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MARINE CHEMISTRY

# Composition and Distribution of Marine Anthropogenic Litter in the Barents Sea

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**Abstract**—Large-scale monitoring of anthropogenic marine litter in the Barents Sea was carried out in 2012–2018. The marine litter composition was estimated by recording by-catch from pelagic and bottom trawling. Litter on the sea surface (floating litter) was also taken into account during visual observations. The contents of 949 pelagic and 1477 bottom trawls were analyzed. Marine litter was recorded in 256 pelagic and 571 bottom trawl catches and in 454 cases during visual observations. Litter was sorted into plastic, wood, metal, rubber, textiles, paper, and glass. The occurrence of plastic prevailed in all litter records. It covered 71% of marine litter observed on the surface, 97% in pelagic trawls, and 78% in bottom trawls. Fishery litter prevailed in plastic litter (about 65% of its weight). Wood was recorded in 19% of surface litter observations, 1% in pelagic trawls and 13% in bottom ones. Metal, rubber, paper, textiles, and glass were occasionally observed; however, their weight (except glass) could be very large. Thus, metal and wood prevailed by weight on the bottom (45 and 36.8%, respectively). Wood prevailed in pelagic layers, being 73% of the total litter weight. The volume of plastic and wood prevailed on the sea surface (50 and 47%, respectively). The average density of all types of litter on the sea bottom was about 7.9 kg/km$^2$. Some significant differences in the litter composition were recorded between the southwestern and northeastern areas of the Barents Sea.

**Keywords:** Barents Sea, marine litter, macroplastic, pelagic zone, sea bottom

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## INTRODUCTION

In recent years, the problem of marine anthropogenic litter has been considered as a real threat to the life of marine animals and normal functioning of ecosystems [16, 42, 47, 49, 53]. Marine litter is defined as any produced or treated degradation-resistant solid material that has been lost, discarded, or unutilized in an environment [53]. Litter observed in seas includes mainly plastic dish, other tanks, synthetic and steel fibers (warps, ropes, fishing nets, traps, and fishing lines), other plastic, paper, and rubber products for various use, building materials, logs, fragments of wood and metal structures, household appliances, mechanisms (including sunken ships) and their parts, and many other things. Plastic (macroplastic) products are invariably among the most common types of marine litter [42, 50–53]. In addition to 61 million tons of synthetic fiber, 322 million tons of plastics were produced throughout the world in 2015 [41]. It was calculated that 4.8 to 12.7 million tons of plastic wastes entered the World Ocean in 2010 alone [34].

The main sources of marine litter in the Arctic seas are terrigenous runoff (including coastal runoff) and wastes from marine activities, such as fishery, shipping, offshore oil and gas exploration and production, and tourism. In particular, terrigenous runoff implies a long-distance transboundary transfer of litter by sea currents and drifting ice. Like any other floating marine litter, plastic can be transferred by currents along the coast and in the open sea [17, 19, 46, 54]. Population density and the intensity of marine activity directly influence the amount of litter discharged into seas [32, 34, 44]. Being widespread and potentially dangerous to ecosystems, marine litter has been recognized a global problem [47, 49] and included in the list of major threats to marine biodiversity [30].

It is known that the amount of plastic entering seas is about 100 times larger than that floating on their surface, despite the buoyancy and durability of many polymers. Litter fouling by hydrobionts is one of the most probable mechanisms responsible for its sinking. Microplastics (particles with a size of less than 5 mm) are recorded less frequently than particles of larger classes; it is very difficult to observe and estimate microplastic volumes in the World Ocean [23].

It is known that 56% of seabird species and 54% of marine mammal species ingest litter and get entangled in sealing tapes, ropes, and fishing nets; many of them die in this case [29, 38, 50, 53]. Large plankton-eating fishes, such as manta ray and whale sharks, can ingest very large amounts of plastic [28]. Litter ingestion may cause intestinal obstruction, internal intestinal damage and related inflammation processes, etc. in animals. In addition, toxic compounds, including those adsorbed on the litter surface, can also enter animal bodies [16, 20, 21, 27]. The concentrations of persistent organic pollutants (polychlorinated biphenyls, polybrominated diphenyl ethers, dichlorodiphenyltrichloroethane, etc.) are several orders of magnitude higher on plastic particles than in the environment [16]. Marine litter contributes to the rafting of organisms and can cause an invasion of alien species [31], which often leads to serious environmental consequences.

The Barents Sea is a highly productive fishery water body with a relatively low level of environmental pollution [10, 11, 33]. The Barents Sea region is characterized by a specific oceanographic regime determined by its geographical location, shallow water, low temperatures, a complex bottom topography, and well-defined frontal zones [9, 10, 12, 43].

## STUDY AREA AND MATERIALS AND METHODS

Studies of the distribution of anthropogenic litter in the Barents Sea have been carried out as part of the joint Norwegian–Russian monitoring program since 2009. This paper analyzes data from 2426 trawl stations (1477 bottom and 949 pelagic stations) implemented from 2012 to 2018.

