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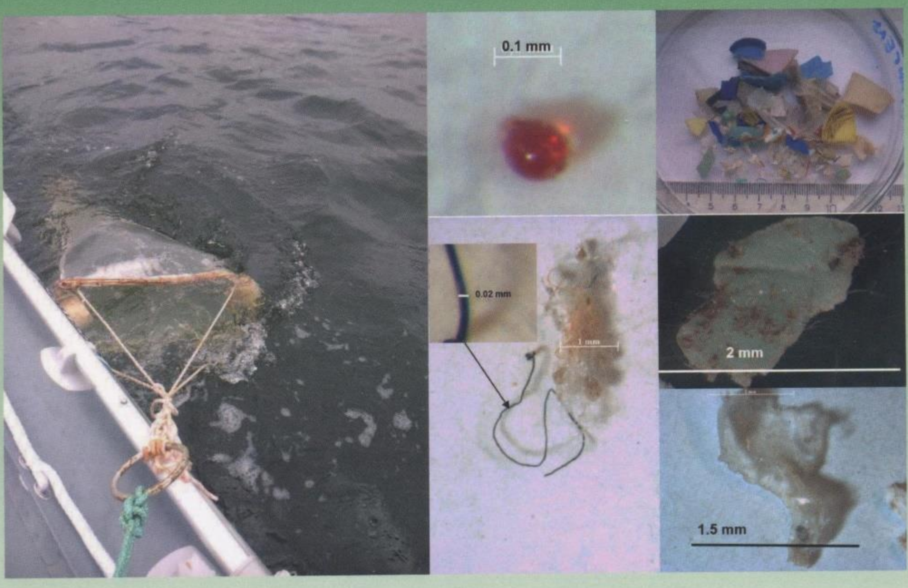
UNEP Regional Seas

MICROPLASTIC POLLUTION in the coastal water of the Peter the Great Gulf: content and distribution. The first stage of survey



POMRAC Technical Report No. 13

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1. Introduction

1. 1. Background

Plastic contamination of the marine and coastal areas has become one of the most important aspects of marine litter issue around the world. The highest concern is raised about the microplastic, i.e. small-sized fragments or unfragmented items with size <5 mm. The marine microplastic is proved to cause harm to the aquatic organisms (P. Davison et al., 2011; F. Murray et al., 2011) and seabirds (M. D. Robards et al., 1995), through both direct harm of ingestion (plastic particles, mistaken by food, may cause indigestion in adult individuals and underdevelopment in young organisms) and contamination with associated chemicals, such as POPs or plasticizers, involving these substances into the trophic chains (Teuten et al., 2009). Therefore, understanding of the situation with microplastic pollution in the NOWPAP region, which is one of the most densely populated area in the world, is necessary. The NOWPAP regional countries, including Japan, People's Republic of China and Republic of Korea already carry out their national marine microplastic studies, while in Russia this activity is new. The coastal water condition is very important for near-shore fisheries and aquaculture. Also, finding probable sources, distribution patterns and structure of microplastic pollutants should be useful in raising concern in the study water areas.

1. 2. Objective of the activity

This project is performed as a RAP MALI activity of NOWPAP POMRAC for the biennium of 2016-2017, and is a survey research of microplastic pollution in the southern part of coastal water area of the Russian Far East.

The overall objective is to reveal microplastic particles in the coastal seawater of the study area, describe their quantities, type/size characteristics, distribution, and possible sources. In the selected areas (mainly in the coastal area near the Tumen River mouth and a beach near Vladivostok) we consider seasonal factor to find any related regularities in the spatio-temporal distribution of contaminants within a year. We also try to compare number and weight of microplastics in the tidal zone, which is a primary target in this study regarding finding possible land-based sources of pollution, with numbers in the nearby water areas located 100-300 meters from the coast.

Prior to starting this activity, preliminary works were carried out to prove that microplastic pollution is an existing threat to the coastal seawater of the Russian NOWPAP area. (Blinovskaya, 2016; Yakimenko and Blinovskaya, 2016; unpublished data by PGI of August 2015). Considering that this project is an early attempt to assess the microplastic contamination in the study area and has a restricted budget, it is expected to become one of the starting points for further related studies.

The importance of this study, besides highlighting the pollution hazard, is its direct relation to the activity of NOWPAP POMRAC on setting Ecological Quality Objectives (objective 5: “Marine litter does not adversely affect coastal and marine environments”). According to the structure of the EcoQOs, further studies of microplastic contamination should include impacts of litter on marine life by monitoring of trends in the amount and composition of litter ingested by marine animals. In this aspect, patterns of coastal microplastic pollution, especially registered hot spots, would be useful as spatial criteria for further studying of contamination of aquatic life with plastic litter.

2. Selection of sampling sites

The Peter the Great Gulf is the largest gulf (9,000 km2) in the Sea of Japan/Easts Sea and consists of three larger bays, i.e. Amur Bay, Ussuri Bay, and Possiet Bay, and smaller bays, such as Nakhodka, Strelok, etc. The Amur Bay coastal area is one of the most populated areas in Primorsky Krai. The Amur Bay washes a considerable part of Vladivostok city located on the Muravyov-Amurskiy peninsula, the home of over 600 thousand people. The coasts of the Ussuri Bay, washing eastern part of the Muravyov-Amurskiy peninsula, and the Nakhodka Bay are also relatively populated areas compared to other coasts of Primorsky Krai.

The sampling sites (fig. 1) are mainly chosen based on the criteria of densely populated and remote areas, though factors of seasonal recreation and river discharge are also considered. On the east of the Amur Bay, we consider urban coastal sites; on the west, small-populated areas (including those used for summer recreation and area near the Razdolnaya/Suifen River mouth).

Fig. 1. Sampling sites: 1) – Khasan Seashore; 2) Cape Nazimov; 3) Minonosok Inlet; 4) Srednyaya Bight; 5) Slavyanka Bay; 6) Perevoznaya; 7) Peschany Peninsula; 8) Chaika Beach; 9) Steklyannaya; 10) Lazurnaya Bay; 11) Strelok Bay; 12) Nakhodka Bay

In the Possiet Bay we consider water area belonging to marine biospheric reserve, and seashore of Khasansky District, located near the Tumen River mouth. In the Ussuri Bay, Nakhodka Bay, and Strelok Bay, we also chose summer recreation areas, urban areas, and sites near river mouths.

3. Methods applied in this study

In this study, we tried to apply the most appropriate and affordable methodology of sampling, sample processing and analysis, as far as at this stage this effort is merely an institutional task.

The sampling and analysis methods already applied by other NOWPAP members, especially Japan (Tokyo University of Marine Science and Technology, Kyushy University) and Republic of Korea (Korean Institute of Ocean Studies and Technologies), were taken into account to develop these studies.

3.1. Sampling methods

Most samples in this study were collected in the tidal zone (0-5 m from the the coastline). Several seawater samples were collected at the distance of 100-300 m from the shore, mainly in the areas of regular survey, to register possible differences in microplastic concentrations depending on the distance from the coastline. The efficiency of this spatial comparison depends on the use of slightly different sampling methods. Below we describe the two methods applied.

3.1.1. Hand net sampling

In this study, we use a plankton net for the sampling in the tidal zone (see table XXXX showing the basic parameters of this net). It is transformed into a hand-net by attaching a retractable rod (the adjusted length is approx. 1-3 meters) to its mouth ring (fig 2 a). The samples are collected along the selected sampling site by horizontal filtering with the net half-submerged into the water (fig. 2 c) To calculate the volume of filtered water, we apply a mechanical flowmeter (Hydro-bios, model 438-110, Germany) attached to the net mouth (fig. 2 b). The volume of filtered water is calculated based on the number of the impeller rotations and the submerged net mouth area. The samples are transferred into plastic bottles of 1000 ml. The volume of filtered water in the tidal zone depends to a considerable extent on the amount of suspended sand and algae in the sampling location. After each filtering, the net walls are rinsed at least thrice from the outside into the related sample containers to include possible remaining plastic particles. After each sampling procedure, the net is rinsed in the fresh water.

Fig. 2. Hand net sampling. Left to right – a) the net with a retractable rod, b) the flowmeter, c) sampling

3.1.2. Neuston net sampling

In addition to the plankton net we used a neuston net to collect water samples at the distance 100-300 m from the shoreline. Table 1 shows the basic parameters of this net.

The manta net/neuston net is considered (Hidalgo-Ruz et al., 2012) as a highly efficient tool for horizontal water sampling in sea. It is very useful for filtering of tens or hundreds cubic meters of water (depending on the mouth area) for a relatively short time (10-20 minutes). The construction of manta net provides its high buoyancy without a need to control the depth of its mouth frame, while the depth of neuston net should be controlled during the tow. We had a neuston net for the research. During the first sampling, the net was directly towed by a motor boat (fig. 3). Later, we attached it (with additional frame providing adjustable fixed depth) to a catamaran dragged by a motor boat. In this case, suddenly reduced towing speed did not result in the submerging of the net frame below sea surface (fig. 4). The average speed of the trawling was 1.5 knots, and the time was 15-20 minutes or more. The water volume was also calculated based on the number of revolutions of flowmeter attached under the boat/catamaran.

Fig. 3. Neuston net sampling. Net directly towed by boat

Fig. 4. Neuston net sampling. Net with adjustable frame is attached to a catamaran

As in case with hand net samples, the filtered neuston trawl was poured into plastic bottles, including water used for rinsing the net walls.
After collection, the samples were brought to the laboratory for further analysis.

