Biological treatment of plant waste water

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Abstract. The article presents research on creation and implementation of a utility model for wastewater treatment plant (bunded filtration fields) in order to reduce the content of pollutants in water coming from the wastewater of a dairy processing plant. After analysing data on actual concentrations of pollutants in the wastewater treatment plant (bunded filtration fields), flow rates, and species composition of riparian vegetation, it was proposed to develop and implement a biological method for wastewater post-treatment using higher aquatic vegetation. For this purpose a utility model prototype of a floating bio-platform was produced, the size and number of structures were determined. The design of the wastewater treatment utility model includes two units: a structural unit and a vegetation unit. The constructive block included: a frame frame, composite masonry mesh, Equality Mark vapour barrier, and polyamide (braided) cord. The plant block is an artificially created phytocoenosis consisting of grass and turf and additionally higher aquatic plants. The design of the floating bioplata model was placed along the mirror of the reservoir in a line behind each other. When ready, several bioplats were connected together and transported through the water to their installation sites. For the conditions of the forest-steppe zone of the Trans-Ural region the assortment of aboriginal plants was selected and the method of their fixation and cultivation on the water surface was developed. The necessary area of covering of a water body by a bioplate for a decrease in the content of polluting substances in the future is calculated. The developed technology can be applied in any climatic zone with an assortment of higher aquatic vegetation characteristic of the area.

1 Introduction

Agriculture as an economic activity is based on meeting the needs of the population for fresh and nutritious food, but is also one of the sources of pollution of the components of the environment [1-7]. At present, the negative impact of agricultural production on the environment, one of which is untreated wastewater [8-17], is advancing. Wastewater carries dangerous chemical compounds, pathogenic microorganisms, biogens included in fertilizers. It is almost impossible to completely eliminate pollution, so the problem is alarming to human life and health [13, 15, 16].

In researches of scientists of the Institute of Industrial Ecology Problems of the North FIC KSC RAS, an effective method for additional treatment of wastewater from various

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pollutants after the primary wastewater treatment by mechanical and physical-chemical methods, floating bioplates technology is noted. This technology is based on the use of natural wastewater treatment mechanisms with the help of hydrophyte plants that grow in or near the water body. This method has no negative impact on the environment, as it does not require additional energy sources other than solar energy or the application of any chemicals [8, 11, 13, 14].

Research objective is to develop and implement a biological wastewater treatment system (filter fields with bunding) for a dairy plant.

2 Materials and methods

The Tyumen Oblast is located mainly in the basin of the lower reaches of the Ob and Irtysh rivers, in the lowlands of western Siberia. The relief of the region is the Lower Plain. The plain is broken up by small depressions occupied by lakes and swamps.

The vegetation cover is primarily characterised by deciduous birch and aspen forests with a dense cover of grasses, with many species of meadow-forest. The soils beneath the forests are grey forest, whereas the interforest areas are black earth. In the interstitial falls there are peat soils - boggy, grassy, peaty and meadow soils. All soils are of heavy and clayey texture [2, 5, 9, 12].

The object of the study was wastewater treatment facilities (filtration fields with bunds) located on the land of the Sitnikovsky Municipal District, outside the settlement boundary, 540 m from the cemetery towards the north-east. Designed for accumulation of waste water of the food industry enterprise processing milk and producing dairy products (Fig.1, Fig. 2).

Fig. 1. Satellite image of storage ponds

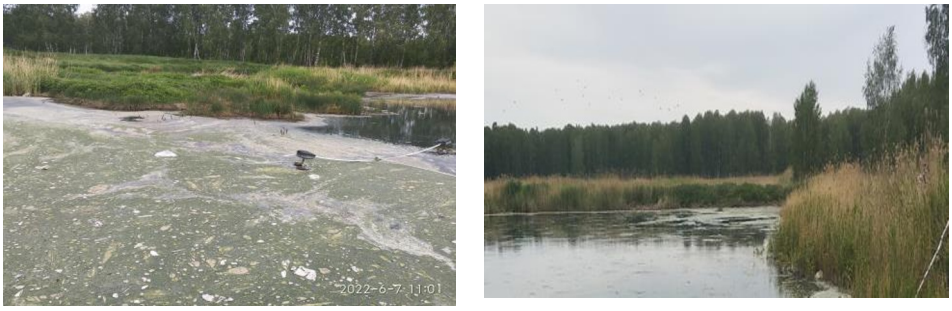

Fig. 2. Photo of the initial condition of the storage ponds

Research methods included visual observations, description of plant species composition near the filtration fields, determination of organoleptic indicators of water (odour, colour), water sampling for chemical analysis.