The Barents Sea is a marginal shelf sea (with a surface area of about 1.42 million km$^2$), located at high latitudes approximately between 69° and 81° N; its average depth is 220 m and maximum depth (in the Bear Island Trough) is 513 m [2]. The bottom topography is characterized by several large (Central Bank and Perseus Bank) and relatively small (North Cape, Spitsbergen, Goose, and North Kanin banks) elevations and large trenches, the Bear Island Trough and Central Basin. Warm and salty Atlantic waters enter the southwestern part of the Barents Sea from the Norwegian Sea. In the north and northeast, cold and desalinated waters of the Arctic Ocean (AO) enter the Barents Sea. The Norwegian Coastal Current runs eastwards along the coastline of the Kola Peninsula and brings desalinated water from the northern coast of Norway [12]. The Litke Surface Current brings cold waters with a low salinity (32–32.5 PSU) from the Kara Sea and carries ice (often even in summer) [2] to the southeastern Barents Sea.

Studies on the composition of marine litter covered the entire water area of the Barents Sea and the adjacent areas of the Norwegian Sea and Arctic Ocean. The location of the implemented stations is given in Fig. 1 based on the example of bottom-trawl stations, the number of which was significantly larger than that of pelagic ones.

To analyze possible geographical differences in the litter distribution in the studied water area, we singled out stations in the southern and western parts of the Barents Sea (795 trawls), located in the zone of influence of warm Atlantic waters [12, 43], as shown in Fig. 1. Among the other stations in the northern and eastern parts of the water area (682 trawls), located mainly in the zone of influence of cold Arctic waters, we singled out stations in the area called the Pechora Sea, which are covered by the zone of influence of Pechora nearshore waters (73 trawls) [12, 43].

Russian studies were carried out by the Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO); Norwegian studies were carried out by the Institute of Marine Research (IMR, Bergen, Norway). The standard distance between stations was 35 nautical miles [22, 32]. Norwegian vessels surveyed the Norwegian economic zone and fish protection zone around Spitsbergen and PINRO vessels (R/V *Vilnius* and R/V *Fridtjof Nansen*) surveyed the Exclusive Economic Zone of the Russian Federation. The stations carried out mainly bottom trawling (the water layer was collected from the bottom up to 5 m) and pelagic trawling (the water layer was collected from the surface to a depth of 60 m). All the vessels used standard trawls and standard equipment for them and an identical trawling procedure, which made the resulting data comparable.

Marine litter recorded during sea surface observations and selected as by-catch during trawling was sorted into the following types (categories): plastic, wood, metal, rubber, textiles, paper, and glass [26, 42]. The "plastic" group ("macroplastic" in the context of this study) included all types of plastics and synthetic fibers (mainly fishery litter). Textiles are understood as fragments of fabrics (or products made of fabrics), the composition of which is considered mainly natural by default, although the actual composition can certainly be different.

Visual observations were made during vessel movement from board only at daytime under suitable weather conditions and at sufficient visibility using binoculars. Litter floating on the sea surface and its coordinates were recorded; the amount of litter was estimated in volumetric units (m$^3$). The visual observation data have some uncertainty due to the above-mentioned limitations and subjective aspects of observers' perception and should therefore be interpreted with some caution. This study used the data of 2012, 2013, and 2016–2018 observations.