Net type	Mouth dimensions, m	Overall length, m	Opening area, m^2	Mesh size, mm
Plankton net	Diameter: 0.2	0.4	0.03	0.1
Neuston net	Width: 0.5 Depth: 0.2	1	0.1	0.1

Table1. Basic parameters of plankton/neuston net we used

3.2. Sample treatment procedure

The sample treatment was mainly based on the protocols adopted from the Korean Institute of Ocean Science and Technology (KIOST), especially in dealing with natural organic matter contained in the samples. It generally coincides with the NOAA sample treatment protocols (Laboratory Methods…, 2015). The following stages are included in the process:

3.2.1. Drying of the sample.

In the laboratory, the collected samples are filtered through a mesh fragment (mesh size 0.1 mm) and the filtered samples are transferred to the beakers (fig. 5). Spatula and minimal amount of distilled water are applied in the process, after that the sample is covered with holed foil to avoid airborne contamination and dried at temperature of 25 C° (ambient temperature) to 60 C° (using desiccator).

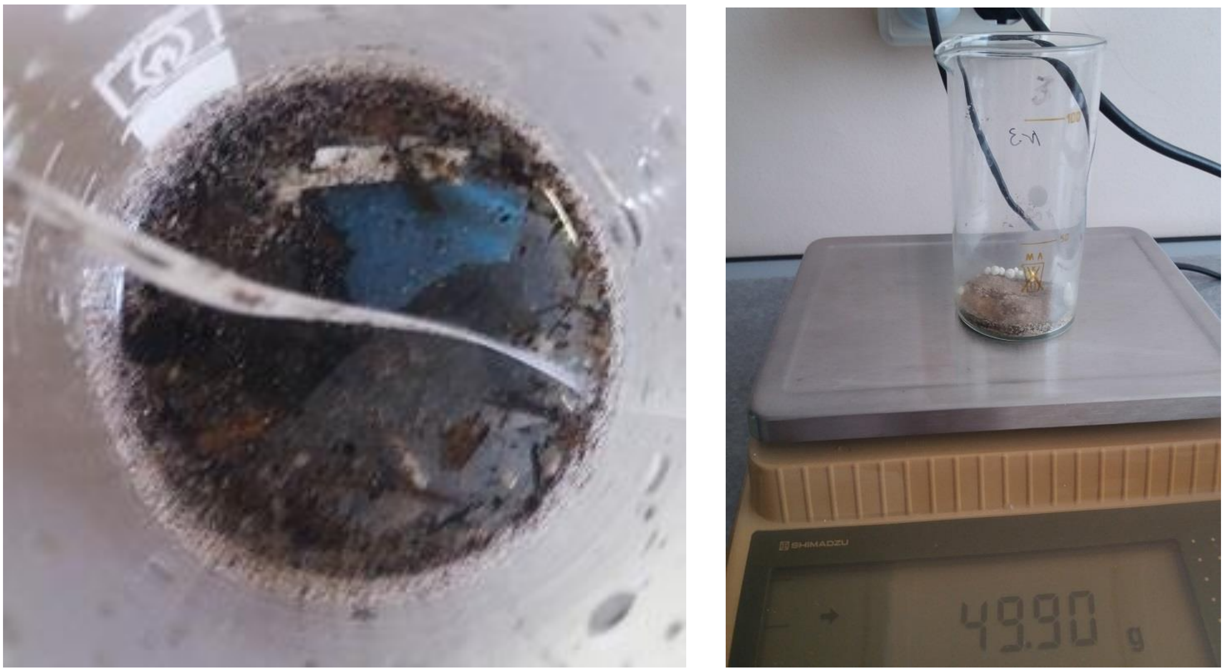


Fig.5. Left- a sample in a beaker before drying, right- a dried sample being weighed

3.2.2. Removal of natural organic matter.

After drying, 20 ml of 0.05 M Fe(II)SO4 water solution is applied to the sample, then 30% H2O2 is added (20mg or more, if necessary) by small portions to remove extra organic matter. In this reaction, Fe(II) is used as a catalyst to accelerate the process of decomposition. After most of organic matter is decomposed by the reaction, 6 grams of NaCl is added per each 20 ml of the sample. After adding NaCl, the sample is carefully mixed with a glass rod to make the solution more homogeneous (fig. 6).

Fig.6. Left - adding hydrogen peroxide; right - NaCl

3.2.3. Density separation and filtering

The next step is transferring of the solution in the density separator funnel, including careful rinsing of the beaker that contained the sample (fig. 7). After that, the funnel is covered with foil to avoid contamination and settled for a day to deposit heavy solid fraction. Next, the lower fraction is drained from the funnel to check for possible miroplastic particles remaining and then it is discarded. The supernatant and particles remaining on the funnel walls are then carefully washed with distilled water into the filtering system. The filters applied are 47mm diameter polycarbonate filters with pore size of 5 μm. After filtering, the particles remaining on the walls of filtering system are carefully transferred to the filter paper using forceps and distilled water. Then filters are dried at room temperature in petri dishes for further analysis.

Fig.7. After density separation in a funnel samples are transferred to polycarbonate filters

3.3. Type/size description of microplastics

Sorting and type-size identification of the plastic particles is carried out using a stereomicroscope (Discovery V12). By size classification, the following major groups are selected: 0.1-1 mm (smaller microplastics), 1-5 mm (larger microplastics), and 5-25 mm (mesoplastics). In this research, the size of the smallest microplastic particles is 0.1 mm corresponding to the sampling mesh size. The size of the plastic particles is determined using the camera application installed on the microscope. Main types of the obtained plastic are identified as follows: fibers (fig. 10 a), fragments (fig. 8), films (fig. 9), and foam (fig. 10 b). We also registered paint fragments and microbeads (fig.11), but as of now, their number tends to be low in the sites of survey.

