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Deep sea sediments of the Arctic Central Basin: A potential sink for microplastics

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Abstract

Deep sea sediments have in the past decade emerged as a potential sink for microplastics in the marine environment. The discovery of microplastics in various environmental compartments of the Arctic Central Basin (ACB) suggested that these contaminants were potentially being transported to the deep-sea realm of this oceanic basin. For the first time, the present study conducted a preliminary assessment to determine whether microplastics were present in surficial sediments from the ACB. Gravity and piston corers were used to retrieve sediments from depths of 855 – 4353 m at 11 sites in the ACB during the Arctic Ocean 2016 (AO16) expedition. Surficial sediments from the various cores were subjected to density flotation with sodium tungstate dihydrate solution ($Na_2WO_4.2H_2O$, density 1.4 g cm^{-3}). Potential microplastics were isolated and analysed by Fourier Transform Infrared (FT-IR) spectroscopy. Of the surficial samples, 7 of the 11 samples contained synthetic polymers which included polyester (n = 3), polystyrene (n = 2),

polyacrylonitrile (n = 1), polypropylene (n = 1), polyvinyl chloride (n = 1) and polyamide (n = 1). Fibres (n = 5) and fragments (n = 4) were recorded in the samples. In order to avoid mis-interpretation, these findings must be taken in the context that (i) sampling equipment did not guarantee retrieval of undisturbed surficial sediments, (ii) low sample volumes were analysed (~ 10 g per site), (iii) replicate sediment samples per site was not possible, (iv) no air contamination checks were included during sampling and, (v) particles <100 µm were automatically excluded from analysis. While the present study provides some preliminary indication that microplastics may be accumulating in the deep-sea realm of the ACB, further work is necessary to assess microplastic abundance, distribution and composition in surficial sediments of the ACB.

Keywords: Microplastic, Marine debris, Arctic Ocean, Sediment, Deep Sea

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1. Introduction

Microplastics are pervasive, persistent contaminants in the world's oceans that warrant concern due to the potential threat they pose to marine organisms. Traditionally, microplastic sampling has been conducted in surface and near-surface waters due to the presumption that the majority of microplastics would be present in that layer of the water column. However, when plastic production and projected plastic input to the ocean was considered, there was an evident mismatch between reported and expected plastic concentrations in surface oceanic waters (Cózar et al. 2014; Eriksen et al. 2014). It was therefore apparent that apart from surface waters, microplastics were present in various environmental compartments in the world's oceans (water column, sea ice, sediments, biota) and that some of these potentially functioned as sinks (Obbard et al. 2014; Woodall et al. 2014). Deep sea sediments have recently been identified as a potential sink for microplastics (Woodall et al. 2014; Bergmann et al. 2017). To date, only a few studies have reported on microplastics in deep sea sediments in various oceanic basins (Van Cauwenberghe et al. 2013; Woodall et al. 2014; Fischer et al. 2015; Bergmann et al. 2017). Despite the fact that each of these studies employed different sampling equipment, extraction techniques and reported microplastic abundance in different units, the consensus was that microplastics have made it to the deep-sea and that they are pervasive in its sediments. Presently, uncertainty still exists regarding

the exact mechanisms that are responsible for the vertical transport of microplastics out of surface oceanic waters and into deep sea sediments.

The Arctic Ocean, though one of the most remote oceanic basins in the world, has been subject to the entry of plastic debris into its ecosystem. It has been suggested that this plastic debris, in particular microplastics, could have entered the Arctic ecosystem via a combination of (i) long-range transport processes, e.g. via oceanic currents (Zarfl and Matthies 2010; van Sebille et al. 2012), biotransport (Mallory 2008; Provencher et al. 2012) and riverine input (Obbard et al. 2014) and, (ii) local anthropogenic activities, e.g. shipping (Tekmann et al. 2017). Specifically, microplastics were discovered in the surface/sub-surface waters and sediments (Lusher et al. 2015; Bergmann et al. 2017; Cózar et al. 2017; Mu et al. 2019) of the Arctic. Further north, in the Arctic Central Basin (ACB), microplastics were recorded in sea ice, biota, such as juvenile polar cod (*Boreogadus saida*) and benthic organisms, and sub-surface waters (Obbard et al. 2014; Kanhai et al. 2018; Kuhn et al. 2018; Peeken et al. 2018; Fang et al. 2018). The fact that microplastics have been reported in the various water layers of the ACB, in particular its deep waters, suggests that these particles are pervasive in the water column and that they are being transported out of its surface waters (Kanhai et al. 2018). It was therefore hypothesized that microplastics would be present in deep sea sediments in the ACB. To our knowledge, the present study sought for the first time to determine whether microplastics were present in surficial sediments of the Arctic Central Basin (ACB) and to establish whether the deep sea in this oceanic basin is possibly acting as a sink for microplastics.

2. Material and methods

The Arctic Ocean, the world's smallest ocean, is comprised of a deep central basin surrounded by extensive continental shelves. The bathymetry of the Arctic Ocean is such that the Lomonosov Ridge divides the central basin into the Canadian (Amerasian) and Eurasian sub-basins (Jakobsson et al. 2004). Within each of the sub-basins, there are further divisions as well as the existence of Abyssal Plains (APs) which are deep water areas of low relief. In the Amerasian basin, the Alpha-Mendeleev Ridge separates the Canada Basin (with its Canadian AP) and the Makarov Basin (with its Fletcher AP) while in the Eurasian basin, the Gakkel Ridge separates the Amundsen Basin (with its Pole AP) and the Nansen Basin (with its Barents AP), (Jakobsson et al. 2004).