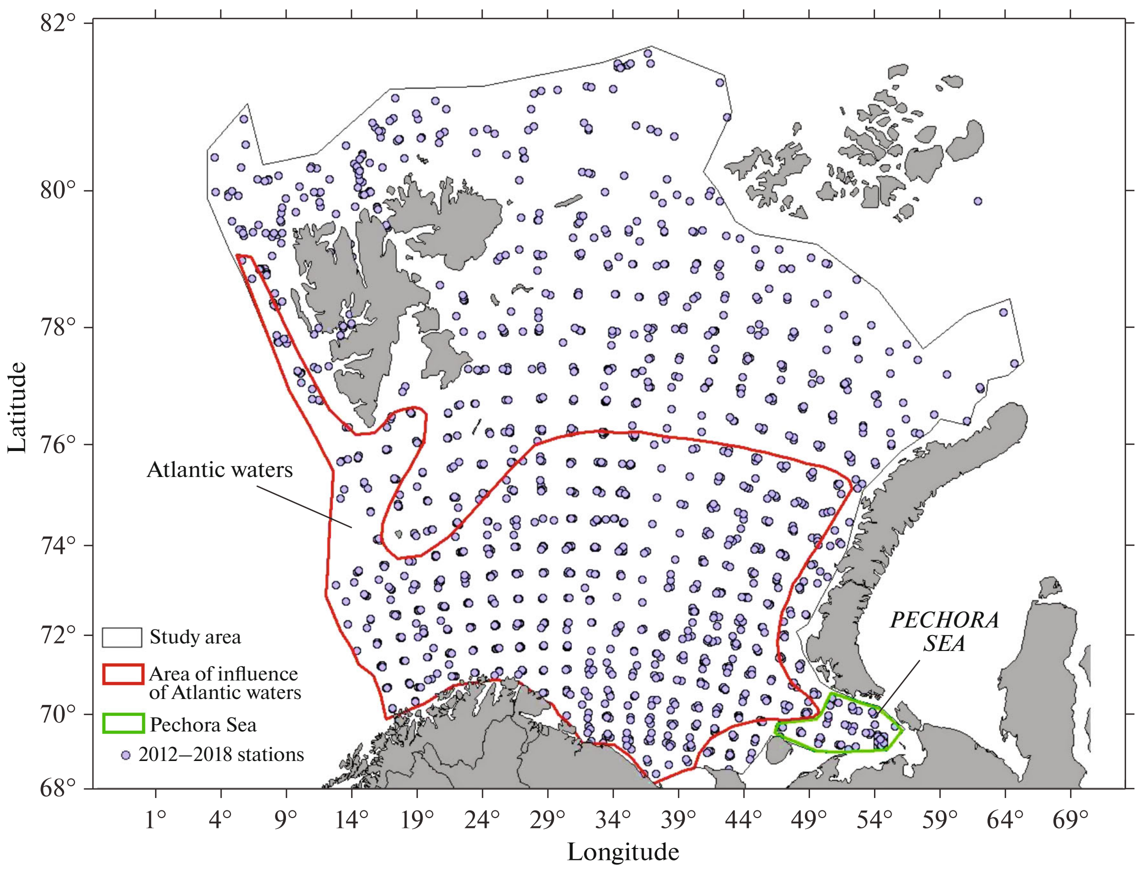


**Fig. 1.** Location of bottom trawl stations in Barents Sea and adjacent water areas. Areas for separate statistical data processing are also shown.

The composition and amount of marine litter in the upper 60 m water layer were recorded in the above-mentioned years during the processing of material collected by an A8-623-000 pelagic trawl (Harstad on Norwegian RVs) with a 4 mm fine mesh insert (trawl opening, 20 × 20 m). Pelagic trawling was carried out at a speed of 3 knots at three horizons (0, 20, and 40 m along the headline), 0.5 nautical miles (926 m) each. Pelagic catches were standardized by a filtered volume of water determined by the towing distance for each trawl, trawl opening, and depth covered. The pelagic litter was calculated in mass units per filtered volume of water (g/m$^3$).

The data on the distribution and amount of marine litter near the bottom are based on bottom trawling using a standard Campelen 1800 bottom trawl with a 15 × 6 m opening and a 22 mm mesh bag. The trawl was equipped with a rockhopper footrope. The standard trawling time was 15 min at a speed of 3–3.5 knots. The litter density on the sea bottom was calculated in g/km$^2$. Trawl catches were standardized using the trawling area (trawling distance × horizontal trawl opening). The research used the data on bottom trawls performed in 2012, 2013, and 2015–2018.

This study did not directly take into account the low catchability of floating objects by pelagic trawl. The catchability of litter by bottom trawl is also unknown; therefore, the research assumed the trawled catch area to be 15 m (80% of the headline length). However, the actual catch zone may be smaller (5.7–10 m). Therefore, the data on the amount of pelagic litter according to this research are closer to the minimum value, while the total volume of anthropogenic litter may be higher in the studied water area.

The data on the record of marine litter from the surface and trawls were used for mapping in the Arcview 3.2 GIS application with bathymetric data from GEBCO. The data were statistically processed using Statistica 10 and MS Excel spreadsheets.

## RESULTS

The research results showed that the most common type of marine litter was plastic. It covered 71% of visual records of litter on the sea surface, 97% in pelagic trawls, and 78% in bottom trawls.

**Litter on the Sea Surface.** Marine litter was observed (recorded) 454 times on the surface of the studied water area. A total of 476 litter items were found. Plas-

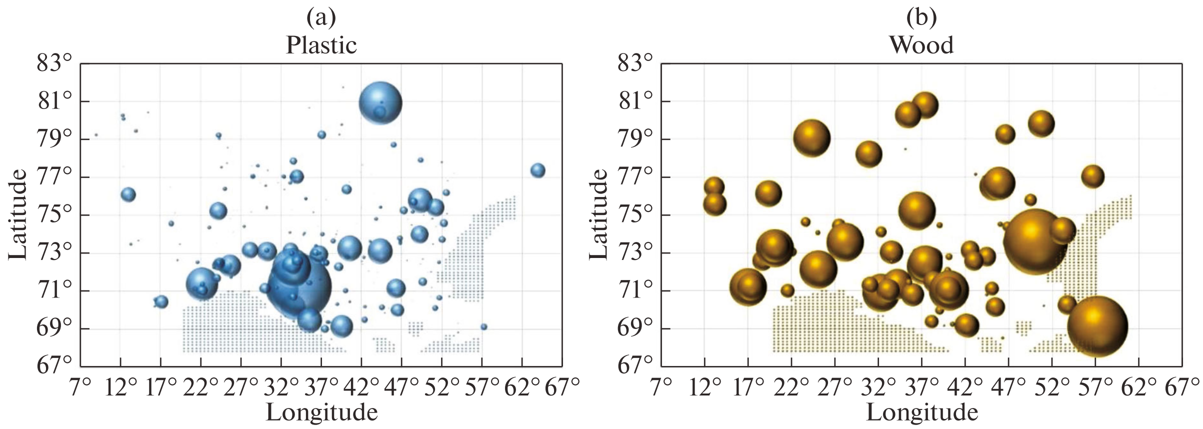


**Fig. 2.** Distribution of volume of plastic and treated wood pollution on surface of studied area. Land location (Scandinavian Peninsula and Novaya Zemlya) is shown on diagrams as a dense cluster of small points at bottom and on right.

tic was most often recorded (338 times); wood and paper were less common (89 and 27, respectively). Other materials were occasionally recorded. The estimated average volume of pollution was 0.053 $m^3$ of litter per record. According to our estimates, the total volume of litter recorded on the sea surface was about 33.5 $m^3$, of which the content of plastic was 50% and that of treated wood (wood material) was 47%. At the same time, wood and plastic were unevenly distributed on the sea surface. As can be seen from Fig. 2, wood occurred relatively evenly in the studied water area, while plastic was observed mainly in its southern part and localized in the streams of the main surface flows of the Barents Sea (the Murman, Murman coastal, Novaya Zemlya, and Kanin currents).

