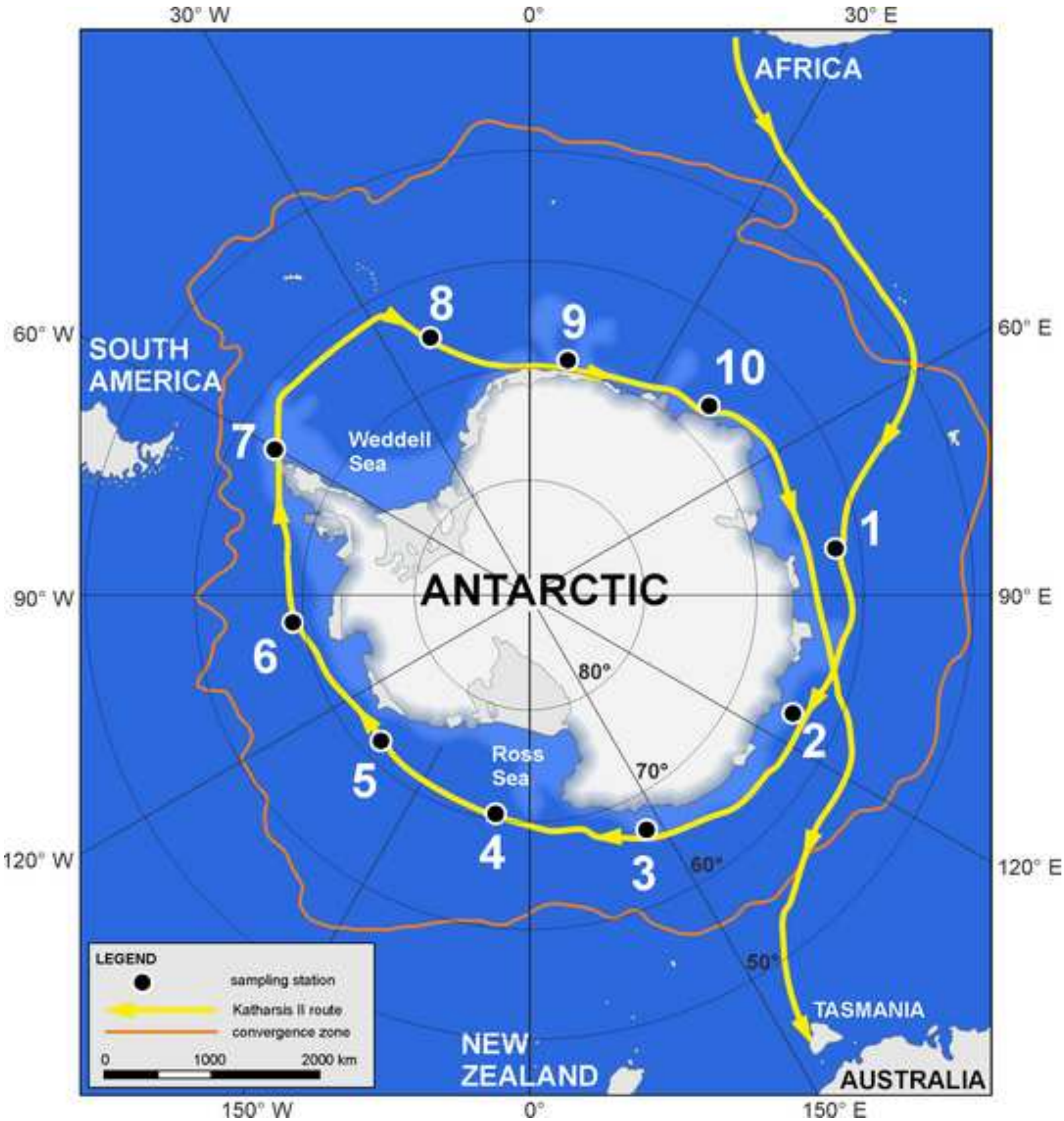

Figure 2
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