ASSESSMENT OF MARINE DEBRIS POLLUTION OF THE COASTLINE OF THE EASTERN PART OF KILDIN ISLAND (BARENTS SEA)

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Abstract

This article examines the pressing issue of the negative impact of marine debris pollution on coastal ecosystems in the Russian Arctic. As part of the "Arctic. General Cleanup" project to clean up Kildin Island, the coastline in the northeast of the island was monitored. The study collected samples, assessed the composition, and estimated the quantity of anthropogenic debris washed ashore. It was found that metal and polymer waste predominate in the marine debris. It was shown that the main source of plastic waste is fishing. This category of marine debris consists primarily of fragments of fishing gear; tourism currently plays a minor role in coastal pollution. During the coastal cleanup, it was discovered that washed-up fishing nets pose a threat not only to wildlife but also to rare plants that grow through the nets and are damaged during waste collection. The results of the study allowed us to assess the nature and extent of pollution on the northeast coast of Kildin Island. Kildin with marine debris, and also to identify the risks of damage to the integrity of the vegetation cover during the implementation of pollution elimination measures.

Keywords : Arctic, Kildin Island, coastline, monitoring, marine debris, fishing gear, waste.

I. Introduction

The "Arctic. General Cleanup" project is being implemented by the Russian Geographical Society, the Russian Ministry of Defense, Rosatom, and AtomEnergoSbyt. Its aim is to clean the island's coastline primarily of metal waste, primarily consisting of washed-up shipwrecks and various ferrous scrap metals (abandoned vehicles, fuel and lubricant storage tanks, etc.). However, coastal pollution is not limited to waste from past economic activities. Kildin Island's growing popularity among tourists and the associated increase in recreational activity pose a risk of littering the area. However, the main source of waste ashore is the sea itself, from where plastic waste (mainly lost or abandoned fishing gear), wood, and rubber are washed up on the shoreline annually.

The aim of this work was to assess the extent and nature of pollution of the north-eastern coast of Kildin Island by marine debris.

The Barents Sea exceeds other regions of the Arctic Ocean in terms of microplastic pollution [1], making monitoring marine debris pollution in this part of the Russian Arctic coastline a pressing issue. Studying coastal pollution trends, analyzing the composition and spatial distribution of marine debris, and identifying its sources on the coast are essential for the sustainable development of coastal ecosystems [2].

Marine debris refers to any objects or materials found in the ocean, on its surface, or washed up on its shores, but not directly related to the marine ecosystem [3]. The total volume of plastic waste entering the oceans is estimated to be approximately 20 million tons per year [4] and is constantly increasing [5]. Fishing is identified as the main source of marine debris [3,6-9]. Up to 1 million tons of plastic are fishing gear [10], and according to some estimates, the total mass of fishing gear lost annually is 6.4 million tons [11].

Waste entering the Arctic Ocean is associated with fishing, river runoff, and transport by currents from the Atlantic [12]. There are no accumulations of drifting waste in the waters, although the potential for the formation of a sixth "garbage patch" in the World Ocean has been noted for the Barents Sea [13]. Currently, waste accumulation occurs primarily on the coasts of the Russian Arctic [3].

Marine debris includes various types of waste: fishing nets, traps, containers, barrels, buoys, fish boxes and other items thrown into the sea, found there accidentally, or carried into the sea by rivers [9]. The chemical composition of fishing gear includes various polymeric materials, such as polypropylene, polyethylene, polyamide, polystyrene, polyethylene terephthalate, polyvinyl chloride, polystyrene foam, polyvinylidene fluoride, polysulfone, ethylene vinyl acetate, as well as steel, lead, and composite materials [14]. All types of plastic gradually degrade in the marine environment under the influence of mechanical factors, disintegrating into small fragments and microparticles [15].

The negative impact of fishing gear washed ashore on coastal ecosystems is generally associated with the risk of entanglement and death of their inhabitants [7,16], the possibility of ingestion of small plastic particles and their accumulation in the bodies of mammals, birds, fish, and invertebrates [6,17-19]. Pollution of the terrestrial environment with micro- and nanoparticles formed during the destruction of polymer waste on the coast is considered potentially more dangerous than in the aquatic environment [20]. The main terrestrial absorber of micro- and nanoparticles is soil [21]. According to some estimates, contamination with micro- and nanoplastics in the terrestrial environment may be 4-23 times higher than in the ocean [22].

