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EFFICIENCY OF FIBROUS CARRIER USE IN BIOTECHNOLOGICALLY INTENSIFIED PROCESS OF ADDITIONAL TREATMENT OF INDUSTRIAL WASTE WATER FROM PETROLEUM PRODUCTS

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Abstract. The paper presents the results of experimental studies on the efficiency of additional treatment of industrial waste water of the plant “Motor Sich JSC” from petroleum products with modern biotechnology of waste water treatment using the fibrous carrier “VIYA”. The comparative analysis of the efficiency of additional treatment of industrial waste water of the plant from petroleum products using the artificial fibrous carrier and the adsorbent “Ecolan” has been carried out.

Key words: fibrous carrier, waste water, petroleum products, treatment facility tank, treatment efficiency.

1. Introduction

Nowadays, in the world practice, the biological method of petroleum contamination treatment based on the use of destructive microorganisms is becoming a priority with any quantities and scales of contamination as the cheapest (does not require significant capital and operating costs, reagents, sorbent or filter material use), effective (allows to achieve a high degree of treatment) and harmless method of treatment (does not cause secondary waste generation as in sorption method) [1].

Nowadays there are a lot of studies on the environment treatment from petroleum products. All of them are based on the selection of the way to immobilize a particular culture. The numerous studies suggest that the highest results of waste water treatment from petroleum products can be achieved with the use of immobilized microorganisms that are attached to the solid carrier, which is largely due to the possibility of achieving an extremely high concentration of cells per unit of the carrier surface; the increase in the mass exchange between the gas and liquid phases in the reactor; the ease of cell division and the liquid which is being cleared. The efficiency of such treatment methods varies in a wide range, which depends on the optimal choice of immobilizer and the strain of microorganisms [2–4].

To immobilize microorganisms, the inert, water-insoluble carriers (beds) are used to fill the volume of the treatment facility, thus, forming a highly developed surface for attachment and maintenance of biomass of microorganisms. Recently, in Ukraine, the fibrous carrier made from synthetic (kapron) fibers “VIYA” has been increasingly used for biological waste water treatment for the hydrobiont immobilization in the waste water treatment facilities. The expediency and efficiency of the use of this fibrous carrier in biotechnologies for waste water treatment has been proved by P. I. Hvozdiak [5–7].

The purpose of our work was to determine the efficiency of additional treatment of industrial waste water of the plant “Motor Sich JSC” from petroleum products using the artificial fibrous carrier “VIYA” and the adsorbent "Ecolan".

2. Experimental part

The efficiency of industrial waste water treatment using the fibrous carrier “VIYA” has been checked at the actual treatment facilities of the plant “Motor Sich JSC” in Zaporizhzhia for 7 months (May-November 2017). The effluent treatment facilities (ETF) No. 54 of the plant are located outside the territory of the enterprise in Shevchenkivskyi district of the city. After treatment industrial waste water flows to the territory of residential development of the city and falls into the small Mokra Moskovka river.

The effluent treatment facilities (ETF) No. 54 are presented with an open four-section tank of 20×50 m

and 3.45 m deep. Each section consists of the inlet, flow, sediment sections, compartment for filters for additional treatment and the chamber for the treated water. The biological treatment of waste water from petroleum products at the treatment facilities of the plant is carried out due to the filter loading (expanded clay, vazopron) as well as the use of adsorbent "Ecolan". The maximum permissible discharge (MPD) of petroleum products in the surface water bodies for the dry period in the effluent treatment facilities (ETF) No. 54 is set at 0.195 mg/dm^3.

Due to the launch of ETF No. 54, approximately 3.5 thousand m^3 of waste water is discharged every day or up to 1202.04 thousand m^3 a year. The pollutant concentrations in the waste water varied in the range of, mg/dm^3: total iron 0.19-0.52; copper ions – 0.013–0.021; aluminum ions – 0.045–0.082; nickel ions – 0.0050–0.0137; chromium ions (III) – 0.005–0.024; chlorides – 354.5–868.6; sulfates – 61.8–70.5; phosphates – 0.96–1.34; fluorides – 0.31–0.46; ammonium nitrogen – 0.43–4.82; nitrites – 0.27–1.20; nitrates – 3.88–5.98; mineralization – 944.0–2021.0; petroleum products – 0.084–9.000; surfactant – 0.054–0.090; organic pollutants for COD – 24.6–48.0 and BCOD5 – 3.76–3.84. The temperature of industrial waste water varied from 18.5 °C to 29.5 °C during May-November 2017.

