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UDC 574.24; 574.633

IMPACT OF HEAVY METALS ACCUMULATION ON THE PHOTOSYNTHESIS PIGMENT CONTENT IN PLANTS FROM THE RIPARIAN AREA OF TYUMEN'S WATER BODIES

SUMMARY. The significant increase in the heavy metal content in the environment is accompanied by their accumulation in plants, which negatively impacts on the growth, development, and productivity. The purpose of the paper is to study the changes in heavy metal concentrations and photosynthesis pigments in the plants growing in the riparian waters of Tyumen. To study the condition of the water bodies, the dominant plants of the riparian zone (Trifolium repens and Plantago major) and higher aquatic plants (Typha latifolia) are investigated. The inverse relation of the heavy metal concentration and photosynthesis pigments is demonstrated. As a result of investigating the general condition of plant pigment systems in the riparian zones of the investigated water bodies in Tyumen, it is stated that the riparian zone plants contain more heavy metals than the aquatic ones; they exert a selective sensitivity to heavy metals. The response of plants to pollution is species-specific.

KEY WORDS. Heavy metals, photosynthesis pigments, biotesting, riparian and aquatic plants.

In the context of industrial development, the environmental pollution by heavy metals has recently increased in the scales which are non-specific for the nature. Therefore, the increase of heavy metal content in the environment is a serious ecological problem nowadays [1], [2].

In spite of the fact that various heavy metals are not essential for plants, they can be actively absorbed and accumulated by a plant, penetrating into the human body through the food chain [3]. The situation is in danger since metals have a cumulative effect and keep their toxic properties for a long time [4]. The significant increase in the heavy metal content in the environment is accompanied by their accumulation in plants, which negatively impacts on growth, development, and productivity.

Hence, the study of the plant response to the heavy metal impact is not only of a great theoretical interest, but also of a practical one. The range of the aspects of this problem is rather wide. Particularly, such issues as absorption, transportation, and accumulation of heavy metals in plant tissues and organs, their influence on the main physiological processes (growth, development, photosynthesis, water exchange, mineral nutrition), and the mechanisms of plant resistance to metals are under investigation [5].

The purpose of the paper was to study the changes in heavy metal concentrations and photosynthesis pigments in the plants growing in the riparian waters.

The heavy metal concentrations in the studied plants were determined according to the standard procedure [6-8]. The contents of photosynthesis pigments (chlorophyll and caratenoids) were determined with a spectrophotometer [9].

To study the condition of water bodies (4 lakes and 2 ponds), we investigated the dominant plants (*Trifolium repens* and *Plantago major*) from the riparian zone (1-2 m distance from the summer low flow in the water reservoir), and higher aquatic plants (*Typha latifolia*).

Lakes Mullashi (in the south-east from the city) and Kuchak (in the north-east from the city) are located outside the city (about 20-50 km). There is a recreation center, a biostation with neighboring suburban summer cottages on the territory of these water bodies. Pond Lesnoy and Lake Krugloye are situated in the green part of the city and they are recreation areas. There is Steam Power Plant 2 nearby Pond Lesnoy. The pollution source of Lake Krugloye is water transport. Pond Yuzhniy is situated in the residential area. Lake Obrochnoye is the heat sink of Steam Power Plant 1 and it is situated nearby. There is a highway over the bridge across it.

All examined water bodies are fresh, low-mineralized (lakes Mullashi, Obrochnoye, Krugloye and Pond Lesnoy) and middle-mineralized (Lake Kuchak and Pond Yuzhniy). By the salt composition, the water bodies are mainly hydrocarbonate-calcium. The only magnesium sulphate water body is Lake Mullashi. The minimal values of chemical indicators of salt composition were registered in the water of Lake Mullashi, the maximum ones were registered in Pond Yuzhniy. Pond Yuzhniy appeared the most favourable one according to hydrochemical water indicators; therefore, it was chosen as the control water body.

The assessment of the condition of plant pigment photosystems allows observing their responses to water bodies pollution. The photosynthesis system as one of the main systems of plant life support rapidly reacts to any, even insignificant, changes in the environment [10].