A similar pattern of the plastic spread by the North Atlantic Current branch in the Arctic has already been recorded earlier [20]. The major amount of plastic was observed in the area of the Murman Rise, while its minimum amount was recorded in the northwestern part of the sea and near Spitsbergen. The maximum amount of plastic and wood per record was 3.38 (a rope coil) and 1.51 $m^3$, respectively, while the minimum amount was 0.000005 and 0.0005 $m^3$; the average values were 0.05 and 0.18 $m^3$, respectively. Metal, rubber, textiles, paper, and glass were recorded only in 49 cases. No correlation was found between the latitude and longitude and the presence of plastic or wood on the sea surface.

**Trawl Catches.** Marine litter was recorded in 571 (38.7%) bottom and 256 (27.0%) pelagic trawl catches, which was higher than the values recorded in previous studies [32]. With respect to the number of observations, the differences in the occurrence of litter in pelagic and bottom trawls can be considered insignificant. However, the bottom component significantly prevailed with respect to the litter weight. Thus, the total weight of marine litter was 1400.9 kg in bottom trawls in the surveyed water area. Pelagic trawls contained only 142.8 kg of litter. This seems to be quite natural if we assume that any pelagic litter is actually dynamic (instant) pollution, while bottom litter characterizes pollution accumulated over many years. Since the level of floating is negative or close to negative, the pelagic litter barely includes metal, glass, and rubber. In any case, metal and rubber, recorded on the sea bottom, are emissions or storm washes from ships. Wood prevailed in the pelagic litter with respect to the weight (104.4 kg), while plastic was most widespread (253 trawls). In the bottom litter, plastic and wood occurred most frequently (510 and 83 trawls, respectively), while metal, wood, plastic, and rubber prevailed by weight: 630.2, 515.2, 141.3, and 103 kg, respectively. The total wet weight of the remaining litter (excluding the weight of metal and rubber) that was brought by sea currents and settled on the bottom was 667.7 kg, which is 4.7 times higher than the total weight of litter in pelagic trawls. The content of fishery tackle (trawl snippet, large plastic floats, rope pieces, etc.) in the "plastic" group was high in trawls; according to the 2015–2018 data, its average concentration was 61.5% during this period, reaching the maximum (86.5%) in 2018.

**Bottom Trawling.** The average concentration of marine litter on the bottom of the studied water area was 948.5 g per trawl, which is 23% higher than the values recorded in previous similar studies [32]. According to our estimates, the density of all types of litter on the bottom of the studied water area was 47.4 kg/$km^2$, while it was previously estimated to be 26 kg/$km^2$ [32].

The distribution pattern of plastic and wood weight significantly differed on the bottom of the studied water area. As follows from Fig. 3, plastic prevailed in the southern part of the studied water area, while wood dominated in the northern part. This clearly confirms the above-presented assumption that plastic and wood differ in the pathways of their entry into the Barents Sea. We statistically analyzed the data on sep-