The artificial fibrous carrier "VIYA" was used for additional treatment of industrial waste water of the plant "Motor Sich" from petroleum products. This carrier makes it possible for certain types of microorganisms that have a high destructive ability to treat water from these hydrocarbons to immobilize on it. In aerobic conditions on an artificial growing, the microorganisms that destroy petroleum products multiply intensively and decompose petroleum products contained in the water of the treatment facilities.

In one of the 4 tanks of ETF No. 54 the floating carrier elements in the form of rafts of 1.50×0.54 m were installed. A fibrous carrier was attached to the bottom of each raft. The fibrous carrier was attached to the raft so that when the raft was placed in the water the carrier was immersed in the water layer. The primary immobilization of microorganisms and other periphytic organisms into the fibrous carrier has been carried out in the aerotanks of the central waste water treatment facilities of Livyi Bereh (CWWTF-1) of "Vodokanal" enterprise in Zaporizhzhia for 24 days. Then the fibrous carrier with immobilized organisms was removed from the aerotank of CWWYF-1 in Zaporizhzhia and transported to the treatment facility of the plant "Motor Sich" where it was placed in the experimental treatment facility tank at the beginning of industrial waste water runoff.

In general, we have mounted and installed 76 rafts with the fibrous carrier for immobilization of micro-hydrobiocenoses for biological additional treatment of waste water from petroleum products in the experimental treatment facility tank. In order to keep the rafts with the fibrous carrier constantly on the surface of the water, they were linked to each other in certain sections (7-8 pieces) and tied to the wooden beams, which were installed in the metal grooves of the treatment facility tank. Thus, wooden beams freely moved (up and down) in the grooves when raising or lowering the level of waste water in the treatment facility tank, Fig.

The content of petroleum products in the water of the effluent treatment facilities (ETF) No. 54 was determined at the beginning, at the end of the treatment facility tank and after expanded clay loading (at the exit of the treatment facility) in two control tanks and in the experimental tank where 76 rafts with the fibrous carrier were placed. In the experimental tank, the content of petroleum products in the middle of the channel was determined (after 40 rafts).

The determination of the concentration of petroleum products in the waste water was carried out by atomic absorption method using an electrothermal analyzer (spectrophotometer by "PerkinElmer") as well as flame analyzer "Hitachi-180" in the complex sanitary and technical laboratory (CSTL) of the environmental department of the plant "Motor Sich JSC", verification certificate on metrological confirmation of measuring capabilities and technical competence of subdivisions and organizations No. 26416904-26/4-3-VL valid till 12.05.2021.

3. Results and discussion

According to the results of the experimental studies in May-July, it was found that the maximum concentration of petroleum products in the waste water at the entrance of the experimental tank, namely 9.704 mg/dm^3 was in the second decade of June, and the minimum – 0.571 mg/dm^3 in the third decade of July. The content of petroleum products in the waste water of the treatment facility after 40 rafts decreased and varied within the range of 0.186–1.404 mg/dm^3, at the end of the tank – (0.329–4.072 mg/dm^3), and at the exit of the tank after expanded clay loading it was within the range of 0.100–1.253 mg/dm^3, Table 1. Thus, the efficiency of treatment of industrial waste water of the plant from petroleum products by the suggested biotechnology after 40 rafts, at the end of the tank and at the exit of the treatment facility was at the level of 53–86 %, 31–73 % and 74–92 %, respectively.

Fig. Seventy-six mounted rafts with fibrous carrier "VIYA" installed
in one experimental storm treatment facility (STF) tank No. 54 of the plant "Motor Sich JSC"

Table 1

Results of additional industrial waste water treatment from petroleum products, mg/dm^3 of the plant "Motor Sich JSC" using the fibrous carrier in 2017

