ЕКОЛОГІЯ ВОДНИХ РЕСУРСІВ

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DEEP PURIFICATION OF WATER IN FILTRATION-REGENERATION BIOPLATO OF HYDROPONIC TYPE

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The comparative analysis of results of researches of efficiency of deep water purification is provided in filtration-regeneration bioplato of hydroponic type and the bioplato of various designs. It is shown that use of an medium drainage for fixed washing with circulating and washing waters of the filtering loading, biofilms, root system of plants and a drainage of the bioplato, and also hydroautomatic purification of circulating and washing waters allows to provide the self-recovered operating mode of a complex of treatment facilities and to reach high quality and stability of water purification. *Keywords:* water treatment, biophytotechnology, higher aquatic plants, bioplato, filtering, self-cleaning filters.

Глибоке очищення води у фільтраційно-регенераційних біоплато гідропонного типу. Бондар О.І., Филипчук В.Л., Курилюк М.С., Айайа Анієфіок. Наведено порівняльний аналіз результатів дослідження ефективності глибокого очищення води уфільтраційно-регенераційних біоплато гідропонного типу та біоплато інших конструкцій. Показано, що застосування середнього дренажу для постійної промивки циркуляційно-промивними водами фільтрувальної засипки, біоплівки, кореневої системи рослин і дренажу біоплато та гідроавтоматичного очищення циркуляційно-промивних воддозволяє забезпечити самовідновлювальний режим роботи комплексу очисних споруд і досягти більш високої якості та стабільності очищення води. *Ключові слова:* очищення води, біофітотехнологія, вищі водні рослини, біоплато, фільтрування, самопромивні фільтри.

Глубокая очистка воды в фильтрационно-регенерационных биоплато гидропонного типа. Бондарь А. И., Филипчук В. Л., Курилюк Н. С., Айайа Аниефиок. Приведен сравнительный анализ результатов исследований эффективности глубокой очистки воды в фильтрационно-регенерационных биоплато гидропонного типа и биоплато различных конструкций. Показано, что использование среднего дренажа для постоянной промывки циркуляционно-промывными водами фильтрующей загрузки, биопленки, корневой системы растений и дренажа биоплато, а также гидроавтоматической очистки циркуляционно-промывных вод позволяет обеспечить самовосстанавливаемый режим работы комплекса очистных сооружений и достичь высокого качества и стабильности очистки воды. *Ключевые слова:* очистка воды, биофитотехнология, высшие водные растения, биоплато, фильтрование, самопромывные фильтры.

Filtration bioplato like facilities for purification and post-purification of household, industrial wastewater, surface runoff become widespread in recent years. Their advantage is that they practically do not require electric power consumption and chemical reagents, significant maintenance and provide high quality water treatment from a wide range of organic and mineral pollutants.

In the bioplato system, complex interrelated aerobic-anaerobic processes occur, which are accompanied by filtration, sorption, absorption and transformation by plants and microorganisms of various compounds and elements. The main mechanism for water purification on bioplato is the activity of hetero and autotrophic organisms. As the highest aquatic vegetation from macrophytes broadleaf cattail, great bulrush, flowering rush, arrowhead, water weed, water lily, calamus root, rootless duckweed, pondweed and others are used.

A positive factor that significantly influences the purification is the formation on the surface of a filtering deposit of the bioplato and the plants root system of biofilm, in which various microorganisms develop in the form of an immobilized bacterial medium and inoculant, through which the organic substances and various toxic compounds are effectively decomposed and removed [1].

Research analysis

Most often in countries with a warm and moderate climate, a bioplato with the above ground water surface is used. Thus, according to research in the UK, the average percentage reduction in pollutant concentrations in household wastewater is 48% for BOD, 83% for suspended substances, 51% for total nitrogen, 13% for phosphorus, 99% for pathogens. In the United States, the degree of household wastewater purification using the water hyacinth according to BOD5 reaches 97-98%. In China, the efficiency of water purification from silver, suspended substances, phosphorus and nitrogen compounds, respectively, was 100%, 91%, 54% and 93%. Bioplato is used effectively for the treatment of household wastewater and surface runoff in the Netherlands, Japan, Norway, Australia and other countries [2; 3; 4].

However, in regions with a warm climate in the open water of the bioplato, harmful insects, including the larvae of the malarial mosquito can propagate. The presence of above ground water surface also causes the formation of harmful aerosols and unpleasant odors. In the open bioplato, the regulation of mass exchange, gas saturation and aeration of water processes is not ensured, the mineralized sludge and sediment are not removed. This leads to colmatation of drainage systems, filtering backfilling, development of anaerobic processes, causes secondary water pollution and a significant reduction in the efficiency of purification from contaminants.

