Short Note

Ecological State Assessment of Subaquatic Soils in the Gulf of Finland

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Ecological State Assessment of Subaquatic Soils in the Gulf of Finland

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Abstract: The aquatic vegetation of the Neva Bay is characterized by high biodiversity and play an important role. In recent years, hydrotechnical works associated with transport and industrial construction have been carried out in the Gulf of Finland. As a result of industrialisation and active anthropogenic impact these areas are a place of hyperaccumulation of nutrients and pollutants. This paper presents results of the ecotoxicological state assessment of subaquatic soils and investigation of the development of macrophyte thicket ecosystems of the Neva Bay.

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The coastline of the Neva Bay of the Gulf of Finland is characterized by a significant development of macrophyte vegetation. The total area of the main aquatic thickets in the Neva Bay is currently 1,214 ha. They occupy about 3% of the area of the bay, with an average width of 160-550 m and in some places up to 800 m, their total length along the shoreline being about 24 km. The higher aquatic vegetation communities of the Neva Bay are characterized by high biodiversity and play an important, multifaceted ecological role. They are habitats, nesting and migration sites for waterfowl and waterbirds, create specific conditions for spawning and nursery of young fish of many species, participate in the processes of self-purification of the aquatic ecosystem, etc.

In recent decades, active hydraulic engineering works have been carried out in the waters of the Gulf of Finland's Neva Bay, mainly related to transport and industrial construction. In the Gulf of Finland, for example, the total volume of dredging for hydraulic construction in the last 15 years was approximately 200 million m^3. In addition, depth support works are carried out annually on inland waterways in significant, not precisely known volumes. The number of artificially formed (reclaimed) areas is also accelerating. Hydro-technical works often have a strong negative impact on the thicket communities. Water turbidity and subsequent sedimentation of suspended sediments worsen the living conditions of hydrobionts, depress aquatic vegetation, disable fish spawning and rearing areas, loose their food base, lead to the loss of migration and nesting sites for birds, and inhibit water purification processes.

If the assessment of the expected impact of planned transport and industrial construction on the coastal ecosystems of the Neva Bay reveals a risk of loss of overgrown areas, this often becomes a serious obstacle to the approval of project documentation, causes opposition from scientific organizations and the general public, makes it difficult for projects to pass state expert review or to choose the most rational construction option. Often such projects are burdened with the conditions of obligatory development and implementation of appropriate compensatory measures - for example, ensuring the protection regime of any other overgrown areas, or even their artificial creation by engineering methods and means.

However, sometimes hydro construction can have a positive impact on the aquatic vegetation. In the Neva Bay there is also active formation of new macrophyte thickets, both near the shores and far from them, on the shoals. This is due to the consequences of the construction of the dams of the St. Petersburg Flood Protection Complex: significant changes in the current field, reduced flow, increased sedimentation and shallowing, pronounced changes in the configuration of the shoreline and bottom relief, etc.

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Thus, a comprehensive assessment of the impact of hydraulic engineering works on overgrown ecosystems is possible only when taking into account the processes of their spatial and temporal dynamics on the scale of the entire Neva Bay and the adjacent water area. It is quite probable that the area of overgrowth is now naturally increasing rather than decreasing throughout the entire water area of the Neva Bay. However, there is no precise information about these important processes.

The ecological properties of these new thicket communities are also hardly studied. Most importantly, there is no information on the substrates, their properties and characteristics, on which these valuable thickets of higher aquatic vegetation grow and on which spawning and nursery of young fish of many species takes place. In this case we are talking about subaquatic soils of the coast of the Neva Bay of the Gulf of Finland, which are favorable substrates for the growth and development of thicket communities that are periodically flooded.

The issue of attributing such subaquatic sediments of water bodies to soils has been considered since the works of Kubiena (1953) and Brewer (1964). In more recent works, bottom sediments with a soil-like profile are more often referred to soil formations (Stolt et al., 2011; Ivlev and Nesterova, 2004; Buurman, 1975, etc.). M.A. Glazovskaya (1972), following the concepts of B.B. Polynov (1948), distinguished subaquatic soils as hydromorphic soils. In the textbook 'Soil Science' (edited by V.A. Kovda and B.G. Rozanov) the group of hydromorphic soils includes maritim (marsh), mangrove and swamp soils, and all of them are coastal.

Hydromorphic and semi-hydromorphic landscapes, such as coastal strips and territories of water bodies, reservoirs, are areas of increased biogeochemical activity. As a result of industrialization and active anthropogenic impact (industrial and agricultural activities) these territories are a place of hyperaccumulation of various biogenic and polluting substances. Since the ecological conditions of the coast are much more dynamic than those of the mainland, not only a directional change of general parameters along the gradient from sea to land, but also a constant change of conditions at each point is revealed.