This study was conducted onboard the Swedish icebreaker Oden between August 8th to September 19th 2016 during the Arctic Ocean 2016 expedition. During the transit of 4943 nautical miles, sediments were retrieved using a gravity corer or a piston corer with an associated trigger weight corer. Cores from 11 stations were sampled for microplastics (Supplementary Table 1, Figure 1).

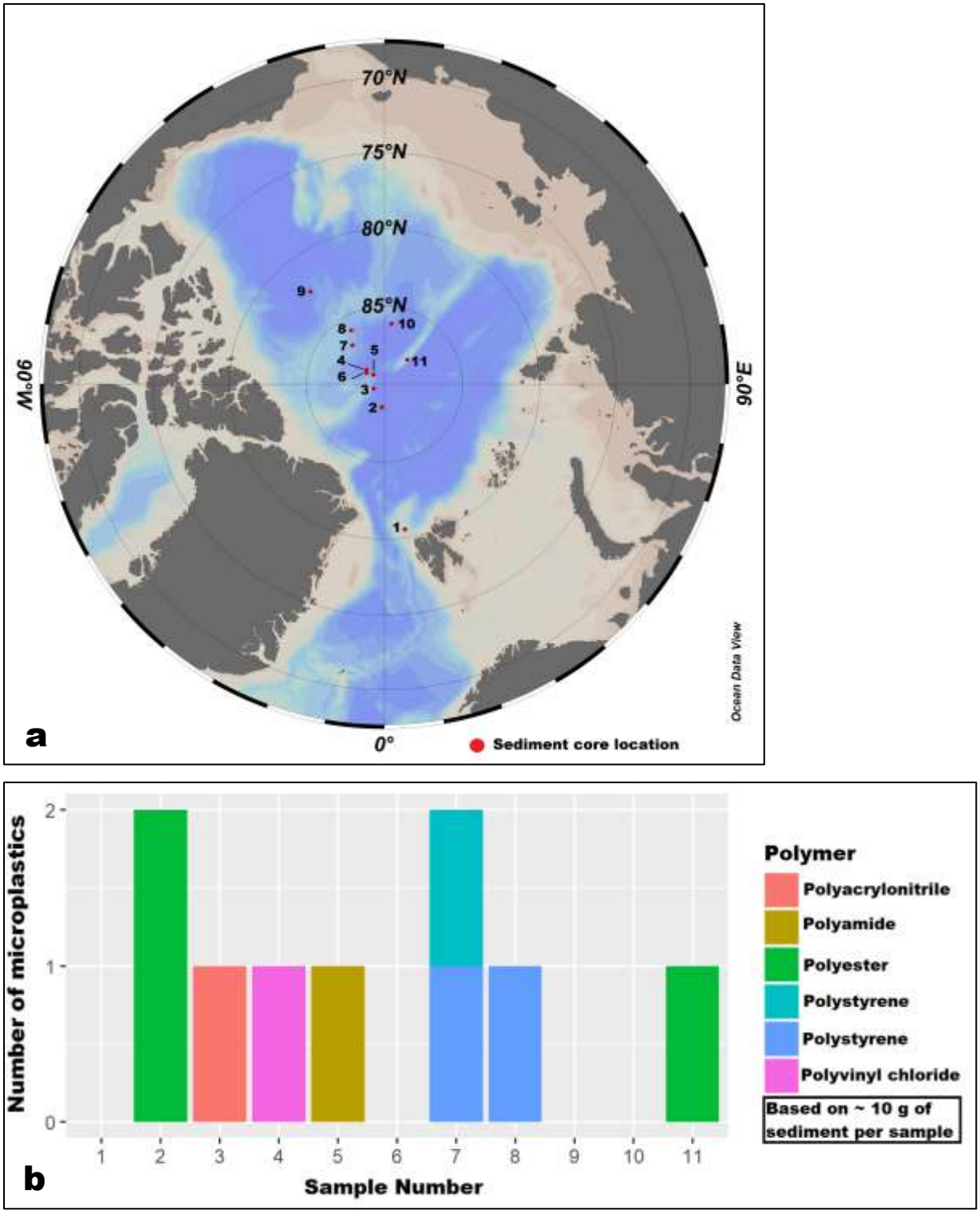

Figure 1: Locations at which sediment cores were collected in the Arctic Central Basin (a) and synthetic polymer composition in surficial sediments from the various cores (b).

[Figure 1a generated using Ocean Data View (ODV) Version 4.7.10 (Schlitzer 2017); Figure 1b generated using R version 3.4.4 (R Core Team 2018)]

Cores were split, wrapped in plastic film (polyethylene) and transported to the laboratory where they were processed prior to sampling for microplastics. Processing usually involved (i) scraping the core half (with a polypropylene scraper) to remove liner fragments and sediment disturbed during core splitting and, (ii) visually describing the lithostratigraphic properties. Sheer strength measurements, sediment pH and samples for paleomagnetic measurements were taken prior to microplastic sampling for four of the eleven cores (gravity and piston cores). Approximately 10 cm^3 of sediment was sampled from the top 2 cm of the working half of each core using a scoop (polypropylene). Sediment samples were placed into clean, labelled plastic bags (polyethylene) and stored in a freezer (-20°C).

