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Possibilities Of Using Eichhornia Crassipes Solms And Lemna Minor L. In Wastewater Phytoremediation

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Abstract

Object: To investigate the efficiency of an urban sewage treatment plant, to study the peculiarities of changes in the concentration of heavy metal ions in wastewater and to assess the biological treatment of wastewater from livestock complexes when Eichhornia crassipes Solms. and Lemna *minor L. are present*.

Methods: Physical properties, chemical composition of wastewater and concentration of heavy metal ions in water were analyzed using the standard methodology by Lurye.

Findings: The possibility of using E. crassipes Solms. and L. *minor L.* at a treatment plant in Osh was confirmed, and experiments showed a positive dynamic of absorption of all forms of nitrogen, phosphorus and heavy metals.

Conclusions: E. crassipes Solms. and L. *minor L.* significantly improve the physicochemical indicators of water; oxidizability decreases, all forms of nitrogen, phosphates, and heavy metal ions decrease, dissolved oxygen increases, and the possibility of contaminating open water bodies, soil and underground waters by the above pollutants is eliminated. The obtained results can be applied for additional treatment of various polluted waters.

Keywords: pigher aquatic plants, heavy metal ions, post-treatment, waste water, bioplato, phytoremediation.

Introduction. The treatment of industrial and municipal wastewater remains an urgent issue, especially due to constantly increasing requirements for the quality of treated wastewater.

Currently, a large volume of clean water is used for various industries. Wastewater used for production is returned to water bodies, negatively influencing the water quality and the self-purification process. Scientists worldwide apply various means to reduce the use of clean water for industrial purposes, including methods of recycling treated wastewater in a closed water circulation cycle. The main objective of the comprehensive study is to improve the efficiency of various wastewater treatments and to obtain scientifically proven data on the quality of wastewater discharged into natural water bodies.

At present, only a small number of enterprises can afford to construct new biological treatment plants. At the aeration stations built in the 60-80s, the load limits are already exhausted, as a rule, due to population growth and the number of new industrial facilities introduced in the 70-80s which dump wastewater into the city collector.

In this regard, researchers pay considerable attention to the intensification of wastewater treatment processes, improvement of technological schemes, development of new effective methods that allow increasing the quality of wastewater discharged into open water bodies, reducing the cost of water and minimizing time-consuming preparation and dosing of reagents.

The present research aims to study the accumulation capacity of representatives of aquatic macrophytes, E. crassipes Solms. and L. minor L., and to determine the efficiency of wastewater treatment of phosphates, nitrogen compounds, surface-active agents, oil products and metals during the cultivation of the above-mentioned plants.

Literature review: biological treatment using aquatic plants is considered effective for urban wastewater. In connection with an increase in the proportion of nitrogen and phosphorus-containing organic substances, there is a tendency of the qualitative composition of polluted waters to change. Biological treatment facilities built in the 60s do not always provide the necessary degree of purification, including from biogenic substances. An optimal way of additional purification of polluted waters from nutrients is the use of higher aquatic vegetation (HAV). Accumulation, disposal, and transformation of toxic substances are a distinctive feature of HAV, making this vegetation indispensable in the general self-purification of water bodies [1, p. 146; 2, p.106; 3, p. 92].

In recent years, USA, Canada, Australia, New Zealand, Sweden, Denmark, Germany, England, France, Switzerland, Israel, Spain, India and Russia use a biological treatment method with HAV, which is considered the simplest, cheapest and most effective method of wastewater treatment and is used in seasonally operating facilities [4, p. 151; 5, p. 84; 6, p. 431].

Experimental studies carried out at Osh Humanitarian Pedagogical Institute confirmed the possibility of using E. crassipes Solms. at the treatment plant in Osh – the dynamics of HAV absorbing all forms of nitrogen and phosphorus is positive. The effect of the biomass harvest time on the yield of E. crassipes Solms., Potamogeton crispus, Azolla caroliniana, Elodea canadensis and Vallisneria spiralis was studied at the experimental site of Osh Humanitarian Pedagogical Institute in order to determine the best option. Almost all the studies reveal that with daily harvest, the average increase in biomass during the day slows down noticeably. It should be noted that the daily increase in the biomass of the above mentioned species of aquatic plants also decreases if the biomass is not collected systematically. Moreover, one of the main factors affecting the slowdown of the daily growth of the studied species is a rapid increase in their density. The most effective growth and accumulation of biomass were observed with regular collection of biomass every 3 days [7, p. 45; 8, p. 11; 9, p. 14].

The use of aquatic plants for wastewater treatment is one of the most promising methods. In the countries of the European Union and in the Russian Federation, including the West Siberian region, this technology is being successfully implemented. Its characteristic advantage is the ability to optimally reduce the cost of treating wastewater from small settlements and, at the same time, improving the effectiveness of the treatment [10, p.35; 11, p. eight; 12, p.100].

In Ukraine since the XX century, the biological method of purification with HAV is optimally used for additional purification of household and industrial wastewater. The Institute of Hydrobiology of the National Academy of Sciences of Ukraine developed a technology for using a bioplato as a system for additional purification of water in rivers that provide fresh water to large settlements [13, p.886; 14, p.99; 15, p. 95].