Sampling and preservation of waste water was conducted in accordance with GOST 31861-2012, GOST 31862-2012, GOST 17.1.5.05-85). Chemical analysis was carried out for 7 parameters (ND on the test method): suspended solids (RD 52.24. 468-2005), Ammonium ion (GOST 29304), phosphates (GOST 18309), BOD5 (PND F 14.1:2:3:4.123), COD (PND F 14.1:2:4.190), sulfates (RD 53.24.405-2005), hydrogen index (PND F 14.1:2:3:4.121-97). Odour definition was carried out according to the requirements of methodical recommendations (PND F 12.16.1-10).

3 Research results

Sampling of water from the wastewater treatment facilities (filtration fields with berm) for chemical analysis was conducted from the first map.

The character of the wastewater odor on the research site according to the scale is marshy, type of odor - slimy, silty. According to the intensity scale the smell was 4 points. Odour intensity was influenced by temperature, pH, degree of water pollution, biological situation and hydrological conditions. The colour of the water varied from black to yellow-green as the water flowed through the maps. The hydrogen index (pH) was -6.9 pH units.

The results of wastewater monitoring carried out in 2021 are shown in Table 1.

Table 1. Pollutant values in wastewater of the treatment plant (bunded filtration fields), 2021.

Indicator	Sampling	Value of the wastewater standard, mg/dm^3 (Hs)*
Suspended solids, mg/dm^3	253.4	300
Ammonium ion, mg/dm^3	89.06	6.09
Sulphates, mg/dm^3	195.7	97.14
BOD5, mg/dm^3	260	300**
COD, mg/dm^3	424	496.47
Phosphate (by P), mg/dm^3	176.39	1.16
Chloride, mg/dm^3	669.0	128.47

* Decree of the Tyumen City Administration No. 163-pk "On Establishing Wastewater Composition Standards" dated September 7, 2020

**Decree of the Government of the Russian Federation of 29.07.2013 No. 644 (revised on 30.11.2021) "On approval of the Rules of cold water supply and wastewater disposal and on amendments to some acts of the Government of the Russian Federation".

In the water sample there is a 14.6 times excess of the normative for the following indicators: ammonium ion, mass fraction of sulphates - 2 times, phosphates - 151 times, chlorides - 5.2 times. Based on the data on actual concentrations of pollutants in wastewater treatment plants (bumped filtration fields), flow rates and species composition of riparian vegetation it was proposed to develop and implement a biological method for wastewater treatment using higher aquatic vegetation [16-18]. For this purpose, a utility model prototype - a floating bio-platform - was manufactured and the size and number of structures were determined.

The construction includes two units - a main frame made of foam plastic and a vegetation frame planted with higher plants intended for further treatment of water bodies from various pollutants after primary treatment by mechanical and physical-chemical methods. The peculiarity of the design is that it is based on the use of natural treatment mechanisms with

the help of hydrophyte plants growing in or near the water body. This design has no negative impact on the environment, as it does not require additional energy sources other than solar energy or the application of any chemicals. (Fig. 3, 4).

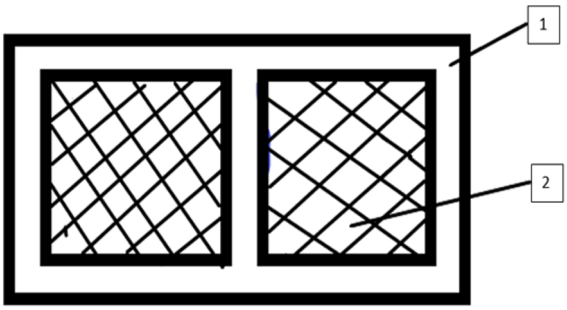

Fig. 3. Bioplate construction: 1 - frame, 2 - mesh

Fig. 4. Prototype

According to literature sources one bioplate can treat from 150 to 200 m² area of the polluted object. The area of the storage pond map is 7000 m², hence the number of bioplates required for effective cleaning of this object is 40 pcs, the total area is 175 m².

Mounting and installation of the biological plate. Creation of a floating biological plate for water body treatment, including structural and vegetative blocks.

The structural unit includes (Fig. 5):

- Frame frame made of extruded polystyrene foam with low thermal conductivity, bioproofness, minimum water absorption, environmental friendliness, durability. - 1;

- masonry composite mesh made of fibreglass reinforcement bars fixed at 90° with a mesh size of 50x50 mm. - 2;

- Equality Sign vapour barrier, type B, a high-strength, one-layer vapour-proof roll-up material, waterproof, temperature-resistant, UV-resistant, long-lasting. - 3;

- 16-stranded polyamide (braided) cord, 4 mm in diameter, flexible, strong, resistant to UV radiation. - 4.