Although it is acknowledged that such a low volume of sediment may not be representative of sediments at individual sampling stations, the sampling technique used in the present study, i.e. coring, limited the volume of sediment that was available per site. Precautions taken onboard the ship to limit cross-contamination included (i) minimal exposure of the sediment samples to the atmosphere, (ii) samples collected/stored in new materials (scoops, bags) and, (iii) sampling conducted by one individual. A record was also kept of all plastic materials that came into contact with the sample during collection and processing. One limitation was that no air contamination check was included during sediment sampling onboard the vessel.

In the laboratory, sediments were defrosted, transferred into clean covered aluminium foil trays and oven dried at 60°C for approximately 96 hours. Approximately 10 g of oven-dried sediment was weighed and placed into a pre-cleaned glass jar. 105 mL of sodium tungstate dihydrate ($Na_2WO_4.2H_2O$, 40 % w/v, density 1.4 g cm^{-3}), as recommended by Frias et al. (2018) and Pagter et al. (2018), was added to each glass jar, the mixture was shaken for approximately 1 minute and the sediments were allowed to settle. From each sample jar, the overlying sodium tungstate dihydrate solution was removed using a pipette and filtered under vacuum onto glass microfiber paper (GF/C), Whatman 47 mm, pore size 1.2 µm, using a Buchner funnel and an Erlenmeyer flask. Minimal volumes of ultrapure water (< 2 mL) were used to wash down the sides of the glass jars with the sediments. Introducing water into the remaining extraction solution can lead to a change in the density of the solution and thus this was minimised. Ultrapure water was also used

to wash the pipette and sides of the Buchner funnel. Filter papers for the samples were placed into clean petri dishes and stored until analysis. Potential contamination was evaluated by using (i) air contamination checks-clean petri dishes with filter paper (n = 2) were exposed to the air during sample processing and, (ii) method blanks-jars devoid of sediment (n = 2) were processed in the same manner as actual samples. Measures taken to prevent contamination in the laboratory included (i) wearing lab coats and gloves during sample processing and, (ii) washing all glass jars used during sample processing with a 6 % nitric acid solution and Ultra-pure water.

Filter papers were visually examined under a dissecting microscope (Olympus SZX10) equipped with a polariser and camera (Q Imaging Retiga 2000R). Potential microplastics were isolated and processed (photographed and length measurements taken) prior to transferring to a clean filter paper in a labelled petri dish (Kanhai et al. 2017). Due to the difficulties that arise when handling particles < 100 µm, such particles were automatically excluded for any analysis. All potential microplastics and any plastic material that was in direct contact with the samples either during sampling or laboratory processing were analysed by Fourier transform infrared (FT-IR) spectroscopy on a Bruker Vertex 70 Infrared Spectrometer coupled to a Hyperion 1000 microscope (Kanhai et al. 2017). Samples which produced spectra with a match < 60 % were automatically rejected while those which produced a match of > 70 % were accepted. All spectra with matches > 60 % were individually examined to ensure that there was clear evidence of peaks from the sample corresponding to known peaks of standard polymers.

3. Results

In the present study, the following plastic materials made direct contact with the sediment samples either during collection or processing (i) plastic film – low density polyethylene (LDPE), (ii) core liner – polyvinyl chloride (PVC) or polycarbonate (PC), (iii) scraper - polypropylene (PP), (iv) sediment collection scoop – polypropylene (PP) and, (v) sample bag – low density polyethylene (LDPE). In the surficial sediment samples, no polyethylene particles were recovered. However, in two instances, synthetic polymers from surficial sediments matched plastic materials used during sample processing but were not eliminated since they were of different colours than the materials used. This was so for 2 particles in sediment core 4 (single PVC fragment, different colour from liner) and sediment core 7 (polypropylene fragment, different colour from collection

scoop/scraper). To assess whether synthetic polymers were introduced during laboratory processing of the samples, air contamination checks (ACs), (n = 2), and method blanks (MBs), (n = 2), were included. No synthetic polymers were found in the air contamination blanks. However, a total of three fibres were found in the two method blanks (MB1 – blue polyester fibre, 1.28 mm; MB2 – blue polyester fibre, 0.49 mm and red polyester fibre, 0.53 mm). All samples were blank corrected such that if any blue or red polyester fibres were found in the sediment samples, they were removed from the final results.

Based on visual identification, fifteen particles from the sediment samples were isolated and subjected to FTIR spectroscopy. Of these, four were natural cellulosic fibres. The remaining eleven were identified as synthetic polymers with one macroplastic (> 5 mm) and ten microplastics (< 5 mm). After blank correction of the samples, there were a total of nine microplastics (<5 mm), (Supplementary Table 2). Synthetic polymers detected in the sediments included polyester (n = 3), polystyrene (n = 2), polyacrylonitrile (n = 1), polyamide (n = 1), polypropylene (n = 1) and polyvinyl chloride (n = 1). Both fibres (n = 5) and fragments (n = 4) were present in the samples. In terms of colour, most of the synthetic polymers were transparent (n = 5) with the remainder black (n = 1), brown (n = 1), white (n = 1) and blue (n = 1). With respect to length, most (n = 5) were < 1 mm, 3 were between 1 – 2 mm and 1 was > 2 mm. Of the surficial sediment samples analysed from the Arctic Central Basin (ACB), 7 of the 11 samples contained between 1 – 2 synthetic polymers (Figure 1b).