Thus, developing bioponds for biological treatment of municipal wastewaters in small settlements, it is necessary to use natural and not introduced flora since this will increase the purification efficiency and reduce the cost of construction and maintenance of treatment facilities. Polluted waters are proved to have a varied chemical composition and a high pH; therefore, selecting resistant HAV species is an urgent task. Currently, scientists worldwide are engaged in selecting HAV species that optimally cleanse the water from various pollutants in different climatic conditions [16, p.10; 17, p. 163;].

A scientific study of phytoremediation of communal-domestic polluted waters by V. spiralis was carried out using different adsorbents in order to select the most effective combination of water macrophytes and sorbents that provide optimal treatment of municipal wastewater. The research results showed that to reduce the pollution of natural reservoirs with communal polluted waters, it is advisable to use aquatic macrophytes in biosorbers in combination with adsorbents [18, p. 35; 19, p. 103].

At Perm State Technical University, analytical experimental studies were carried out to assess the possibility of using HAV for the accumulation of various biogenic elements in phytoremediation of urban wastewater. The purpose of this scientific work is to develop the most effective technology and technical solutions for purifying the content of nutrients in biological treatment of urban wastewater with the help of HAV representatives V. spiralis and P. crispus which optimally extract nitrogen and phosphate salts [20, p. 45; 21, p. 1616].

Materials and research methods: For the study, 5 samples of wastewater from the treatment plant in Osh were taken: 1 – entrance to the sewer, 2 – exit after mechanical treatment, 3 – exit from sedimentation tanks, 4 – exit after biological treatment, 5 – after filtration, 6 – after biological treatment with E. crassipes Solms., 7 – after biological treatment with L. minor L. The plants were cultivated for 9 days in the wastewater taken from the filtration stage.

To determine the possibility of using them for additional purification from heavy metal ions under laboratory conditions, E. crassipes Solms. and L. minor L. were cultivated in a 5-liter aquarium. To adapt the aquatic plants, tap water was settled for two days, and the plants were kept in the aquarium for 7 days at the water temperature of 21^0C. During the experiment, 500 g of E. crassipes Solms. and L. minor L. were placed in the aquarium, and the preliminarily settled water was changed every 3 days. The studies in natural light conditions were carried out in three repetitions for 30 days. The salts of heavy metals were preliminarily added to the water (iron 2.5 mg/L; copper 0.5 mg/L; zinc 1.2 mg/L). The concentration of heavy metal ions in the water was chemically analyzed by standard methods every 7 days. Water without plants contaminated with heavy metals was used as control.

The amount of ammonium nitrogen was determined according to the ‘Methodology for measuring the mass concentration of ammonium ions in treated wastewater by the photometric method with Nessler's reagent FERD (federal environmental regulatory documents) 14.1-95’. The amount of nitrate nitrogen was determined according to the ‘Methodology for measuring the mass concentration of nitrate ions in natural and waste waters by the photometric method with salicylic acid FERD 14.1: 2.4-95’. The amount of nitrite nitrogen was determined according to the ‘Methodology for measuring the mass concentration of nitrite ions in natural and waste waters by the photometric method with Greiss’s reagent FERD 14.1: 2.3-95’. The amount of phosphates was determined according to the ‘Methodology for measuring the mass concentration of phosphate ions in natural and treated wastewater by the photometric method of reduction with ascorbic acid FERD 14.1: 2.112-97’.

The mass concentration of the determined objects was carried out under normal laboratory conditions: ambient temperature 21 ± 4^0C, atmospheric pressure 85-105 kPa, relative humidity 81 ± 4%, AC frequency 50 ± 2 Hz, mains voltage 220 ± 9 V.

Results: 1. Results of biological treatment of wastewater from the treatment plant in Osh.

For a comparative study, the authors offered post-treatment methods using HAP E. crassipes Solms. (Sample 6) and L. minor L. (Sample 7). The plants were cultivated for 9 days in the wastewater taken from the filtration stage.

1.1. Changes in physical readings at different stages of purification.

Data on physical indicators are presented in Figure 1.

