Accumulation of biomass and heavy metals in communities of coastal aquatic vegetation of reservoirs in the North-West of Russia

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Abstract. The seasonal aspects of biomass dynamics and heavy metals accumulation in biomass were investigated for 27 species of high aquatic plants of shallow water reservoirs of North-West of Russia with different level of sediments pollution with heavy metals. It is shown that the character of seasonal dynamics of biomass and heavy metals accumulation differs at species, belonging to different ecological groups. The maximal accumulation of biomass and heavy metals at helophytes and submersed species is observed at the end of vegetation season, but for aquatic plants with floating leaves it is typical in the middle of vegetation. In polluted shallow water bodies, all groups demonstrate more fast accumulating of heavy metals and more shot period of active biomass accumulation.

1. Introduction
Aquatic vegetation can have a key role in the processes of self-purification of lakes [1] and in purification of shallow waters by constructed ecosystems, but the mechanisms of accumulation of biomass and toxicants in various groups and species of aquatic plants are studied fragmentally [2]. The lack of data on the accumulation of biogenic and non-organic substances and pollutants (including heavy metals (HM)) in vegetation of North-West of Russia, especially in various climatic conditions, makes it difficult to assess the role of this aquatic plant in maintaining the ecological balance of water bodies [3].

The present study is devoted to investigation of the seasonal dynamics of aquatic plants biomass and HM accumulation in shallow water bodies of North-West of Russia with different level of sediments pollution with HM (Sr, Pb, As, Ni, Cu, Fe, Co, and Zn).

2. Methods
27 common for North-West of Russia species of vascular aquatic plants were studied: Butomus umbellatus L., Carex acuta L., Carex aquatilis Wahlenb., Eleocharis palustris L., Equisetum fluviatile L., Glyceria maxima C. Hartm, Holmb Phragmites communis Cav., Trinex Sagittaria sagittifolia L., Scirpus lacustris L., Sparganium erectum L., Sparganium emersum Rehm., Iris pseudacorus L., Typha angustifolia L., Calla palustris L., Comarum palustre L., Menyanthes trifoliata L., Nuphar lutea L., Smith Nuphar pumila Timm, DC Nymphaea candida, Polygonum amphibium L., Sparganium gramineum Georgi Potamogeton natanis L., Potamogeton gramineus L., Stratiotes aloides L., Elodea canadiensis Michx., Utricularia vulgaris L., Potamogeton perfoliatus L., Potamogeton pustulosus L., and Myriophyllum spicatum L. [4, 5]. HM content was also investigated in filamentous algae Ulotrix sp. The field studies and sampling were done in 2010-2020 during the vegetation season from April to
October once in 6 shallow water reservoirs of the Leningrad Region (LR) and Karelia with depth not more than 2 m and total area not less than 1 km². According to regional normative [6], two reservoirs had a very low level of sediments pollution with HM, other two had a middle level (1.2 – 2 times higher than normative level), and two more had a high level (more than 2 times higher than normative level). The first group consisted of Bolshoe Rakovoe lake (LR) and Leshovoe lake (Karelia), the second group – of Gupuyrvi (LR) and Nikonovskoe (K) lakes, and the third group – of Samarka reservoir (LR) and the aquatory of the Southern shore of Neva bay (LR).

The biomass quantity was measured by the harvesting method. Its yearly production was determined by the calculation, taking into account the maximal biomass value and fall during the season [7]. The content of HM in various organs of plants was investigated by X-ray fluorescent spectrometry for Sr, Pb, As, Ni, Cu, Co, Zn, Fe, Mn, and Ti, according to the method of determination of elements and element oxides in soil and sediment samples FR.1.31.2018.32143.

3. Results
The results of the study show different patterns of biomass and HM accumulation during the season at different groups of aquatic plants. The seasonal dynamics of biomass accumulation in helophytes is characterized by the maximum at the end of vegetation (Fig. 1). For submerged species, biomass accumulation is in most cases similar to that for helophytes, but at some communities there is often a situation of rapid loss of a part of biomass and secondary growth (Fig. 1). Species with floating leaves differ in the character of biomass accumulation: some have a clear visible maximum (like Nymphaeae candida), some, like Nuphar lutea, may have several generations of vegetative organs during the season. The specifics of the relationship between biomass values and annual production varies among different groups of aquatic plants. Annual production of a number of species of plants with floating leaves (Nupar lutea, Potamogeton species, etc.) can vary greatly at plants in different lakes even in similar growing conditions and the implementation of this parameter requires seasonal observation on a particular reservoir.

The HM accumulation is individual for each species of aquatic plants. The characters of the HM accumulation differ significantly for most species from different ecological groups of aquatic plants, but also can differ for species within one ecological group (Fig. 2).

Figure 1. The seasonal dynamics of HM accumulation in dry biomass of aquatic plants.
Figure 2. HM accumulation in biomass of different groups of aquatic vegetation.

Figure 3. The seasonal dynamics of HM accumulation in dry biomass of aquatic plants in (a) polluted and (b) non-polluted shallow water bodies. Blue – helophytes, pink – species with floating leaves, green – submerced species.

It is shown that HM accumulation in all the studied species has similar patterns (Fig. 3):
- HM content increases during ontogenesis of individual organs up to die-off and then gradually decreases;
- the accumulation of each HM is individual for species;
- the accumulation of HM in aquatic plant community area unit is more determined by the biomass than by the accumulative capacity of individual species and groups for different HMs.

In conditions with more high pollution of sediments with HM, the seasonal dynamics of total HM accumulation differs from one in non-polluted habitats. In polluted conditions, the active vegetation
time is shorter for all studied groups, and the HM accumulate more intensively in the first and the middle parts of vegetation, juvenile and flowering plant (Fig. 3). This effect was observed for all species (Fig. 3b), but for the group of species with floating leaves it was expressed stronger.

4. Conclusion

It has been found that determination of annual or seasonal HM accumulation in aquatic plant biomass should take into account losses during the season. This is especially significant for species with a developed perennial rhizome from the group of plants with floating leaves, since data obtained without taking into account seasonal losses can be underestimated by 2-3 times in the vegetation of lakes in the North-West of Russia.

The accumulative capacity of HM in aquatic plants differs for species and ecological groups. High aquatic vegetation accumulates less HM, than filamentous algae per unit of biomass. Among the higher aquatic plants, some species were found with comparatively higher and lower accumulation of HM (Sr, Pb, Zn, Ni, and MnO) in biomass unit. For all the studied ecological groups of plants, there is observed more high accumulation of Sr, Zn, and Cr. The HM accumulation is higher for helophytes and coastal bogs species. A number of HM (Co, V, and TiO₂) are very few accumulated by higher plants, as opposed to filamentous algae.

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