However, the impact of coastal marine debris on biota remains understudied. The impact of marine debris on organisms in aquatic environments has been studied to a much greater extent. The mechanisms of micro- and nanoplastic penetration and pathological changes in organisms have been extensively studied, primarily in marine environments and, to a lesser extent, in freshwater ecosystems (Table 1).

Table 1. *The negative impacts of marine debris and microplastic particles on marine organisms*

Item No.	Group of organisms	Nature of impact	Consequences for the body	Sources
1.	Phytoplankton	- filtration of microparticles from the water column; - sorption of pollutants and microorganisms on the surface and subsequent entry into a living organism	- reduction of absorption of CO_2, light and nutrients; - decrease in chlorophyll content and efficiency of photosynthesis; - reduction in growth rates, cell density and biomass productivity; - stimulation of the production of reactive oxygen species (ROS)	23-28

2.	Zooplankton	- filtration of microparticles from the water column; - sorption of pollutants and microorganisms on the surface and subsequent entry into a living organism	- changes in intestinal microbiota; - decreased appetite, survival and fertility, congenital malformations; - growth suppression, reduction in body size; - reduction of lipid concentration; - oxidative and immunological stress	23-28
3.	Marine invertebrates	- filtration of microparticles from the water column; - penetration into tissues from the surface of the body; - sorption of pollutants and microorganisms on the surface and subsequent entry into a living organism; - entanglement in fishing nets; - direct and secondary (with food) ingestion	- decrease in filtering activity (bivalves); - change in diet; - toxic effects of polymer particles and pollutants sorbed on their surface; - decreased reproductive function; - physical and chemical toxic effects, including changes in enzymatic activity, gene expression, and histopathological effects [Hsieh] - oxidative stress; - changes in lipid-glucose metabolism processes; - negative changes in growth at the larval stage	15.23-33
4.	Fish	- entanglement in fishing nets; - sorption of pollutants and microorganisms on the surface and subsequent entry into a living organism; - direct and secondary (with food) ingestion	- death due to entanglement; - changes in swimming behavior; - decreased growth rate, reduction in body size and weight; - toxic effects of polymer particles and pollutants sorbed on their surface; - physical and chemical toxic effects, including changes in enzymatic activity, gene expression and histopathological effects.	23-25,27,29,34-37
5.	Sea turtles	- entanglement in fishing nets; - direct and secondary (with food) swallowing; - penetration of microplastics into eggs on polluted beaches	death due to entanglement; - decreased reproductive success; - gender imbalance associated with changes in the sex ratio with increasing sand temperatures on beaches contaminated with microplastics.	27,29,34,38

6.	Birds	- direct and secondary (with food) swallowing; - transfer of plastic particles from adult birds to chicks during feeding; - inhalation of fine particles; - entanglement in fishing nets	- intestinal inflammation; - suppression of enzymatic activity of the stomach, liver and pancreas; - inflammation and fibrosis of the tissues of the kidneys and spleen; - oxidative stress, apoptosis and autophagy in thymus tissues; -obstruction of the airways; - pathological changes in the reproductive organs, in particular the testicles; - changes in food metabolism: plastic particles can be mistaken for food, causing a false feeling of satiety; - death due to entanglement	29,34,36,39-47
7.	Mammals	- entanglement in fishing nets; - direct and secondary (with food) ingestion	- death due to entanglement; - neurotoxic, cytotoxic, immunotoxic effects of pollutants (heavy metals, polycyclic hydrocarbons, pesticides, etc.) sorbed on their surface by polymer particles; - histopathological effects; - the appearance of congenital defects; - infertility.	23,29,34,48-50

II . Materials and methods

The survey was conducted in 2023 on the northeastern coast of Kildin Island. The island is located in the Barents Sea, 20 km east of Kola Bay. A route-based method was used for visual inspection of the coastline. Cleanup efforts on Kildin Island have been ongoing since 2017. The Russian Northern Fleet has removed approximately 1,000 tons of metal waste from various sections of the island's coast.

In this regard, in accordance with the generally accepted methodology, an assessment of marine debris pollution was carried out in the eastern part of the island near the Sundukki outlier rocks in coastal areas where cleanup activities had not previously been carried out.

