

USING OF *Lemna minor* FOR POLLUTED WATER TREATMENT FROM BIOGENIC ELEMENTS

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Received 09.06.2019

Revised 17.07.2019

Accepted 30.10.2019

The aim of this work was to establish the possibility of *Lemna minor* usage to improve the efficiency of wastewater treatment from nitrogen and phosphorus compounds.

Due to their pollution resistance, *Lemna minor* is often used for wastewater remediation. It is capable of absorption and transformation of various compounds, promotes the deposition of suspended matter, saturates water with oxygen, intensifies the purification processes. Due to the rapid growth rate, duckweed absorbs a large amount of pollutants, thereby purifying water from them. However, there is insufficient data and information on the efficiency of nitrogen and phosphorous compounds extraction by *Lemna minor* wastewater. That is why the research direction was to determine the efficiency of wastewater treatment from biogenic nitrogen and phosphorus compounds by higher aquatic plants of *Lemna minor*.

The necessary conditions for cultivation of higher aquatic plants of *Lemna minor* in autumn and winter were established. The efficiency of using duckweed of different mass for purification of waste water from biogenic compounds of nitrogen and phosphorus was investigated. The usage of duckweed together with other higher aquatic plants to investigate wastewater from biogenic nitrogen and phosphorus compounds was investigated.

It was established that the efficiency of sewage treatment in the autumn-winter period should adjust the mode of illumination and temperature regime.

Key words: wastewater, biological treatment, phosphates, nitrates, *Lemna minor*.

Biogenic compounds can enter the surface waters both naturally (leaching from the topsoil, atmospheric precipitation, various processes in the reservoir itself), and as a result of human activity through wastewater discharge from industrial, household, agricultural and livestock complexes [1–5]. Exceedance of maximum permissible concentrations of biogenic compounds in wastewater lead to surface water's flowering and eutrophication, increase of the content of biogenic and organic compounds, oxygen decrease, appearance of anaerobic zones in the bottom layers, increase of water turbidity, color change, contamination with microorganisms, including pathogens [6, 7]. With the accumulation of excess organic matter in the bottom sludge, the processes of

formation of methane, hydrogen, hydrogen sulfide, ammonia take place. This leads to formation of gas bubbles, which, when dissolved in the water, have a toxic and damaging effect on the flora and fauna, which significantly damages indicators of drinking water when using the reservoir as a source of water supply [8, 9]. Therefore, the problems of the effective of nitrogen and phosphorus compounds removal from wastewater before their discharge into natural reservoirs and the improvement of existing biological wastewater treatment technologies are important [10].

The aim of the work was to study promising methods of wastewater biological treatment from biogenic compounds using higher aquatic plants *Lemna minor* to improve the efficiency

of wastewater treatment with nitrogen and phosphorus compounds, reduce the construction and operation costs of wastewater treatment plants, ensure the quality of treated water in accordance with existing discharge standards in natural ponds.

The objective was to determine the optimal conditions and to establish the efficiency of wastewater treatment from biogenic compounds of nitrogen and phosphorus by higher aquatic plants *Lemna minor*. That is why the experimental part was based the experiments using this type of plant. Today biological ponds are considered as an economic and promising method of biological treatment and purification of household, some non-toxic industrial sewage and atmospheric waters [11–12]. Also, biological ponds do not require the use of chemical reagents, and are characterized by ease of maintenance [11, 13, 14].

The principle of wastewater treatment in biological ponds is the same as the natural self-purification processes that can be observed in aquatic and near-water natural ecosystems. Higher aquatic have the abilities to absorb biogenic and organic compounds, accumulate heavy metals and biodegradable organic substances. Higher aquatic plants are capable of absorbing nitrogen, phosphorus, potassium, calcium, magnesium, manganese, sulfur, cadmium, copper, lead, zinc, phenols, petroleum products, synthetic surface active substances, etc. [15].

Higher aquatic plants are also noted for their properties of oxidizing (due to oxygen income to the reservoir during photosynthesis) and detoxification (due to the ability of plants to transform toxic substances into non-toxic ones). Biological ponds are often used to reduce the values of BOD and COD and further precipitate suspended matter due to the filtration capacity of higher aquatic plants [16].

Lemna minor is a species of free-floating higher aquatic plants belonging to one of the smallest flowering plants in the world. The duckweed biomass buildup increases with stagnant water and high concentrations of biogenic compounds of nitrogen and phosphorus [17–19]. Duckweed is widespread in slow-moving freshwater reservoirs: ponds, swamps, lakes, streams. Due to rapid growth rate, duckweed absorbs a large amount of contaminants, thereby purifying water from them [20]. Phosphate and nitrate are removed in biosorption process by root and leaf cells followed by assimilation [3].