The plant unit includes:

- Artificially created phytocoenosis consisting of grass and turf and additionally planted higher aquatic plants.

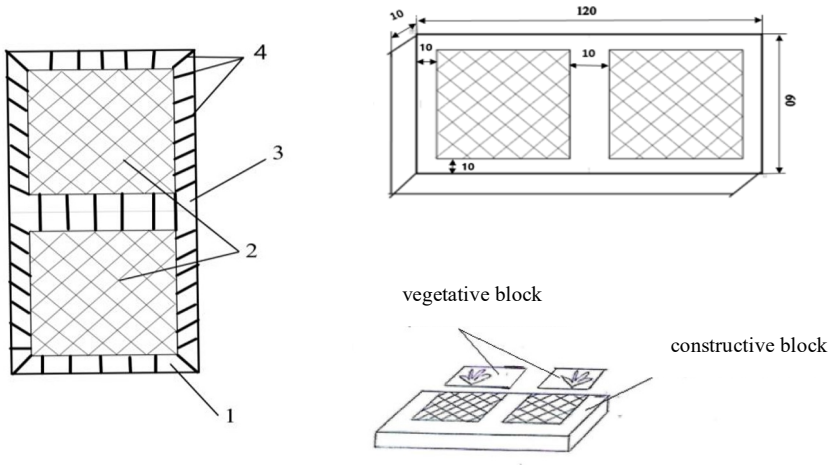

Fig. 5. Structural block. 1 - frame frame; 2 - masonry mesh; 3 - vapour barrier; 4 - polyamide cord

The design of this utility model involved several assembly steps. A prepared 120x60 cm styrofoam frame was covered with vapour barrier around the entire perimeter and wrapped with cord on top. Nets were inserted into the frames' windows, piercing the polystyrene foam with their sharp ends.

On pre-prepared grass and turf mats, sized 40x45 cm, higher aquatic plants, not more than 5-6, typical for the given natural-climatic territory, were planted and then placed on the prepared mats (Fig. 6).

The selected species composition of the turf included: Bluechip bluegrass, Everest bluegrass, NuGlade bluegrass, Impact bluegrass, taken in a ratio of 1:1:1:1 (by mass) [10]. The seeding rate of the seed mixture was 150 g/m². In the above-ground part, the grown turf had a grass stand of 6.0±0.4 cm in height, with a density of 2000.4±102.2 shoots/dm²; in the underground, a viable (2.0±0.3 cm thick) 'felt' cushion of interwoven and penetrating vermiculite substrate roots.

The number of plants per bioplate was calculated so that it could keep artificially created phytocoenosis afloat with a total weight of up to 30 kg. Additional macrophytes were planted in the turf: broad-leaved cattail (Týpha latifólia), common reed (Phragmítes austrális), common shepherdwort (Alisma plantago-aquatica) and double-row barley (Hōrdeum dīstichon).

Fig. 6. Stages of installing the bioplate

The installation of the bioplate was carried out on June 7, 2022, after the establishment of positive air temperature. The meteorological conditions at the time of bio-platform installation were as follows: air temperature - 19ºC, air humidity - 70%, water temperature - 3ºC, wind speed - 16 km/hour.

Floating bio-boards are placed along the mirror of the reservoir in a line behind each other. When ready, several bio-boards were joined together and transported through the water to their installation sites. The entire line of bio-platforms was secured along the banks of the reservoir using ropes and carabiners (Figure 7).

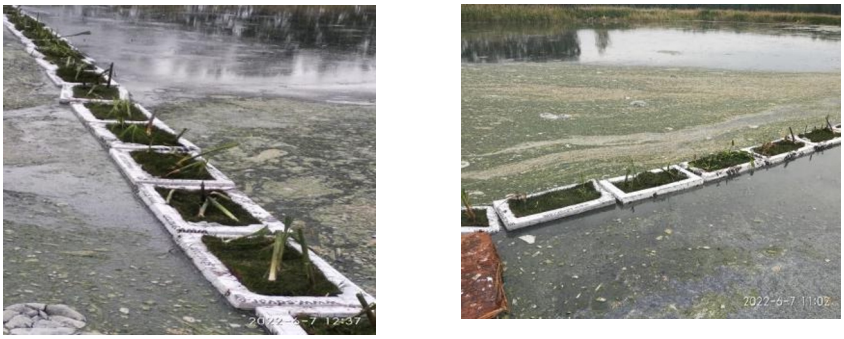

Fig. 7. Installation of the bioplate

4 Conclusion

In the work, the monitoring of pollutants in wastewater from the treatment plant (bunded filtration fields) will continue. The useful model developed of a floating bioplate for wastewater treatment can be applied in other climatic zones with locally appropriate species of higher aquatic vegetation.

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