Flying plastics
Ocurrence of microplastics in arctic fresh water ponds on Svalbard

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Abstract
We studied the occurrence of microplastics in surface water of 44 shallow arctic ponds in Kongsfjorden, Svalbard. In only 4 ponds, we did not find any microplastic. In the other 40 ponds the amount of microplastic fibres per 100 litre ranged from 1 to 608 with an average of 89. The sizes of the fibres were in the range of the size of the zooplankton in the samples, but we did not find any sign of ingested samples in zooplankton. We were unable to find a geographical explanation for the variation in the amount of microplastics in each sample. The distance from the village nor the north-south or east-west sides of the fjord played a role. Large variation in fibre numbers were found in lakes close to eachother. While sampling, we dressed ourselves in a red coat, to recognize any samples originating from our clothing. To our surprise we found red fibres in 42 of our sampled ponds with a range from 5 to 188 red fibres in each sample per 100 litre and an average of 43 red fibres per sample. This shows how complicated sampling of microplastics is.

1. Introduction

Microplastic pollution has become a major type of pollution. Since the last decennium, a lot of research is conducted on this topic, especially in marine water systems (e.g. Li et al. 2024). Recently, it has been discovered that the extent to which microplastic is spread throughout the world has been severely underestimated, as it can even be found on top of glaciers (Gonzålex Peiter et al. 2024, Rosso et al. 2024). These locations are completely isolated from oceans or river systems. Which means that microplastic has another way to be transported: through the atmosphere (Allen et al.2019, Björnsen (2023). This plastic is nearly invisible for human being, due to its transparency and its size. Microplastic are very small pieces of plastic that measure only 1µm up to 2mm in size. They are also found in fresh water lakes (Dusausey et al. 2021). People are just starting to realize that this type of pollution can affect micro-organisms and zooplankton (Cole et al. 2013).
In the Netherlands, studies on microplastic on similar isolated lakes have resulted in the discovery that microplastic is not only more abundant in the water than was previously believed, but it is also present inside zooplankton (Kong et al. 2019).

2. Materials & Methods

2.1 Study site

Study sites were located around the Kongsfjorden on Spitsbergen. Spitsbergen is the largest island of the Norwegian archipelago Svalbard, located in the Arctic Ocean. This island features an Arctic climate but is also influenced by the warm water inflow from the Atlantic current on the southwest side, leading to daily temperatures varying from 2 ˚C to 9 ˚C in summer (Based on weather reports collected during 2012–2021, Time and Date AS, n.d.). The research town Ny-Ålesund (78°56′N 11°56′E) is located in west Spitsbergen in the Kongsfjorden with numerous ponds in its vicinity. Retreating ice left depressions in rocks that have filled up with meltwater creating small and shallow ponds, often less than 1 meter deep. The ponds become ice-free beginning of July latest and completely freeze again at the end of September. This study includes 44 ponds (Figure 1 and Table 1) and sampling time occurred beginning/mid-August 2021 (Figure 4 for example pictures of the studied ponds).

2.2 Sampling design

One zooplankton sample per pond was collected. To collect the sample, 100 L of water was randomly taken from a pond with a 10 L bucket and sieved through a plankton net with a mesh size of 35 µm. The content was stored in 200mL bottles (Figure 2) (Van Geest *et al.* 2007). The samples were preserved with formaldehyde (4%) upon arrival in the laboratory the same day they were taken. During sampling, red lab coats were worn to check for contamination of red fibers from the clothing in the samples.

2.3 Microscopical analysis

2.3.1 Species identification

The samples were analyzed using an inverted microscope (Olympus IMT-2) with an SplanApo 4x and SplanApo 10x magnification lenses. The 100 L samples represent only a fraction of the total zooplankton content of a pond. Therefore, the samples were split with a Folsom splitter to obtain suitable subsamples for microscopic analysis (Figure 3). The zoo-plankton were cleaned from the formaldehyde first by separating the fluid with a sieve, whereafter the content of the sample was put in the plankton splitter. The splitter was moved back and forth ten times to create equally divided parts, after which the contents were deposited in small containers. The process was repeated until the desired density was reached, maximally splitting eight times. Samples were analyzed for the presence of Cladocera, Copepoda, and Rotifera, and were identified to the lowest possible taxonomic level. For Cladocera this was species level, and for Daphnia, life stages were also included (embryo, juvenile, adult, and adults carrying ephippia). Copepoda were identified to order for adults, and nauplius stage was unspecified and counted as C*opepoda nauplii*. Rotifera were identified to either phylum, in case of little identifiable features, or genus, in case of enough identifiable features present to determine them as such. Species eys and pictures from Bledzki & Rybak (2016) and Koste (1978) were used for species identification.