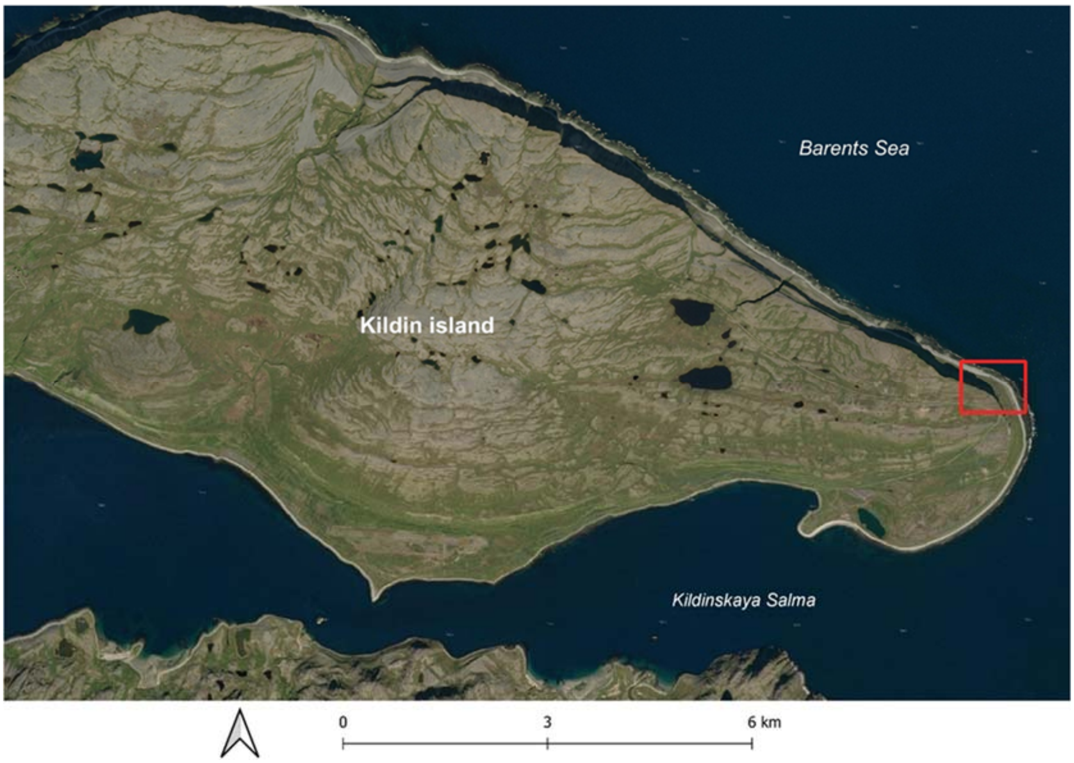

Fig. 1: *Study location.*

To study the nature of pollution and quantify marine litter, the Frame method was used [51]. During the study, the coastline was divided into zones of 1 km2 each. For each zone, a description of the coast was provided, indicating the type of mesorelief, the composition and structure of sedimentary materials on the coastline, and the predominant type of vegetation. Gently sloping areas of the sea coast were selected for the study. The coordinates of the collection points for litter samples were recorded using a navigator. Depending on the type of beach, three sample plots were selected on 100 m long sections of the coastline, with transects laid every 30 m. These plots were used to collect litter samples, determine their size and weight, and then collect them in square polygons of 10 x 10 m (Fig. 2). The boundary of the first polygon is established from the boundary of the maximum water level at high tide, i.e., the littoral zone is not taken into account. For ease of counting, the boundaries of the polygon are fenced with tape or a measuring tape.

Fig. 2: *Schematic diagram of the area where sampling and quantitative accounting of marine litter will be carried out.*

The amount of marine litter at each landfill was assessed based on its composition (waste made from polymeric materials, glass, and metals was isolated) and particle size. The study used the following particle size classification: meso-litter – 0.5-20 cm; macro-litter – 20-50 cm; mega-litter – 50-100 cm; giga-litter – 100+ cm. All types of litter larger than 20 cm were weighed.

The following materials and equipment were used for the work: counters, rangefinder, steelyard (up to 50 kg), barrier tape, garbage bags (with handles).