Materials and Methods

A model solution with the KNO_3 salt was prepared to determine the efficiency of nitrate extraction with *Lemna minor*. The 0.2 g sample of KNO_3 salt was measured on laboratory scales. Then sample was dried in a drying oven at 110 °C. After drying, salt was moved to a desiccator for cooling. The 0.08 g sample of dried KNO_3 salt was measured on laboratory scales. Then, weighting was transferred to a 1000 ml volumetric flask and filled with distilled water to the mark. The opening of the measuring flask was covered and its content was mixed thoroughly. The solution thus prepared contained a concentration of nitrates — 50 mg/dm³.

The 0.2 g sample of KH_2PO_4 salt was measured on laboratory scales. Then sample was dried in a drying oven at 110 °C. After drying, salt was moved to a desiccator for cooling. The 0.02 g sample of dried KH_2PO_4 salt was measured on laboratory scales. Then, weighting was transferred to a 1000 ml volumetric flask and filled with distilled water to the mark. The opening of the measuring flask was covered and its content was mixed thoroughly. The solution thus prepared contained a concentration of phosphates — 10 mg/dm³. The model solution with a concentration of nitrates of 50 mg/dm³ and phosphates of 10 mg/dm³ was prepared to simulate household wastewater.

Experimental installations in the form of model biological ponds with size of 12×9×2 cm, 216 ml volume, made of plastic were used for the research. In total, 32 models of such installations were used in experimental studies. For the experiment, the model biological ponds was filled with a suitable model solution, biological plant material and left for the required period of time on the windowsill with direct sunlight.

All experiments were divided into two series: the first, the study of the biological treatment effectiveness with higher aqueous plants in a model solution from nitrates; the second, the study of the biological treatment effectiveness in a model solution from phosphates.

In the first experiment series, the determination of the purification efficiency of the model solution containing NO_3^- concentration of 50 mg/dm³ was carried out. In all installations, the volume of the model solution was 100 ml. All experiments were performed under the same conditions. The duration of the experiment was 7 days (144 hours). 8 model installations were used.

Higher aquatic plants of *Lemna minor* were the biological agent. Two types of duckweed sample weightings were used: $m_1 = 11$ g and $m_2 = 22$ g. Sample weightings were used to determine the effect of the duckweed biomass amount on the process of phosphorus and nitrogen removal. The experimental ponds were filled with model solution and the biological agent was distributed as follows: installations 1, 2, 3, 4 were loaded with higher aquatic plants *Lemna minor* 11 g each, and installations 5, 6, 7, 8 — 22 g each. The samples were analyzed on the second, fifth, and seventh days of the experiment. On the first day of the experiment, an analysis of the NO_3^- ions concentration was performed for water samples from installations 1 and 5; on the third day — from installations 2 and 6; on the fifth day — from installations 3 and 7; on the seventh day — from installations 4, 8. The ion meter I160 MI and the electrode measuring to it ELIS -121 NO_3^- were used to determine the concentration of NO_3^- ions in the solutions.

The experimental data were processed using a Microsoft Excel software. Data were considered significant at $P < 0.05$.

After biological treatment, the concentrations of nitrates and phosphates in treated water should be 10 mg/dm^3 and 2 mg/dm^3 , respectively, before being discharged into natural waterbody [4, 20].

Results and Discussion

The change in the concentration of NO_3^- ions in the model solution depending on the duration of the treatment is presented at Fig. 1. The efficiency of the treatment

was determined based on on the obtained concentrations (Fig. 2).

Therefore, from the obtained results, it could be argued that the purification of contaminated water from nitrogen compounds occurred differently, depending on the mass of duckweed involved.

Decrease of nitrate concentration in the model solutions was better in Experiment 2, where a larger sample of *Lemna minor* duckweed was used. This is evidenced by the calculated efficiency of purification, where the purification effect in the experiment with a biomass density of 0.1 g/cm^2 (m_1) was 83.1% against 91.8% in the experiment with a biomass density of 0.2 g/cm^2 (m_2).

Fig. 3 shows the change in the concentration of phosphates depending on the duration of the purification process.

The efficiency of the model solution treatment from phosphates depending on the duration was determined from the obtained results (Fig. 4.).

The decrease in phosphate concentration in model solutions was better in Experiment 4, where a larger sample of *Lemna minor* duckweed was used. This is evidenced by the calculated efficiency of purification, where the treatment effect in the experiment with a biomass density of 0.1 g/cm^2 (m_1) was 72% against 80% in the experiment with a biomass density of 0.2 g/cm^2 (m_2).

