Supplemental information:

Microplastic fiber emissions from wastewater effluents: abundance, distribution, and exposure risk for biota in an arctic fjord

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Transport modelling to predict distribution and accumulation zones

The Finite-Volume Community Ocean Model (FVCOM) is an unstructured 3D grid model where the spatial grid resolution can vary within a domain, typically with lower resolution in the open ocean to resolve the larger-scale currents, and higher resolution near complex coastlines (Chen et al. 2003).

The velocity field has the primary role in mapping out the pathways of any kind of floating object including microfibers in the marine environments. It is assumed that alongside the large-scale processes which affect the whole fjord dynamics, the small-scale processes in the fjord interior are also highly of importance in determining the microfibre distribution patterns. Here, to investigate the behavior of microfibers and the Adventfjorden and possible mapping of the distribution of the microfibers beyond this fjord we have applied a dedicated nested high-resolution hydrodynamical model. To resolve the multi-scale processes which contribute to the transport and distribution, we implemented a three-dimensional version of the unstructured grid (FVCOM; see Chen et al. 2003, 2007). FVCOM is an advanced coastal circulation model widely utilized for its ability to simulate spatially and temporally evolving geophysical conditions of complex and dynamic coastal regions. The model skill has been evaluated comparing with analytical or semi-analytical solutions as well as with in situ data over large spatial and temporal scales (see, e.g., Chen et al. 2003, 2007; Cowles 2008; Isobe and Beardsley 2006; Weisberg and Zheng 2006; Frick et al. 2007; Cowles 2008; Ghaffari et al 2020).

The daily mean flow filed reanalysis data were available on a 4 km horizontal resolution grid, with 34 sigma layer vertical resolution. Daily mean values of salinity and temperature are used at the boundary. To model a real rather than an averaged situation: any kind of averaged currents was assumed inappropriate as they would significantly reduce the current velocity magnitude, a synthetic hourly velocity field is facilitated by combining the tidal velocity field from a 2D setup of FVCOM (tidal model) and the daily averaged velocity field form Nordic 4 km. The model was forced with the output from AROME-arctic, which is a regional short-range high-resolution forecasting system for the European Arctic with 2.5 km grid spacing and 65 vertical levels (Müller et al. 2017, Køltzow et al. 2019). The model system is based on the HARMONIE-AROME configuration of the ALADIN-HIRLAM numerical weather prediction system (Bengtsson et al. 2017). Data for the outer hydrodynamical and atmospheric models were downloaded from MET Norway threads Service at the Norwegian Meteorological Institute (https://thredds.met.no/thredds/catalog.html). The river runoff is prescribed using daily means from climatic mass balance, snow conditions, and runoff in Svalbard (see Reference; Reconciling Svalbard Glacier Mass Balance; A long-term dataset of climatic mass balance, snow conditions, and runoff in Svalbard (1957–2018).

Transport model

Numerical models are efficient tools for the investigation of transport of pollution in the marine environment (Kershaw, 2015). Synthetic fibres as pollution due to their large abundance, are more threatening pollutants than larger particles, especially for most of the benthic communities (ref), however, their sources and concentrations are poorly known. There are various kinds of primary and secondary sources of fibres in the marine environment, e.g. household and industrial wastewaters, fishing nets and ship ropes, plastic bags, and disposed clothes, etc. (Cole et al., 2011; Kershaw, 2015). However, in our case, the household source through the Longyearbyen wastewater is considered as the main source for microfibre pollution in Adventfjorden. For that purpose we set an unstructured ultra-high-resolution hydrodynamical model, with 34 sigma-layer with a constant vertical resolution for 170 m and shallower area, and constant 5 m for upper 50 m and lower 20 m for depths larger than 170m.To simulate the wastewater plume, release and transport of microfibers, we adopted a stepwise modeling approach. In Adventfjorden, wastewater discharges to the marine environment at 60 m depth, which entails a proper understanding of the physical behavior of plume in the water column. Hence, we introduced microfibers as adjustable tracers into the plume of the wastewater. The plume behavior in the water column is modeled to find the layer where the plume and microfibers locate in the water column under density control. Based on the temperature, salinity, and velocity of the discharge, the stagnation depth and entrainment caused by the change in the plume's trace element, temperature, salinity, and volume as it stops are calculated using the formulas presented in Morton, 1956. The results from this step are used to calculate how wide the plume is at all depth levels the plume moves through. If the plume is wider than the area represented by the calculation point, many enough neighboring points are activated so that the area of the plume becomes smaller than the total area of the calculation points. This area is a function of the depth, so that a typical plume becomes wider the higher it rises and affects the mass, salt, transport, and tracer flux at all activated calculation points and depths.