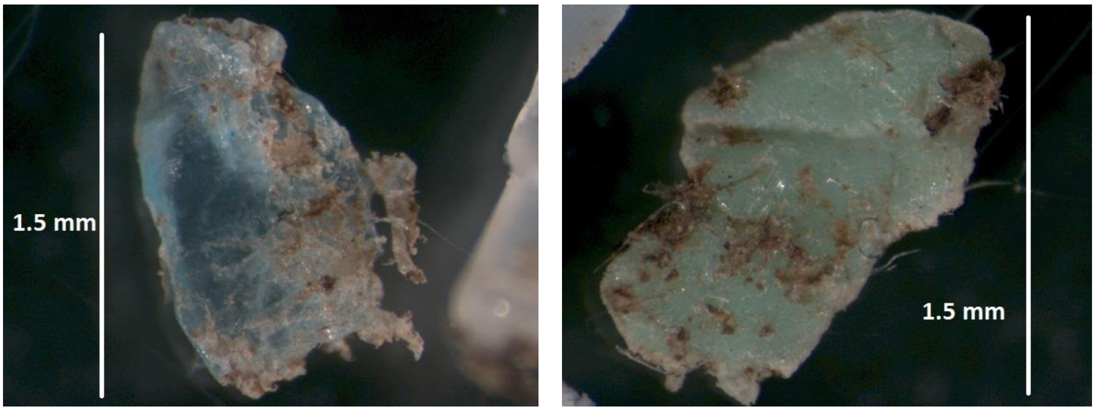


Fig.8. Fragments

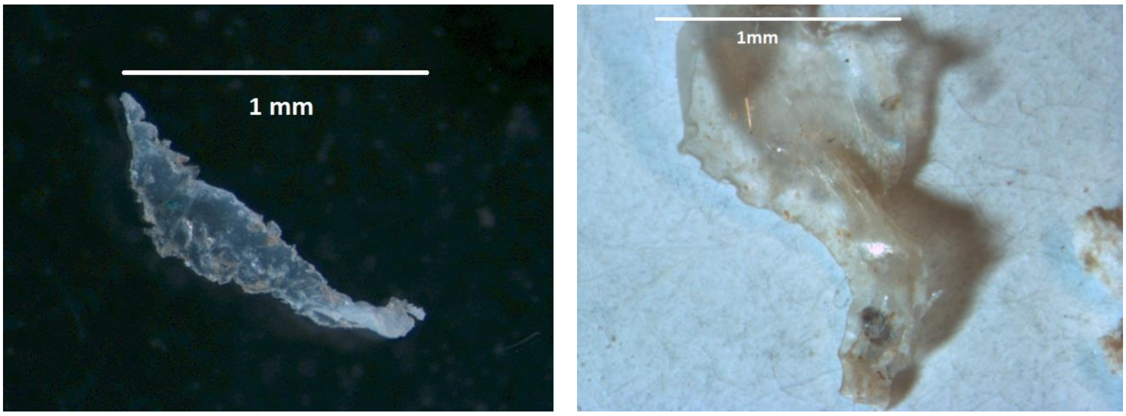


Fig.9. Films

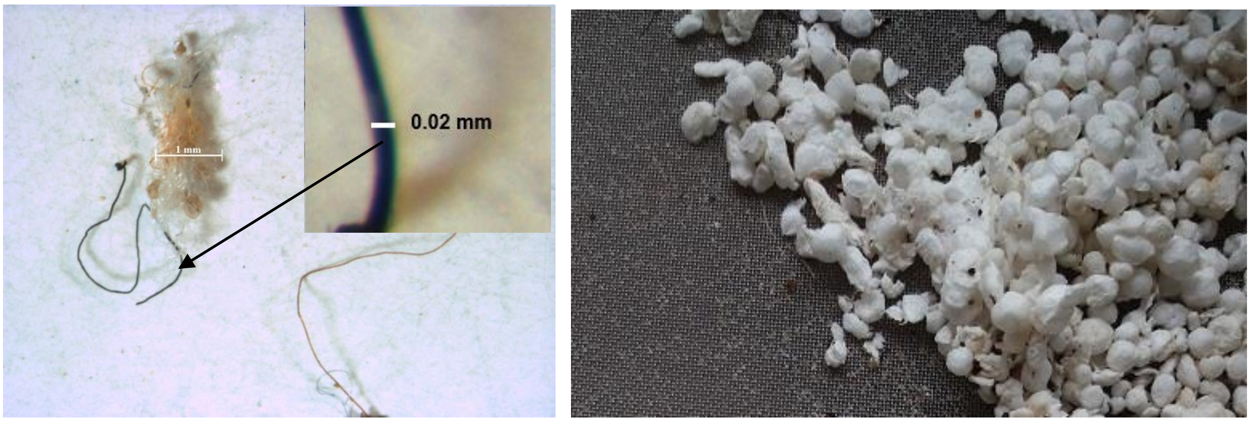


Fig. 10. a) Fibers; b) Foam (EPS) on 0.3 mm steel mesh

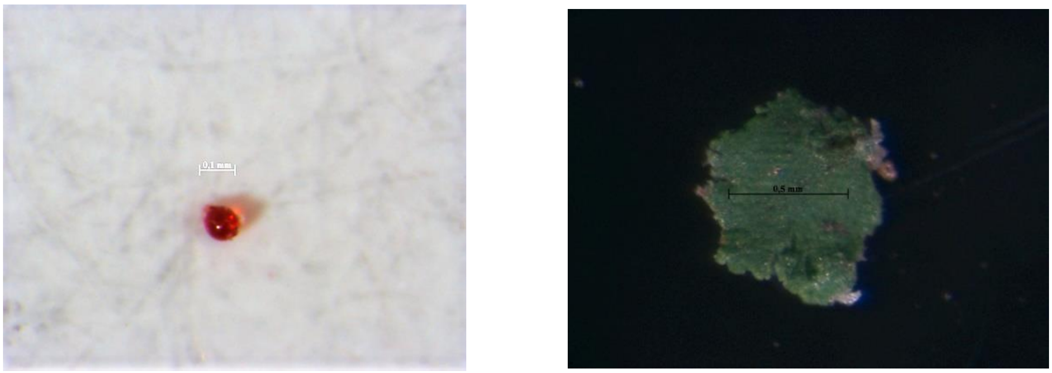


Fig.11. a) microbead (diameter 0.1 mm); b) paint fragment (diameter 0.6 mm)

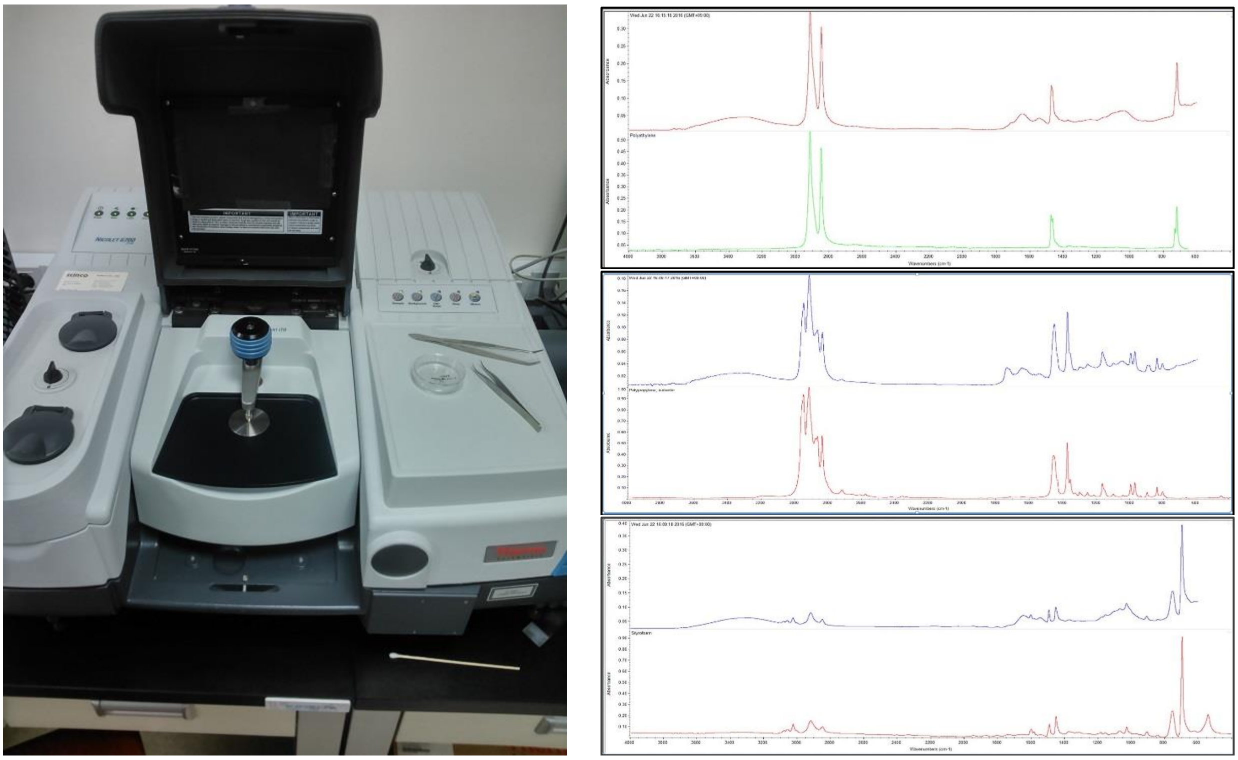


Fig.12. FTIR spectrometer and IR-spectra of the most frequent polymer types in the marine environment (Polyethylene(PE), Polypropylene (PP), and Polystyrene(PS)). Reference spectra of each polymer type are depicted below actual spectra of marine microplastics.

3.4. Weight measurement

During the type/size identification the plastic-like objects are retrieved from each sample and transferred to preliminarily weighed envelopes made of tracing paper for determining their weight with analytical scale. Before weighing, the envelopes with and without plastics are dried under 80degrees C for 4 hours to remove extra water contained by the tracing paper.

3.5. Polymer type identification

Identification of polymers (fig.12) is conducted with application of attenuated total reflection spectroscopy (ATR) using Diamond ATR device set on the Fourier transform infrared spectrometer (Thermo Nicolet 6700). The spectrum of each identified object is determined based on a series of scans ($\Sigma = 32$).

4. Distribution of plastic particles

Fig. 13 shows generalized distribution of microplastics among the selected sampling sites of the coastal area of the Peter the Great Gulf. This data is actual for summer and fall seasons and is compiled considering samples collected in 2016 and 2017. As we processed the initial sampling data, we tried to focus our further survey on the sites showing higher concentrations of microplastic particles. These sites are the coastal area adjoining to the Tumen River mouth and the eastern part of the Amur Bay.

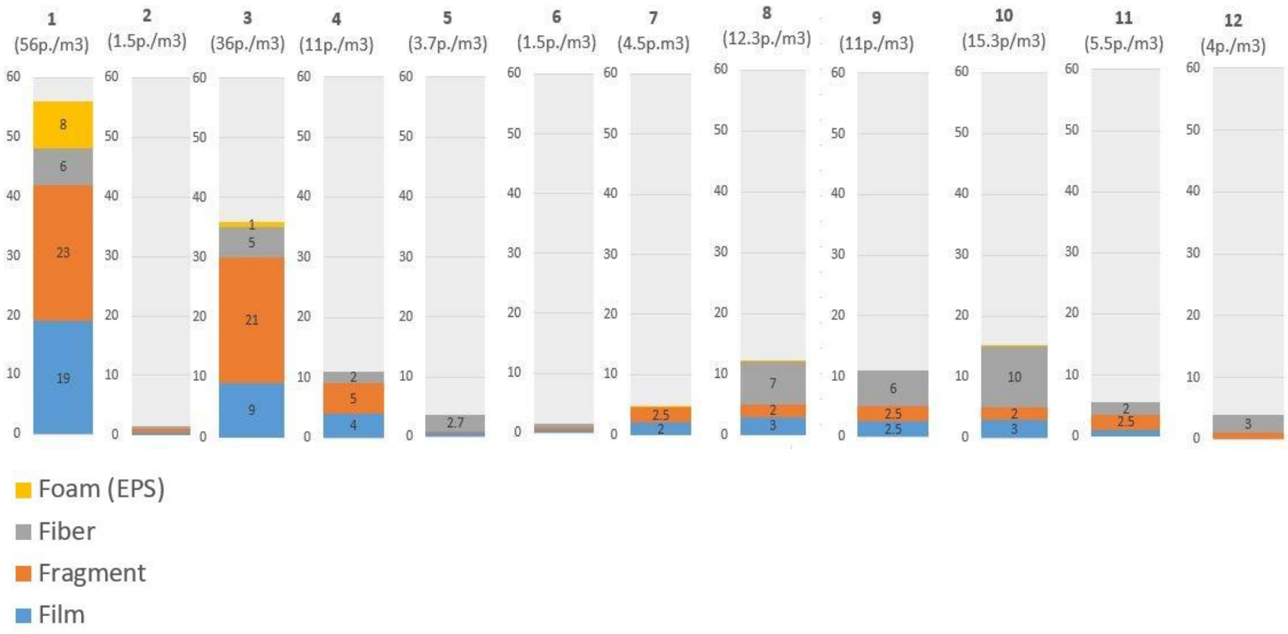


Fig. 13. Generalized distribution of floating micro-and mesoplastic particles in the tidal zone of the Peter the Great Gulf in July-September 2016-2017

Below we describe each selected site starting from the southwest of the study area. Description includes information on the geographical location, composition of floating microplastics, possible sources of contamination, seasonal peculiarities, etc.

4.1. Khasan seashore (Site 1)

This area is situated far from inhabited localities and is difficult to assess due to its remoteness. No considerable economic activities, except seasonal bird hunting, are registered there. Tourists and beach goers are basically not allowed in that area wthout permission because it is neighboring to the state border. We chose this site for the survey because it is very close to the Tumen River mouth (approximately 5 km from the estuary). The Tumen River is an important transboundary water body shared by the three countries, including China, North Korea, and Russia. Despite the fact that the river is not used for shipping since 1940, its basin is densely populated (by approximately 2 million people in China and North Korea). That is why we suggested that the river may serve as a source of microplastic pollution in the selected area. The sampling site is located on a wide and long sandy beach (approximately 10-15 km in length) stretching from the river estuary to the Sivuchya Bay, which belongs to the Far Eastern Marine Biospheric Reserve. We collected three samples in this location: in September 2016 , in July 2017, and in October 2017. Each sample displayed high concentrations of micro-and meso plastic fragments in the tidal zone. As of now, these figures considerably exceed floating microlitter concentrations from all other sampling sites we selected.

