Reconstruction experience of the wastewater treatment plant (Kargasok village, Tomsk region, Russia) using «constructed wetlands» technology

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Abstract. Considered wastewater treatment plants (WWTP), located in Kargasok village (Tomsk region (average annual temperature -1.5°C)) are intended for complete biological treatment of household and close to them in the composition of the industrial effluent of the village. The design capacity of treatment is 700 m³/day. Sewage treatment facilities, performed according to the standard project TP 902-2-154 (without sludge sites and chlorination site of treated effluents) in conditions of low temperature of wastewater and the existing system of their supply for treatment did not provide a significant reduction in the degree of contamination of the effluent. Thus, the maximum excess of permissible discharges was observed for ammonium (at 162.21 mg/dm³ from the approved standards). The activities carried out in 2005 (construction of the phytocard1 (FK1), a siphon outlet device leveling the hydraulic load on the phytocard1 (FK1) and preventing the breakthrough of floating substances from the aeration tanks into the secondary sedimentation tanks (VO)) significantly increased the efficiency of the WWTP. Achieved standards for intestinal microflora, in a discharge in the river Ob there are no parasites and coliphages. The average annual cleaning efficiency for suspended substances was at least 95%, for organic substances - at least 70%, for ammonium - at least 58%. The nitrification process was not observed. To clean the effluent from the remaining nitrogen, the construction of an additional phytocard (FC2) was required. It was possible to reach the standards for permissible discharge after the final treatment of effluents at FK2 only for suspended substances and BOD filled gas, for the remaining pollutants it was not possible to reach the standards. This is due to a violation of the design of the FK1 and incorrect construction work at the FK2, which did not allow the ice to be hung out at both the FK2 and FK1. Approaches to the reconstruction of the WWTP in Kargasok village can be used for similar objects.

1. Introduction
In Russian Federation, the current state of the sewage treatment plant ensures that the established standards for permissible discharge (NDS) of pollutants and microorganisms with sewage into the receiving water body are achieved in fairly rare cases [1]. If it is impossible to comply with NDS, limits can be set (temporarily agreed discharges) on the basis of permits valid only during the period of environmental protection measures, the introduction of the best existing technologies and (or) the implementation of other environmental projects taking into account the phased achievement of the established standards for permissible discharges of substances and microorganisms [2]. The establishment of limits is allowed only if there are plans to reduce discharges agreed with the
executive authorities exercising state management in the field of environmental protection. Plans for reducing discharges must be technologically, financially and organizationally justified. Different environmental measures may cause different reductions in pollutants. At the same time, not all measures reducing the amount of discharges reduce the burden on the environment, that is, they have an environmental effect. The aim of the work is to approve a plan for the reconstruction of wastewater treatment plants using the “constructed wetland” technology to reduce the discharge of pollutants and microorganisms with sewage Kargasok in river Ob.

2. Materials
The object of study is sewage treatment plant located in the Kargasok village in the north of the Tomsk region (average annual temperature -1.5°C). The population of the village is 7896 people (2012) [3]. Kargasok is located on the left bank of the r. Ob, 460 km from the city of Tomsk.

Sewage treatment facilities of the MUP Kargasoksky “Teplovodokanal” of biological type were built according to the TSNIEP project (TP 902-2-154 1968), put into operation in 1992, and have a design capacity of 700 m3/day. and the maximum hourly discharge of wastewater is 65 m3, the coefficient of uneven inflow of wastewater Kmax. = 2.52. The wastewater treatment plant is designed for the complete biological treatment of household waste and those close to it in terms of the composition of the village’s industrial effluent.