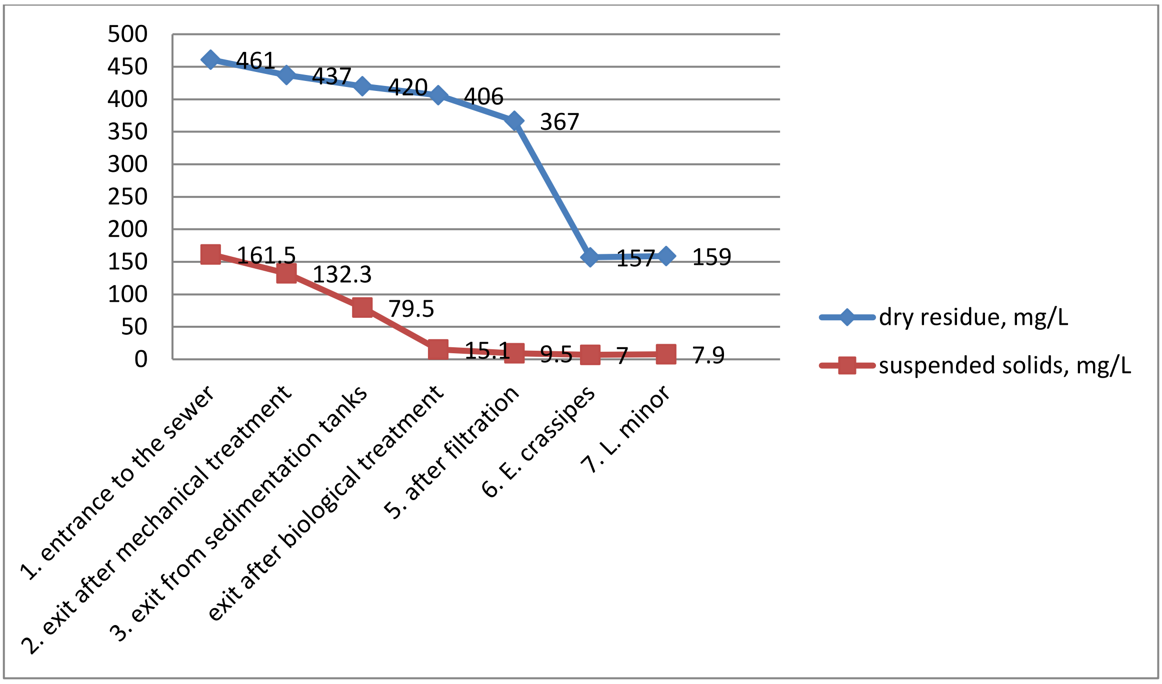


Figure 1. Changes in physical readings at different stages of purification.

After additional treatment using E. crassipes Solms., suspended substances decreased to 7.0 mg/L (purification efficiency 95.61%), using L. minor L. – to 7-9 mg/L (95.05%).

The quality of wastewater treatment from dry residue after additional treatment with E. crassipes Solms. is 65.81% (decreased to 157 mg/L), L. minor L. – 65.37% (159 mg/L).

1.2. Changes in chemical parameters at different stages of purification.

Table 1. Chemical indicators of wastewater treatment plant in Osh

No.	Type of drains	COD mg/L	Oil produ	NH_4^+, mg/L	PO_4^{3+} mg/L	surfac e-	Al^{3+}, mg/L	Fe^{2+3+} mg/L	P_{tot} mg/L	Cu^{2+}, mg/L	Zn^{2+}, mg/L

			cts mg/L			active agents, mg/L					
1	entrance to the sewer	428.5	2.46	32.29	14.69	2.60	0.397	0.67	8.30	0.018	0.128
2	exit after mechanical treatment	368.8	2.37	29.05	14.91	2.31	0.326	0.40	7.33	0.016	0.123
3	exit from sedimentation tanks	265.3	1.91	5.81	14.09	1.90	0.268	0.34	5.37	0.013	0.116
4	exit after biological treatment	82.7	0.063	2.93	11.89	0.082	0.090	0.20	3.86	0.0036	0.031
5	after filtration	67.6	0.050	1.27	10.49	0.078	0.073	0.18	3.42	0.0036	0.005
6	E. crassipes solms.	26.2	0.028	0.87	1.23	0.056	0.061	0.070	0.80	0.002	0.004
	efficiency,%	93.85	98.82	97.27	91.56	96.90	84.41	89.55	90.24	84.20	96.11
7	L. minor L.	30.2	0.035	1.23	0.62	0.060	0.056	0.072	0.66	0.0030	0.005
	efficiency,%	92.92	98.53	96.15	95.71	97.65	85.67	89.25	91.93	83.67	95.36

After additional treatment with E. crassipes Solms., the chemical oxygen demand (COD) decreased to 26.2 mg/L (93.85%), with L. minor L. to 30.2 mg/L (92.92%).

In relation to iron, oil products and synthetic surfactants, the aforementioned plants have relatively equal high efficiency (from 88.87% to 98.82%).

Chemical indicators improve after additional treatment with water macrophytes: the content of phosphate ions decreases (E. crassipes Solms. 91.56%, L. minor L. 95.71%). All forms of nitrogen are excluded (E. crassipes Solms. 97.2%, L. minor L. 96.15%), the content of total phosphorus is significantly reduced (E. crassipes Solms. 90.24%, L. minor L. 91.9%). Oxygen dissolved in water appears, wastewater becomes clear, and odor is eliminated.

Efficiency of wastewater treatment from zinc content: E. crassipes Solms. 96.11%, L. minor L. 95.34%.

After cultivation of the above plants, the content of copper and iron is reduced to 81.04%.

The scientific experiments show that E. crassipes Solms. and L. minor L. have the greatest accumulation capacity in relation to Fe, Cu, and Zn. This explains the species differences of aquatic plants in their ability to accumulate toxic substances.

2. Biological post-treatment of wastewater from heavy metals.

From 2011 to 2012, the authors carried out laboratory experiments to determine the biological method for additional purification of contaminated wastewater from heavy metal ions using HAP representatives E. crassipes Solms. and L. minor L.

First, the authors studied the possibility of purifying polluted waters from iron, copper, and zinc ions during different cultivation of E. crassipes Solms. and L. minor L. The experiments revealed that E. crassipes Solms. significantly decreases the concentration of heavy metal ions in water.