Fig.14. Beached EPS on the Khasan shore (28 September 2016)

Sampling date, dd/mm/yy	Sample volume, m^3	Basic fragment types, p./m^3		Polymer types	Number, p./ m^3	Weight, mg/m^3
27/09/2016	2.5	Fragment	12	PE, PP, PS	54	15.8
		Film	21	PE, PP		
		Fiber	11	Nylon, Polyester, PP		
		Foam	10	PS		
28/07/2017	3.6	Fragment	23	PE, PP, PS	56	57.6
		Film	19	PE, PP		
		Fiber	6	Nylon, Polyester, PP		
		Foam	8	PS		
11/10/2017	2	Fragment	10	PE, PP	31	6.9
		Film	14	PE, PP		
		Fiber	5	Nylon, Polyester,		
		Foam	2	PS		
Average number/weight					47	26.7

Table 2. Khasan seashore, description of floating micro- and mesoplastics in the tidal zone

Besides the fact that the concentrations of floating plastic particles are higher than elsewhere in this study, number of EPS particles was not less than 8p./m3 in all three samples (14-25%) , which is also very peculiar to this area. The beach is covered with dense patches of foam spherules or larger EPS fragments (fig. 14), and we calculated that beached EPS micro- and mesoplastic reaches 95-99% of all other plastic fragments.

4.2. Cape Nazimov (Site 2)

This site is located in the apex of the Posyet Bay, northeast to the previously described sampling site. This area borders with few inhabited localities and with the port of Possiet (approx. 4,500 people). Cape Nazimov is a popular recreation place in summer, though it is uninhabited. We suggested that the water area could be polluted with microplastics considering its relative vicinity from the highly littered site. Nevertheless, microplastic concentrations there tend to be low (0.5-2 p./m3). We collected two samples from the area, in September 2016 and in June 2017. During the recreational season, the concentrations turned to be even lower than in late September. It is difficult to accurately assess which fragment types prevail there due to low total number of floating microplastic particles in both samples (approx. 5 m^3 contained 15 microplastic particles)

Sampling date, dd/mm/yy	Sample volume, m^3	Basic fragment types, p./m^3		Polymer types	Number, p./ m^3	Weight, mg/m^3
29/09/2016	2.4	Fragment	1	PE	3	0.1
		Film	2	PE, PP		
		Fiber	-	-		
		Foam	-	-		
28/07/ 2017	2.7	Fragment	-	-	3	0.05
		Film	2	PE, PP		
		Fiber	1	Polyester		
		Foam	-			
Average number/weight					3	0.075

Table 3. Cape Nazimov, description of floating micro- and mesoplastics in the tidal zone

4.3. Minonosok Inlet (site 3)

The Minonosok Inlet is a small water area in the Posyet Bay, which is a part of the western section of the Far Eastern Marine Biosphere Reserve (FEMBR). This area is aquaculture farms for the cultivation of such commercial species as scallop and oyster. These farms provide for the restoration of natural scallop population in the reserve.

Sampling date, dd/mm/yy	Sample volume, m^3	Basic fragment types, p./m^3		Polymer types	Number, p./ m^3	Weight, mg/m^3
04/06/2016	0.9	Fragment	21	PE, PP	36	11.9
		Film	9	PE, PP, PTFE		
		Fiber	5	Nylon, PE		
		Foam	1	PS		

Table 4. Minonosok Inlet, description of floating micro- and mesoplastics in the tidal zone

Sampling date, dd/mm/yy	Sample volume, m^3	Basic fragment types, p./m^3		Polymer types	Total number, p./ m^3	Weight, mg/m^3
04/06/2016	15	Fragment	0.4	PE	0.7	n/a
		Film	0.3	PE, PP		
		Fiber	-	-		
		Foam	-	-		

Table 4.1. Minonosok Inlet, description of floating micro- and mesoplastics collected by neuston trawl

We had a chance to join the cruise of R/V Nasonov in late May-early June 2016 and collected samples in Minonosok Inlet (table 4 and 4.1.) and in Srednyaya Bight (table 5 and 5.1.), which both belong to the FEMBR. We cannot describe seasonality impact in the inlet because we collected only one sample there, but evidently, weathered PE buoys on the shore considerably litter the water area with microplastics.

4.4. Srednyaya Bight (site 4)

Sampling date, dd/mm/yy	Sample volume, m^3	Basic fragment types, p./m^3		Polymer types	Number, p./ m^3	Weight, mg/m^3
05/06/2016	1.1	Fragment	5	PE	11	0.5
		Film	4	PE, PP		
		Fiber	2	Nylon		
		Foam	-	-		

Table 5. Srednyaya Bight, description of floating micro- and mesoplastics in the tidal zone

Sampling date, dd/mm/yy	Sample volume, m^3	Basic fragment types, p./m^3		Polymer types	Total number, p./ m^3	Weight, mg/m^3
05/06/2016	15	Fragment	0.13	PE, PP	0.4	n/a
		Film	0.27	PE, PP		
		Fiber	-	-		
		Foam	-	-		

Table 5.1. Srednyaya Bight, description of floating micro- and mesoplastics collected by neuston trawl


Fig. 15. Left - Srednyaya Bight, right- Peschany Peninsula

4.5. Slavyanka Bay (site 5)

The area we chose for sampling is a tourist beach exposed to an intense flow of recreants in summer. Local population in adjoining areas is relatively small (around 12,000 people), therefore we suggested that as in case with larger litter, seasonal input of microplastics (especially of primary type) would be higher in summer. We collected samples in late September 2016 and in July 2017 (table 6).

Sampling date, dd/mm/yy	Sample volume, m^3	Basic fragment types, p./m^3		Polymer types	Number, p./ m^3	Weight, mg/m^3
28/09/2016	2.2	Fragment	-	-	0.5	<0.01
		Film	-	-		
		Fiber	0.5	Polyester		
		Foam	-	-		
28/07/ 2017	2	Fragment	0.5	PE	5.5	0.2
		Film	1	PE, PP		
		Fiber	4	Polyester		
		Foam	-			
Average number/weight					3	0.1

Table 6. Slavyanka Bay, description of floating micro- and mesoplastics in the tidal zone

4.6. Perevoznaya Bight (site 6)

This water area is situated near an inhabited locality with small population number (less than 1,000 people). This is also not a popular place for recreation, so we did not expect to find many plastics in the water. However, we sampled this area only once and cannot be sure if any seasonal impact is peculiar there.

Sampling date, d/m/y	Sample volume, m^3	Basic fragment types, p./m^3		Polymer types	Total number, p./ m^3	Weight, mg/m^3
28/09/2016	2	Fragment	0.5	-	1.5	0.05
		Film	0.5	-		
		Fiber	0.5	Polyester		
		Foam	-	-		

Table 7. Perevoznaya Bight, description of floating micro- and mesoplastic in the tidal zone

4.7. Peschany Peninsula (site 7)

This area is also low populated, though local people use the adjoining water area for fishing. Also, it is located opposite to the Vladivostok city. The table below (table 8) shows the results of sampling we carried out in September 2016 and in July 2017.

Sampling date, d/m/y	Sample volume, m^3	Basic fragment types, p./m^3		Polymer types	Total number, p./ m^3	Weight, mg/m^3
28/09/2016	3	Fragment	-	-	3.5	0.5
		Film	3	PE, PP		
		Fiber	-	-		
		Foam	0.5	PS		
26/07/ 2017	4.7	Fragment	1.5	PE	6.7	2.03
		Film	5	PE, PP		
		Fiber	0.2	Polyester		
		Foam	-	-		
Average number/weight					5.1	1.3

Table 8. Peschany Peninsula, description of floating micro- and mesoplastics in the tidal zone

4.8. Chaika beach (site 8)

This is a narrow pebble-covered beach (approx. 10 meters in width) located on the western coast of the Amur Bay. This site is exposed to urban area impacts as it is located in close vicinity to Vladivostok city. Also it is used for summer recreation and amateur fishing. This location is near to Pacific Geographical Institute and easy to assess. Due to this fact we carry out more detailed seasonal monitoring in the tidal zone, and compare summer data for the tidal zone to neuston trawling data (usually in July-August). The table 9 shows the results of tidal water sampling in 2016-2017.

Sampling date, d/m/y	Sample volume, m^3	Basic fragment types, p./m^3		Polymer types	Total number, p./ m^3	Weight, mg/m^3
21/07/2016	2	Fragment	1	PE	11	2.1
		Film	7.5	PE, PP		
		Fiber	2	PP, Polyester		
		Foam	0.5	PS		
16/02/ 2017	3	Fragment	-	-	0.3	<0.001
		Film	-	-		
		Fiber	0.3	Polyester		
		Foam	-	-		
16/05/ 2017	3	Fragment	7	PE	15.6	2.25
		Film	2.3	PE, PP		
		Fiber	6.3	Polyester, PE, PP		
		Foam	-	-		
18/06/ 2017	2.5	Fragment	3.2	PE, PP	14.4	2.08
		Film	3.2	PE, PP		
		Fiber	8	Polyester, PP		
		Foam	-	-		
16/07/ 2017	3	Fragment	2	PE	12	1.9
		Film	3	PE, PP		
		Fiber	7	Polyester		
		Foam	-	-		
08/08/ 2017	3.1	Fragment	2	PE	17.5	2.1
		Film	7.5	PE, PP		
		Fiber	8	Polyester, nylon		
		Foam	-	-		
16/09/ 2017	3	Fragment	0.5	PE	7.5	0.2
		Film	1	PE		
		Fiber	6	Polyester, nylon		
		Foam	-	-		
18/10/ 2017	2.8	Fragment	-	-	5	0.1
		Film	1	PE		
		Fiber	4	Polyester		
		Foam	-	-		
15/11/ 2017	3	Fragment	-	-	5.3	0.03
		Film	0.3	PE		
		Fiber	5	Polyester, nylon		
		Foam	-	-		
Average number/weight					9.8	1.2

Table 9. Chaika Beach, description of floating micro- and mesoplastics in the tidal zone

Fig. 16. Chaika beach, late November

Besides seasonal sampling in the tidal zone, we collected several samples by trawling. In general, ratio of plastics collected by neuston net trawl to those collected by the hand net was approximately 10 times lower.

