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Prospects of application of Elodea canadensis Michx in the complex assessment of the state of small rivers in the zone of influence of technogenic objects of the Kalush mining and industrial district (Kalush district, Ivano-Frankivsk region, Ukraine)

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SUMMARY

The breach of natural balance arose as a result of anthropogenic transformation of rocks during the operation of Kalush-Holynsk deposit of potassium salts, due to irrational location of tailings, dumps, accumulating tanks and long functioning of objects of chemical industry (landfill of toxic waste of Oriana-Halev Limited company in particular). The most pronounced are the changes in the river ecosystems of the region, due to the violation of hydrogeological conditions and the introduction of a wide range of pollutants into the environment. The rivers of the region belong to the Carpathian part of the Dniester river and take part in the formation of its runoff, so their anthropogenic transformation can lead to the breach of the entire Dniester river ecosystem. Systematic control over changes in river water quality indicators is an urgent task of ecological and applied research and a prerequisite for effective management of the ecological condition of the entire Dniester river basin.

The research was conducted in 2020-2021. The ecotoxicological condition of the Sivka, Sapohiv, Limnytsia rivers was assessed on the sections of their flow through the Kalush mining and industrial area and on the relevant background areas

he presented experiment was preceded by chemical-analytical studies to determine the cationic-anionic composition, background hydrological indices and organochlorine compounds. The results allowed us to state that the studied rivers can be referred to three quality classes: the Sivka river - to the 7th class (extremely polluted waters); the Sapohiv river – to the 3rd class (moderately polluted waters); the Limnytsia river – to the 2nd class (clean water). At the same time, chlorides are a priority factor of the pollution of the Sivka river, and traces of hexachlorobenzene are present in the water of the the Sapohiv river.

Introduction

The ecological and technogenic situation in the zone of influence of the Kalush mining district in Ivano-Frankivsk region not only makes a threat to the national security of Ukraine, but is also one of the most acute environmental problems of an interstate nature. The breach of natural balance arose as a result of anthropogenic transformation of rocks during the operation of Kalush-Holynsk deposit of potassium salts, due to irrational location of tailings, dumps, accumulating tanks and long functioning of objects of chemical industry (landfill of toxic waste of Oriana-Halev Limited company in particular). The most pronounced are the changes in the river ecosystems of the region, due to the violation of hydrogeological conditions and the introduction of a wide range of pollutants into the environment. The rivers of the region belong to the Carpathian part of the Dniester river and take part in the formation of its runoff, so their anthropogenic transformation can lead to the breach of the entire Dniester river ecosystem. Systematic control over changes in river water quality indicators is an urgent task of ecological and applied research and a prerequisite for effective management of the ecological condition of the entire Dniester river basin.

The aim is to evaluate the prospects of using morpho-functional parameters of Elodea canadensis Michx as bioindication markers for integrated biological monitoring of river ecosystems of the Kalush mining and industrial area.
The object of the research is reactivity and bioindication perspective of morpho-functional parameters of Elodea in the conditions of salt and organochlorine pollution of river water in the zone of influence of technogenic objects of the Kalush mining and industrial area; the subject is the character of changes in the analyzed indicators in space and for the action of different types of pollutants. The choice of the test object is caused by its sensitivity to the influence of aquatic toxicants and prevalence in nature.

Method and Theory

The research was conducted in 2020-2021. The ecotoxicological condition of the Sivka, Sapohiv, Limnytsia rivers was assessed on the sections of their flow through the Kalush mining and industrial area and on the relevant background areas (Fig. 1).

The samples of sampling were determined on the rivers taking into account their distance from the source of pollution: Fold 1 – background, at a distance of 500 m to the potential source of pollution; Fold 2 – directly near the source of pollution; Fold 3 – at a distance of 500 m after the source; Fold 4 – at a distance of 1000 m (Andrusyak, 2008). The presented experiment was preceded by chemical-analytical studies to determine the cationic-anionic composition, background hydrological indices and organochlorine compounds. The results allowed us to state that the studied rivers can be referred to three quality classes: the Sivka river - to the 7th class (extremely polluted waters); the Sapohiv river – to the 3rd class (moderately polluted waters); the Limnytsia river – to the 2nd class (clean water). At the same time, chlorides are a priority factor of the pollution of the Sivka river, and traces of hexachlorobenzene are present in the water of the the Sapohiv river.