Indicator	Date of waste water sampling										
	23.05	06.06	15.06	18.07	25.07	03.08	17.08	29.08	05.09	12.09	14.11
Concentration at the facility entrance	1,198	0,759	9,704	1,260	0,571	1,071	2,120	2,165	0,845	0,247	0,248
Concentration after 40 rafts	0,291	0,186	1,404	0,376	0,271	0,249	0,238	0,273	0,209	0,132	0,190
Concentration at the facility end	0,329	0,204	4,072	0,343	0,394	0,247	0,314	0,324	0,217	0,186	0,175
Concentration at the facility exit	0,100	0,134	1,253	0,195	0,149	0,166	0,151	0,160	0,146	0,123	0,093
Treatment effect, %: after 40 rafts	75,7	75,5	85,5	70,2	52,5	76,8	88,8	87,4	75,3	46,6	23,4
Treatment effect, %: at the facility end	72,5	73,1	58,0	72,8	31,0	76,9	85,2	85,0	74,3	24,7	29,4
Treatment effect, %: at the facility exit	91,7	82,3	87,1	84,5	73,9	84,5	92,9	92,6	82,7	50,2	62,5

In two control tanks, the average concentration of petroleum products in waste water at the entrance was 0.103–1.486 mg/dm^3 in May-July. At the end of these tanks, the content of petroleum products in water increased and varied within the range of 0.207–13.582 mg/dm^3. The maximum concentration of petroleum products in the control tanks was registered in the second decade of June (9.464 mg/dm^3 and 17.770 mg/dm^3), which exceeded the MPD of the chemical substances for the dry period 49 and 91 times respectively, Table 2–3. After expanded clay loading, the concentration of petroleum products in the treated water at the exit of

two tanks was within the norm. It was 0.073–0.170 mg/dm^3 in May, the first decade of June and July. In the second decade of June, after expanded clay loading, in the treated water of these tanks, excess levels of petroleum products (from 2.6 to 12.9 MPD) were registered. The efficiency of waste water treatment from petroleum products in the control tanks of this treatment facility during the testing period (with the use of adsorbent "Ecolan") at the end of the tanks and at the exit of the treatment facility averaged 9 % and 38 % respectively.

Thus, the experiments proved that the efficiency of industrial waste water treatment of the plant from petroleum products using the fibrous carrier in May-July 2017 at the end of the tank and at the exit, after expanded clay loading, was 7 and 2.2 times higher compared to the traditional technology of waste water treatment at this enterprise.

Table 2

Results of additional treatment of industrial waste water from petroleum products, mg/dm^3 of the plant "Motor Sich JSC" using adsorbent "Ecolan" in the control tank No. 1 in 2017

Indicator	Date of waste water sampling										
	23.05	06.06	15.06	18.07	25.07	03.08	17.08	29.08	05.09	12.09	14.11
Concentration at the facility entrance	0,084	0,306	2,309	0,326	0,258	0,234	0,191	0,211	0,275	1,462	1,230
Concentration at the facility end	0,319	0,249	9,464	0,466	0,305	0,463	0,223	0,238	0,197	0,161	0,148
Concentration at the facility exit	0,077	0,073	0,497	0,148	0,148	0,157	0,134	0,140	0,161	0,114	0,110
Treatment effect, %: at the facility end	0,0	18,6	0,0	0,0	0,0	0,0	0,0	0,0	28,4	89,0	88,0
Treatment effect, %: at the facility exit	8,3	76,1	78,5	54,6	42,6	2,9	29,8	33,6	41,5	92,2	91,1

Table 3

Results of additional treatment of industrial waste water from petroleum products, mg/dm^3 of the plant "Motor Sich JSC" using adsorbent "Ecolan" in the control tank No. 2 in 2017

Indicator	Date of waste water sampling										
	23.05	06.06	15.06	18.07	25.07	03.08	17.08	29.08	05.09	12.09	14.11
Concentration at the facility entrance	0,122	0,521	0,663	0,213	0,176	0,700	0,199	0,223	0,196	0,966	0,253
Concentration at the facility end	0,361	0,164	17,77	0,824	0,421	0,277	0,231	0,287	0,195	0,139	0,157
Concentration at the facility exit	0,117	0,097	2,506	0,170	0,149	0,183	0,145	0,201	0,279	0,111	0,114
Treatment effect, %: at the facility end	0,0	68,5	0,0	0,0	0,0	60,4	0,0	0,0	0,5	85,6	37,9
Treatment effect, %: at the facility exit	4,1	81,4	0,0	20,2	15,3	73,9	27,1	9,9	0,0	88,5	54,9