4. Discussion

Elucidation of the transport and fate of microplastics in the marine environment is a critical step towards assessing the threat that these contaminants potentially pose to organisms inhabiting different compartments of an ecosystem. In the Arctic Central Basin (ACB), only a few studies have reported on microplastic presence in the sea ice, biota and water column (Obbard et al. 2014; Kuhn et al. 2018; Kanhai et al. 2018; Peeken et al. 2018). Based on these studies, the key suggestions regarding microplastics in this oceanic basin are that (i) sea ice acts as a sink and means of transport for microplastics, and (ii) the pervasiveness of microplastics in the various water layers of the ACB indicates that there is vertical transport of microplastics out of surface waters into deeper waters (Obbard et al. 2014; Kanhai et al. 2018; Peeken et al. 2018). In context,

the findings of the present study expand the knowledge base about microplastics in the Arctic Ocean by providing preliminary information that suggests microplastics are present in surficial sediments of the Arctic Central Basin and that within this oceanic basin the sediment compartment is potentially acting as one of the sinks for microplastics. Microplastic presence on the seafloor of the ACB lends credence to the suggestion that there is vertical transport of microplastics within the water column. Laboratory and field studies have shown that marine organisms, such as zooplankton, larvaceans and other pelagic filter feeders, which are capable of ingesting microplastics and egesting them in their faecal pellets and discarded houses (as in the case of the larvaceans), could contribute to the vertical flux of microplastics in the water column when their waste products sink (Cole et al. 2016; Katija et al. 2017). The incorporation of microplastics into marine aggregates and the biofouling of microplastics are other processes which may influence the vertical transport of these particles in the water column (Long et al., 2015; Fazey and Ryan 2016).

The presence of microplastics in sediments of the Arctic Central Basin implies that interactions between these particles and deep-sea organisms that inhabit or depend upon this environmental phase is plausible. Although the Arctic Ocean has generally been regarded as oligotrophic, the fact remains that marine organisms do inhabit its' deep-water environment with the most speciose groups being arthropods, foraminiferans, annelids and nematodes (Bodil et al. 2011). Depending on the foraging behaviours and feeding habits of deep-sea benthos in the ACB, the possibility exists that some of them may be interacting with microplastics in the sediment phase. Recently, Fang et al. (2018) reported that microplastics were discovered in 11 different benthic species that were recovered from depths of 35 – 151 m in the Bering-Chukchi Sea shelves. Fibres were the predominant type of microplastics found in the organisms with synthetic polymers including polyamide, polyethylene, polyester and cellophane (Fang et al. 2018). Microplastics were also discovered in 3 different phyla (Echinodermata, Arthropoda, Cnidaria) of deep sea organisms recovered from depths of 334 – 1783 m in the equatorial mid-Atlantic and SW Indian Ocean (Taylor et al. 2016). Although the presence of a contaminant in the marine environment does not directly imply harm, laboratory experiments have indicated that benthic organisms exposed to microplastics in sediments may be negatively impacted. For example, Wright et al. (2013) reported that exposure of the deposit-feeding marine polychaete worm (*Arenicola marina*) to unplasticised

polyvinyl chloride (UPVC) led to a depletion in energy reserves of the worms which could have been caused by reduced feeding, longer gut residence time of ingested matter and inflammation.

The present study confirmed via FT-IR spectroscopy that polyesters were recovered from surficial sediments of the ACB. Such findings are corroborated by previous studies which investigated other environmental phases in this oceanic basin. Obbard et al. (2014) reported that of the synthetic polymers found in sea ice, the majority were polyester (21 %). Kanhai et al. (2018) similarly found that of the synthetic particles present in the sub-surface waters, polyesters (74 – 78 %) were also predominant. Upon melting, sea ice can act as a local source of microplastics to the water column (Obbard et al. 2014; Peeken et al. 2018). Synthetic polymers that are present in surface waters of this oceanic basin could then be subject to vertical transport, persist in the water column as evidenced by Kanhai et al. (2018) and at some stage a fraction of these particles could end up in the sediment phase. Of interest is the fact that the present study found low density polymers such as polypropylene and polystyrene fragments in the sediments of the ACB. Based on the inherent densities of the virgin resins, such particles are unlikely candidates for the sediment phase in that they are positively buoyant and are expected to float. However, this suggests that there are mechanisms operating within the ACB that could be affecting the density of these particles and in effect causing them to end up in the sediment phase. Long et al. (2015) showed that under laboratory conditions marine aggregates of various algal species (*Chaetoceros neogracile*, *Rhodomonas salina*) were capable of incorporating and concentrating polystyrene microbeads which in turn led to an increase in their sinking rates. Such mechanisms can potentially explain the presence of low-density polymers in surficial sediments of the ACB. Of note is the fact that the present study is not the first to report the presence of low density polymers in deep sea sediments since polyethylene and polypropylene particles were found in surficial sediments from the Fram Strait (Bergmann et al. 2017).

Within the last decade, deep-sea sediments were for the first time identified as a potential sink for microplastics with four studies reporting on the issue in various oceanic basins (Supplementary Table 3). Comparison between these studies is particularly challenging and not straightforward due to the fact that each used different sampling equipment, extraction techniques and reported microplastic abundance/concentration in different units (Supplementary Table 3). Microplastic