At the Institute of Hydrobiology of the National Academy of Sciences of Ukraine, open bioplato of various designs for water purification, which showed high efficiency was investigated [5]. Wide research and implementation of such structures is carried out at the Institute of Ecological Problems (Kharkiv) [6]. In the State Ecological Academy of Postgraduate Education and Management (Kiev), the bioplato with floating filling in the form of special rafts with aquatic plants and algae planted in them has been developed [7]. Closed hydroponic filtration bioplato were proposed by the Scientific and Engineering Center "Potential-4". In them, the water level is lower than the upper level of filling, in which the planted aquatic plants and algae and their root system is constantly washed with water moving vertically from top to bottom or from the bottom up.

At the same time, in such closed hydroponic filtration bioplato there is a gradual colmatation of the root system of aquatic plants and algae, pore space of filtering fill and drainage with biofilm and mineralized sediment, accumulation of sludge in the bottom part of structures, decrease in the flow of oxygen and nutrients to the root system of aquatic plants and algae, which can lead to a decrease in efficiency work of facilities, peptization of sediment and secondary pollution of water.

The purpose of the article is to highlight the results of the development and investigation of the filtration-regenerative bioplato of hydroponic type (FRBHT) in which constant and controlled washing and regeneration in the hydro-automated mode of the filtering backfill, the root system of the aquatic plants and algae (APA) and drainage systems are realized.

Research methodology

Filtration-regenerative bioplato of hydroponic type (FRBHT-1), in which the water level is below the upper level of the filtration filling, was investigated at the municipal wastewater treatment facilities in the town of Kivertsi (Volyn region) and in the city of Kamenka-Buzka (Lviv region).

Bioplato (FRBHT-1), which explored in Kivertsi (see Fig.), consisted of a rectangular ferroconcrete reservoir (1) 13 m wide, 50 m long and 2.6 m deep, in which a two-layer activated biopreparations – inoculum filtering filling was placed (2, 15). The upper layer of the filtering filler (2) consisted of a mixture of granite and basalt gravel fractions of 35-50 mm, the bottom layer (15) from the blown granite-basalt gravel fraction of 10-25 mm. The thickness of all layers of the filtering fillings was 2100 mm, in which the upper filtering granite-basalt layer had 1400 mm.

In the thickness of the filter filling (2 and 15) the upper (6), middle (5) and lower (4) drainages, which were placed evenly across the entire area of the reservoir, were mounted. The upper drainage (6) of the source water distribution was located in the radical system of higher water plants-macrophytes and moisture-loving trees (APA) (8) and connected to the water supply pipeline for purification (1), as well as to the pipeline of circulating and rinsing water and collector (pipeline) clarified washing water of a self-washing foam polystyrene filter. The bottom drainage (4) for collecting and removal the purified water was placed on the bottom of the reservoir at the bottom of the filter filling. The medium drainage (5) for collection and removal of circulating and rinsing water was placed in a filter filling between the upper and bottom drainages.

As the APA, we used willow of energy species (40-45%), reed (30-35%), broadleaf cattail (15-10%), miscanthus (10-5%), calamus and other higher water volunteers (5%), the root system of which was in the upper part of the filter filling (2) were used.

The self-washed polystyrene foam filter (11) for filtering treatment of circulating and rinsing water was made in the form of a cylindrical steel tank in which the filter filling was made of granules of foamed polystyrene. The filter is equipped with a device (12) for the hydro-automatic cleaning of the filter filling (operated without operators and latches).

FRBHT-1 works as follows. The water for purification is fed by the collector (3) to the upper part of the bioplato (1), distributed over the drainage over its area and filtered from top to bottom through the upper layer of the filter filling (2). Since in FRBHT-1 the water level is below the upper level of the filtration filling, in which the APA are planted, then their root system is constantly washed with water moving vertically from the top to the bottom.

Then the water is filtered through the bottom layer of the filling (15). Purified water (filtrate) is collected by the lower drainage system (4), move out off by the collector (7) into the contact reservoir and then pass into the reservoir or sent to the consumer after additional post-treatment and disinfection.