Wastewater treatment plant in Kargasok village in conditions of low temperature effluent and the existing system of supplying them for cleaning did not provide a noticeable decrease in the degree of contamination. The salvo mode (5-7 volleys with a volume of up to 50 m3 in 20-30 minutes each), the flow of effluent through a pressure collector caused the flooding of even floating substances. The capacity of the riser of treated wastewater is about 30 cubes per hour. As a result of the overflow of aerotanks and secondary settlers, overflow of drains occurs through the semi-submerged board and the removal of suspended substances (raw silt and flocculated microflora) and floating impurities. Under these conditions, the absence of a disinfection system (not done during construction) was not a dangerous, but a favorable factor, since the treatment with chlorine of wastewater that is not sufficiently purified from organic substances would lead to a catastrophic increase in the toxicity of runoff due to the formation of organochlorine compounds [4]. The absence of sludge grounds and utilities for the pumping of sediment from the aeration tanks for drying and disposal forced the operating organization to remove the sediment with moisture much more than 85% to the landfill, which was a gross violation of the rules for landfill operation [5]. Discharged into the river. Ob water on a number of indicators (ammonium, suspended solids, BOD) did not meet the standards for allowable discharge of pollutants. This happened, firstly, due to the low temperature of the effluents entering the treatment (biological treatment with activated sludge requires constant maintenance of the temperature not lower than 13°C), and the second reason is the removal of the activated sludge due to low temperatures.

3. Results and discussion
To increase the efficiency of the functioning of the wastewater treatment plant, it was decided to reconstruct it. Of the possible cleanup measures, the “constructed wetland” technology was chosen (constructed marshland), since it compares favorably with other ways of treating effluents with low capital cost, minimal operating and energy costs, but large areas are required to accommodate “constructed wetlands”. “Constructed wetlands” are environmentally engineered wetland ecosystems that integrate physical, chemical, and biological processes that involve wetland vegetation, soils, and their associated microbial communities in a wastewater treatment process [6].

The “constructed wetlands” technology is divided into two types depending on the location of the hydraulic design line. Free water surface (FWS) wetlands are surface flow systems. Outwardly, they are very similar to the natural swamps by the presence of stagnant water and aquatic plants rooted in the soil layer at the bottom of the swamp. Sewage in such systems passes through the leaves, stems and roots of plants. Such a system is used at the FK1 wastewater treatment plant Kargasok.
The functioning of the constructed wetland was planned in the territory of the north of the Tomsk region, therefore foreign and domestic experience in using this technology in similar climatic conditions was studied. Thus, examples in Denmark (130 structures), Sweden and Norway (71), Canada (67) and North America (600) indicate that artificially created wetlands as post-treatment facilities are effective even at low temperatures. At the same time, the winter decrease in the activity of the systems is insignificant in comparison with the warm season [7].

Russia has experience in using “constructed wetlands” in arctic conditions, where one of the significant advantages of such systems over other methods of water treatment is manifested - maintaining the effectiveness of wastewater treatment even at low temperatures and the lack of seasonal fluctuations in efficiency. In the framework of an international project (Russia, Finland, Sweden, the Netherlands) in the village. Shongui of the Murmansk region created the world's only bioplato for wastewater treatment outside the Arctic Circle [8]. Under conditions of even lower average annual temperatures (–1.5 ° C) and freezing winters (down to –53 ° C), several systems of subsurface and surface runoff in the Tomsk region are effectively used [9].

FK1 is a platform with sides of 50.71 m × 48.88 m. The whole phytomap space is covered with rubble 0.2 m high. Sewage enters the diffractor FC1 by gravity from secondary settling tanks through a 290 m pipeline through an overflow well. After passing through FK1, the purified water is collected in the drain and through the filling level control device (URUZ) the pipe enters the outlet well, from where it is discharged to the r. Ob.

To clean the effluent from the remaining nitrogen (after the phyto map1), it was necessary to equip the second phytomap (FK2). The area of phyto maps2 is 4285 m2. FK2 receives wastewater that has been cleaned at FK1 through the pipeline to the FK2 diffuser. FC2 consists of two consecutive sections. The bottom of FK2, strictly horizontal in cross section, is made with a longitudinal slope of 0.001 and filled with gravel fraction crushed with ridges 3 m wide and 0.3 m high. The distance between the ridges along the top is 0.4 m. In the summer of 2011, the operating organization will need to land in grape of cattail and reed Phragmites Australis (roots, seedlings).