We modified and employed the Eulerian tracer concentration and transportation module of FABM framework (Bruggeman and Bolding 2014) to advect microfiber under the control of the ambient flow field. At the stagnant depth, the mixed volume, salt, temperature, and tracer are emitted at a given number of calculation points in the hydrodynamic model, which then simulates the secondary scatter. Since, presumably, a very weak current is required to prevent the fiber from settling, we adopted a numerical procedure that prevents microfibers from settling and keeps them drifting in the near-bottom water layer if the ambient waters are not stagnant.

We assumed that almost all types of microfibers with different properties are present in the wastewater. However, it is not practical to model the wide spectrum of microfibers. Hence, we expanded the microfibre parameter space by setting numerical scenarios based on four distinguished microfibre classes, which are well representative of microfiber composition in Adventfjorden. I.e., Experiment1, buoyant PP microfibers that are lighter than the ambient water (sigma = 0.9 g/cm^3); Experiment2, neutral microfibers (sigma = 1 g/cm^3); Experiment3, PA microfibers which are slightly heavier than the ambient waters (sigma = 1.170 g/cm^3); and finally Experiment4, heavy wool microfibers (sigma = 1.390 g/cm^3).

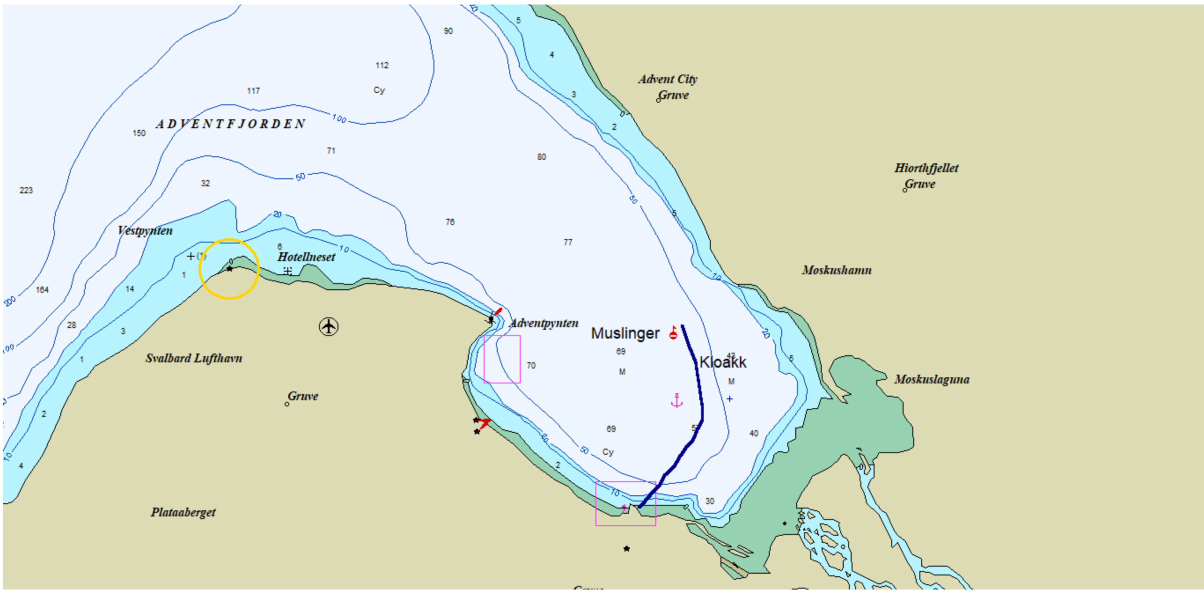

Figure S1: Map of location of wastewater effluent pipe, Longyearbyen settlement

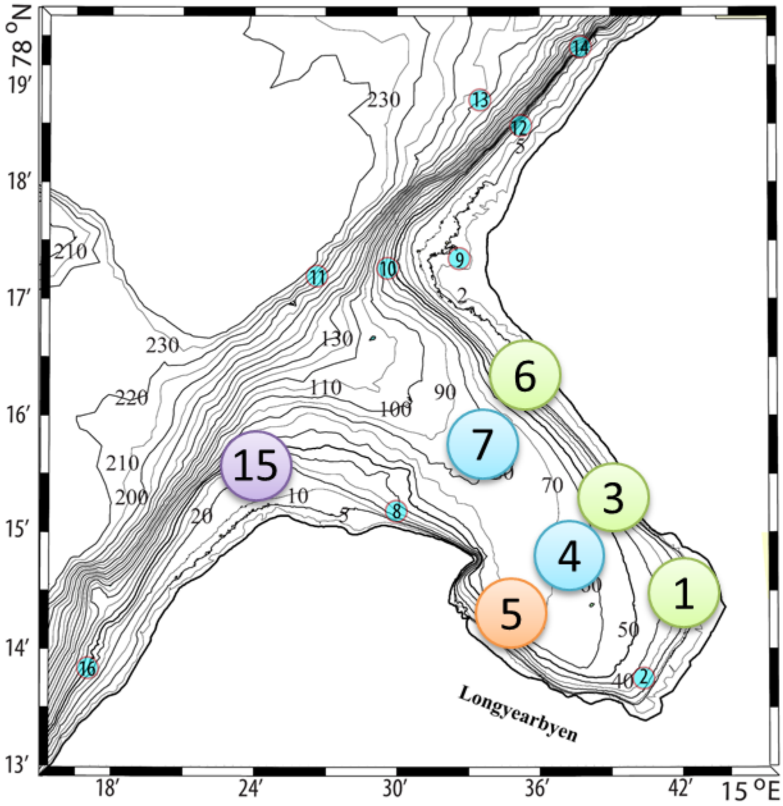

Figure S2: Model checkpoints for which organism abundances were estimated from published data. Checkpoints 1, 3, and 6 represent shallow stations along the northern coast, checkpoint 5 a station at approximately 55 m depth near the southern coast, checkpoints 4 and 7 deep stations between 60 and 85 m depth and checkpoint 15 a shallow station near the mouth of the fjord.

Table S3: Station names in references used to derive biota numbers for equivalent model check points. Plankton data were collected in June, meroplankton data were collected in May/June, and benthos data were collected in August/September.

	station name							***Reference***
microfibers	1	3	4	5	6	7	15	this study
plankton	AF1	AF2			A NC		IsA	Vereide 2019
meroplankton				A+B				Kuklinski et al. 2013
benthos		A1	LYB-2	13-15		16		Cochrane & Evenset 2020