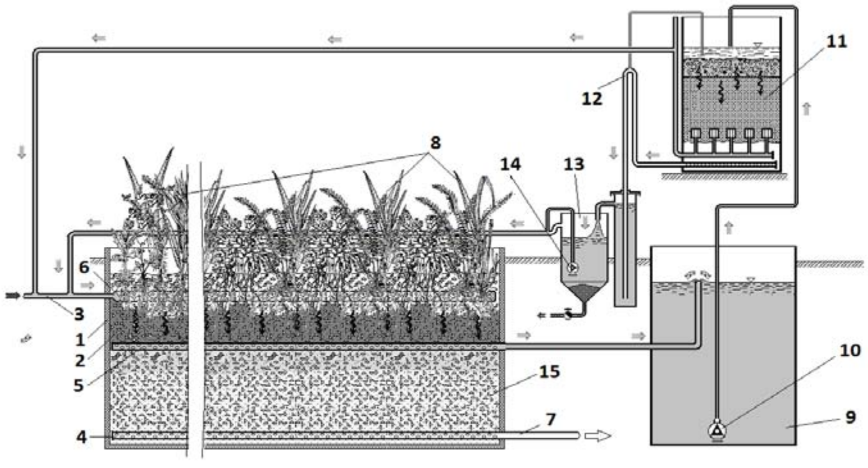

Fig. Principal scheme of FRBHT-1:

1 – body of bioplato, 2 – upper layer of filter filling, 3 – water supply collector for purification, 4 – bottom drainage for draining purified water, 5 – medium drainage for collection and removal of circulating and rinsing waters, 6 – upper drainage of water distribution in the inter-root system of APA, 7 – collector for draining purified water (filtrate),8 – higher aquatic plants and / or moisture-loving trees (APA), 9 – storage device for circulating and rinsing waters, 10 – pump, 11 – self-washed polystyrene foam filter, 12 – Hydro-automatic filter washing device, 13 – tank-developer of filter rinsate, 14 – pump of developer rinsate, 15 – bottom layer of filter filling

Since during the filtration of water the active sludge film, suspended mineral and organic impurities accumulate in the filter filling, a part of the filtered water is continuously removed from the lower zone of the root system of the APA by an medium drainage (5) into the storage device (9) and then periodically or continuously by a pump 10) is supplied for post-treatment from a slurry for a self-washing polystyrene filter (11). As a result, intensive mass transfer takes place in the root-filtering filling and washing of the inter-root space of the APA (8). Purified circulating and rinsing water is returned to the bioplato through the collector (3). The filter (11) is periodically washed with a device for hydro-automatic washing (12).

The duration of the research was 3 stages for 12-30 days during 18 months of production operation of the bioplato. The main variants of the bioplato operation were investigated: 1 – without the use of medium drainage in the bioplato and foam polystyrene filter (the bioplato analogue of the closed hydroponic filtration bioplato of the "Potential-4" design was investigated); 2 – during cyclic (periodic) washing of the filtering filling of bioplato with the use of a self-washing foam polystyrene filter; 3 – with a constant washing of the filtering filling of the bioplato using a self-washing foam polystyrene filter.

Research results

The exploitation results of bioplato in different variants showed the following. When the bioplato operates in the first variant, in which the washing of the filtering filling was periodically performed in a manual mode by stopping the work of the facilities for 40-90 minutes and draining the wash water 6 times during the research period and 3 times during the setting up period of the bioplato operation, it is possible to obtain fairly stable cleaning water results.

However, essential shortcomings of such biophytopurification of water is the need for periodic stopping of the bioplato operation for the regeneration of the filtering filling and for the continuous monitoring of the facilities by qualified service personnel. With a higher content of suspended substances in the source water, rapid and uncontrolled colmatation of the root system of the APA, drainage and filtering of the bioplato occurs, which leads to a deterioration in the quality of water purification due to the development of anaerobic processes, a deterioration in the mass exchange of the root system with "raw" water, significant complication of control over the operation of the complex of structures, especially during periods of prolonged rainfall, early snowfall, flooding.

The operation of FRBHT-1 in the second variant was carried out without interruption of the supply of water for purification and periodic washing of the filtration filling of the bioplato. This variant allows to obtain more stable results of water purification compared to the first variant. The efficiency of water purification in this way compared with some parameters with the previous variant was on average 20-30% higher. The disadvantages of the second variant of water purification are the necessity of manually setting the modes and changing the periodicity of the washing cycles of the filtering filling of the bioplato and the constant control over the work of the complex of structures in case of fluctuations of water quality indicators at the entrance to the bioplato.