Figure 1: Example photographs of the studied ponds, taken in August 2021.
Top-left is pond G04, top-right is pond KFM06, bottom-left is pond KFM13, bottom-right is pond KFM34.

Pond code	Coordinates north	Coordinates east	Sample date	micro plastic	red fiber
KFM01	78.92650	11.93971	5-8-2021	224	112
KFM02	78.92603	11.92271	6-8-2021	92	40
KFM06	78.91092	12.08112	12-8-2021	0	60
KFM07	78.94079	11.82509	8-8-2021	4	76
KFM09	78.93420	11.81800	8-8-2021	132	188
KFM12	78.96565	12.07055	15-8-2021	8	8
KFM13	78.96588	12.02781	15-8-2021	9	23
KFM15	78.95391	11.64373	16-8-2021	3	56
KFM21	79.00800	11.97285	6-8-2021	136	128
KFM22	78.92394	11.88216	6-8-2021	12	11
KFM32	78.94056	11.83511	8-8-2021	21	31
KFM33	78.92120	12.33784	17-8-2021	128	0
KFM34	79.00076	12.07819	17-8-2021	320	48
KFM35	79.00169	12.07930	17-8-2021	384	0
G01	78.89401	12.07579	13-8-2021	3	53
G04	78.89881	12.08822	13-8-2021	4	34
G06	78.90130	12.09401	13-8-2021	92	78
G07	78.90131	12.09758	13-8-2021	0	18
G08	78.90157	12.10333	13-8-2021	2	96
G09	78.90128	12.10585	13-8-2021	4	48
PL01	78.92412	11.92005	6-8-2021	170	70
PL02	78.94518	11.84945	8-8-2021	400	48
PL03	78.91092	11.82915	11-8-2021	1	6
PL04	78.91257	11.82945	11-8-2021	7	16
PL05	78.91272	11.83158	11-8-2021	2	24
PL06	78.91323	11.83392	11-8-2021	2	9
PL07	78.91322	11.83300	11-8-2021	2	15
PL08	78.91398	11.83467	11-8-2021	16	29
PL09	78.91433	11.83640	11-8-2021	96	36
PL10	78.91480	11.83670	11-8-2021	36	16
PL11	78.91470	11.83855	11-8-2021	57	53
PL12	78.91765	11.88540	11-8-2021	608	75
PL13	78.92078	11.90297	13-8-2021	13	35
PL14	78.89622	12.07847	13-8-2021	0	26
PL15	78.89902	12.08493	13-8-2021	100	22
PL16	78.90167	12.09543	13-8-2021	16	20
PL17	78.90135	12.09910	13-8-2021	0	5
PL18	78.90052	12.10087	13-8-2021	28	24
PL19	78.89955	12.10288	13-8-2021	1	18
PL20	78.90473	12.08043	13-8-2021	4	41
PL21	78.90412	12.07922	13-8-2021	1	29
PL22	78.90400	12.06470	13-8-2021	16	12
PL23	78.95287	11.65977	16-8-2021	373	43

Table 1: Overview of all the studied ponds including the pond names, coordinates and the amount of microplastic (n/100 ltr) and red fibres (n/100 ltr)..

Figure 2: Map of Kongsfjorden (located on the island of Spitsbergen, Svalbard) showing the pond locations. Due to close proximities of the ponds not every single point is clearly visible. See table 1 for exact coordinates.

Figure 3. Fresh zooplankton sample in a bottle

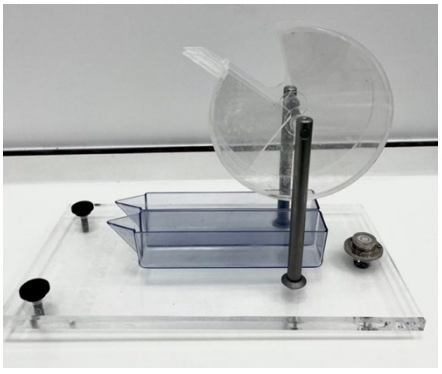

Figure 4. Folsom plankton splitter.