abundance in surficial sediments of the ACB was estimated to range between 0 – 200 microplastics kg^{-1} dry sediment based on the findings of the present study. However, it is unlikely that these estimates are reflective of the situation in the ACB since (i) the equipment used for sample retrieval (gravity and piston corers) may have led to the collection of disturbed surficial sediment samples, (ii) low sample volumes (~ 10 g per site) were used to assess microplastic abundance, (iii) the density of the extraction solution was only 1.4 g cm^{-3} and thus could have excluded high density polymers, (iv) replicate sediment samples per site was not possible, (v) particles < 100 µm were excluded by virtue of the procedure used to identify/isolate potential microplastics. During the AO16 expedition, gravity and piston corers were used to retrieve sediments from several metres in depth from the ACB. Among the corers, gravity and piston corers are not guaranteed to retrieve undisturbed surficial sediment samples due to the shock wave that they generate during descent (Gallmetzer et al. 2016). It is therefore likely that any shock waves generated by the corers used in the present study may have triggered a resuspension of surficial material (sediments and microplastics) into the water column leading to an overall reduction and subsequent underestimation of microplastic abundance in the samples. When sampling surficial marine sediments, equipment such as box and multi-corers may be more suitable for the recovery of undisturbed surficial sediment samples (Georgiopoulou 2018). Box corers were recommended by Frias et al. (2018) due to (i) the minimal impact they have on surface deformation of sediments and, (ii) their ability to maintain sediment integrity during sampling.

Furthermore, due to the heterogenous nature of sediments, it is unlikely that the low sample volumes (~ 10 g of sediment) used in the study were reflective of the situation at the respective sites. Future studies should ensure that replicate samples are collected per site. Multi-corers may be particularly useful since they can facilitate the collection of replicate samples in a single deployment. When density separation is used to extract microplastics from sediment samples, the density of the extraction solution is important in determining which synthetic polymers are extracted from the samples. Although sodium tungstate dihydrate (density 1.4 g cm^{-3}) was used in the present study based on a safety-price index assessment (i.e. cost and health hazard), the density of the solution could have led to the exclusion of some high-density polymers (Frias et al. 2018). Loder and Gerdts (2015) recommended the use of zinc chloride based on its cost effectiveness and its higher density of 1.8 g cm^{-3}. However, the health hazard is high for this particular extraction

solution (Frias et al. 2018). Finally, the methods employed by investigators for the isolation and identification of microplastics influences the final reported microplastic abundance. In the present study, particles < 100 µm were automatically excluded from analysis. However, it must be noted that at the Atlantic gateway to the Arctic Ocean i.e. the Fram Strait, Bergmann et al. (2017) reported that the majority (80 %) of microplastics in surficial sediments from that area were < 25 µm. Bergmann et al. (2017) used a combination of ATR-FTIR spectroscopy as well as a µFTIR microscope equipped with a focal plane array detector to detect microplastics. It is therefore likely that if similar analytical techniques were employed to analyse the surficial sediment samples of the present study, higher microplastic abundances may have been reported, especially in the cases where zero microplastics were reported in certain samples.

Another limitation of the present study is the non-inclusion of an air contamination check during sampling onboard the vessel. Such a check would have been necessary to rule out airborne contamination during sampling. Since this was not done, the possibility exists that one or more of the particles reported as present in the surficial sediments of the ACB could have been introduced into the samples as a result of airborne contamination. The findings of the present study should therefore be regarded as preliminary and be used as a justification for future studies which can provide more comprehensive assessments of microplastics in deep-sea sediments of the Arctic Central Basin.

5.0 Conclusion

To our knowledge, this is the first study to present preliminary information regarding microplastics in surficial sediments of the Arctic Central Basin (ACB). The potential discovery of these particles in the sediment phase of this seemingly remote oceanic basin emphasizes the pervasiveness of microplastics in the marine environment. The possible presence of microplastics, specifically low-density polymers such as polypropylene (PP) and polystyrene (PS), in the sediment phase of the ACB suggests that there are mechanisms operating within this oceanic basin that are potentially affecting the density of microplastics and that are potentially driving the vertical transport of these particles through the water column. Microplastics that are present in sediments of the ACB are likely to interact with organisms inhabiting or depending upon this environmental phase. At present, whether those interactions are occurring with benthic organisms within the ACB and the

consequences of those interactions to individual organisms and the ecosystem services that they perform remains uncertain. Due to the numerous limitations of the present study, the findings should not be taken as conclusive regarding the status of microplastics in the surficial sediments of the ACB but instead be used as a foundation for future work seeking to quantify microplastic abundance, distribution and composition in surficial sediments of the Arctic Ocean.

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References

Bergmann, M., Wirzberger, V., Krumpen, T., Lorenz, C., Primpke, S., Tekman, M.B., Gerdts, G., 2017. High Quantities of Microplastic in Arctic Deep-Sea Sediments from the HAUSGARTEN Observatory. Environmental Science & Technology 51 (19), 11000-11010. https://doi.org/10.1021/acs.est.7b03331

Bodil, B.A., Ambrose, W.G., Bergmann, M., Clough, L.M., Gebruk, A.V., Hasemann, C., Iken, K., Klages, M., MacDonald, I.R., Renaud, P.E., Schewe, I., Soltwedel, T., Włodarska-

Kowalczuk, M., 2011. Diversity of the arctic deep-sea benthos. Marine Biodiversity 41 (1), 87-107. https://doi.org/10.1007/s12526-010-0078-4

Cole, M., Lindeque, P.K., Fileman, E., Clark, J., Lewis, C., Halsband, C., Galloway, T.S., 2016. Microplastics Alter the Properties and Sinking Rates of Zooplankton Faecal Pellets. Environmental Science & Technology 50 (6), 3239-3246. https://doi.org/10.1021/acs.est.5b05905

Cózar, A., Echevarria, F., Gonzalez-Gordillo, J.I., Irigoien, X., Ubeda, B., Hernandez-Leon, S., Palma, A.T., Navarro, S., Garcia-de-Lomas, J., Ruiz, A., Fernandez-de-Puelles, M.L., Duarte, C.M., 2014. Plastic debris in the open ocean. Proceedings of the National Academy of Sciences 111 (28), 10239-10244. https://doi.org/10.1073/pnas.1314705111