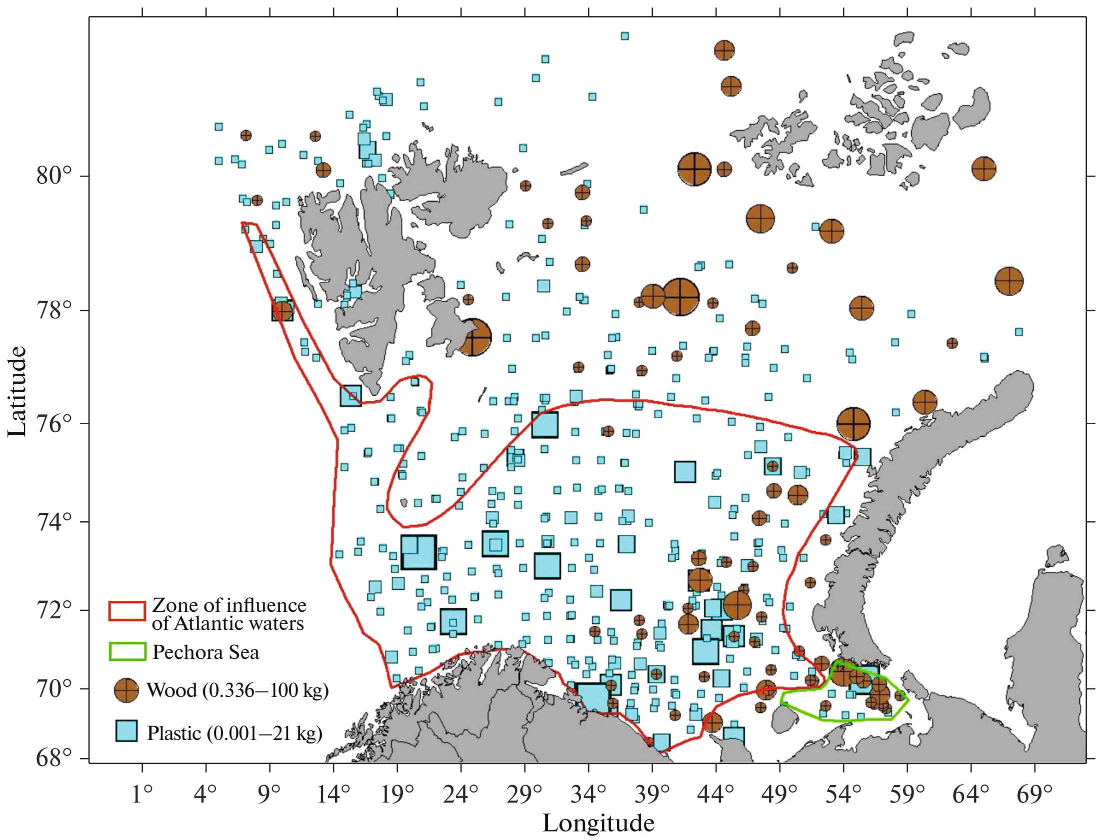


**Fig. 3.** Distribution of plastic and wood weight at bottom trawl stations in studied water area.

arate water areas for a detailed assessment of this problem (see Fig. 1). As follows from the results presented in Table 1, significant differences in the composition and level of litter pollution were revealed between the bottoms of the southwestern part of the Barents Sea (Atlantic waters) and the water areas to the north and east of this part (in the zone of influence of Arctic waters).

Whereas the total weight of litter collected in the two compared main areas does not significantly differ, the Arctic waters have a minimum content of paper and rubber and, at the same time, a significant amount of wood. Almost 77% of total litter on the bottom of the Arctic region is wood (mainly logs) by weight. Its amount is 9 times higher here than in the area of influence of Atlantic waters.

The diagram of the composition of litter from bottom trawls in Fig. 4 also shows significant differences in the litter composition between the zones of influence of Atlantic waters and Arctic waters, as well as the absence of metal, paper, and rubber in the Pechora Sea. The Pechora Sea differs from the other Arctic waters by a higher occurrence of wood in bottom trawls. The areas of the Novaya Zemlya Trench and Prirazlomnaya oil-producing platform are particularly noteworthy in this respect.

It should be noted that wood is not a foreign and potentially hazardous (to the extent that it occurs in the Barents Sea) component of the marine environment, unlike plastic and metal. It can be considered as an acceptable substrate for the colonization of marine organisms and detritivore feeding. Wood decay processes at low temperatures and high salinity levels under AO conditions are strongly inhibited and not accompanied by a release of a noticeable amount of chemicals (such as phenols, methanol, mercaptans, and resin and carboxylic acids) harmful to hydrobionts [5, 8, 15].

**Pelagic Trawling.** The average content of marine litter in the upper 60-m water layer in the studied area was 150.5 g per trawl, which is 2.6 times higher than the values recorded in previous similar studies [32]. The density of all types of litter in the upper part of the pelagic zone was 135.52 kg/km$^3$ (our estimates); among them, plastic was only 34.05 kg/km$^3$. This pollution can be considered insignificant. For comparison, the average plastic content in the pelagic zone was 390 t/km$^3$ in the coastal area of the Bali Island in the Indian Ocean (one of the most plastic-polluted areas in the world ocean) [28].

The main feature of the results of pelagic trawling was that all types of litter, except plastic, occurred either occasionally (textiles and paper) or absent in the

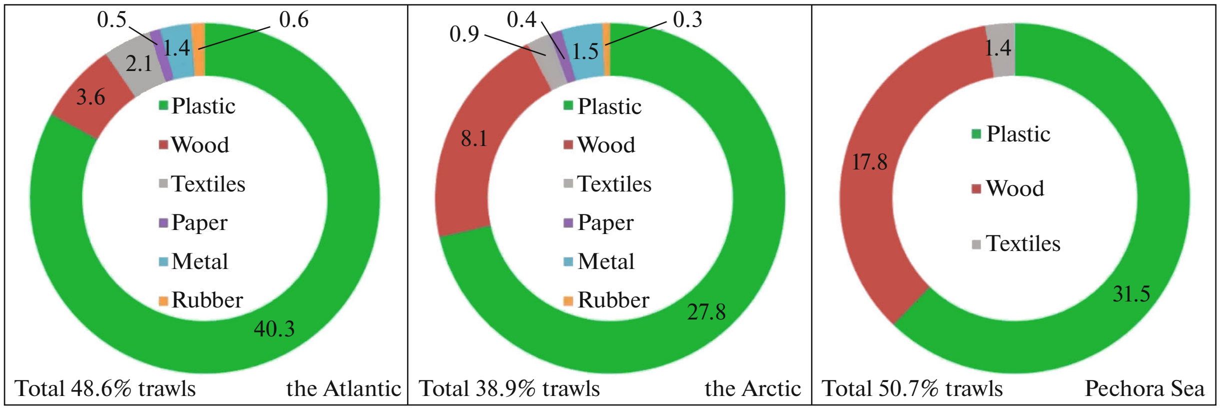


**Fig. 4.** Qualitative composition of litter in bottom trawls for studied areas of Barents Sea (see map in Fig. 1). Total percentage of trawls containing all litter types is given at bottom left.

zone of influence of Atlantic waters ($n$ = 495) (see Fig. 1) (Fig. 5). The average plastic content was 246 ± 166 g per trawling. The number of trawls that contained plastic was 139, or 28.1%, which was lower than its occurrence in bottom trawls in the same water area (40.4%). The calculated plastic density in Atlantic waters was about 62161 g/km$^3$.