During the work of the intensive part of the cleaning with aeration and air heating (the mode at the time of the examination of the sewage treatment plant), a noticeable decrease in pollutants after passing through the aeration tanks and VO was observed only for ammonium, which is associated with its blowing. The ammonium concentration decreased from 162.71 mg / dm3 to 55-65 mg / dm3. But even with these values, ammonium is an inhibitor of activated sludge. Aeration did not allow suspended solids to settle, and subject to the salvo intake of wastewater to the sewage treatment plant, they, together with the floating substances, entered the secondary settling tanks and were salvaged into the water receiving facility (Ob river). When implementing measures to improve the work of sewage treatment plants (construction of FK1), aeration was turned off in order to settle some suspended substances in the aeration tanks, thereby reducing environmental damage by reducing energy consumption by at least 1,056,000 rubles / year (in 2005 prices). ) In the summer it was planned to export the accumulated sediment to the first silt site (IP1), built together with FK1. Sludge dehydrated with the help of higher aquatic vegetation was taken to the landfill. A siphon outlet was built, preventing the filling of aeration tanks during salvo flow of effluent, resulting in cleaning efficiency from floating impurities (100%) and suspended solids 51-55% (from 766 - 190 mg/l to 380 - 86 mg/l). Individual samples - up to 36 mg / l. Ammonium stripping was already carried out not in aeration tanks, but in a natural way at FK1, on which the BOD value also decreased. The disinfecting effect was most likely due to a high concentration of ammonium, since it has a detrimental effect not only on the microflora of the activated sludge, but also on the intestinal microflora.

After the construction of FK1, the average annual cleaning efficiency for suspended substances was at least 95%, for organic substances - at least 70%, for ammonium - at least 58%. Standards were reached for intestinal microflora, in a discharge in the r. Ob parasites and coliphages were absent. The
nitrification process was not observed. Such results were achieved by hanging the ice sheet. Before the onset of stable frosts, the release from the URUZ was transferred to the release of effluent through a riser 1 m high, so the FK1 was filled with drains to the top of the riser. After the formation of reliable ice on the surface of the water, the discharge of effluent switched to the operating mode. The ice sheet was held by the edges on the embankment of the phytocard, and its middle was supported by concrete pillars mounted on FK1. Between the ice and the bottom of the phytocard, along which the sewage was drained, a metered airbag was formed, which is a heat insulator and a source of oxygen for microorganisms that oxidize pollutants, as well as for the root system of plants. Snow fell on the ice sheet, which provided additional thermal insulation for the cleaning zone. Plastic pipes with a diameter of 100 mm with taps at the end were installed in the wells for metered ventilation.

During the construction of the FK2 and the second sludge site (IP2), the design of the FK1 was disrupted and the hanging of the ice became impossible. It was not possible to hang the ice on FK2 either, because the end of construction was scheduled for late autumn, while the embankment was carried out by blocks of frozen land, and no tightness was observed. The operating organization refused to eliminate the indicated defects during construction. After that, neither FK1 nor FK2 defended ice from the frost, while FK1 sharply reduced productivity, but due to the work of FK2, it was possible to achieve standards for permissible discharge for suspended substances (more than 98%) and ammonium (not less than 86%). In terms of nitrates and phosphates, a positive cleaning efficiency was not achieved. If the two analyzed phytocards functioned correctly, the cleaning efficiency would be several times higher.

4. Conclusion

Wastewater Kargasok village is heavily polluted, since most of it enters the sewage treatment plant from septic tanks, and only a small proportion of the incoming waste is sewed. Under these conditions, the “constructed wetlands” technology acts as a supplement to the intensive part of the cleaning. Under other conditions, when wastewater is polluted to a much lesser extent, a designed swamp may be an alternative to traditional wastewater treatment methods. After analyzing the effectiveness of wastewater treatment after they pass the phytocards1 and phytocards2, it should be concluded that the “constructed wetlands” technology can be successfully applied in the Tomsk region, subject to certain requirements (hanging ice sheets).

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