Cózar, A., Marti, E., Duarte, C.M., Garcia-de-Lomas, J., van Sebille, E., Ballatore, T.J., Eguiluz, V.M., Gonzalez-Gordillo, J.I., Pedrotti, M.L., Echevarria, F., Trouble, R., Irigoien, X., 2017. The Arctic Ocean as a dead end for floating plastics in the North Atlantic branch of the Thermohaline Circulation. Science Advances 3 (e1600582). https://doi.org/10.1126/sciadv.1600582

Eriksen, M., Lebreton, L.C.M., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryan, P.G., Reisser, J., 2014. Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. PLoS ONE 9 (12), e111913. https://doi.org/10.1371/journal.pone.0111913

Fang, C., Zheng, R., Zhang, Y., Hong, F., Mu, J., Chen, M., Song, P., Lin, L., Lin, H., Le, F., Bo, J., 2018. Microplastic contamination in benthic organisms from the Arctic and sub-Arctic regions. Chemosphere 209, 298-306. https://doi.org/10.1016/j.chemosphere.2018.06.101

Fazey, F.M.C., Ryan, P.G., 2016. Biofouling on buoyant marine plastics: An experimental study into the effect of size on surface longevity. Environmental Pollution 210, 354-360. https://doi.org/10.1016/j.envpol.2016.01.026

Fischer, V., Elsner, N.O., Brenke, N., Schwabe, E., Brandt, A., 2015. Plastic pollution of the Kuril–Kamchatka Trench area (NW pacific). Deep Sea Research Part II: Topical Studies in Oceanography 111, 399-405. https://doi.org/10.1016/j.dsr2.2014.08.012

Frias, J., Pagter, E., Nash, R., O'Connor, I., Carretero, O., Filgueiras, A., Viñas, L., Gago, J., Antunes, J., Bessa, F., Sobral, P., Goruppi, A., Tirelli, V., Pedrotti, M.L., Suaria, G., Aliani, S., Lopes, C., Raimundo, J., Caetano, M., Palazzo, L., Lucia, G.A.d., Camedda, A.,

Muniategui, S., Grueiro, G., Fernandez, V., Andrade, J., Dris, R., Laforsch, C., Scholz-Böttcher, B.M., Gerdts, G., 2018. Standardised protocol for monitoring microplastics in sediments. JPI-Oceans BASEMAN project. https://doi.org/10.13140/RG.2.2.36256.89601/1

Gallmetzer, I., Haselmair, A., Stachowitsch, M., Zuschin, M., 2016. An innovative piston corer for large-volume sediment samples. Limnology and Oceanography: Methods 14 (11), 698-717. https://doi.org/10.1002/lom3.10124

Georgiopoulou, A., 2018. Seafloor Sediment and Rock Sampling. In: Micallef, A., Krastel, S., Savini, A. (Eds.), Submarine Geomorphology. Springer International Publishing, Cham, pp. 75-92. https://doi.org/10.1007/978-3-319-57852-1_6

Jakobsson, M., Grantz, A., Kristoffersen, Y., Macnab, R., MacDonald, R.W., Sakshaug, E., Stein, R., Jokat, W., 2004. The Arctic Ocean: Boundary Conditions and Background Information. In: Stein, R., MacDonald, R.W. (Eds.), The Organic Carbon Cycle in the Arctic Ocean. Springer, Berlin. https://doi.org/10.1007/978-3-642-18912-8_1

Kanhai, L.D.K., Officer, R., Lyashevska, O., Thompson, R.C., O'Connor, I., 2017. Microplastic abundance, distribution and composition along a latitudinal gradient in the Atlantic Ocean. Marine Pollution Bulletin 115 (1-2), 307-314. https://doi.org/10.1016/j.marpolbul.2016.12.025

Kanhai, L.D.K., Gårdfeldt, K., Lyashevska, O., Hassellöv, M., Thompson, R.C., O'Connor, I., 2018. Microplastics in sub-surface waters of the Arctic Central Basin. Marine Pollution Bulletin 130, 8-18. https://doi.org/10.1016/j.marpolbul.2018.03.011

Katija, K., Choy, C.A., Sherlock, R.E., Sherman, A.D., Robison, B.H., 2017. From the surface to the seafloor: How giant larvaceans transport microplastics into the deep sea. Science Advances 3 (8), e1700715. https://doi.org/10.1126/sciadv.1700715

Kuhn, S., Schaafsma, F.L., van Werven, B., Flores, H., Bergmann, M., Egelkraut-Holtus, M., Tekman, M.B., van Franeker, J.A., 2018. Plastic ingestion by juvenile polar cod (*Boreogadus saida*) in the Arctic Ocean. Polar Biology, 1-10. https://doi.org/10.1007/s00300-018-2283-8

Löder, M.G.J., Gerdts, G., 2015. Methodology Used for the Detection and Identification of Microplastics—A Critical Appraisal. In: Bergmann, M., Gutow, L., Klages, M. (Eds.),

Marine Anthropogenic Litter. Springer International Publishing, Cham, pp. 201-227. https://doi.org/10.1007/978-3-319-16510-3_8

Long, M., Moriceau, B.l., Gallinari, M., Lambert, C., Huvet, A., Raffray, J., Soudant, P., 2015. Interactions between microplastics and phytoplankton aggregates: Impact on their respective fates. Marine Chemistry 175, 39-46. https://doi.org/10.1016/j.marchem.2015.04.003