In August 2015 we collected preliminary samples by towing of a plankton net in that area to find any plastic fragments in the seawater to substantiate the necessity of this research. Despite the fact that various tools were applied (neuston net with rectangular mouth and opening area of 0.1 m^2 against plankton net with circular mouth and opening area of 0.03 m^2), the collected data seems to be very important showing high concentrations of fibers in that area (table 10)

Sampling date, d/m/y	Sample volume, m^3	Basic fragment types, p./m^3		Polymer types	Total number, p./ m^3	Weight, mg/m^3
12/08/2015	≈120*	Fragment	0.01	PE, PS	1.7	n/a
		Film	0.05	PE, PP		
		Fiber	1.6	n/a		
		Foam	-	-		
		Microbead	0.01	PE		
21/07/ 2016	47	Fragment	0.25	PE	1.1	0.08
		Film	0.14	PE, PP		
		Fiber	0.71	Polyester		
		Foam	-	-		
		Microbead	-	-		
08/08/2017	65	Fragment	0.18	PP, PE, PS	0.6	0.05
		Film	0.12	PE, PP		
		Fiber	0.22	Polyester, PE		
		Foam	0.08	PS		
		Microbead	0.01	PE		
Average number/weight					1.13	0.06

Table 10: Chaika beach, description of floating micro- and mesoplastics collected by neuston trawl

*We did not use flowmeter in August 2015. The volume of filtered water was calculated by the formula: V=Qt, where Q is water discharge and t is time.

Q was calculated as follows:

Q=vS,

where v is the speed of the boat, and S is the net opening area.

4.9. Steklyannaya Bight (site 9)

This bight is located in the Ussuri Bay and is also exposed to impact of Vladivostok city. This site is also used for summer recreation. We collected tidal zone samples and neuston samples (tables 11 and 12) to compare concentrations in two largest bays of the gulf (i.e. the Amur Bay and the Ussuri Bay).

Sampling date, dd/mm/yy	Sample volume, m^3	Basic fragment types, p./m^3		Polymer types	Total number, p./ m^3	Weight, mg/m^3
20/06/2017	3.2	Fragment	2.7	PE, PP, PS	11	0.3
		Film	2.7	PE, PTFE		
		Fiber	5.6	Polyester, PE, PP		
		Foam	-	-		
08/08/2017	3	Fragment	1.7	PE, PP	10.7	0.25
		Film	2	PE, PP		
		Fiber	7	Polyester		
		Foam	-	-		
Average number/weight					10.8	0.27

Table 11. Steklyannaya Bight, description of floating micro- and mesoplastics in the tidal zone

Sampling date, d/m/y	Sample volume, m^3	Fragment types, number, p./m^3		Polymer types	Number, p./ m^3	Weight, mg/m^3
08/08/2017	62	Fragment	0.01	-	0.13	0.005
		Film	-	-		
		Fiber	0.12	Polyester, PE		
		Foam	-	-		

Table 12. Steklyannaya Bight, description of floating microplastics collected by neuston trawl

4.10. Lazurnaya Bay (site 10)

Lazurnaya Bay is a part of the Ussuri Bay. This is a wide and long sandy beach with strongly expressed seasonal human load, being the most popular recreational site in the vicinity of Vladivostok city. We sampled this site in October 2017 and in July 2017. The results of sampling are shown below (table 13).

Sampling date, d/m/y	Sample volume, m^3	Fragment types, number, p./m^3		Polymer types	Total number, p./ m^3	Weight, mg/m^3
20/10/2016	3	Fragment	1	PE, PP, PS	9	0.1
		Film	1	PE, PTFE		
		Fiber	7	Polyester, PE, PP		
		Foam	-	-		
09/08/2017	3.1	Fragment	2	PE, PP, PS	15.3	0.8
		Film	3.3	PE, PP		
		Fiber	9.7	Polyester, PP		
		Foam	0.3	PS		
Average number/weight					10.8	0.27

Table 13. Lazurnaya Bay, description of floating micro/mesoplastics collected in the tidal zone

4.11. Strelok Bay (site 11)

It is a bay in the eastern part of the gulf. The population in the adjoining area is much lower than along eastern coast of the Amur Bay and western coast of the Ussuri Bay, though this area is used for summer recreation as most of coastal areas in the survey. Only one sample was collected in autumn. The results of sampling are shown below (table 14).

Sampling date, d/m/y	Sample volume, m^3	Fragment types, number, p./m^3		Polymer types	Total number, p./ m^3	Weight, mg/m^3
04/09/2017	2	Fragment	2.5	PE, PP	5	0.4
		Film	0.5	PE		
		Fiber	2	Polyester		
		Foam	-	-		

Table 14. Strelok Bay, description of floating micro- and mesoplastics in the tidal zone

4.12. Nakhodka Bay (site 12)

The Nakhodka bay washes the city of Nakhodka and adjoining port area. We collected only one sample in the autumn, so there is a need for more detailed seasonal study in this area. Table 15 shows the results of sampling.

Sampling date, d/m/y	Sample volume, m^3	Fragment types, number, p./m^3		Polymer types	Total number, p./ m^3	Weight, mg/m^3
04/09/2017	3	Fragment	1	PE	4	0.1
		Film	-	-		
		Fiber	3	Polyester, PP		
		Foam	-	-		

Table 15. Nakhodka Bay, description of floating micro- and mesoplastics in the tidal zone

5. Discussion

5.1. Hotspots

By the results of this survey, the most noticeable hotspots of microplastic pollution in the tidal zone of the Peter the Great Gulf are the coastal area near Tumen River estuary and the adjoining water areas in the southern part of the Posyet Bay and coastal area around the Muravyov-Amursky Peninsula (eastern part of the Amur Bay and western part of the Ussuri Bay), i.e. the area belonging to Vladivostok agglomeration. The highest concentrations of microplastics in the seawater were registered along the coastline of Khasan district (Khasan Seashore), reaching 54-56 plastic particles of various shape and size per 1m^3. Contamination in the tidal zone of Minonosok Inlet (south-eastern part of the Posyet Bay) is also high, reaching 36 particles per m^3. Near Vladivostok agglomeration, the eastern coast of the Amur Bay and the western coast of the Ussuri Bay are exposed to microplastic contamination to approximately similar extent, reaching 11-16 particles per m^3 and 10-15 particles per m^3 correspondingly.

The lowest concentrations of microplastics in the tidal zone are registered in the northern part of the Posyet Bay and in the Perevoznaya Bay (3 particles per m^3 and 1.5 particles per m^3)

5.2. Morphological composition

The composition of microplastics in the tidal zone differs for each location. In number, all morphological types obtained from the Khasan area (near Tumen River estuary) prevail or comparable to other sampling locations. Number of fragments there is comparable to Minonosok Inlet, but considerably overcomes all other sites (6-20 times). Number of films overcome all sampling locations (2.5–20 times). Number of fibers in the tidal zone of Khasan is comparable to concentrations registered near the Vladivostok agglomeration, but also higher than elsewhere in this survey. Foamed styrene concentrations are relatively low in the gulf, except Khasan area (up to 10 times higher than in other sampling locations).

Table16 shows minimum and maximum concentrations of microplastics by morphological type, though for many sites this distribution may be disputable due to low total number of microplastic particles collected or only one sampling made. The table does not include winter samples because only one site was selected for winter sampling (Chaika Beach).

Sampling site	Fragment, Number/m^3		Film, Number/m3		Fiber, Number/m3		Foam, Number/m3	
1) Khasan shore	12-23	(22-41%)	14-21	(39-34%)	6-11	(11-20%)	8-10	(14-19%)
2) Nazimov Cape	0-1	(0-33%)	9	(67%)	0-1	(0-33%)	0	(0%)
3) Minonosok Inl.	21	(58%)	4	(25%)	5	(14%)	1	(3%)
4) Srednyaya B.	5	(46%)	0-1	(36%)	2	(18%)	0	(0%)
5) Slavyanka Bay	0-0.5	(0-9%)	0.5	(0-18%)	0.5-4	(73-100%)	0	(0%)
6) Perevoznaya B.	0.5	(33.3%)	3-5	(33.3%)	0.5	(33.3%)	0	(0%)
7) Peschany Pen.	0-1.5	(0-22%)	2.3-7.5	(75-86%)	0-0.2	(0-3%)	0-0.5	(3-22%)
8) Chaika Beach	1-7	(22-44%)	2-2.7	(14-22%)	2-8	(39-56%)	0-0.5	(0-3%)
9) Steklyannaya	1.7-2.7	(16-19%)	1-3.3	(19-25%)	5.6-7	(51-53%)	0	(0%)
10) Lazurnaya	1-2	(11-13%)	0.5	(11-22%)	7-9.7	(63-78%)	0-0.3	(0-2%)
11) Strelok Bay	2.5	(44.5%)	0	(11%)	2	(44.5%)	0	(0%)
12) Nakhodka B.	1	(25%)	2	(0%)	3	(75%)	0	(0%)

Table 16. Minimum and maximum concentrations of microplastic particles by morphological type

5.3. Size differentiation

For most of the sampling sites the fraction of 0.1 – 1 mm was the most abundant, ranging from approximately 55 to 30-35 percent, followed by the 1-5 mm fraction (45-25 percent). Mesoplastics was found mainly in the most contaminated areas, for example near the Tumen River estuary (fig. 17).