2.3.2 Count Strategy

Counting was done by creating two different subsamples to separate the zooplankton and microplastic counts. Subsample 1 was zooplankton, containing all species of Rotifera, Copepod adults, Copepoda Nauplii, Daphnia, Chydorus & Macrothrix. Subsample 2 was for microplastic, subdivided into different lengths of microplastic as well as red fibers (Table 2). The first step of the microscopic analysis was to screen the cuvette with a 4x magnification lens and count all Daphnia. Other zooplankton and microplastic were counted with a 10x10 magnification lens afterward. Depending on the density of the zooplankton, one or multiple cuvettes of a known volume were counted. Counting stopped when 100 observations were reached, however, if this amount could not be reached after analyzing 4 cuvettes, the counting stopped. Observations were converted into number of individuals per liter of pond water. After completing the microscopical analysis, species concentrations (n/L) per sample was calculated by the program COUNT. Prior to data analysis concentration was converted to number of individuals per 100L.

2.4 Data analyses

Data analysis was mainly done using Excel for the graphical analysis. Such graphs were used to visualize the amount of the different categories of microplastics in the samples.

Table 2: Overview of the fiber categories counted during the microscopical analysis based on length and material.

Material type	Length
Microplastic	0 – 500 µm
Microplastic	500 – 1000 µm
Microplastic	1000 – 2000 µm
Microplastic	2000 µm
Red fiber	0 – 500 µm
Red fiber	500 – 1000 µm
Red fiber	1000 – 2000 µm
Red fiber	2000 µm

Table 3. Every zooplankton taxa found in the studied ponds around Kongsfjorden.

Taxa	Species
Cladocera	*Daphnia pulex*
	Macrothrix hiternicus
	Chydorus sphearicus
Copepoda	*Harpacticoida sp.*
	Calanoida sp.
	Cyclopoida sp.
	Nauplii
Rotifera	*Adnineta*
	Brachionus
	Cephalodella
	Colurella
	Euchlanis
	Keratella
	Lecane
	Lepadella
	Lopocharis
	Monommata
	Mytilinia
	Notholca
	Ploesoma
	Polyarthra
	Rotifera sp.
	Testidunella
	Trichocerca
	Trichotria

3. Results

3.1 General overview of taxa

A total of 3 zooplankton taxa and 24 families were recorded in the studied ponds (Table 3). Not all taxa were found in the same sample. Overall, the most common Cladocera species was *Daphnia pulex*, more specifically the adult stage. Cyclopoids were most abundant copepod and among the rotifers, Keratella and Polyarthra were most common. Some rotifers were impossible to identify because the sample is fixated and the organisms 'freeze' or collapse which does not show their actual shape. These organisms were noted as *'Rotifera sp*.'

3.2 Microplastic

There where 4 out of 44 ponds where no microplastic were found (KFM06, G07, PL14, PL17) and in 2 out of 44 ponds did not contain any red fibers (KFM33, KFM35) (table 1, figure 5). The total counts of all categories of microplastic and red fibers show that the red fibers with a length between 0-500 µm had the highest count (figure 6). From all microplastics, the lengths between 500-1000 µm had the highest count and the >2000 µm plastics the lowest. Red fibers with a length of >2000 µm were least observed.

Furthermore the length of all categories including zooplankton was put beneath each other to get a good overview of whether the lengths of the plastic possibly fit inside the zooplankton (figure 7). The lengths are in order from longest to shortest. Lengths of zooplankton was based on measurements taken during this study and standard length measurements from the program COUNT. The graph shows that zooplankton of all different should in theory be able to ingest all microplastic sizes, expect for the largest pieces of >2000 µm which is likely too long to be ingested. We did not observe any ingested fibres in zooplankton.