In the leaves of *Trifolium repens* from the four examined water bodies (Lake Mullashi, Pond Lesnoy, Lake Kuchak and Lake Obrochnoye), the increase of total concentration of photosynthesis pigments (Fig. 1) was registered in relation to the values of plants from the Pond Yuznhiy area ($\alpha<0.95$). The similar responses were registered for *Typha latifolia* ($\alpha<0.95$), growing in the investigated water bodies. The responses in the leaves of *Typha latifolia* were expressed more than those of *Trifolium repens*.

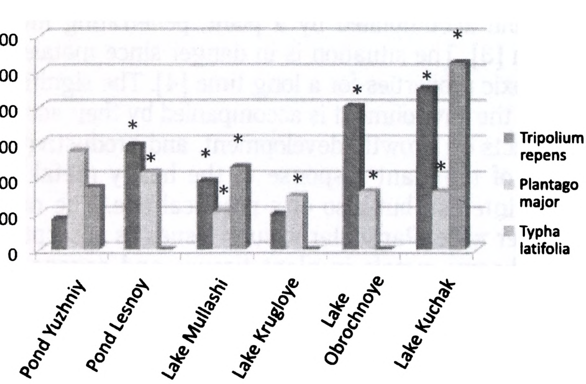

Fig. 1. Total photosynthesis pigment concentrations in the leaves of some plants in the investigated water bodies

Note: * statistically-valid discrepancies in relation to Pond Yuzhniy, where $\alpha<0.95$.

The high total photosynthesis pigment concentration in the studied plants may be connected with the activization of the photosynthetic apparatus, provoked by high energy demands which are connected with the neutralization of the impact of such pollutants as phenols (determined as oil products) and organic and suspended substances with excessive MAC in the water bodies and around them.

It is known [10-11] that pollutants can possess a stimulating effect. Such pollutants may include different types of biogenes, ions, and biogenic ions. The increase of photosynthesis pigment concentration may be connected with water bloom and with the increased content of such substances as natural phenols, iron, ammoniacal nitrogen, phosphate ion, and also with the increased water temperature of Lake Obrochnoye (the heat sink of Steam Power Plant 1), speeding up metabolic processes in the plants.

The total photosynthesis pigment concentration in the leaves of Plantago major from the riparian zones of lakes Mullashi, Krugloye, Obrochnoye, Kuchak and Pond Lesnoy was lower than that one in the plants of Pond Yuzhnyi (α<0.95). One should pay attention to the different responses of the plants. Alongside with the increase in total photosynthesis pigment concentration of *Tropolium repens* and *Typha latifolia,* the decrease of the studied indicator in the leaves of *Plantago major* from the riparian zones of the same water bodies was registered. This fact proves that there are different responses of these plants to pollution.

The adaptive strategy of every species of plants has its own direction; consequently, it has its own mechanism of protection from the negative environmental impact including the anthropogenic one.

The evaluation of heavy metal content in the plants allows detecting the degree and the duration of water pollution by heavy metals. Plants as the majority of biological objects possess the property to accumulate various elements. The species of plants differ by their resistance to heavy metals and the ability to accumulate them. [12]. The most common features of heavy metal impact on plants are the photosynthesis inhibition, the distortion of assimilate transportation and mineral nutrition, the change of water and hormonal status of organisms, and the growth inhibition [13].

The total heavy metal concentration (Fig. 2) in the leaves of *Tripolium repens* collected from the riparian zone of the investigated water bodies (lakes Obrochnoye, Kuchak and Mullashi) has a lower value than that one in the plants growing in the riparian zone of Pond Yuzhniy (α<0.95).

The total heavy metal concentration in the leaves of *Plantago major* from the outskirts of all investigated water bodies is lower than that one in the plants from the area of Pond Yuzhniy, except for the total heavy metal concentration in the leaves of *Plantago major* from the riparian zone of Lake Krugloye, where α<0.95.

The total heavy metal concentration in the leaves of *Typha latifolia* from Lake Kuchak is higher (α<0.95) than that one in the plants from Pond Yuzhniy.