In addition to plastic, pelagic trawls from Arctic waters ($n$ = 454) contained wood, textiles, and paper. Plastic also prevailed with respect to the frequency of occurrence; it was found in 114 trawls (25.1%) at an average weight of 15.0 ± 4.5 g per trawl. This is more than 15 times lower than the above-mentioned value for Atlantic waters. Other types of litter occurred rarely. Wood prevailed with respect to the weight, being 97.7% of the catch, or 104406 g in total. The calculated density of plastic, wood, textiles, and paper in Arctic waters was 3375, 206 745, 1210, and 212 g/km$^3$, respectively. However, these data should be considered as approximate values due to the very small number of trawls with the latter three types of litter ($n$ = 3, 3, and 1, respectively). Wood was found only to the north of Spitsbergen. No litter was recorded in pelagic trawls ($n$ = 11) from the Pechora Sea.

The final expert estimate (interpolation) of the litter weight throughout the studied sea area was 72667 t on the bottom and 45691 t in the water column. Analysis of the results did not reveal stable time trends for the content of marine litter in the surveyed water area over the studied period.

## DISCUSSION

A feature of the litter distribution on the Barents Sea bottom is the prevailing amount of plastic in the southwest and wood in the north and northeast.

**Table 1.** Statistical data on the content of marine litter in bottom trawls from different parts of the studied water area, g

| Area, parameter | Plastic | Wood | Textiles | Paper | Metal | Rubber | Total litter |
|---|---|---|---|---|---|---|---|
| Atlantic waters: | | | | | | | |
| weight in all trawls | 118071 | 50752.6 | 2143.3 | 8186.5 | 516904 | 102868 | 798925 |
| average per 1 trawl | 369 | 1812.6 | 126.1 | 2046.6 | 46991.3 | 20573.6 | |
| per 1 km$^2$ | 7425.9 | 3192 | 143.8 | 514.9 | 32509.7 | 6469.7 | |
| Arctic waters: | | | | | | | |
| weight in all trawls | 23245.6 | 464452 | 810 | 14 | 113288 | 157 | 601966 |
| average per 1 trawl | 122.4 | 8444.6 | 135 | 4.7 | 11328.8 | 78.5 | |
| per 1 km$^2$ | 1704.1 | 34050.7 | 59.4 | 1.03 | 8305.6 | 11.5 | |
| Pechora Sea: | | | | | | | |
| weight in all trawls | 15609 | 22797 | 238 | 0 | 0 | 0 | 38645 |
| average per 1 trawl | 678.7 | 1753.6 | 238.0 | – | – | – | |
| per 1 km$^2$ | 10691.2 | 15614.7 | 163.0 | – | – | – | |
| Total weight for all litter types | 141317 | 515204 | 2953.3 | 8200.5 | 630192 | 103025 | 1400891 |