Table 2. Additional purification of wastewater from ions of heavy metals using E. crassipes Solms. and L. minor L.

No	Plants	Fe, mg/L			Zn, mg/L			Cu, mg/L		
		Before experiment	After experiment	% purification	Before experiment	After experiment	% purification	Before experiment	After experiment	% purification
1	E. crassipes	2.3	0.03	98.7	1.3	0.02	98.5	0.6	0.02	96.7
2	L. minor	2.5	0.05	98.0	1.3	0.2	84.6	0.6	0.06	90.0

Thus, the content of iron decreased from 2.3 mg/L to 0.03 mg/L, zinc from 1.3 mg/L to 0.02 mg/L, copper from 0.6 mg/L to 0.02 mg/L. The period of purification of contaminated water to the maximum permissible concentration is 22 days for zinc, 24 days for iron and 28 days for copper.

An experiment with L. minor L. showed that the content of iron in 25 days decreased from 2.6 mg/L to 0.05 mg/L, copper in 29 days decreased from 0.6 mg/L to 0.06 mg/L, zinc in 28 days decreased from 1.3 mg/L to 0.2 mg/L. It was found that during the cultivation of L. minor L., the percentage of water purification from ions of heavy metals is much lower than with E. crassipes Solms.

A comparatively high purification effect was established with the joint cultivation of E. crassipes Solms. and L. minor L. (zinc content 0.02 mg/L, iron 0.03 mg/L, copper 0.023 mg/L) (Fig. 2)

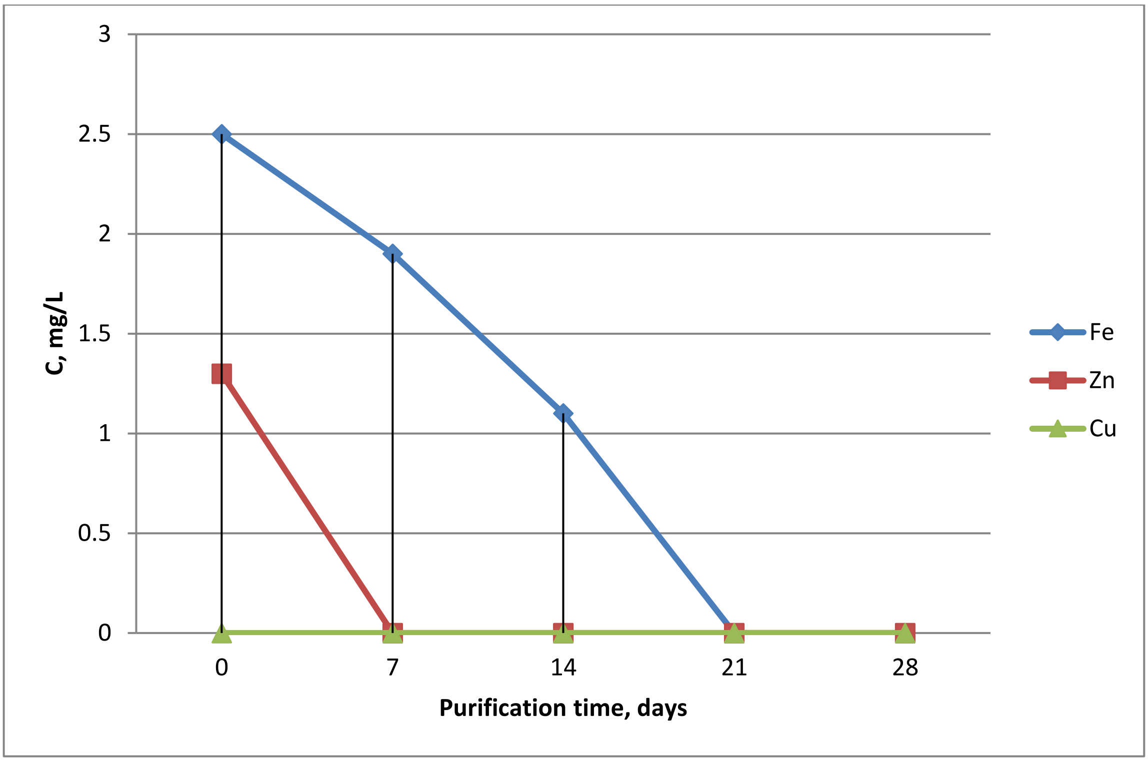


Figure 2. Time-dependent changes in the concentration of heavy metal ions during the joint cultivation of E. crassipes Solms. and L. minor L.

Thus, using E. crassipes Solms. and L. minor L. purifies polluted waters from iron, copper and zinc ions to the maximum permissible concentration and will effectively reduce the possibility of pollution of natural water bodies with heavy metal ions.