Water quality biotesting was performed in artificial microecosystems of aquarium type with a volume of 6 dm^3 in factor-based laboratory conditions (Andrusyak, 2008). Intra-tissue concentrations of photosynthetic pigments were determined photocolorimetrically with pre-extraction with ethanol by centrifugation. The concentration of chlorophyll and carotenoids was calculated by the Werner-Wettstein formulas (Musienko et al., 2001).
The sensitivity of the links of the trophic network of hydroecosystems was evaluated by the percentage of inhibition of morphophysiological test traits of aquatic organisms, which was calculated by the formula:

$$I = 100\ \% - [(K_1 \times 100\ \%) / K_2],$$

where I is the index of inhibition of test traits of aquatic organisms (per cent); K_1 is the average value of the test response of plants in the control; K2 is the average value of the test response of plants in control.

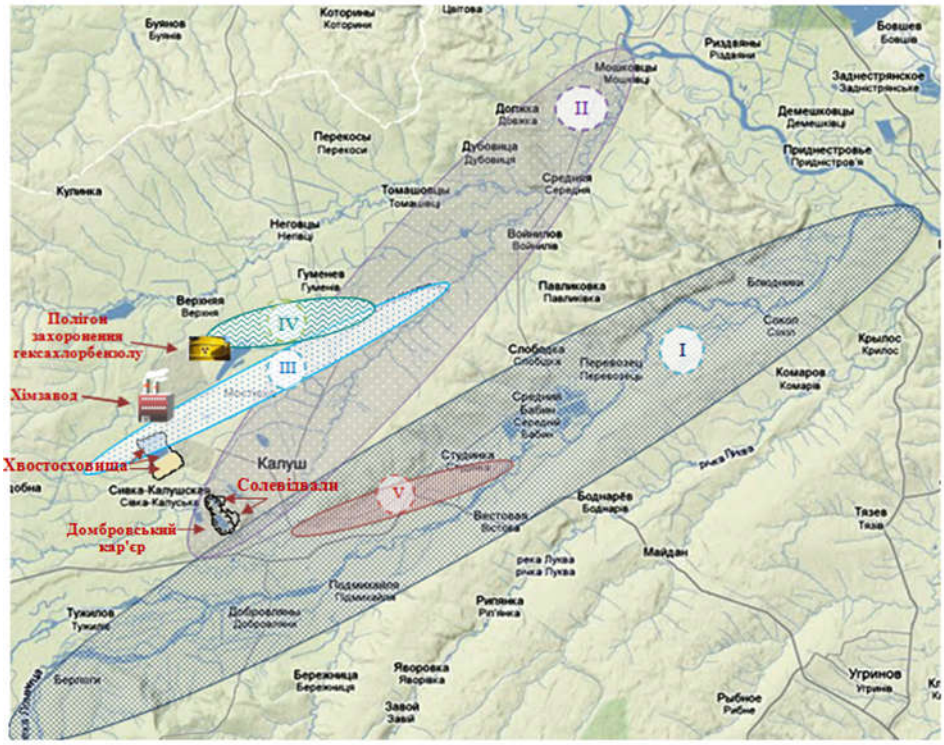

Figure 1 *The diagram of the main technogenic objects of the Kalush mining district and catchment areas of the studied rivers: I – the Limnytsia river; 2 – the Sivka river; 3 – the Sapohiv river.*

The index of water toxicity of small rivers was determined by the change of test indicators of aquatic organisms concerning control by the method of construction of model maps according to the adapted method by N.S. Andrusyak (Andrusyak, 2008).

Mathematical calculations and interpretation of the obtained results were performed using the MS Excel 2019 editor.

Examples

The growth and development of Elodea canadensis Michx in microcosms with water of the studied rivers were evaluated by the change in the length of the main and lateral shoots, as well as by the growth of roots. When exposed to water samples of the Limnytsia and Sivka rivers, no trustworthy difference between the length of the main shoot of control and experimental plants was found (Table 1).