As a result of the experiments performed and the calculations made, we could conclude the treatment efficiency of biogenic compounds of nitrogen and phosphorus in model solutions at a concentration of 50 mg/dm^3 and 10 mg/dm^3 , respectively.

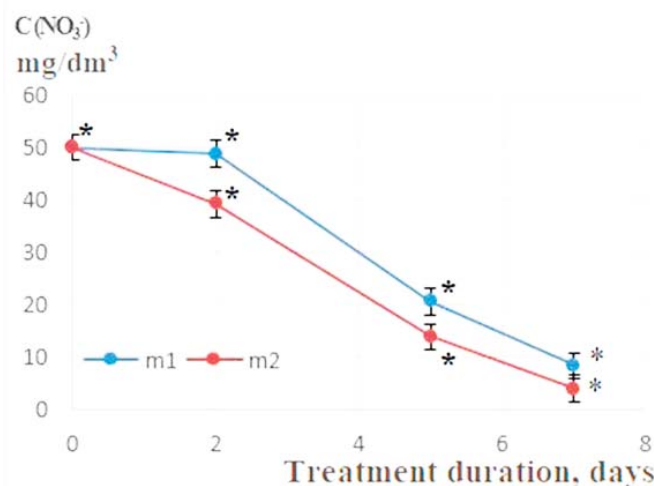


Fig. 1. The change in the concentration of nitrates in the model solution from the duration of the process and the mass of duckweed in the installation: m_1 — 11 g; m_2 — 22 g

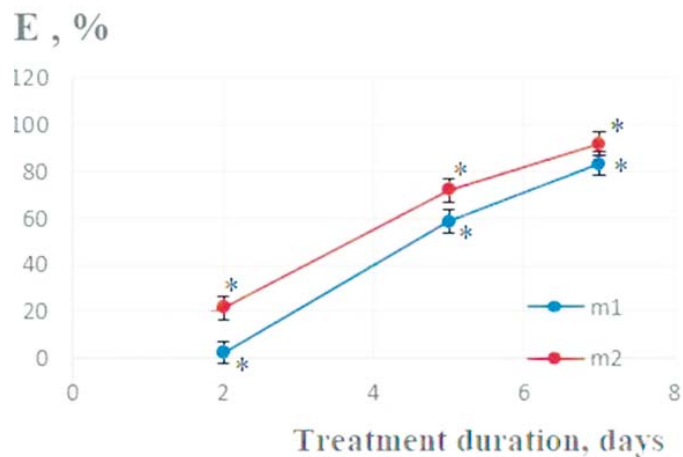


Fig. 2. The change in the nitrate treatment effect in the model solution from the duration of the process and the mass of duckweed in the installation: m₁ — 11 g; m₂ — 22 g

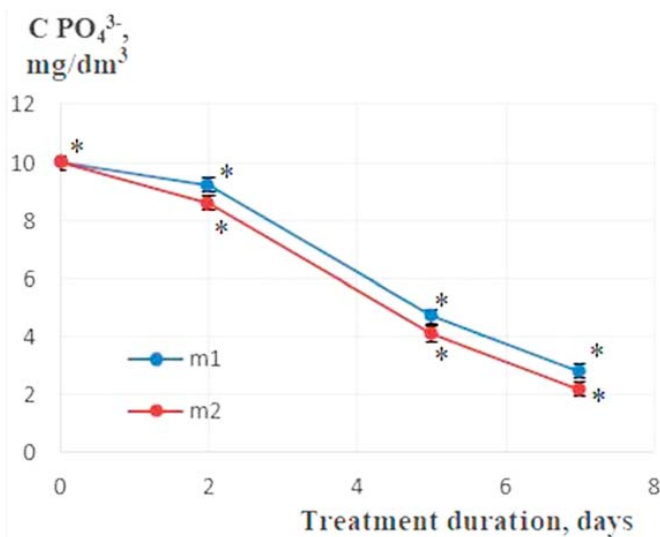


Fig. 3. The change in the concentration of phosphates in the model solution from the duration of the process and the mass of duckweed in the installation: m₁ — 11 g; m₂ — 22 g