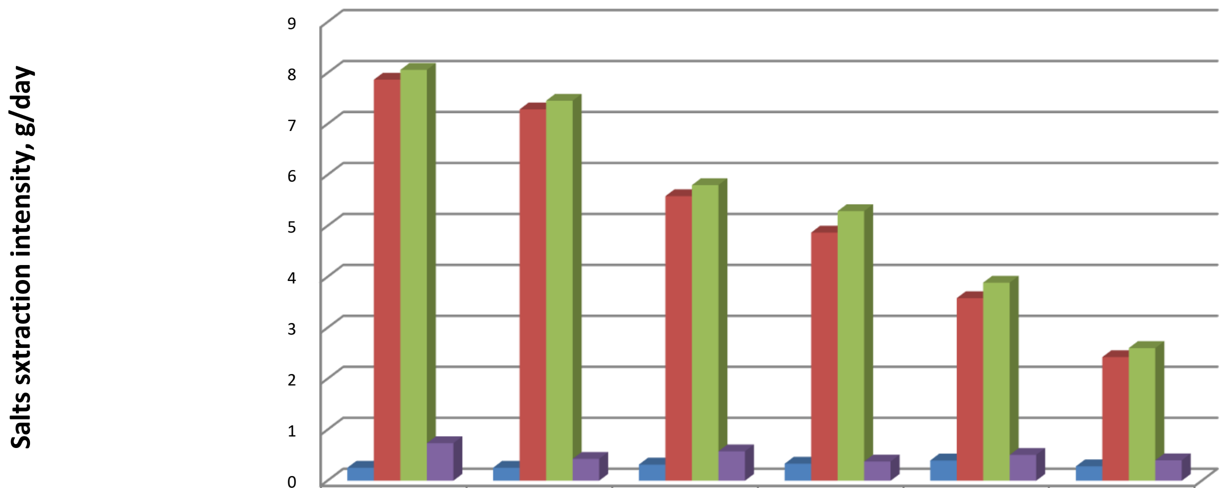
3.Applying E. crassipes Solms. and L. minor L. to purify water from nitrogen and phosphorus salts.

Studies at Osh Humanitarian Pedagogical Institute confirmed the effectiveness of the representatives of floating HAP, E. crassipes Solms. and L. minor L. in reducing the amount of phosphorus and nitrogen salts during the biological treatment of wastewater from livestock complexes.

To study the extraction of biogenic elements from purified wastewater, research was carried out on the dependence of the rate of phosphorus and nitrogen salts absorption on the flow rate of wastewater and the density of plant biomass. In the course of the experiment, the effluent flow rate varied from 6 to 47 m^3/day, and the L. minor L. biomass density was 500, 800, and 1000 g/m^2. Scientific experiments were carried out in the spring-summer season, in the Institute laboratory.

3.1. Intensity of purification of phosphorus and nitrogen salts using L. minor L. at the raw biomass density of 500 g/m^2.

Figure 3 shows the results of scientific experiments to study phosphorus and nitrogen salts extraction using L. minor L. when the biomass density is 500 g/m^2.



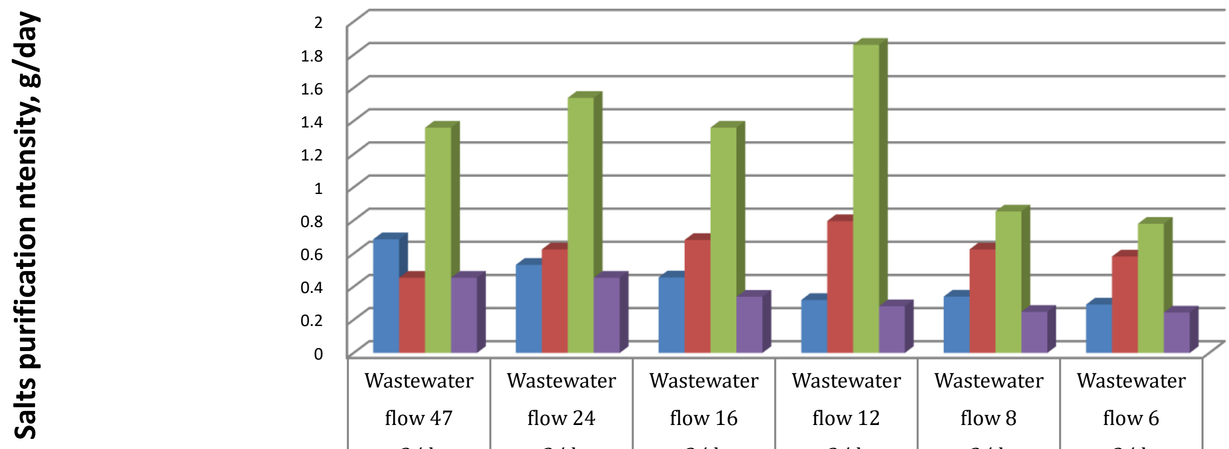
	Wastewater flow 47 m3/day	Wastewater flow 24 m3/day	Wastewater flow 16 m3/day	Wastewater flow 12 m3/day	Wastewater flow 8 m3/day	Wastewater flow 6 m3/day
ammonia nitrogen, g/day	0.255	0.255	0.317	0.335	0.397	0.282
nitrate nitrogen, g/day	7.869	7.286	5.583	4.869	3.583	2.426
nitrite nitrogen, g/day	8.062	7.456	5.801	5.29	3.886	2.603
phosphates, g/day	0.737	0.429	0.577	0.377	0.506	0.401

Fig. 3. Intensity of phosphorus and nitrogen salts extraction using L. minor L. (raw biomass density 500 g/m^2).