Lusher, A.L., Tirelli, V., O'Connor, I., Officer, R., 2015. Microplastics in Arctic polar waters: the first reported values of particles in surface and sub-surface samples. Scientific Reports 5, 1-9. https://doi.org/10.1038/srep14947

Mallory, M.L., 2008. Marine plastic debris in northern fulmars from the Canadian high Arctic. Marine Pollution Bulletin 56 (8), 1501-1504. https://doi.org/10.1016/j.marpolbul.2008.04.017

Mu, J., Qu, L., Jin, F., Zhang, S., Fang, C., Ma, X., Zhang, W., Huo, C., Cong, Y., Wang, J., 2019. Abundance and distribution of microplastics in the surface sediments from the northern Bering and Chukchi Seas. Environmental Pollution 245, 122-130. https://doi.org/10.1016/j.envpol.2018.10.097

Obbard, R.W., Sadri, S., Wong, Y.Q., Khitun, A.A., Baker, I., Thompson, R.C.C.E.F., 2014. Global warming releases microplastic legacy frozen in Arctic Sea ice. Earth's Future 2 (6), 315-320. https://doi.org/10.1002/2014ef000240

Pagter, E., Frias, J., Nash, R., 2018. Microplastics in Galway Bay: A comparison of sampling and separation methods. Marine Pollution Bulletin 135, 932-940. https://doi.org/10.1016/j.marpolbul. 2018.08.013

Peeken, I., Primpke, S., Beyer, B., Gütermann, J., Katlein, C., Krumpen, T., Bergmann, M., Hehemann, L., Gerdts, G., 2018. Arctic sea ice is an important temporal sink and means of transport for microplastic. Nature Communications 9 (1), 1505. https://doi.org/10.1038/s41467-018-03825-5

Provencher, J.F., Gaston, A.J., Mallory, M.L., O'hara, P.D., Gilchrist, H.G., 2012. Ingested plastic in a diving seabird, the thick-billed murre (*Uria lomvia*), in the eastern Canadian Arctic. Marine Pollution Bulletin 60 (9), 1406-1411. https://doi.org/10.1016/j.marpolbul.2010.05.017

R Core Team, 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Schlitzer, R., 2017. Ocean Data View. https://odv.awi.de

Taylor, M.L., Gwinnett, C., Robinson, L.F., Woodall, L.C., 2016. Plastic microfibre ingestion by deep-sea organisms. Scientific Reports 6, 33997. https://doi.org/10.1038/srep33997

Tekman, M.B., Krumpen, T., Bergmann, M., 2017. Marine litter on deep Arctic seafloor continues to increase and spreads to the North at the HAUSGARTEN observatory. Deep Sea Research Part 1: Oceanographic Research Papers 120, 88-99. http://dx.doi.org/10.1016/j.dsr.2016.12.011

Van Cauwenberghe, L., Vanreusel, A., Mees, J., Janssen, C.R., 2013. Microplastic pollution in deep-sea sediments. Environmental Pollution 182, 495-499. http://dx.doi.org/10.1016/j.envpol.2013.08.013

Van Sebille, E., England, M.H., Froyland, G., 2012. Origin, dynamics and evolution of ocean garbage patches from observed surface drifters. Environmental Research Letters 7 (4), 1-6. https://doi.org/10.1088/1748-9326/7/4/044040

Woodall, L.C., Sanchez-Vidal, A., Canals, M., Paterson, G.L.J., Coppock, R., Sleight, V., Calafat, A., Rogers, A.D., Narayanaswamy, B.E., Thompson, R.C., 2014. The deep sea is a major sink for microplastic debris. Royal Society Open Science 1 (4). https://doi.org/10.1098/rsos.140317

Wright, S.L., Rowe, D., Thompson, R.C., Galloway, T.S., 2013. Microplastic ingestion decreases energy reserves in marine worms. Current Biology 23 (23), R1031-R1033. http://dx.doi.org/10.1016/j.cub.2013.10.068

Zarfl, C., Matthies, M., 2010. Are marine plastic particles transport vectors for organic pollutants to the Arctic? Marine Pollution Bulletin 60 (10), 1810-1814. http://dx.doi.org/10.1016/j.marpolbul.2010.05.026

Supplementary Table 1: Site-specific information for sediment cores sampled for microplastics in the Arctic Central Basin

Sample No.[a]	Core ID	Latitude	Longitude	Location in the ACB	Water Depth (m)	Core Type[b]
1	AO16-1-GC1	80.5532	8.0520	Yermak Plateau	855	GC
2	AO16-2-PC1	88.5022	-6.6195	Amundsen Basin	4353	PC
3	AO16-3-TWC1	89.2530	-66.6097	Foot of Lomonosov Ridge	3777	TWC
4	AO16-4-TWC1	88.5290	-128.5048	Marvin Spur	3936	TWC
5	AO16-5-TWC1	89.0780	-130.5470	Crest of Lomonosov Ridge	1253	TWC
6	AO16-7-PC1	88.6332	-121.4477	Marvin Spur	3941	PC
7	AO16-8-GC1	86.7795	-140.6433	Alpha Ridge	2620	GC
8	AO16-9-TWC1	85.9557	-148.3258	Alpha Ridge	2212	TWC
9	AO16-10-TWC1	82.3980	-141.2450	Nautilus Basin	2872	TWC
10	AO16-11-TWC1	86.0993	173.1877	Makarov Basin	3066	TWC
11	AO16-12-TWC1	87.8577	136.9875	Crest of Lomonosov Ridge	1269	TWC