In general, all studied plants are affected by heavy metals because their accumulation was registered in all investigated water bodies. *Trifolium repens* has accumulated heavy metals to a larger extent than other plants growing in Pond Yuzhniy and Lake Obrochnoye.

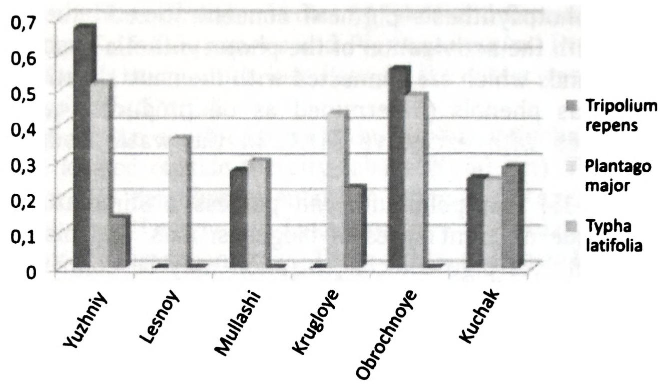

Fig. 2. Total heavy metal concentration in the plants from the investigated areas, in mg/kg of leach

Note: all data are statistically-valid in relation to Pond Yuzhniy, where $\alpha<0.95$.

One should pay attention to the fact that the aquatic plants are less exposed to heavy metal pollution than the plants of the riparian zone. It is probably connected with the biological features of organisms. Thus, the aquatic plants as the majority of other biological objects of different organization levels exert a selective sensitivity to heavy metals.

Probably, there is a relation between the photosynthesis pigment content and the general heavy metal concentration. Large heavy metal concentrations cause the inhibition of photosynthetic activity of plant pigment systems. Many heavy metals belong to the vital elements which carry out structural and regulatory functions [14].

The force of connection between the total concentrations of photosynthesis pigments and heavy metals is direct and low (r=0.19 — *Trifolium repens*, r = 0.2 — *Plantago major* and *Typha latifolia*) in all studied species growing in the area of Pond Yuzhniy. *Plantago major* from the riparian zone of Lake Mullashi has the high inverse relation (r=-0.57) between the total concentrations of photosynthesis pigments and heavy metals. In all other variants, the inverse relation is not high (from r=-0.16 to r=-0.43). On account of the correlation analysis of plant pigment system responses to heavy metal pollution, it is evident that heavy metals are not critical components of general pollution of water bodies and their shores.

The high inverse relation of *Plantago major* may be connected with the fact that while the heavy metal concentration increases, the inhibition of photosynthesis pigments occurs. As for Lake Mullashi, it is situated alongside the highway and it is the recreation area, thus, the heavy metal pollution of the riparian zone occurs. Due to the developed fibrous root system which is found in the top surface soil, *Plantago major* is more exposed to pollution.

Conclusions

1. As a result of the long-time heavy metal pollution of the riparian zone in the investigated water bodies, the plants have a higher heavy metal concentration than the aquatic plants growing in Pond Yushniy and Lake Obrochnoye due to the close highway location.

2. The increase of the general photosynthesis pigment concentration in the leaves of *Trifolium repens* from the areas of lakes Kuchak, Obrochnoye, Mullashi and Pond Lesnoy was registered as the response to the existing pollutants.

3. Responses of the plants to pollution are species-specific. In the leaves of *Plantago major* from the riparian zones of lakes Mullashi, Krugloye and Obrochnoye, the total heavy metal concentration was lower than that one in the plants from Pond Yuzhniy. Probably, thus the total photosynthesis pigment concentration in the leaves of *Plantago major* from the riparian zones of lakes Mullashi, Krugloye, Obrochnoye, Kuchak and Pond Lesnoy was lower than that one in the plants from Pond Yuzhniy.

4. Heavy metals belong to the components of the general water pollution because in all the variants the correlation between the total photosynthesis pigment concentration and the total heavy metal concentration in the plants is low and inverse (except for *Plantago major* from the riparian zone of Lake Mullashi).

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