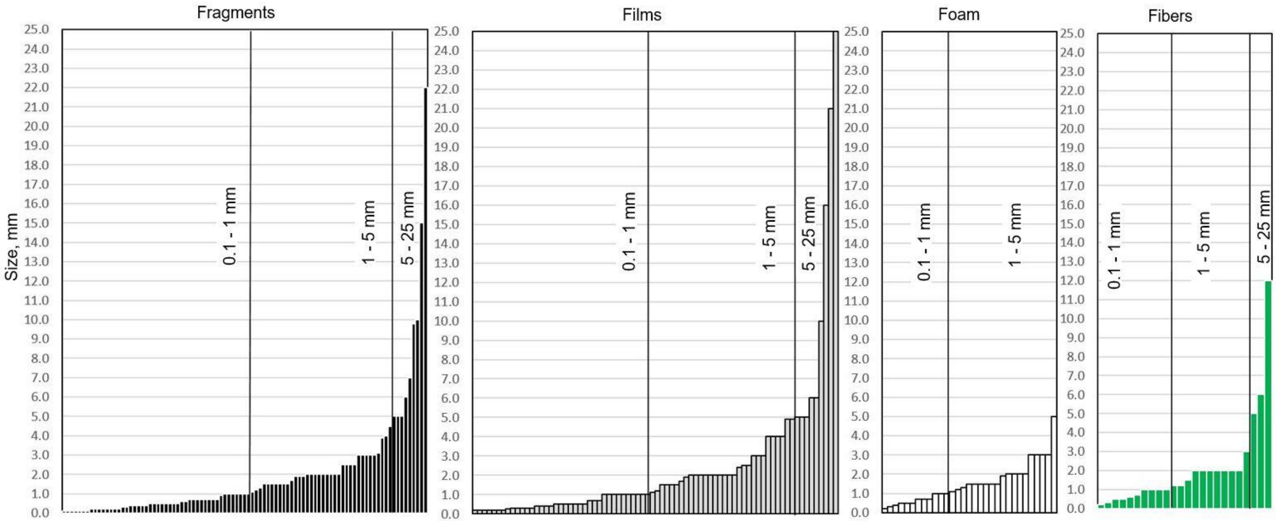


Fig. 17. Size range of floating microplastic particles in the tidal zone of Khasan seashore, July 2017 (0.1-1 mm – smaller microplastics, 1-5 – larger microplastics, 5-25 – mesoplastics)

5.4. Polymer composition

Regarding polymer type composition, in the most reliable (considering the total number of microplastics) sampling sites prevailing is polyethylene (50-70%) and it is followed by polypropylene (16-36%) and polystyrene (8-25%). Fig. 18 shows distribution of polymers in key sampling locations. However, regarding other polymer types, such as polyester or nylon, this may be not exactly true because in case with fibers we identified less than 10% of total number, as we did not use FTIR-microscope. Among the microfiber samples that we managed to identify, approximately 50% were polyester, the other 15-20% were nylon and the rest were PP and PE, and two fibers were PS.

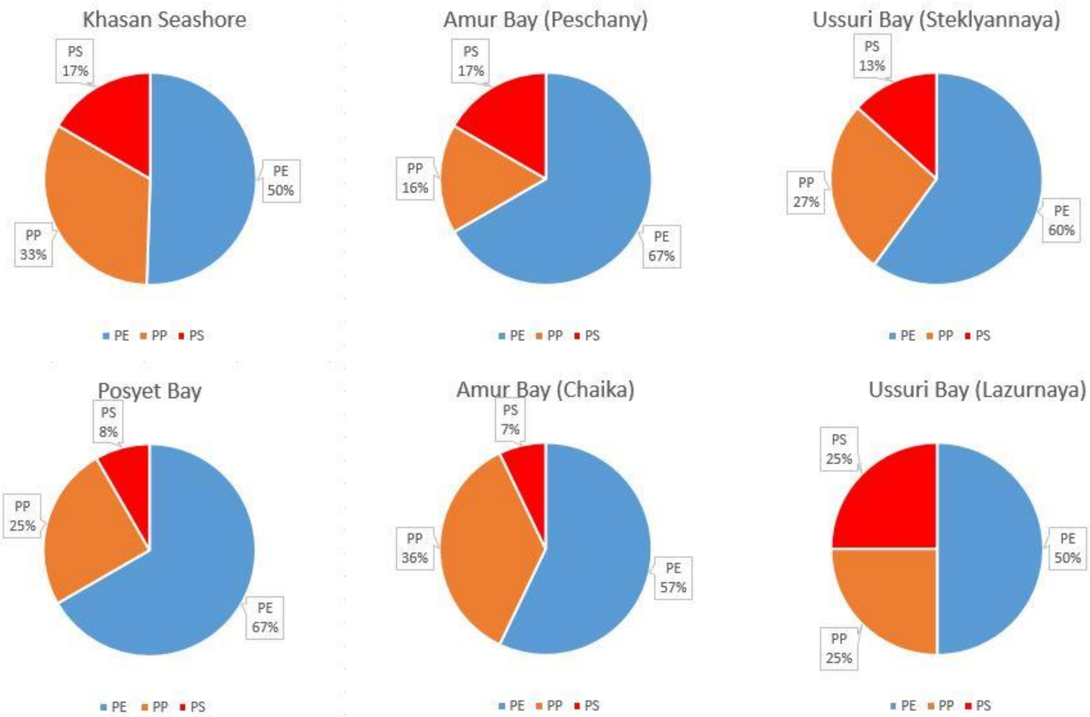


Fig. 18. Distribution of basic polymer types in key sampling locations

5.5. Comparison of hand net sampling results and results of neuston trawling

Unlike hand net samples, we collected neuston samples only in summer. That is why we can compare summer trawls and summer hand net samples (table 17). We conducted neuston net trawling in four locations, including Minonosok Inlet, Srednyaya Bight, eastern part of the Amur Bay (near Chaika Beach), and western part of Ussuriisky Bay (Steklyannaya Bight). The table below shows differences between concentrations in the tidal zone and 100-300 meters from the coast. In general, the concentrations of plastic particles in the coastal water outside tidal zone is nearly ten times lower in comparison with tidal water.

Sampling location	Sampling method	Sampling date, d/m/y	Fragment types, number, p./m^3		Number, p./ m^3	Weight, mg/m^3
1) Minonosok Inlet	Hand net sampling	04/06/2016	Fragment	21	36	11.9
			Film	9		
			Fiber	5		
			Foam	1		
	Neuston trawling	04/06/2016	Fragment	0.4	0.7	n/a
			Film	0.3		
			Fiber	-		
			Foam	-		
1) Srednyaya Bight	Hand net sampling	05/06/2016	Fragment	5	11	0.5
			Film	4		
			Fiber	2		
			Foam	-		
	Neuston trawling	05/06/2016	Fragment	0.13	0.4	n/a
			Film	0.27		
			Fiber	-		
			Foam	-		
2) Chaika beach (eastern part of the Amur Bay)	Hand net sampling	16/07/2017	Fragment	2	12	1.9
			Film	3		
			Fiber	7		
			Foam	-		
	Neuston trawling	08/08/2017	Fragment	0.18	0.6	0.05
			Film	0.12		
			Fiber	0.22		
			Foam	0.08		
			Microbead	0.01		
3) Steklyannaya Bight (western part of the Ussuri Bay)	Hand net sampling	08/08/2017	Fragment	1.7	10.7	0.25
			Film	2		
			Fiber	7		
			Foam	-		
	Neuston trawling	08/08/2017	Fragment	0.01	0.13	0.005
			Film	-		
			Fiber	0.12		
			Foam	-		

Table 17. Comparison of hand net /neuston net samples

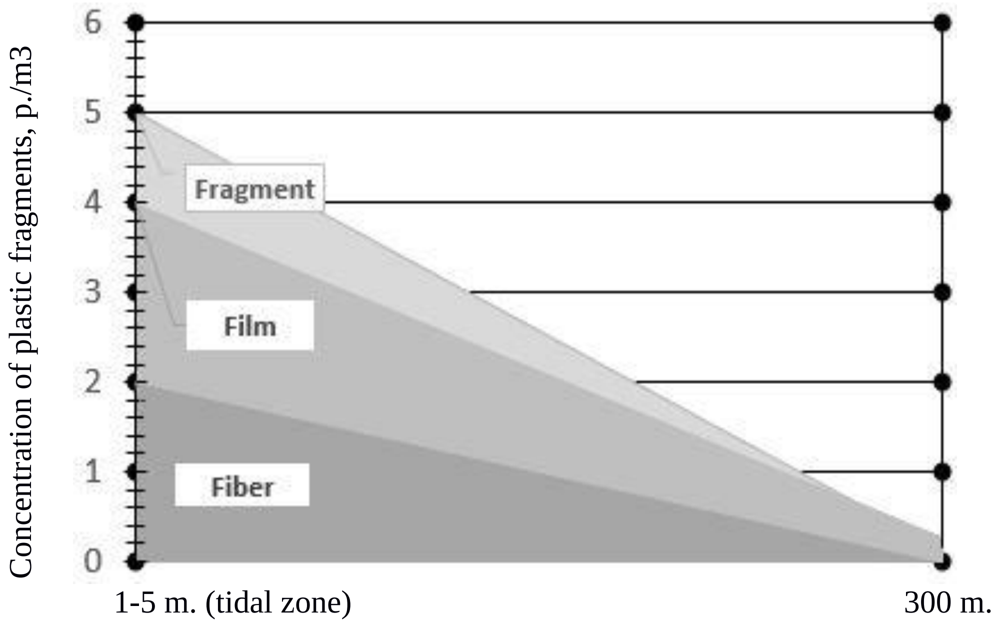


Fig. 19. An example of varying concentrations of 3 types of plastic fragments from tidal zone to 300 meters seawards (Srednyaya Bight, June 2016)

5.6. Comparison of microplastic concentrations in the study area and worldwide

In view that it is difficult to find enough data on microplastics in the tidal water (except intertidal sediments) for global comparison, we can compare global data on microplastics collected by neuston/manta net trawling in the coastal water (table 18)