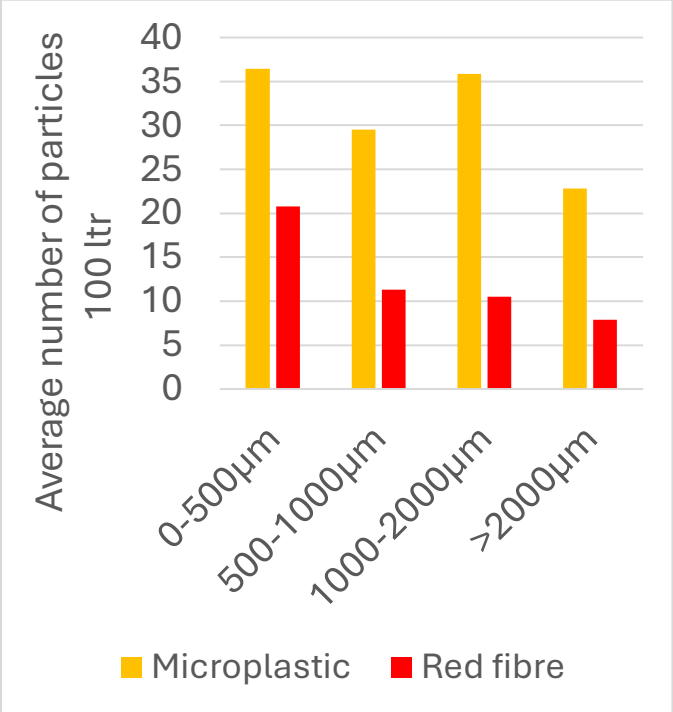

Figure 5: The average number of microplastic and red fibres per 100 ltr of different sizes in all samples.