[a]Sample numbers correspond to those on Figure 1a; [b]GC (Gravity core); PC (Piston core); TWC (Trigger weight core)

Supplementary Information related to particle size and organic carbon content analysis

Method: For particle size analysis, approximately 0.1 g of wet sediment from each sediment core was transferred to a test tube. To this, 3 mL of sodium metaphosphate solution (10%) was added and the total volume brought to 10 mL using de-ionized water. The contents of the tube were stirred, ultrasonicated for approximately 30 seconds to facilitate disaggregation and then transferred to the Hydro LV wet dispersion unit of a Mastersizer 3000 laser diffraction particle size analyser (Malvern Instruments, UK). De-ionized water was used to bring the final volume in the wet dispersion unit to 600 mL prior to analysis. The particle size of surficial sediments from each core was based on the analysis of three sub-samples. Following Pagter et al. (2018), approximately 3 g of dried sediment (105 °C, 4 h) from each sample was placed into a furnace at 450 °C for 6 hours in order to estimate the organic content of the sediment samples based on loss on ignition. Grain size composition of the surficial sediment data was conducted using Gradistat Version 8 (Blott 2010).

Results: Regarding the particle size composition of the sediments, all sampled sites had a predominance of fine-grained sediments where the percentage of silt (59 – 87 %) > clay (10 - 24 %) > sand (1 – 23 %) > gravel (0 – 0.2 %), (Supplementary Table 1). Organic content of the surficial sediment samples ranged between 2.3 – 4.6 % (Supplementary Table 1).

Reference:

Blott, S., 2010. Gradistat Version 8: A grain size distribution and statistics package for the analysis of unconsolidated sediments by sieving or laser granulometer. Kenneth Pye Associates Limited, Berkshire, UK.

Supplementary Table 2: Synthetic polymer composition and grain sizes of surficial sediments in the Arctic Central Basin

	Sample Number										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Grain size composition (%)											
Total Gravel (%)	0.0	0.0	0.0	0.1	0.0	0.1	0.2	0.0	0.0	0.1	0.0
Total Sand (%)	3.3	5.2	1.2	7.5	12.4	15.2	17.5	16.4	22.6	10.2	7.5
Total Silt (%)	86.9	73.6	76.4	68.4	70.5	65.6	63.4	63.0	59.3	69.8	73.7
Total Clay (%)	9.8	21.2	22.5	24.1	17.1	19.2	18.9	20.5	18.0	19.8	18.7
Organic content (%)	4.6	4.0	4.4	3.5	3.3	2.6	3.4	3.6	2.6	2.3	2.8
Polymer Type (n)											
Polyacrylonitrile (PAN)			1								
Polyamide (PA)					1						
Polyester (PES)		2									1
Polypropylene (PP)							1				
Polystyrene (PS)							1	1			
Polyvinyl chloride (PVC)				1							
Total number of synthetic polymers	0	2	1	1	1	0	2	1	0	0	1
Size (mm); Type (Fi-fibre; Fr-fragment) of microplastics		1.84 (Fi) 1.38 (Fi)	0.47 (Fi)	0.91 (Fr)	3.58 (Fi)		0.88 (Fr) 0.54 (Fr)	0.45 (Fr)			1.03 (Fr)
Microplastic concentration											
Mass of dry sediment used (g)	10.02	10.12	7.86	9.83	10.20	10.89	9.31	10.09	10.07	10.36	4.54
Microplastic concentration (items kg^{-1})	0	198	127	102	98	0	215	99	99	97	220

Supplementary Table 3: Microplastics in deep sea sediments of various oceanic basins

Location	**Depth (m)**	**Sampling Equipment**	**Extraction Method**	**Microplastic abundance**	**Synthetic polymers**	**Study**
Porcupine Abyssal Plain Nile Deep Sea Fan Atlantic Sector of the Southern Ocean	1176 – 4843	Multicorer	Density flotation, NaI (1.6 g cm^{-3})	0.5 particles cm^{-3} (average, n = 11) 1 particle cm^{-3} (max)	No data	Van Cauwenberghe et al. (2013)
Subpolar North Atlantic Ocean NE Atlantic Ocean Mediterranean Sea SW Indian Ocean	300 – 3500	Megacorers Boxcorers	Density flotation, NaCl, Ludox-TM 40 extraction	1.4 - 40 pieces per 50 ml (mean ± s.e., 13.4 ± 3.5)	PA, PES, Acrylic Rayon	Woodall et al. (2014)
Kuril-Kamchatka Trench, NW Pacific	4869 - 5768	Box corer	Sieve-washing of sediments	60 - 2020 pieces m^{-2}	No data	Fischer et al. (2015)
HAUSGARTEN observatory, Fram Strait	2340 - 5570	Multiple corer	Density separation, zinc chloride (1.8 g cm^{-3})	42 – 6595 microplastics kg^{-1} dry sediment	18 polymer types detected. Majority: PE, PA, PP	Bergmann et al. (2017)
Arctic Central Basin	855 - 4353	Gravity and piston corer	Density separation, sodium tungstate dihydrate (1.4 g cm^{-3})	0 - 200 microplastics kg^{-1} dry sediment	PA, PAN, PES, PP, PS, PVC	This study

PA-Polyamide, PAN-Polyacrylonitrile, PES-Polyester, PP-Polypropylene, PS-Polystyrene, PVC-Polyvinyl chloride