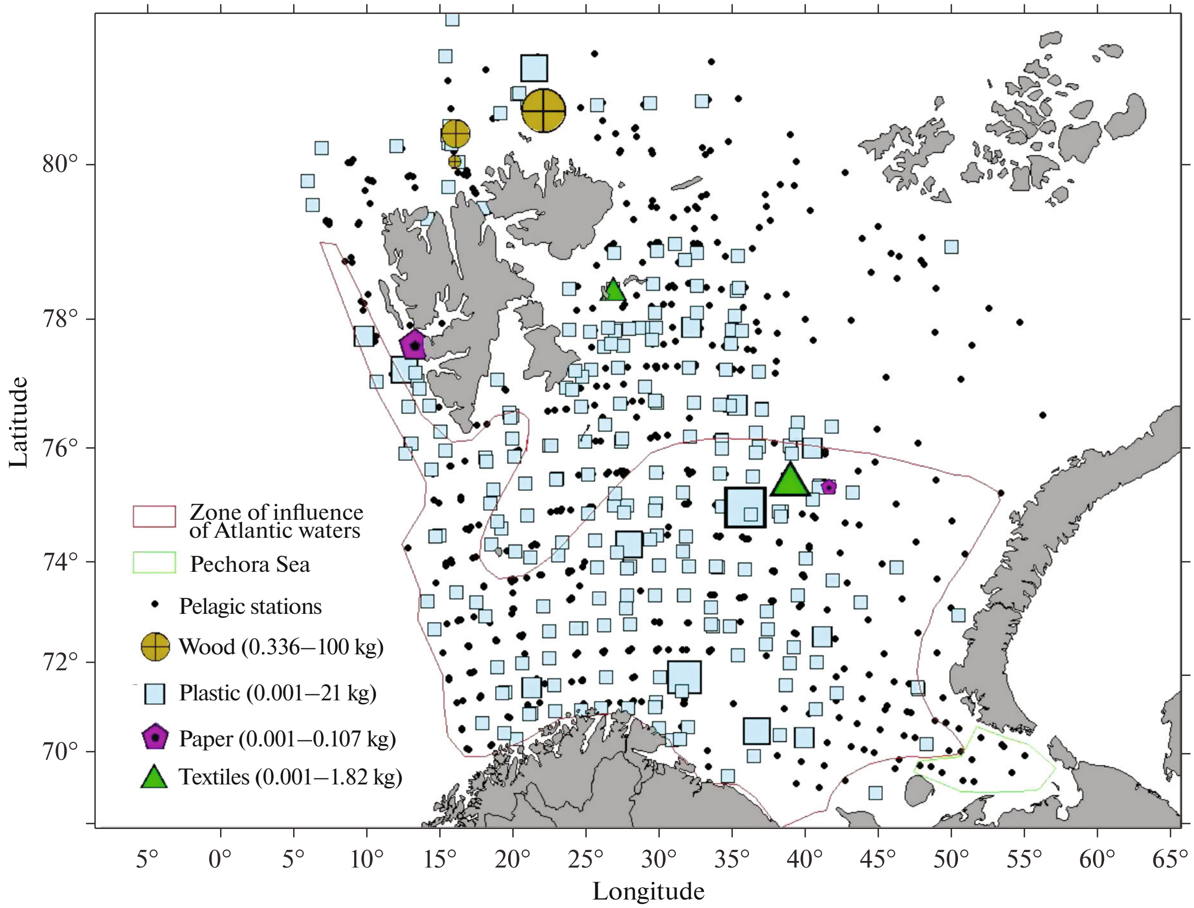


**Fig. 5.** Distribution of marine litter weight in pelagic trawls in studied area.

According to the published data [46], the qualitative composition of plastics is more diverse on the sea bottom than in water masses. Along with polyethylene, polypropylene, and polystyrene, polyester, polyamide, and polyacrylonitrile are also often recorded here [36]. The sea bottom is the final accumulation zone for all floating ocean plastics. The biological fouling of plastic floating in water leads to an increase in its density, followed by its sinking to the underlying water layers and bottom. As a rule, plastic is covered with a film of bacteria and then colonized by unicellular algae and invertebrates [16]. The rate of sedimentation of plastic depends on its density, surface area, and particle size, as well as on environmental factors, such as temperature and the amount of nutrients (biogenic material), which influence the rate of biological fouling [46].

For example, the average litter content proved to be 2.2 times lower (103 kg/km$^2$) on the bottom of the Barents Sea than on the bottom of the Adriatic Sea (the research was carried out with a rapido trawl) [48]. According to other data based on a video survey of the bottom in the western Barents Sea, the litter content was 101 kg/km$^2$ at depths less than 100 m and 144 kg/km$^2$ at depths of 100–400 m [19]. However, these data do not make it possible to read the images and determine the litter weight on the bottom in terms of calculation, which undoubtedly has a greater error than direct weighing of the material. On the other hand, the data presented in [18] confirm the conclusion [32] that the content of litter on the bottom of the Barents Sea increases with depth.

The amounts of wood found on the bottom in the Arctic zone indicate that this litter results from long-term pollution caused by timber floating along Siberian rivers, as well as along the rivers of Arkhangelsk oblast in the southeastern Barents Sea (Pechora Sea). One of the main causes of wood entry into the open sea is obviously ice drift in large northern rivers, mainly the Yenisei, Ob, and Pechora. In addition, it is necessary to take into account dispersed wood stocks in river mouths. Thus, these reserves vary from 400000 to 1.5 million m$^3$ at the mouth of the Yenisei River according to some data [1]. Wood accumulated in the mouths of Siberian rivers can be captured by fast ice and carried to the central Arctic Basin in spring and summer, where it begins to drift west with ice towards the Barents Sea [6, 7, 14]. The ice then enters the Fram Strait and northeastern Barents Sea, where it melts (together with ice brought mainly from the Kara Sea) and, as a consequence, discharges the litter. After ice melt, wood enters the water and gradually sinks to the bottom.

In the 1990s, large accumulations of storm wood were recorded near the Tersk and Kandalaksha coasts of the White Sea, on the coasts of Eastern Murman and the Kanin Peninsula (a log heap with a volume of 2800 $m^3$ was recorded), in Pechora Bay, in the bays of the Novaya Zemlya archipelago, and at the mouths of the Ob and Yenisei rivers [4]. The greatest wood losses are observed in loose floating (downstream timber delivery in bulk), which was banned everywhere in 1995 after the introduction of the Water Code of the Russian Federation. Before the ban, timber merchants annually rafted 8–9 million $m^3$ of wood along rivers and waterbodies of Arkhangelsk oblast alone, which was reduced by 5 million $m^3$ immediately after the introduction of the ban [3]. At present, timber is usually rafted along Russian rivers in smaller quantities and rafting units, namely, by bag boom towing and timber rafting with less significant wood losses. Timber floating is currently used for timber transportation both along the rivers of Arkhangelsk oblast (Northern Dvina, Vaga, Mezen, Pinega, etc.) and in the Angara–Yenisei Basin. For instance, riverside timber industry enterprises in Arkhangelsk oblast prepared 116 rafts with 1025000 $m^3$ of timber for shipping to consumers in 2005–2006 [3].