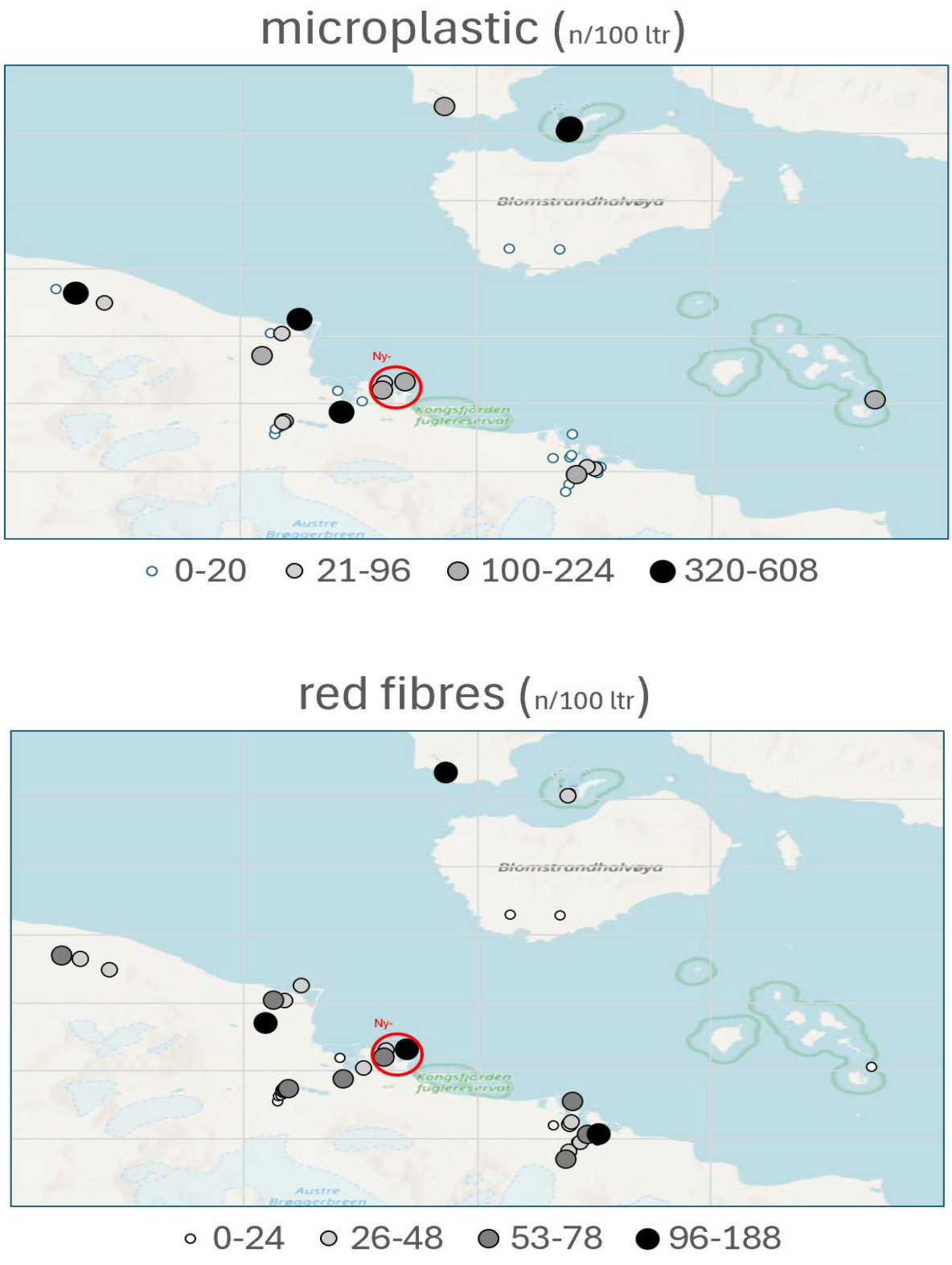

Figure 6: Map showing the number of fibres per 100 ltr found in different localities. presence of microplastics. The categories are based on equal groups, the first number is the minimal numbe of fibres, the second one is the maximum number of fibres in each category. Top panel is amount of microplastic fibres, bottom panel is the amount of red fibred per location.

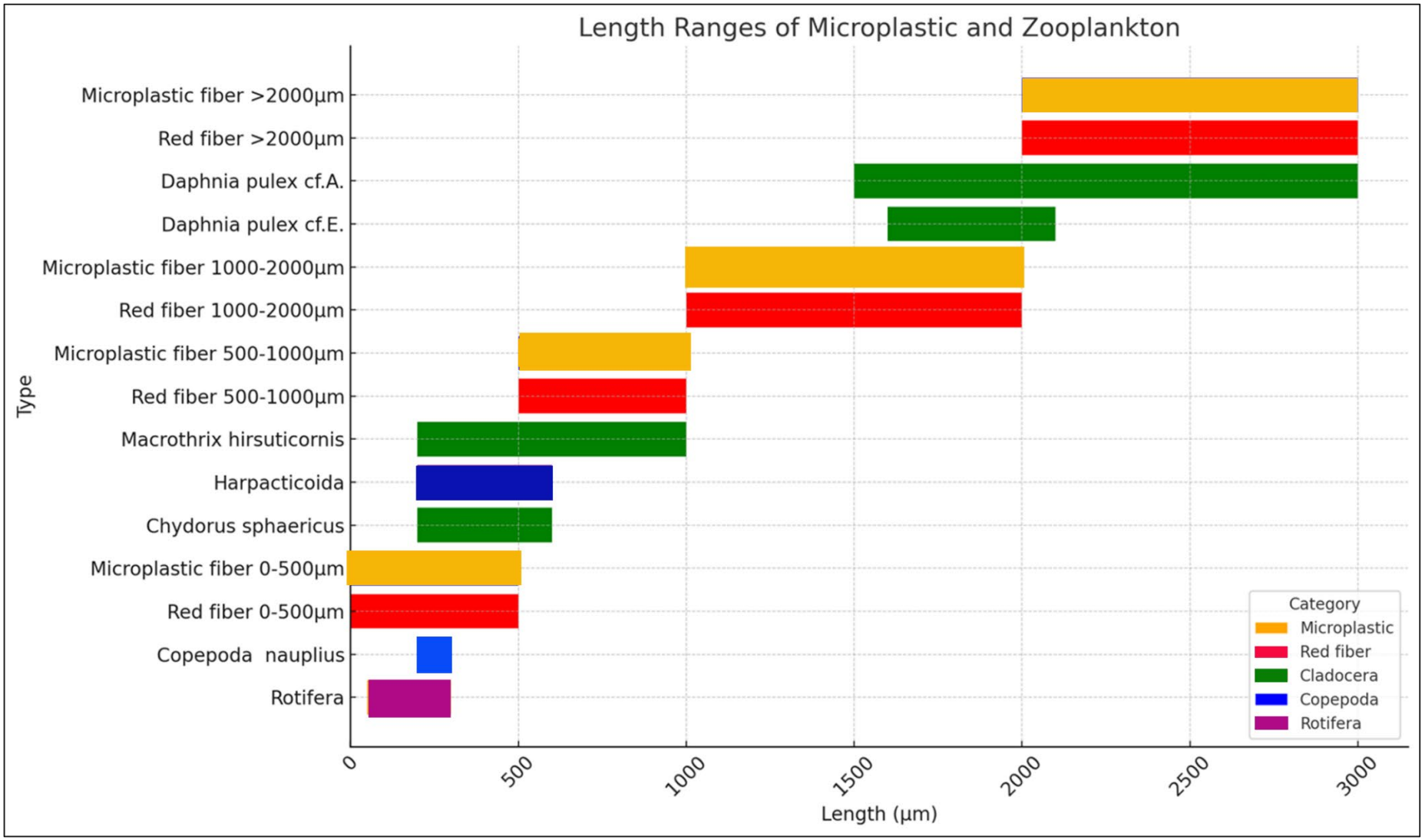

Figure 7: Graph showing the lengths (µm) of the microplastics, red fibers and zooplankton species. The bars clearly show where the lengths overlap. Lengths are based on the measurements taken during the microscopical analysis of this study and the standard lengths used by the program COUNT.