The experiments reveal that at the wastewater flow rate of 8 m^3/day, the intensity of ammonia nitrogen extraction is recorded. The flow rate of 47 m^3/day gives the highest extraction rate for phosphates, nitrite nitrogen and nitrate nitrogen.

3.2. Intensity of phosphorus and nitrogen salts purification using L. minor L. (raw biomass density 800 g/m^2).

Figure 4 shows the results of phosphorus and nitrogen salts extraction using L. minor L. (raw biomass density 800 g/m^2).



	Wastewater flow 47 m3/day	Wastewater flow 24 m3/day	Wastewater flow 16 m3/day	Wastewater flow 12 m3/day	Wastewater flow 8 m3/day	Wastewater flow 6 m3/day
ammonia nitrogen, g/day	0.686	0.532	0.456	0.32	0.34	0.292
nitrate nitrogen, g/day	0.454	0.625	0.682	0.796	0.625	0.582
nitrite nitrogen, g/day	1.36	1.54	1.36	1.86	0.854	0.78
phosphates, g/day	0.454	0.454	0.339	0.282	0.248	0.244

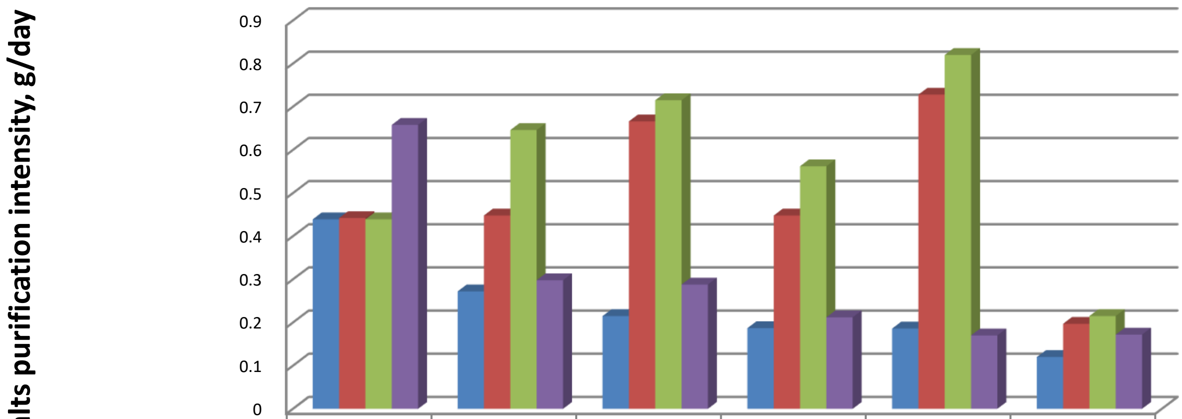
Figure 4. Intensity of phosphorus and nitrogen salts purification using L. minor L. (raw biomass density 800 g/m^2).

At the flow rate of 47 m^3/day, the optimal extraction of ammonium nitrogen occurs at the rate of 0.686 g/day. The highest rate of extraction of nitrite nitrogen (1.86 g/day) and nitrate nitrogen (0.796 g/day) was recorded at 12 m^3/day. At 47 and 24 m^3/day, the maximum rate of phosphate extraction occurs (0.454 g/day).

3.3. Intensity of phosphorus and nitrogen salts purification using L. minor L. (raw biomass density 1000 g/m^2).

The processes of extracting salts of phosphorus and using L. minor L. (raw biomass density 1000 g/m^2) were investigated (Fig. 5).

At the flow rate of 47 m^3/day, the maximum rate of phosphates extraction (0.658 g/day) and ammonium nitrogen (0.439 g/day) occurs. At the flow rate of 8 m^3/day, the maximum extraction of nitrite nitrogen (0.82 g/day) and nitrate (0.728 g/day) occurs.



	Wastewater flow 47 m3/day	Wastewater flow 24 m3/day	Wastewater flow 16 m3/day	Wastewater flow 12 m3/day	Wastewater flow 8 m3/day	Wastewater flow 6 m3/day
ammonia nitrogen, g/day	0.439	0.272	0.215	0.187	0.186	0.12
nitrate nitrogen, g/day	0.442	0.448	0.666	0.448	0.728	0.197
nitrite nitrogen, g/day	0.439	0.646	0.715	0.562	0.82	0.215
phosphates, g/day	0.658	0.298	0.288	0.212	0.17	0.172