The operation of FRBHT-1 in the third variant was carried out by continuous washing of the bioplato filtration filling without affecting the subjective factor and stopping the water supply for cleaning and stopping its operation. This variant showed stable and best results. Compared with the previous variants, it allowed to improve the degree of water purification by individual control parameters by 50-70%, especially when water is fed with a higher content of suspended substances and nutrient compounds of nitrogen and phosphorus due to the improvement of mass transfer processes in the root system of filtering filling and constant flushing of mineralized films of active sludge.

The degree of sewage purification during bioplato operation in various variants is shown in the table. As can be seen from the results of research, the highest degree of purification was observed in the treatment of sewage in the third variant. On the basis of researches, a number of methods have been developed for water purification and FRBHT-1 structures, which are protected by Ukrainian patents [9; 10].

Conclusions

The results of the research showed that the use of the filter-regenerative bioplato of hydroponic type (FBBHT-1) in comparison with the known technological schemes of biophytopurification of water and bioplato designs allows for the constant automatic washing of the filtering filling, the root system of APA and bioplato drainage and hydro-automatic cleaning of circulating and rinsing waters to provide self-healing operation of a complex of treatment facilities. This enables, regardless of the size and productivity of the bioplato, the cyclicality of water supply, the climatic conditions to achieve higher quality and stability of non-reagent water purification, to abandon the maintenance staff and to continuously monitor the work of the complex of water treatment biophytostructures.

Table 1

Degree of sewage purification at various variants of FRBHT use

No	Indicator	Concentration at the entrance to FRBHT-1, mg/dm^3		The average efficiency of sewage purification		
		After settling	After purification in aerotanks and settling	Variant 1	Variant 2	Variant 3
1	Suspended substances	60	15	60-80	65-90	85-95
2	Biochemical Oxygen Consumption 5	65	15	65-80	70-90	85-95
3	Chemical consumption of oxygen	180	60	50-75	55-80	70-90
4	Ammonium nitrogen	2,5	0,5	75-80	80-87	95-99
5	Phosphates	6,5	2,5	55-65	63-72	70-85
6	Oil products	15	4,0	80-85	85-90	95-99
7	SPAR	4,0	1,5	75-80	79-85	90-97

References

1. Дикиева Д.М., Петрова И.А. Химический состав макрофитов и факторы, определяющие концентрацию минеральных веществ в высших водных растениях. Гидробиологические процессы в водоемах / Под ред. И.М. Распопова. – Л.:Наука, 1983. – С. 107–213.
2. Healy A., Cawleyb M. Nutrient Processing Capacity of a Constructed Wetlandin Western Ireland. // J. Environ. Quality. 2002. – P. 1739–1747. 31.
3. Gleichman-Verheyc E.G., Putten W.H., Vander L. //Alvalwaterzuvering met helofytenfilters, een haalbaarheidsstudie. – Tijdschr. watervoorz. en. afvalwater. 25, № 3. – 1992. – P. 56–60.
4. Blankenberg A.-G.B., Braskerud B.C. «LIERDAMMEN» – a wetland testfield in Norway. Retention of nutrients, pesticides and sediments from a agriculture runoff: Diffuse Pollut. Conf. :Dublin, 2003. – P. 128–130.
5. Волга А.С., Кравец В.В. Очистка и обессоливание воды в гидромелиоративном канале при момощи высшей водной растительности в условиях поливного хозяйства // Сб.тр. Всесоюзн.конф. по ВВР и прибрежным растениям, – Борок, 1977. – С. 107–109.
6. Ладыженский В.Н., Саратов И.Е. Защита водных объектов от загрязненияповерхностным стоком с территории полигонов ТБО. 1-ая Конференция с международным участием «Сотрудничество для решения проблемы отходов», 6 февраля 2004 г. Харьков, Украина. – С. 6–7.
7. Кравець В.В., Остапенко Н.В. Використання біологічних ставків з вищими водяними рослинами в практиці очищення стічних вод // Інформаційний бюлетень Держбуду. – Київ, 2002. – № 4. – С. 38.
8. Коцарь Е.М. Инженерные сооружения типа «биоплато» как блок доочистки иводоотведения с неканализованных территорий / Тез. докл.междунар. конф. «Aquaterra». Санкт-Петербург, 1999. – С. 72–73.
9. Курилюк О.М., Курилюк М.С., Филипчук В.Л. та ін. Синергетичний комплекс очищення води AQUA-U-ELION.174. Патент № 95617 // Промислова власність. – 2014. – № 24. – 10 с.
10. Курилюк О.М., Курилюк М.С., Бондар О.І. та ін. Фітобіоплато з підземним біореактором-фільтром AQUA-123U. Патент № 97064 // Промислова власність. – 2015. – № 4. – 13 с.