Location	Mesh size (µm)	MP (par. /m3)	References
SE Black Sea	200	600–1200	Aytan et al., 2016
China, Yangtze Estuary	32	500–10200	Zhao et al., 2014
China, Yangtze Estuary	333	0.03–0.455	Zhao et al., 2014
SE Korea, coast	50	592–1299	Kang et al., 2015
SE Korea, coast	330	4.22–44.28	Kang et al., 2015
Sweden, coast	80	150–2400	Norén, 2008
NE Pacific (off British Columbia CA)	62.5–250	8–9180	Desforges et al., 2014
NE Atlantic	250	2.46	Lusher et al., 2014
Portugal, coast	180–335	0.002–0.036	Frias et al., 2014
Southern California coast	333	5–7.25	Moore et al., 2002
NW Mediterranean	333	0.116	Collignon et al., 2012
Mediterranean coast of Israel	333	7.68	van der Hal et al., 2017
Central-W Mediterranean	500	0.15	de Lucia et al., 2014
Arctic polar waters	333	0.34 ± 0.31	Lusher et al., 2015
Southeast Bering Sea	505	<0.1	Doyle et al. (2011)
Bohai Sea, China	330	0.33 ± 0.36	Zhang et al. (2017)
Peter the Great Gulf, NW Pacific, Russia	100	0.13 – 1.7	This study

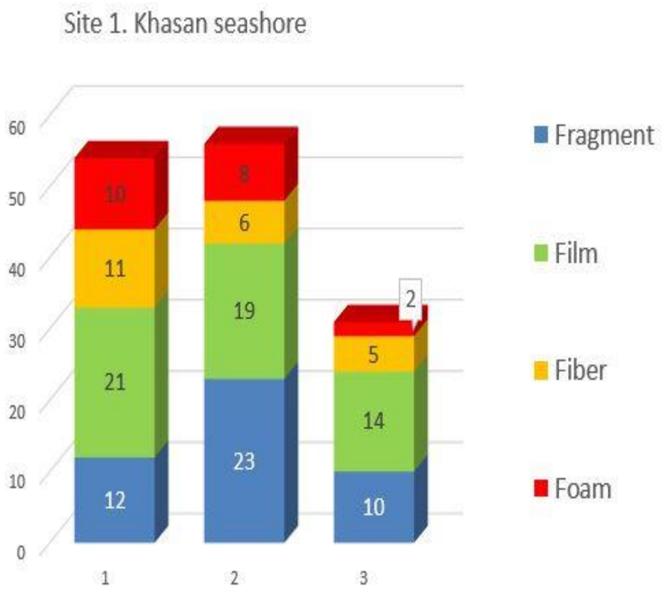
Table 18. Global comparison of microplastic pollution in the coastal marine water areas

5.7. Suggested seasonal factor and land-based sources

One of the basic goals of this study was to identify possible impact of seasonal factor and land-based pollution sources on the structure and concentrations of microplastics. For several sites it was impossible to collects seasonal samples. For example, on sites 3, 4, 6, 11, and 12 only one sample per each site was collected (summer samples for sites 3, 4, and 6 and autumn samples for sites 11 and 12). For five sampling sites, 2 samples were collected in summer and in autumn (2,5,7,9, and 10). At site 1, we collected 3 samples (2 in autumn and 1 in summer). At site 8, nine samples were collected (July 2016; February, May, June, July, August, September, October, and November 2017). Based on this information we will try to analyze seasonal differences in the microplastic pollution structure (where two or more seasonal samples are available) according to possible land based sources and in case with single samples we will only try to consider possible land-based source impacts.

At site 1, which is exposed to strong impact from the Tumen River, we collected three samples (sample 1 in September 2016, sample 2 in July 2017, and sample 3 in October 2017). Overall number of microplastic particles is almost similar in sample 1 and sample 2 (54 and 56 p./m3, accordingly) but reduces in sample 3 (31 p./m3). We see that number of fibers and films is higher in summer (fig.20, left). The amount of EPS foam is also higher in warmer season (1 and 2). Strong increase of fragments is observed in July 2017. A possible explanation of these fluctuations is the intensity of Tumen River discharge, which decreases in autumn. Several additional sampling we carried out in the lower reaches of the Tumen River evidence that increased/decreased concentrations of microplastics in the river water correspond to the increased/decreased concentrations of microplastics in the samples from marine coastal water near the estuary collected at the same time.

At site 2 it is difficult to suggest any seasonal changes, as the concentrations of microplastics are very low comparable to site 1, despite their relative vicinity (table 3).



Site 3. Minonosok Inlet

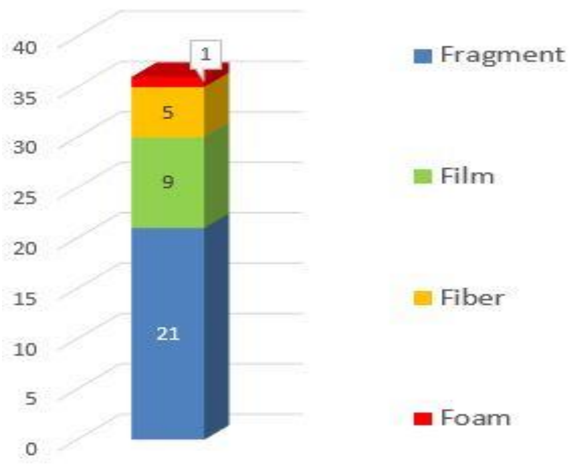


Fig. 20.
left - seasonal variation of microplastic structure in the tidal water of site 1 (Khasan seashore) in particles per m^3. (1- September 2016, 2 – July 2017, and 3 – October 2017);
right - structure of microplastic in the tidal zone of Minonosok Inlet (June 2016)

At site 3 there is an evidence that fragmentation of beached derelict aquacultural gear is a source of numerous fragments in the structure of microplastics (fig.20, right). The large amount of beached EPS also evidences that there is an increased transport of plastic litter from the Tumen River (Kozlovskii et al., 2016)

Site 4 is a remote natural protected area and unlike site 3, it is not exposed to any aquacultural activities. Therefore it is difficult to suggest possible land-baased sources of pollution there (table 5).

Site 5 (a beach near the Slavyanka settlement) is a typical recreation area. The samples were collected there in late September 2016 and in late July 2017 (the time of increased recreant inflow). The summer sample was characterized by comparatively higher concentrations of microplastics, while in late September the pollution was minimal (fig.21, upper left).

Sites 9 and 10 are also characterized by seasonal recreation impact and in this relation can be compared to site 5. Another important factor is their close vicinity to the urban area. In all cases, increased concentrations of microplastic particles are observed in summer (July - August). Another important aspect is that basic component of microplastics in the tidal zone in sites 5, 9, and 10 are fibers (fig. 21).

At site 6, only one sample was collected and total microplastic concentrations were comparatively low (1.5 p./m3). Because of that, it is difficult to suggest any impact of land sources of pollution especially considering that the territory adjoining to this site is low populated and is not used for recreation.

At site 7 we also collected two samples: in late September 2016 and in late July 2017. The sources of pollution there are difficult to identify because it is located not far from the Razdolnaya/Suifen River mouth and just opposite to the urban area of Vladivostok. Also, the site experiences some impact of small-scale fisheries (fig. 21, upper right)

The most regular monitoring was carried out in the tidal water of **Site 8** (Chaika Beach). Nine samples were collected in 2016 and 2017, including winter, spring, summer, and autumn samples (fig. 22). Varying concentration and structure of microplastic contamination are evident for this site. The lowest concentration is peculiar for winter season. Because this area is ice covered in winter, the reason for such small concentration compared to other seasons may be the ability of the ice cover to contain plastic particles. Consequently, microplastic contamination of the unfrozen water under the ice is minimal.

In spring, concentrations of microplastics considerably increase and is comparable to summer concentrations.

In autumn, the concentrations gradually decrease.

Structure of microplastics in this area evidence high contamination with fibers, both in the tidal zone and in the bay (fig. 22 and 23). It is similar to sites 5, 9, and 10. This may be a result of wastewater discharge, so there is a need for the related monitoring.

A study (Browne et al., 2011) evidence that machine-washing of garments may produce several thousand fibers per wash. One of suggestions indicated in this study is that late in the year the increment of in fiber concentrations from land-based sources should be evidenced up to 700 % due to washing of heavier winter clothes. In case with Chaika area, no evidence of higher concentrations of fibers was evidenced in late autumn (fig. 22).

Sites 11 and 12 were sampled only once in autumn 2017 so more observation is needed to conclude on the possible land-based impacts and seasonal distribution of microplastics in the water.