The litter recorded on the bottom of the Pechora Sea is characterized by a low diversity: it contains only plastic, wood, and textiles; however, it has the highest density of plastic (see Table 1). Since the population on the coast of the Pechora Sea (Nenets Autonomous Okrug) is one of the lowest in Russia (0.25 people/km) [13], it can be assumed that litter is mainly transported to the Pechora Sea together with sea current waters, ice from the Kara Sea, and Pechora River runoff. This is confirmed by the fact that the highest plastic content (15 kg per trawl) was recorded for the station in the southern Novaya Zemlya Trench.

The spread of macroplastic in the studied water area, in particular, in its southwestern part, suggests the significant effect of fishery on pollution of the water area, as noted earlier [32]. This is also indicated by its composition, which (as noted above) is dominated by fishery litter and equipment fragments. For example, the second largest plastic object (1.5 $m^3$) that we recorded during visual observations was a trawl coil at 81° N (see Fig. 1). The Barents Sea is an area with high fishing activity throughout the year. In addition to fishery (for cod, haddock, American plaice, etc.), shrimps and crabs (king crab and opilio crab) are also caught in the Barents Sea. There are numerous salmon breeding farms (aquaculture) along the Norwegian coast. The reduction of ice cover and intensification of oil and gas activity in recent years have led to an increase in shipping development in this area [24, 35].

Our results show that the content of marine litter varied depending on the density of the material, sea currents, topography, geographic location, and intensity of economic activity in the water area. This is consistent with observations from other areas of the World Ocean [17, 25, 28, 45].

The litter in the pelagic zone of Atlantic waters was almost exclusively plastic. The pelagic zone is an important grazing area, where plankton, juvenile fishes, and adult pelagic fishes accumulate during summer–autumn. The concentration of different food types attracts predators, such as large fishes, marine mammals, and seabirds. Plastic particles can be ingested by fishes, marine mammals, and seabirds. Predators can be attracted by the sun reflecting on plastic, which resemble reflections of fish eyes, scales, etc., in the water [38]. Plastic can also resemble jellyfish and comb jellies, which serve as food for fishes and seabirds [38]. Plastic types, such as polyethylene, polypropylene, and polystyrene, are most widespread in seas; their proportion reaches 92.2% of all polymers recorded in the epipelagic zone [46]. Polypropylene and polyethylene are characterized by a low density (0.90–0.97 $g/cm^3$) and, accordingly, a high buoyancy level, which allows them to persist on the surface or in the water column for a longer time. The density of polystyrene varies from 0.04 to 1.01 $g/cm^3$ and is close to the density of seawater (1.03–1.04 $g/cm^3$). The lower water temperature and higher salinity lead to an increased amount of high density polymers in the water column [37].

As in our case, studies of the content of plastics on the surface and in the water column of the Baltic Sea [18] and on the surface of the North Atlantic Subtropical Gyre [39] and East Pacific Gyre [40] revealed no clear trend in its variation in abundance in recent decades. Further research of the pathways of marine litter transport and its accumulation in the Barents Sea and Russian Arctic, as well as the environmental consequences of this phenomenon, is required.

## CONCLUSIONS

The large amount of data from long-term monitoring of the Barents Sea indicate a widespread distribution of marine litter floating on the surface, in the upper 60-m water layer, and on the bottom.

Compared to the data from previous studies, marine litter has begun to occur more often and in greater amounts on the sea bottom and in the pelagic zone of the Barents Sea, although the total values of its content do not yet raise serious concerns. Unfortunately, it can be stated that floating plastic is found everywhere in the Barents Sea. It is distributed mainly by the large quasi-stationary surface currents of the Barents Sea (North Cape, Murman, Novaya Zemlya, and other currents). For this reason, the largest accumulations of plastic are observed in the southwestern part of the studied area.

The relatively low plastic pollution of the pelagic zone in the eastern and northeastern parts of the Barents Sea (the zone of influence of Arctic and coastal Arctic waters) indicates a currently moderate anthropogenic load on these water areas. However, timber rafting and the intensive human activity on the Arctic coast during the Soviet era had a significant impact on this region; the result of this impact can now be seen in a significant occurrence of wood on the sea bottom (on average, over 30 $kg/km^2$). It is likely that timber is transported to the eastern and northern parts of the Barents Sea by sea ice as a result of its westward drift in the Kara Sea.

It was noted that the Pechora Sea region (the southeastern part of the Barents Sea) significantly differs in the litter composition not only from its southwestern part, but also from the main area of influence of Arctic waters. For instance, the highest density of plastic on the bottom was recorded in the Pechora Sea. Therefore, the bottom of the Pechora Sea is intensively polluted both with plastic and wood.

Fishery and other marine activities are the most stable source of marine litter entry to the Barents Sea. A certain contribution at the high latitudes of the AO comes from the long-range transport of litter by sea ice as a result of oceanic drift.

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