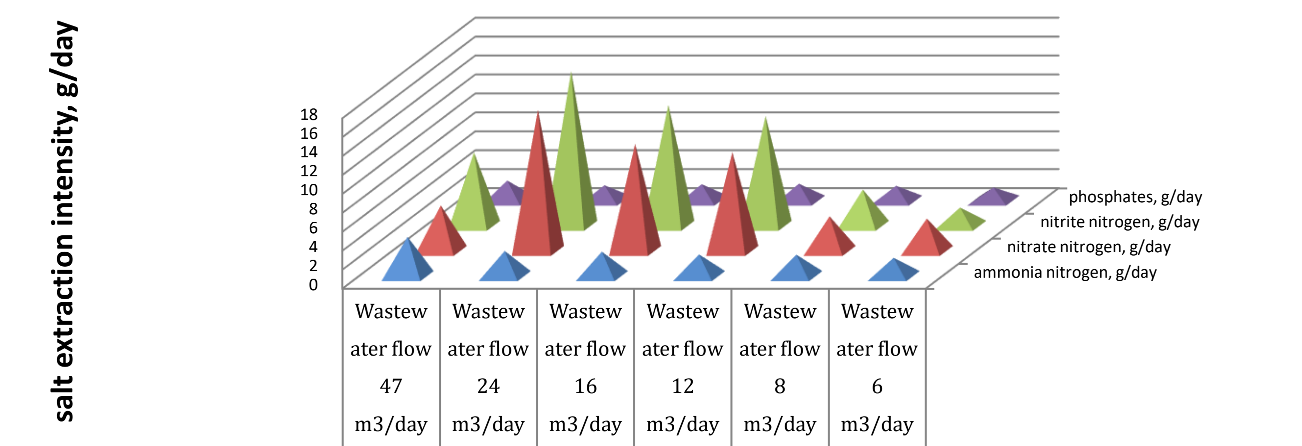
Figure 5. Intensity of phosphorus and nitrogen salts purification using L. minor L. (raw biomass density 1000 g/m^2).

3.4. Intensity of phosphorus and nitrogen salts purification using E. crassipes Solms. (raw biomass density 1000 g/m^2).

Several laboratory experiments were set to study the processes of extracting phosphorus and nitrogen salts using E. crassipes Solms. with the biomass density of 1000, 1500 and 2000 g/m^2. The laboratory conditions (air and water temperatures) were optimal. A positive trend was revealed in the absorption of all forms of phosphates and nitrogen by E. crassipes Solms.

Figure 6 shows the data of laboratory studies of phosphorus and nitrogen salts extraction with the biomass density of 1000 g/m^2.

As shown by the experiments, the optimal rate of ammonia nitrogen extraction was observed when the effluent flow rate was set at 47 m^3/day; in this case, the efficiency is 0.439 g/day. When the flow rate of wastewater is set at 24 m^3/day, the effective rate of nitrate nitrogen extraction is 14.92 g/day, and that of nitrite nitrogen is 16.343 g/day. The effective rate of phosphate extraction was observed when the wastewater flow rate was set at 47 m^3/day. The efficiency is 2.13 g/day.

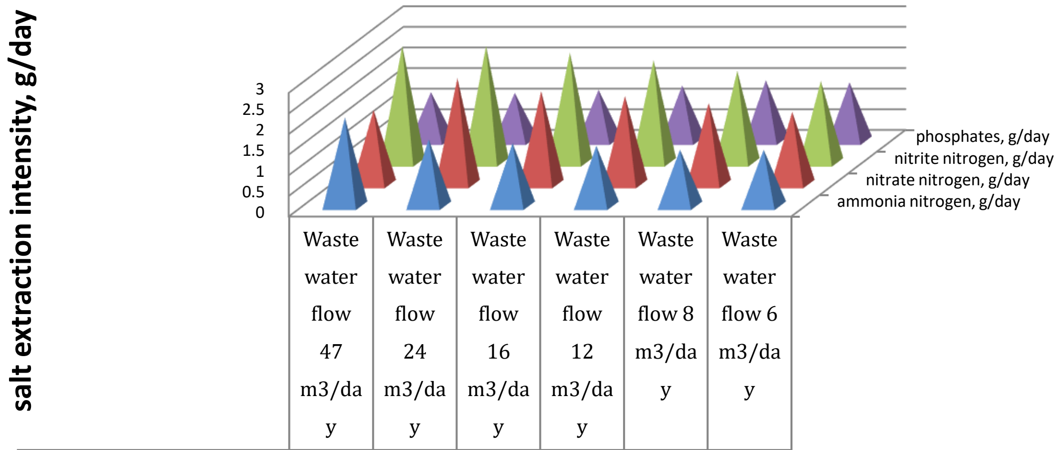


	Wastewater flow 47 m3/day	Wastewater flow 24 m3/day	Wastewater flow 16 m3/day	Wastewater flow 12 m3/day	Wastewater flow 8 m3/day	Wastewater flow 6 m3/day
ammonia nitrogen, g/day	4.157	2.663	2.589	2.297	2.272	1.936
nitrate nitrogen, g/day	4.82	14.92	11.32	10.43	3.66	3.43
nitrite nitrogen, g/day	7.757	16.363	12.789	11.597	3.832	1.936
phosphates, g/day	2.13	1.63	1.74	1.79	1.57	1.4

Figure 6. Intensity of phosphorus and nitrogen salts purification using E. crassipes Solms. (raw biomass density 1000 g/m^2).

3.5. Intensity of phosphorus and nitrogen salts purification using E. crassipes Solms. (raw biomass density 1500 g/m^2).

The experiments on the efficiency of phosphorus and nitrogen salts extraction using E. crassipes Solms. (raw biomass density 1500 g/m^2) showed that wastewater treatment led to a significant decrease in the content of ingredients in water (Fig. 7).