III . Results and their discussion

The research was conducted on the northeastern shore of Kildin Island near a dirt road. The shore is rocky and gently sloping, with vegetation typical of the supralittoral zone of northern seas, dominated by *Mertensia. maritima* (L.) Gray, *Honckenya peploides ssp. diffusa* (Hornem.) Á. Löve, *Ligusticum scoticum* L., *Leymus arenarius* (L.) Hochst .

During the study, 21 10 x 10 m2 polygons were surveyed at three sample plots. The results of the component composition determination are shown in Fig. 3.

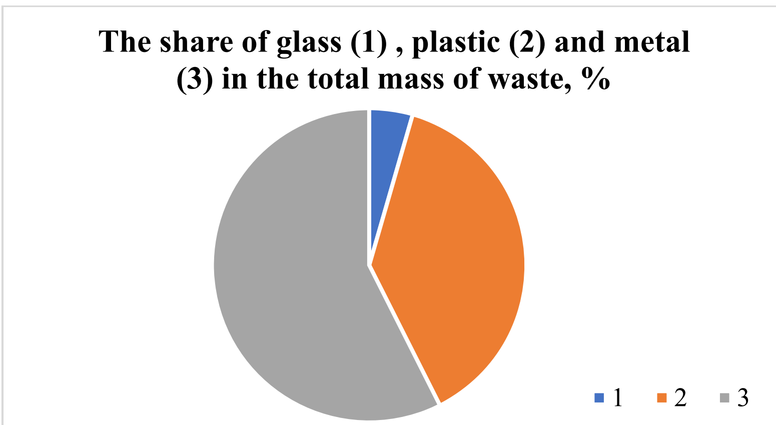

Fig. 3: *Ratio of waste components on the surveyed part of the coastline of Kildin Island.*

The shoreline is shown to be polluted primarily by metal waste, the largest fraction of which consists of various scraps left on the island from past economic activities. Metal objects typically arrive on the island as marine debris attached to more buoyant particles (wood, plastic). The proportion of plastic is somewhat smaller, although, upon visual assessment, polymeric debris occupies a larger area of the shore than metal debris, as these debris are larger in size and have a lower density. Plastic debris consists primarily of fragments of fishing nets and fish storage boxes, indicating that fishing vessels are the primary source of polymeric waste.

The low proportion of glass is explained by the fact that the survey sites are located on an island, and waste primarily reaches the shore by sea. Glass items are fragile, quickly lose their integrity, and settle to the bottom. Among the glass waste, only small, sealed bottles with no contents or only a small amount of liquid were recorded.

In studies conducted on the beaches of the Baltic Sea [6,52], polymeric materials occupy the leading position in terms of contribution to the total pollution (52.7%), followed by cigarette butts (15.3%), the share of glass is 7%, and metal is 2.4%. Similar ratios of components of marine litter were revealed as a result of studies conducted on the islands of the Novaya Zemlya and Franz Josef Land archipelagos [3,53], on the coast of the Sea of Azov [54], and the Gulf of Guinea [55].

An analysis of the proportion of debris particles of various size categories shows (Fig. 4) that only small objects are found among the glass debris; larger ones are absent, as they break and sink. Metal debris is represented by all size categories, and the objects have various configurations. Among the metal debris classified as giga-trash, fragments of wire or wooden box lining are found; long and massive finds (such as a wheel axle) are rare.

Plastic waste comes in all size categories except giga-waste. This includes various bottles, pieces of fishing nets and crates, and bags.