Table S4: Microfiber (MF) abundances at selected check points (CP) and depths [m] for four different fiber types: light MF, neutral MF, heavy MF, and very heavy MF. Sums (sum) denote the number of fibers accumulated in this compartment after 100 hours of fiber release from the waste water pipe, maxima (max) denote the highest number of fibers present in this compartment at any point in time during 100 hours of fiber release from the effluent pipe. NA = CP bottom depth < depth layer.

Light MF							
0-5 m	**CP 1**	**CP 3**	**CP 4**	**CP 5**	**CP 6**	**CP 7**	**CP 15**
Sum	28894673	50723904	5490462	167814	**80756676**	596977	459
Max	4389245	6705759	1198550	10867	6241898	106083	50
5-20 m							
Sum	5880	11629	51219	47230	127921	8457	106
Max	1311	3104	15210	8710	46203	1722	24
20-50 m							
Sum	10	NA	591	426	NA	13	NA
Max	7	NA	74	74	NA	1	NA
50-100 m							
Sum	NA	NA	0	0	NA	0	NA
Max	NA	NA	0	0	NA	0	NA
Neutral MF							
0-5 m	**CP 1**	**CP 3**	**CP 4**	**CP 5**	**CP 6**	**CP 7**	**CP 15**
Sum	30729983	43016626	7866469	4783451	55596744	2603674	42215
Max	1260944	2546423	778060	258921	3158198	96819	5469
5-20 m							
Sum	4584064	5069091	2502611	7210115	7456647	516871	18418
Max	373499	238380	177424	374873	496866	25020	2322
20-50 m							
Sum	149996	NA	554893	1100779	NA	2236	0
Max	38581	NA	70433	75526	NA	160	0
50-100 m							
Sum	NA	NA	1747	8237	NA	86	NA
Max	NA	NA	356	1010	NA	5	NA
Heavy MF							
0-5 m	**CP 1**	**CP 3**	**CP 4**	**CP 5**	**CP 6**	**CP 7**	**CP 15**
Sum	734533	880108	433490	19931	2245122	11070	89

Max	149136	112923	47330	1063	651420	1453	12
5-20 m							
Sum	21468292	21562609	1575487	328594	60654877	160819	214
Max	2423776	800591	85104	22716	1987062	19704	36
20-50 m							
Sum	84775523	NA	2463944	5213765	NA	839905	NA
Max	8352172	NA	176221	187074	NA	54698	NA
50-100 m							
Sum	NA	NA	2713280	13296767	NA	499581	NA
Max	NA	NA	201260	1456617	NA	23396	NA
Very heavy MF							
0-5 m	**CP 1**	**CP 3**	**CP 4**	**CP 5**	**CP 6**	**CP 7**	**CP 15**
Sum	9830	50020	22113	21	98836	24	0
Max	3899	29262	4928	3	53213	5	0
5-20 m							
Sum	1451351	40465705	60265	708	28094411	1044	0
Max	472133	2957572	7045	179	1587563	285	0
20-50 m							
Sum	23893308	NA	381091	16617	NA	5746	NA
Max	4119377	NA	85053	1235	NA	804	NA
50-100 m							
Sum	NA	NA	2201191	149699	NA	22117	NA
Max	NA	NA	154209	11893	NA	3900	NA