Substantial area of subaquatic, coastal territories is subjected to flooding, which leads to fundamental changes in biogeochemical processes occurring in soils and associated bottom soils. There is a change in redox regimes, slitisation, and an increase in the mobility of biogenic elements. In these aquatic ecosystems accumulation of biogenic elements and their transformation under the action of biota takes place, this process represents an important ecological problem for the region, as it leads to eutrophication of the water body, which is observed in the water area of the Neva Bay every season. As a result of eutrophication and algal blooms, the quality of water in the reservoirs decreases, which leads to deterioration of the quality of life of the local population and the quality and quantity of agricultural production. This requires the reaction of modern science and justification of effective decision making. Solving the problem of reservoir eutrophication and ensuring food security is a significant step within the framework of the Decade of Science and Technology in Russia and strengthening Russia's 'green image' on the world stage.

The most important task is also to study the ecotoxicological state of the studied coastal landscapes and their impact on the quality of life of the population, since as a result of their flooding, various substances from the water area are reintroduced into the biogeochemical cycle.

Thus, subaquatic soils with their vegetation reveal themselves as one of the sectors of the global biogeochemical cycle with inherent ratios of chemical elements. Located at the land-sea boundary, such soils play the role of a peculiar natural filter that retains some mineral components and selectively absorbs certain chemical elements.

Therefore, it is obvious that for a comprehensive assessment of the state of very valuable from the point of view of biological diversity overgrown ecosystems of coastal landscapes, as well as further adequate assessment of damage from the impact of hydraulic engineering works on the aquatic vegetation ecosystems and selection of compensatory conservation measures, it is necessary to know and take into account:

- properties and ecotoxicological state of subaquatic soils of the studied coastal landscapes
- and peculiarities of dynamics of thicket communities in the Neva Bay depending on the level of anthropogenic factor impact.

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For the purpose of the research, the thickets of higher aquatic vegetation were preliminarily divided into 3 categories according to succession stages:

(1) Long-established, with relatively stable projective area of water area coverage and high biodiversity;

(2) Relatively unstable, having emerged or significantly changed the area of projective cover during the available observation period before the establishment of the St. Petersburg Flood Protection Complex;

(3) Relatively recent (due to anthropogenic changes in the hydrological regime of the Neva Bay);

(4) Overgrowth that has occurred directly near the St. Petersburg Flood Protection Complex and far from it.

Three types of water areas were identified for each of these categories:

(a) The first - outside the influence of hydraulic engineering works and with minimal action of other anthropogenic factors (undisturbed state),

(b) The second - outside the influence of hydraulic engineering works with an average level of other anthropogenic factors (background state),

(c) the third - in the zone of influence of hydraulic engineering works under the average level of action of other anthropogenic factors (impact state).

According to the position of the sites in relation to the St. Petersburg Flood Protection Complex, the sites were divided into:

A-distant from the Flood Protection Complex,

B-adjacent to it.

Thus, the zones for the search of reference sites covered the following 14 combinations of successional stage and level of impact (Figure 1).