4. Discussion

We expected a gradient in the amount of microplastics with distance from human activity. This was not found. In the three most eastern lakes in figure 6, which are close together far away from the village of Ny-Ålesund, the amount of microplastics and red fibres vary a lot and are not correlated. Even the sampled lakes on islands and the north side of the fjord contain large amount of microplastics and no correlation between microplastics and red fibres. Figure 8 shows the amount of fibres in sampled lakes with the distance of the lake to the village of Ny-Ålesund. There is no correlation.

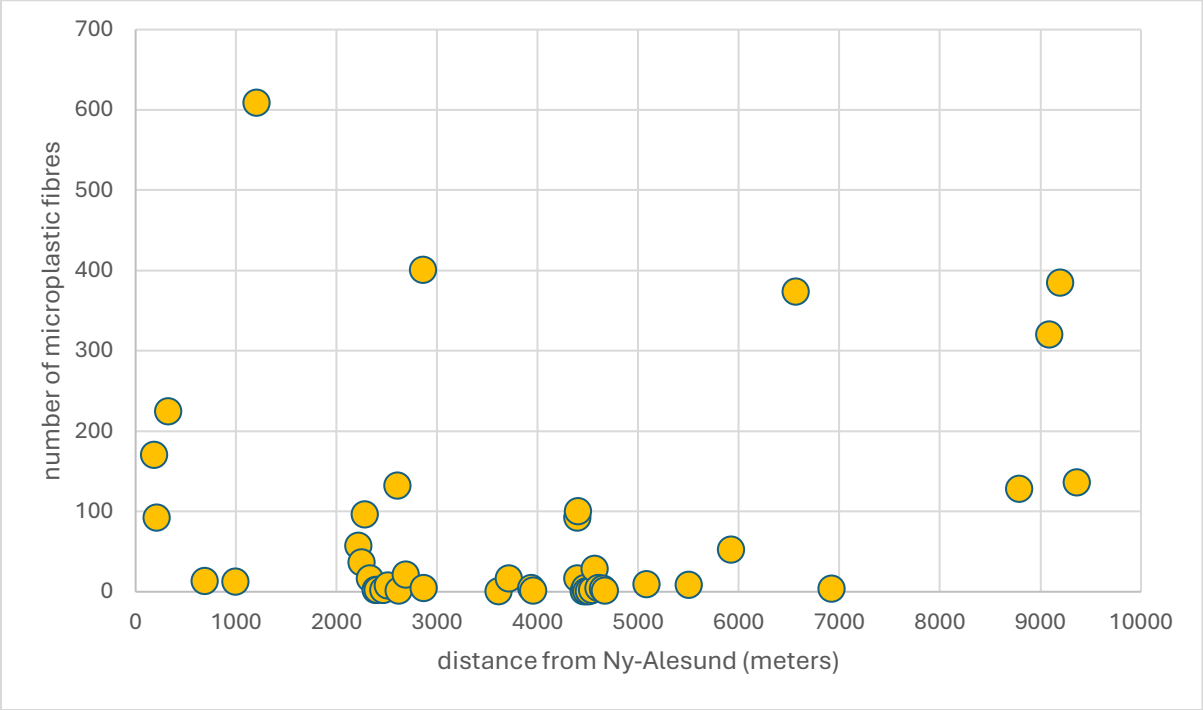

Figure 8 : The amount of microplastic fibres in a sample against the distance from the center of the village in meters.

In the samples red fibers were also frequently found. As mentioned above, during sampling red lab coats were worn to test for the contamination of clothing. Red fibers were found in 95% of the studied ponds, indicating that during sampling clothing introduces fibers into the waterbodies. This is an important awareness for future scientific research. By wearing distinct coloured clothing, we were able to quantify this pollution introduced by the scientist, despite our careful strategy of sampling and storing all material in newly bought steel buckets, sieves and bottles, It shows how easily samples are polluted by fibres introduced during sampling.