Slow appearance of necrotic spots was also found in the water of the Sivka river. The water of the Sapohiv river has a high toxicity for the indicated test indicator. It is known that under favorable environmental conditions, the main shoot of Elodea forms numerous branches. Violation of the development of lateral shoots of Elodea canadensis plants was stated. In all the studied water samples depression of growth of lateral shoots of the test plants in comparison with the control value was

revealed. The minimum length of lateral shoots of test plants was recorded in water samples Fold 1 of all studied rivers.

Table 1 *The percentage of inhibition of vegetative bodies growth and productivity indexes of Elodea canadensis Michx in microecosystems, per cent of the background value*

Fold number	Length of the main shoot	Length of lateral shoots	Lengthy of roots	Necrotized leaves	Biomass	Number
the Limnytsya river						
2	ND	52	90	25	22	ND
3	ND	43	87	13	Ч	ND
4	ND	33	75	8	Ч	ND
the Sivka river						
2	ND	100	100	22	33	ND
3	ND	100	100	11	22	ND
4	ND	70	96	6	17	ND
the Sapohiv river						
2	*	*	*	*	*	100
3	32	100	100	30	45	ND
4	22	73	100	10	39	ND

*ND – trustworthy difference in control was not detected; * – test object died.*

Achieving the state of physiological maturity of Elodea (maximum rooting) have not been recorded by us in any version of the experiment. The complete absence of Elodea roots was found in the water of the Sivka and Sapohiv rivers. Against the background of inhibition of growth of the main and lateral shoots during the visual inspection of plants in the water of the Sapohiv river, the presence of necrotic spots was recorded. Necrotization of plant parts, loss of turgor and inhibition of growth processes led to a decrease in the biomass of Elodea canadensis. Similar to other test indicators, plant biomass is the lowest in the water of the Sapohiv river, the highest is in the Limnytsia river. When moving away from the dominant sources of influence, the degree of manifestation of the analyzed trait gradually decreases.

Elodea plants died during the experiment in the water of Fold 2 of the Sapohiv river (near the landfill of toxic waste, namely hexachlorobenzene and its derivatives). On the 5th day of functioning of the microcosm, the Elodea plant lost turgor, the color changed from dark green to dusky yellow-green. At the same time the plants were localized at the bottom of the microcosm. The complete death of the plants was observed on the 20th day of the experiment.

It is known that the toxic effects of various pollutants are manifested in changes in the photosynthetic system of higher aquatic plants, namely in quantitative changes in the pigment composition. The determination of the content of photosynthetic pigments is informative enough to establish the degree of harmfulness of pollutants, ways of adaptation of plants to them, as well as to normalize and predict anthropogenic load in the conditions of the environment.

From the data shown in Table 2, it is seen that with the approach to the source of contamination, the number of photosynthetic pigments decreases in all experimental variants. The highest percentage of inhibition of photosynthetic pigments was found in the water of the Sivka river in Fold 2.

Against the background of reduced chlorophyll content, the amount of carotenoids also decreases, which indicates a weakening of adaptive abilities and reduction of plant tolerance (Zylov, Stom, 1989). Thus, the high sensitivity of the Elodea pigment complex to water pollution by industrial pollutants of the Kalush mining and industrial area was determined.

Table 2 *The percentage of inhibition of the content of photosynthetic pigments of Elodea*

Target number	Chlorophyll a	Chlorophyll b	Carotenoids
the Limnytsia river			
2	22	ND	63
3	ND	ND	61
4	ND	ND	59
the Sivka river			
2	33	ND	63
3	22	ND	58
4	17	ND	29
the Sapohiv river			
2	*	100	*
3	45	ND	81
4	39	ND	49

Conclusions

Toxic influence of industrial pollutants in the zone of influence of technogenic objects of the Kalush mining and industrial area at the biotestor is manifested by the change of morphometric and physiological and biochemical indicators. The maximum changes were observed during exposure to the waters of the Sapohiv river; the minimum – the Limnytsia river.

The length of roots and lateral shoots of Elodea was marked by the maximum reactivity, and accordingly by the bioindication perspective, at the organ level, and at the molecular level by the intra-tissue concentrations of carotenoids.

The studied morpho-functional parameters are recommended for implementation as bioindication markers of the ecotoxicological state of rivers in the zone of influence of technogenic objects of the Kalush mining and industrial area.

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