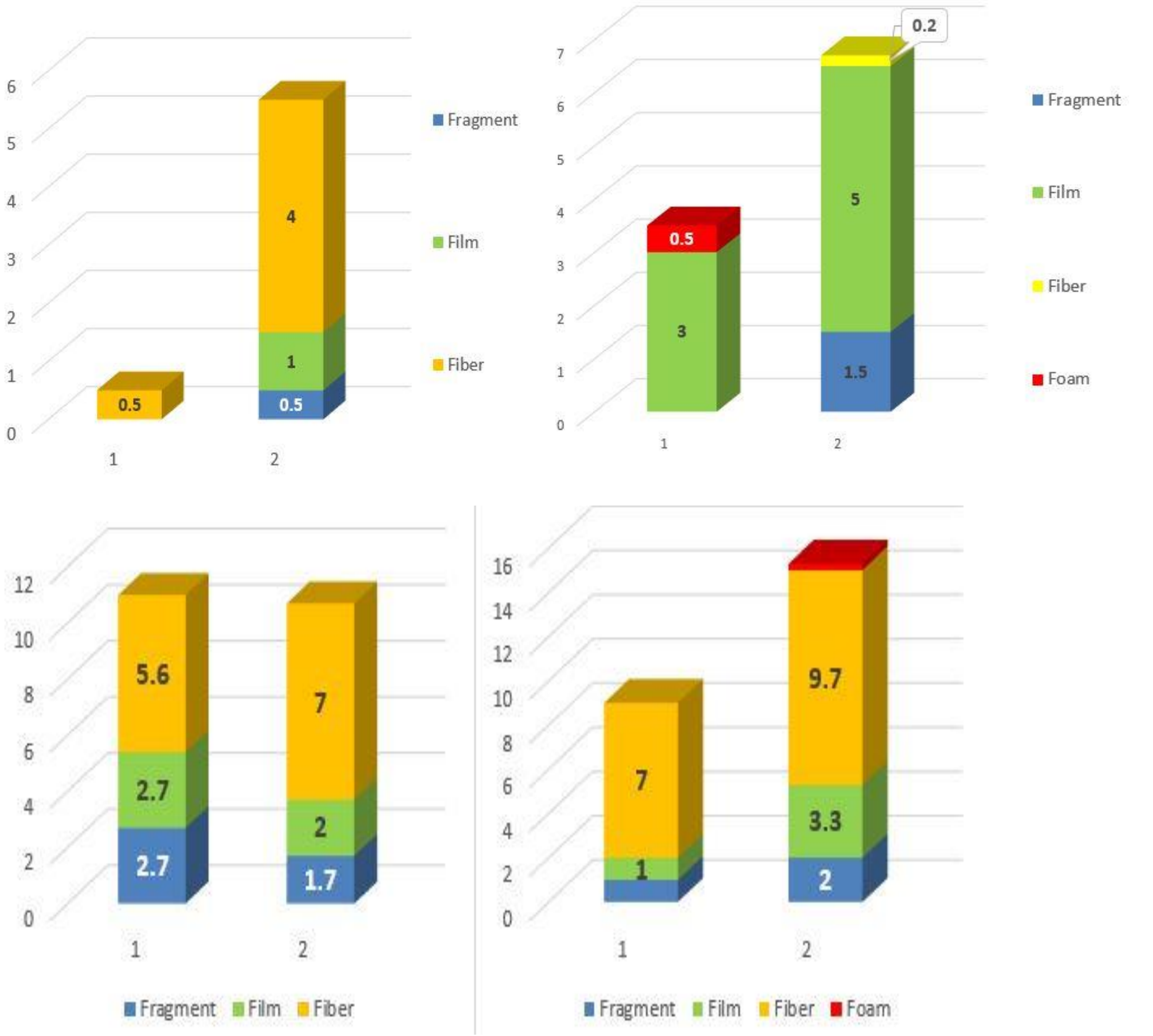


Fig. 21

Upper left - seasonal variation of microplastic structure in the tidal water of site 5 (Beach near Slavyanka Settlement) in particles per m^3. (1- September 2016, 2 – July 2017);
Upper right - seasonal variation of microplastic structure in the tidal water of site 7 (Peschany peninsula) in particles per m^3. (1- September 2016, 2 – July 2017)
Lower left – June and August structure of microplastics in the tidal water of site 9;
Lower right - seasonal variation of microplastic structure in the tidal water of site 10

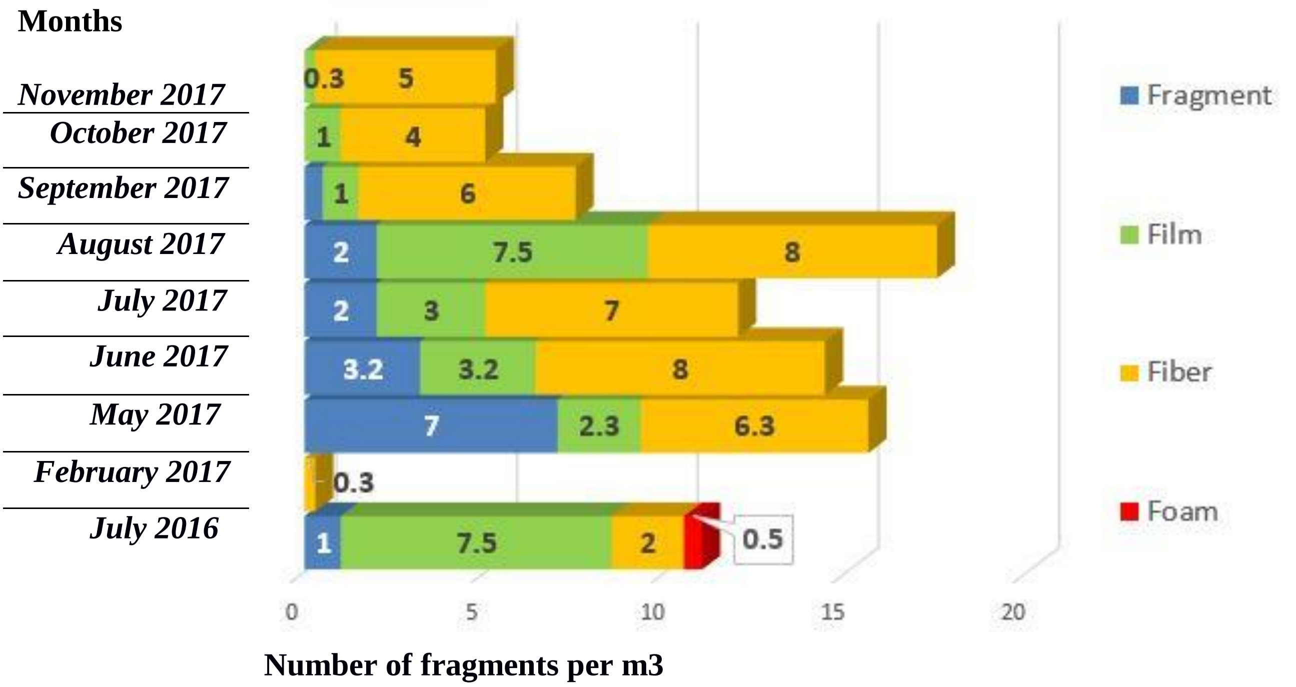


Fig. 22. Seasonal variation of microplastic structure in the tidal water of site 8 (Chaika Beach) in particles per m^3.

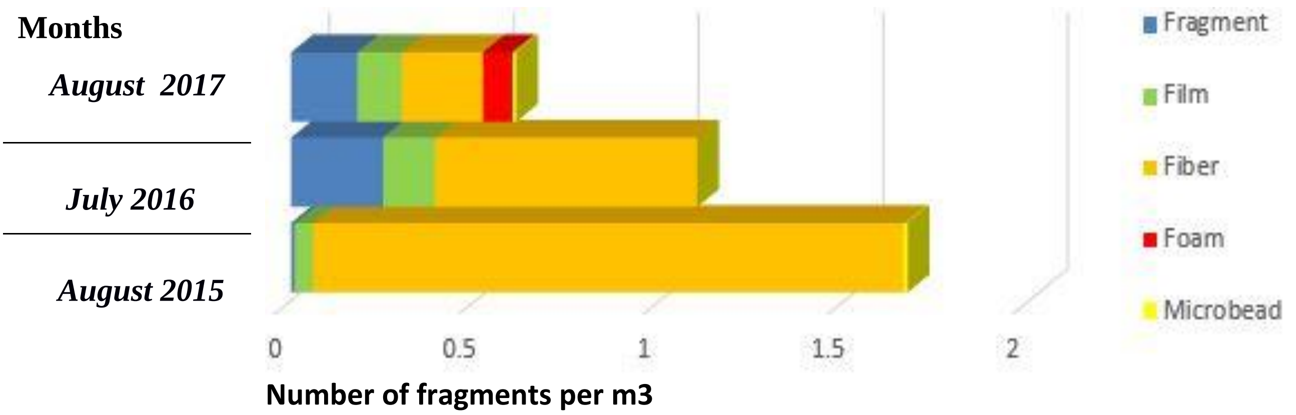


Fig. 23. Seasonal variation of microplastic structure in the bay (neuston trawl) near site 8 (Chaika Beach) in particles per m^3.

6. Conclusion

This is one of the first surveys of the microplastic coastal water pollution in the Russian part of NOWPAP area, and there are several findings.

Some general conclusion can be drawn that the microplastic pollution issue is actual for the southern Far East of Russia, though its scale is evidently lower than in the neighboring NOWPAP countries.

During this survey we identified the most important local hotspots of microplastic pollution, including the Tumen River estuary area as the most outstanding, and to a lesser extent coastal water in the vicinity of Vladivostok agglomeration (inner part of the Amur Bay water area).

Based on the seasonal changes and structure of microplastic particles from different sampling sites we can identify the most evident land-based sources of the contamination. For example, river discharge in case with the Tumen River estuary area, or coastal degradation of derelict domestic waste or fishing/aquacultural gear on remote shores which lack regular cleanups, for example in the Minonosok Inlet. Within urban and recreational areas there is an evidence of higher concentrations of fibers. In case with recreational locations, which are exposed to an increased anthropogenic load in summer, total summer concentrations of microplastics and especially fibers are higher. In case with urban areas, where fibers are the basic morphological type of microplastics, possible source of the contamination is domestic wastewater discharge (after machine washing). Due to this fact, additional survey of the effluent is necessary.

In general, it is evident that further survey in the coastal marine area of southern Far East of Russia is necessary with a detailed assessment of suggested land-based pollution sources. Particularly, specific attention should be paid to the river discharge and urban wastewater.

It is also necessary to assess possible negative impacts on marine and freshwater biota in the Russian part of NOWPAP.

7. Acknowledgement

We thank NOWPAP member countries for approving this activity at the 20th IGM and express our cordial gratitude to our distinguished colleagues from the NOWPAP member countries who assisted us in developing methods for this study and teaching us their national procedures of microplastic monitoring.

In particular, we would like to thank Dr. Sang Hee Hong and her colleagues from Korean Institute of Ocean Science and Technology (KIOST) who provided the protocols for water sample treatment and FTIR analysis,

Dr. Keiichi Uchida and his colleagues from Tokyo University of Marine Science and Technology (TUMSAT) who invited us for the joint marine litter research cruise in the Japanese coastal water of NOWPAP and provided field training for microplastic sampling,

And, of course, Dr. Atsuhiko Isobe and his colleagues from Kyushu University who provided us the microplastic assessment methodology applied in Japan.

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