Different species of zooplankton have varying size ranges, determining their susceptibility to micro-plastic ingestion. By comparing their length distributions to those of the plastic particles, we could identify which species are at the highest risk of ingesting plastic and how plastic. Many aquatic organisms, including zooplankton filter-feed on particles within a specific size range. If microplastics fall within the same size spectrum as their natural food sources, they may be ingested unintentionally. This can lead to starvation, reduced energy intake, and physiological stress, impacting

zooplankton populations and higher trophic levels through bioaccumulation. The size overlap between zooplankton and microplastics therefore influence how microplastics move through food webs. If small microplastics are consumed by primary consumers like copepods and cladocerans, they can be transferred to larger predators, such as *Lepidurus arcticus*, a carnivorous zooplankton and eventually Barnacle geese *Branta leucopsis* or Arctic terns *Sterna paradisaea*, which have been observed as predators of *Lepidurus arctcus*. This process can introduce harmful pollutants, as plastics often adsorb toxic chemicals from their surrounding environment.

Preliminary tests did not show an effect of sample date, sample time within a sample date, the size of the lake surface or the size of the drainage area of each lake, We plan another sampling in a few lakes to test repeatability of our results.

References

Allen, S., Allen, D., Phoenix, V. R., Le Roux, G., Durántez Jiménez, P., Simonneau, A., ... & Galop, D. (2019). Atmospheric transport and deposition of microplastics in a remote mountain catchment. *Nature geoscience*, *12*(5), 339-344.

Bjørnsen, A. (2023). *Abundance and Characteristics of Microplastics in Atmospheric Deposition from the Arctic and Mainland, Norway* (Master's thesis, NTNU).

Bledzki, L. A., & Rybak, J. I. (2016). Freshwater Crustacean Zooplankton of Europe: Cladocera & Copepoda (Calanoida, Cyclopoida) Key to species identification, with notes on ecology, distribution, methods and introduction to data analysis. Springer International Publishing. https://doi.org/10.1007/978-3-319- 29871-9

Cole, M., Lindeque, P., Fileman, E., Halsband, C., Goodhead, R., Moger, J., & Galloway, T. S. (2013). Microplastic ingestion by zooplankton. *Environmental science & technology*, *47*(12), 6646-6655.

Dusaucy, J., Gateuille, D., Perrette, Y., & Naffrechoux, E. (2021). Microplastic pollution of worldwide lakes. *Environmental Pollution*, *284*, 117075.

González-Pleiter, M., Lacerot, G., Edo, C., Pablo Lozoya, J., Leganés, F., Fernández-Piñas, F., Rosal, R., and Teixeira-de-Mello, F.: A pilot study about microplastics and mesoplastics in an Antarctic glacier, The Cryosphere, 15, 2531–2539, https://doi.org/10.5194/tc-15-2531-2021, 2021.

Kong, X., & Koelmans, A. A. (2019). Modeling decreased resilience of shallow lake ecosystems toward eutrophication due to microplastic ingestion across the food web. *Environmental science & technology*, *53*(23), 13822-13831.

Koste, W. (1978). Rotatoria: Die Rädertiere Mitteleuropas ; ein Bestimmungswerk ; Überordnung Monogononta. 2. Tafelband. (Vol. 2).

Li, Y., Lu, Z., Zhang, X., Wang, J., Zhao, S., Shen, J., ... & Yang, Y. (2024). Microplastics in surface seawater of Kongsfjorden, Svalbard, Arctic. *Environmental Technology & Innovation*, *36*, 103819.

Rosso, B., Scoto, F., Hallanger, I. G., Larose, C., Gallet, J. C., Spolaor, A., ... & Corami, F. (2024). Characteristics and quantification of small microplastics (< 100 µm) in seasonal svalbard snow on glaciers and lands. *Journal of Hazardous Materials*, *467*, 133723.

Van Geest, G. J., Hessen, D. O., Spierenburg, P., Dahl-Hansen, G. A. P., Christensen, G., Faerovig, P. J., Brehm, M., Loonen, M. J. J. E., & Van Donk, E. (2007). Goose-mediated nutrient enrichment and planktonic grazer control in arctic freshwater ponds. Oecologia, 153(3), 653–662 https://doi.org/10.1007/s00442-007-0770-7

Pictures of sampling, dressed in red with steel equipment

Despite taking care, red fibers were found in 42 out of 44 samples.