	Waste water flow 47 m3/day	Waste water flow 24 m3/day	Waste water flow 16 m3/day	Waste water flow 12 m3/day	Waste water flow 8 m3/day	Waste water flow 6 m3/day
ammonia nitrogen, g/day	2.14	1.612	1.522	1.453	1.362	1.36
nitrate nitrogen, g/day	1.797	2.572	2.254	2.14	1.968	1.754
nitrite nitrogen, g/day	2.826	2.826	2.665	2.482	2.219	1.973
phosphates, g/day	1.18	1.162	1.237	1.342	1.465	1.42

Figure 7. Intensity of phosphorus and nitrogen salts purification using E. crassipes Solms. (raw biomass density 1500 g/m^2).

Figure 7 shows that E. crassipes Solms. most effectively purifies water from ammonium nitrogen when the flow rate is 47 m^3/day, their content decreases 2.14 g/day. Visual observations reveal that the plant successfully adapted to these conditions, as it grew and multiplied well.

Establishing the wastewater flow rate of 24 m^3 /day showed that the efficiency of nitrite and nitrate nitrogen extraction is significantly increased at the rate of 8 m^3 /day. The extraction efficiency is 2.272 and 2.826 g/day. Establishing the flow rate of 8 m^3 /day ensures the optimal rate of phosphate extraction (1.465 g/day).

3.6. Intensity of phosphorus and nitrogen salts purification using E. crassipes Solms. (raw biomass density 2000 g/m^2).

Table 3 shows the data of laboratory studies of phosphorus and nitrogen salts extraction with the biomass density of 2000 g/m^2.

The highest efficiency was achieved at the wastewater flow rate of 47 m^3 /day; the efficiency is 1.192 and 2.412 g / day. The flow rate of 24 m^3 /day ensures effective nitrate nitrogen extraction – 2.436 g/day; and 6 m^3 /day allows effectively purifying the water from phosphates – 1.218 g/day.

Table 3. Intensity of phosphorus and nitrogen salts purification using E. crassipes Solms. (raw biomass density 2000 g/m^2).

Wastewater flow, m^3/day	indicators, g/day			
	ammonia nitrogen	nitrate nitrogen	nitrite nitrogen	phosphates
47	2.412	1.192	2.435	1.135
24	1.186	2.436	2.312	1.218
16	1.172	2.112	2.172	1.136
12	1.179	1.862	1.929	1.152
8	1.166	1.612	1.666	1.152
6	1.156	1.486	1.532	1.132

The above results are due to an increase in the biomass density due to changes in illumination (abiotic factors), which led to a decrease in the efficiency of extraction of nutrients and disrupted photosynthesis.

Discussion. The ability of E. crassipes Solms. and L. minor L. to reduce the concentration of pollutants in water systems is experimentally proven. Quantitative data is obtained on the concentrations of pollutants that can be accumulated by certain species of HAP. The research reveals that the potential scope of biotechnology applicability using E. crassipes Solms. and L. minor L. is very wide. An obstacle to its use is the insufficient amount of scientific data on the ecological characteristics of E. crassipes Solms. and L. minor L. in the conditions of the South of Kyrgyzstan, necessary to ensure that the performance indicators correspond to the calculated design values. The obtained data are necessary for solving modern problems of organizing biotechnological hydrophyte systems of various types, including closed water supply systems, and solving problems of water purification and additional purification of terrestrial hydrophyte systems.

Conclusion

1. The chemical parameters are improved after additional purification of E. crassipes Solms. and L. minor L. with aquatic macrophytes: the content of phosphate ions decreases, all forms of nitrogen are excluded, and the content of total phosphorus is significantly reduced. Oxygen dissolved in water appears, wastewater becomes clear, and odor is eliminated.

2. The joint cultivation of E. crassipes Solms. and L. minor L. increases the efficiency of water purification from ions of heavy metals. These plants can be applied for additional purification of polluted waters on a special technically equipped bioplato.

3. When the biomass density of E. crassipes Solms. increases from 1000 to 2000 g/m^2, the amount of biogenic elements extracted from wastewater decreases: nitrate nitrogen from 4.156 to 1.192 g/day, nitrogen ammonia from 16.362 to 1.156 g/day, nitrite nitrogen from 14.91 to 1.532 g/day, and phosphates from 2.12 to 1.132 g/day.

4. The highest efficiency of extraction of ammonium nitrogen (0.686 g/day) with L. minor L. is observed when the biomass density is 800 g/m2; the biomass density of 500 g/m^2 ensures the highest efficiency for nitrogen nitrates (7.869 g/day), nitrogen nitrite (8.062 g/day) and phosphates (0.737 g/day).

5. Wastewater flow rate decreased from 47 to 6 m^3/day per 1 m^3 of structure decreases the rate of extraction of biogenic elements from wastewater: nitrate nitrogen from 14.91 to 1.486 g/day, ammonium nitrogen from 41566 to 1.156 g/day, nitrite nitrogen from 16.362 to 1.532 g/day, phosphates from 2.12 to 1.132 g/day for E. crassipes Solms.

6. For L. minor L., the optimal extraction of phosphates and ammonium nitrogen was recorded at the waste flow rate of 47 m^3/day at the biomass density of 1000 g/m^2. Nitrogen nitrates and nitrites are effectively extracted at the wastewater flow rate of 8 m^3/day at the biomass density of 1000 g/m^2.

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