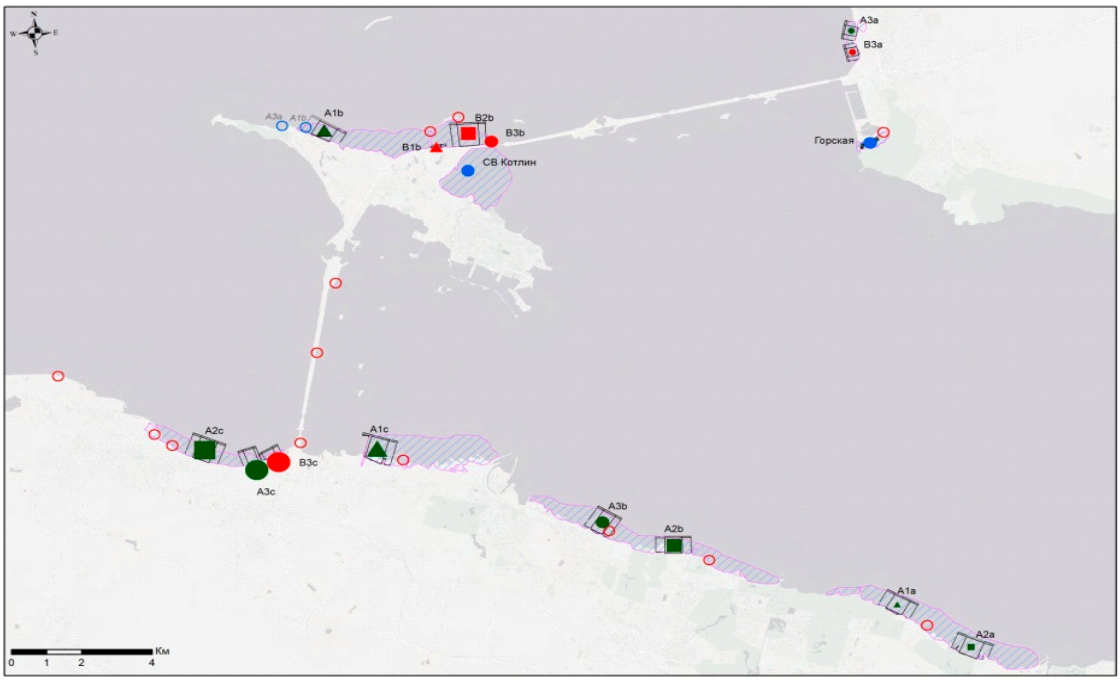

Figure 1. Schematic diagram of the study sites.

The majority of the survey area is located on reclaimed land in the coastal zone of the Gulf of Finland and is therefore technogenically transformed. In the Gulf of Finland coastal zone alluvial sandy sediments may fragmentarily contain psammozems, which belong to the underdeveloped soils

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department and represent a bedding-peat horizon lying directly on the sandy soil-forming rock. Areas of unconfined sands may also be common in parts of the coastline.

On the vast part of the study area the areal of marsh phytocenoses was formed. With some protection from the processes of tidal and surge forces, against the background of general hydromorphic and stagnant water, this area is subject to waterlogging processes, marsh soils have not yet had time to form.

Biocenoses of marine coasts are mainly experiencing high anthropogenic pressure. Among the different ecosystems, coastal and marine ecosystems are exposed to anthropogenic environmental factors, which include tourist visits, land reclamation and agricultural land development.

The modern period of soil formation on the territory of the region began after the melting of the glacial cover about 12 thousand years ago. Glacial waters left behind various forms of relief (kams, ozy, drumlins, zvontsy, etc.) and a cover of Quaternary rocks of variegated lithological composition and heterogeneous composition, which became mother rocks for modern soils. Marine transgressions levelled the glacial relief in the part of the territory adjacent to Lake Ladoga, the Gulf of Finland and the Neva River, bounded by the indigenous shore of the ancient sea - glint.

In the conditions of increasing anthropogenic pressure on landscapes, it is necessary to protect soils, which fulfil the functions of preserving the gene pool of natural plants, microorganisms, insects and animals typical of the region's ecosystems.

Soils of sea coasts are doubly influenced by land on the one hand and water on the other. This is manifested both in the specificity of geomorphological processes and in the geochemical fluxes of substances that come from both land and sea water. Due to this, soils located in the intertidal zone are characterized by complex genesis and dynamic development.

On the coast of the Gulf of Finland, the forest rarely comes close to the littoral, but very often a strip of seaside meadows is formed between the littoral and the forest. In areas with wind-protected shores, seaside meadows occupy large areas, extending some distance to the sea. During surge winds or tidal waters, these areas are flooded by sea water for a short period of time and are largely submerged. Here, marsh soils are formed under plant communities of near-water phytocenoses in close proximity to the sea.

Marsh soils are peculiar subaquatic soils of deltaic melts and coastal marches, which develop under the influence of tidal or surge waters. The peculiarity of marsh soils is conditioned by their almost permanent flooding. Soil profile is not differentiated, there is only one AC horizon enriched with humus and reducing compounds (Figure 2).

Figure 2. Soil profile of subaquatic soils of deltaic flats (marsh soils).

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As a result of the conducted research, a method of integrated assessment of the ecological value of subaquatic soils and melts was developed, which provides a reasonable quantitative approach to selecting a regime for their protection and use. It was found that the man-made fluvial lands (resulting from the alteration of the marine environment by hydro-construction) provide a full-fledged replacement of fluvial ecosystems lost during hydro-construction after the latent initial period of their succession. The greatest value is demonstrated by the melts outside the zones of hydraulic works impact and those formed due to stimulating effects of hydraulic works more than 15 years ago (the latter are more resistant to anthropogenic impacts). Younger thickets, resulting from the stimulating effects of hydraulic construction, have a lower ecological value and provide an incomplete set of 'ecosystem services'. Their potential is revealed only gradually, after a latent primary formation period of more than 10-15 years. In addition, a quantitative inventory of the resources of the main massifs of the Neva Bay melts was carried out, the value of ecosystems was determined, the results were mapped, and recommendations on the optimal use and protection of the melts were given.

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