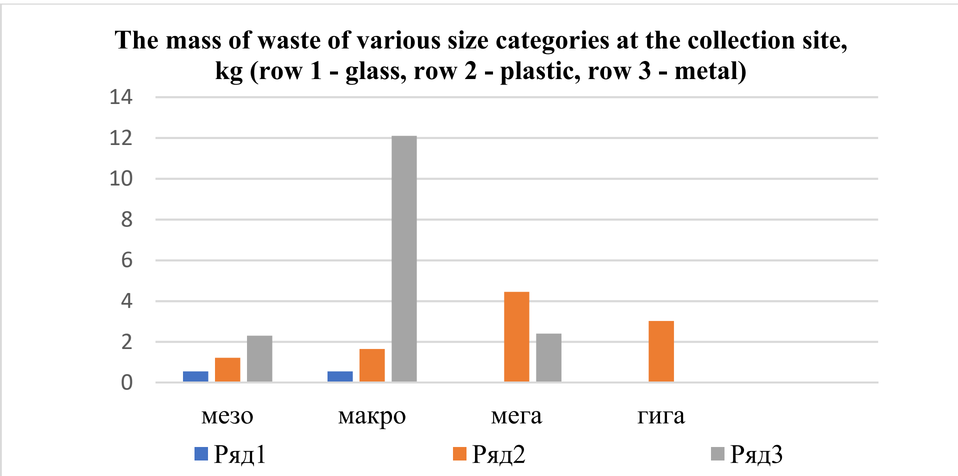

Fig. 4: *Distribution of detected waste samples by size categories.*

Litter particles are distributed unevenly along the shoreline. Areas located along the high-tide line are lightly polluted, but the amount of litter increases slightly with distance from the water's edge. At a distance of 30-40 meters, litter is virtually absent, but at distances greater than 40 meters, its amount increases again (Fig. 5). This spatial distribution of marine litter is likely related to the coastal topography and surf in this part of the island. Apparently, in relatively calm weather, litter accumulates within a short distance of the water, and during strong storms, it is carried significantly higher, creating a relatively clean stretch of shore.

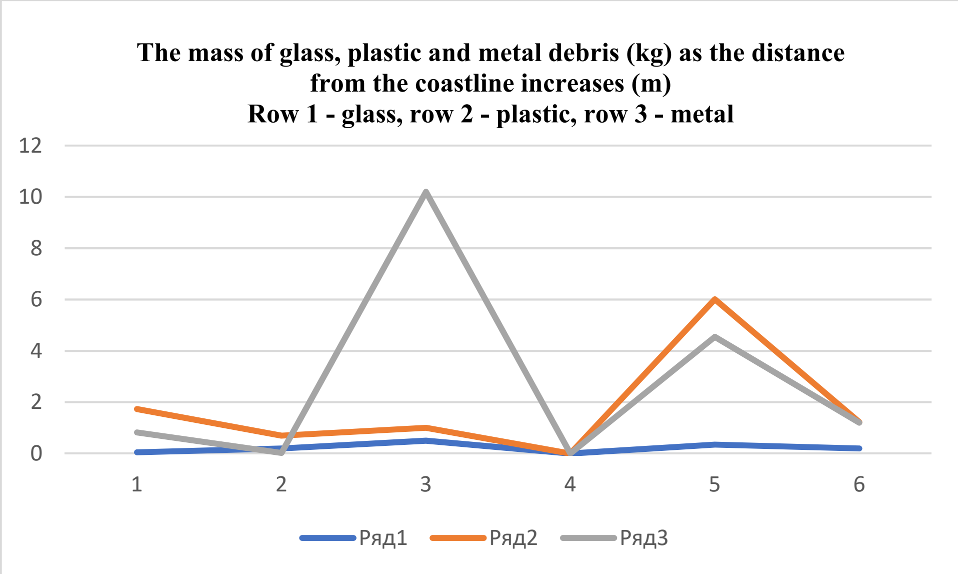

Fig. 5: *Spatial distribution of marine debris on Kildin Island.*

During the cleanup of the area, it was discovered that fragments of fishing nets pose a serious problem, as plant shoots often grow through them and removing the nets is impossible without damaging the above-ground parts of the plants (Fig. 6).

Fig . 6: *Shoots of Mertensia maritima (L.), sprouted through fishing networks .*

Kildin Island is home to a number of protected plant species [56,57]. The most valuable and vulnerable are Polemonium boreale Adams and Rhodiola rosea L. are confined to coastal habitats. Lake Mogilnoye, located in the southeastern part of the island, is home to the Kildin cod, an endemic species of the Murmansk region [58]. A number of bird species nest on the island [59].

Thus, cleaning coastal ecosystems from marine debris requires the use of technologies that reduce the risk of damage to flora and fauna.

V. Conclusion

A study of the component composition showed that the main source of marine debris on the northeastern coast of Kildin Island is fishing. The shoreline is polluted primarily by fishing gear: nets, fish boxes, etc. Tourism currently plays a less significant role in polluting the area. The deposition of debris on the shoreline depends on seasonal storm activity and the direction of coastal currents.

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