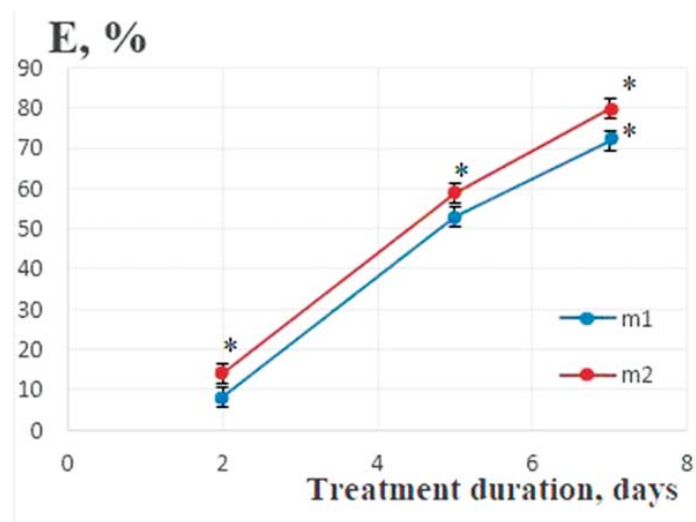


Fig. 4. The change in the phosphate treatment effect in the model solution from the duration of the process and the mass of duckweed in the installation: m₁ — 11 g; m₂ — 22 g

It has been found that with the increase of *Lemna minor* biomass, the treatment efficiency of nitrogen and phosphorus compounds in model solutions does not decrease, but rather increases. Even with the high density of the plants, there is enough light for photosynthesis and no death of duckweed is observed in the lower layer. The duckweed planted in a single layer shows good results, and the water in the model solutions treated by this method can be diverted to the nitrate content of the reservoir and require a slight purification of the phosphate content. The efficiency of such purification by nitrogen is 83% and phosphorus — 72%, and the concentrations of NO_3^- and PO_4^{3-} ions after purification are 8.45 mg/dm^3 and 2.8 mg/dm^3 , respectively.

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ВИКОРИСТАННЯ *Lemna minor* ДЛЯ ОЧИЩЕННЯ ЗАБРУДНЕНОЇ ВОДИ ВІД БІОГЕННИХ ЕЛЕМЕНТІВ

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Метою роботи було встановити можливість використання *Lemna minor* для підвищення ефективності очищення стічних вод від сполук азоту та фосфору.

Ряску *Lemna minor* завдяки її стійкості часто використовують для ремедіації стічних вод. Вона здатна до засвоєння та трансформації різних сполук, сприяє осадженню завислих речовин, насичує воду киснем, інтенсифікує процеси очищення. Через швидкі темпи росту ряска поглинає велику кількість забруднювальних речовин, очищуючи від них воду. Однак немає достатньої кількості даних та інформації стосовно ефективності вилучення ряскою *Lemna minor* сполук азоту та фосфору зі стічних вод. З огляду на це в роботі було визначено напрям досліджень щодо встановлення ефективності очищення стічних вод від біогенних сполук азоту та фосфору вищими водними рослинами *Lemna minor*.

Встановлено необхідні умови культивування вищих водних рослин *Lemna minor* в осінньо-зимовий період; досліджено ефективність використання ряски різної маси для очищення стічних вод від біогенних сполук азоту та фосфору, застосування ряски разом з іншими вищими водними рослинами для очищення стічних вод від біогенних сполук азоту та фосфору.

З'ясовано, що для ефективності очищення стічних вод в осінньо-зимовий період необхідно регулювати режим освітленості і температурний режим.

Ключові слова: стічні води, біологічне очищення, фосфати, нітрати, *Lemna minor*.

ИСПОЛЬЗОВАНИЕ *Lemna minor* ДЛЯ ОЧИЩЕНИЯ ЗАГРЯЗНЕННОЙ ВОДЫ ОТ БИОГЕННЫХ ЭЛЕМЕНТОВ

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Целью работы было установить возможность использования *Lemna minor* для повышения эффективности очистки сточных вод от соединений азота и фосфора.

Ряску *Lemna minor* благодаря ее устойчивости часто используют для ремедиаии сточных вод. Она способна к усвоению и трансформации различных соединений, способствует осадению взвешенных веществ, насыщает воду кислородом, интенсифицирует процессы очистки. За счет быстрых темпов роста ряска поглощает большое количество загрязняющих веществ, тем самым очищая от них воду. Однако нет достаточного количества данных и информации об эффективности извлечения ряской *Lemna minor* соединений азота и фосфора из сточных вод. Именно поэтому в работе было определено направление исследований по установлению эффективности очистки сточных вод от биогенных соединений азота и фосфора водными растениями *Lemna minor*.

Установлены необходимые условия культивирования высших водных растений *Lemna minor* в осенне-зимний период; исследована эффективность применения ряски различной массы для очистки сточных вод от биогенных соединений азота и фосфора, использование ряски вместе с другими высшими водными растениями для очистки сточных вод от биогенных соединений азота и фосфора.

Установлено, что для эффективности очистки сточных вод в осенне-зимний период необходимо регулировать режим освещенности и температурный режим.

Ключевые слова: сточные воды, биологическая очистка, фосфаты, нитраты, *Lemna minor*.