During the biological treatment of industrial waste water from petroleum products using the fibrous carrier in August-November, it was found that at the entrance of the experimental tank, the concentration of petroleum products in the waste water varied within the range of 0.247–2.165 mg/dm^3. The concentration of petroleum products in the waste water after 40 rafts decreased and varied within the range of 0.132–0.273 mg/dm^3, at the end of the tank it was 0.175–0.332 mg/^{dm3}. After treatment, the content of petroleum products in the treated water at the entrance of the experimental tank was within the range of 0.093–0.166 mg/dm^3. The efficiency of industrial waste water treatment from petroleum products in the experimental tank after 40 rafts, at the end of the tank and at the exit of the treatment facility was at the level of 23–89 %, 25-85 % and 50–93 %, respectively, see Table 1.

In the control tanks, the average concentration of petroleum products in the waste water was 0.195–1.214 mg/dm^3 during the testing period. At the end of the tanks the concentration of petroleum products varied within the range of 0.150–0.370 mg/dm^3. After expanded clay loading, the average concentration of petroleum products in the treated water at the exit of the control tanks was within the range of 0.112–0.220 mg/dm^3, that is, 1 and 1.4 times excess of the MPD compared to the norm was found twice for the dry period (the third decade of August and the first decade of September), Table 3. The average efficiency of waste water treatment from petroleum products in the control tanks of the treatment facility using the adsorbent "Ecolan" at the end of the tanks and at the exit of the treatment facility was 33 % and 48 %, respectively.

Thus, the experiments proved that the efficiency of industrial waste water treatment from petroleum products using the fibrous carrier in August-November 2017 at the end of the tank and at the exit, after expanded clay loading was 2 and 1.6 times higher than the traditional technology of waste water treatment at this enterprise.

It should also be noted that during the testing period (May-November 2017), the efficiency of waste water treatment from petroleum products using the adsorbent "Ecolan" was at the level of 0 % for 55–64 % of samples at the end of the control tanks and 18 % of samples for one control tank after expanded clay loading (at the exit of the treatment facility), Table 2–3.

As a result of biological additional treatment of industrial waste water of ETF No. 54 of the plant “Motor Sich JSC” using petroleum oxidizing microorganisms and organisms of the periphyton of the fibrous carrier “VIYA” for seven months, the average concentration of petroleum products in the experimental tank at the exit decreased almost 8 times (from 1.835 mg/dm^3 to 0.243 mg/dm^3). During the treatment of industrial waste water of the plant from petroleum products using the adsorbent "Ecolan", the concentration of petroleum products in the control tanks at the exit of the treatment facility decreased 2 times (from 0.505 mg/dm^3 to 0.265 mg/dm^3).

In general, the average efficiency of the treatment of industrial waste water of the plant “Motor Sich JSC” from petroleum products in the experimental tank after 76 rafts with the fibrous carrier “VIYA” at the end of the tank was 62 %. In the control tanks (without the use of the fibrous carrier), the average level of waste water treatment from petroleum products using the adsorbent “Ecolan” in this period was 22 %. That is, the given data confirm that the efficiency of additional treatment of industrial waste water of the plant from petroleum products using the fibrous carrier is 2.8 times more efficient than in case of the traditional technology using the adsorbent “Ecolan”, Table 4–5.

The average efficiency of waste water treatment from petroleum products in the experimental tank with the fibrous carrier at the exit after expanded clay loading was at the level of 80 %. In the control tanks (without the use of the fibrous carrier), the degree of waste water treatment from petroleum products at the exit after expanded clay loading averaged 43 %. The above data also confirm that the efficiency of additional treatment of industrial waste water of the plant from petroleum products using the fibrous carrier is almost 2 times more efficient than in case of the traditional technology using the adsorbent "Ecolan", Table 4–5.

Table 4

Efficiency of treatment of industrial storm waste water from petroleum products using fibrous carrier “VIYA” of the plant “Motor Sich JSC” in May-November 2017

Testing period	Content of hydrocarbons, mg/dm^3		Treatment effect, %	Content of hydrocarbons, mg/dm^3	Treatment effect, %	Content of hydrocarbons, mg/dm^3	Treatment effect, %
	entering water	after 40 rafts		at the facility end		at the facility exit	
Experimental channel with fibrous carrier "VIYA"							
May-July	2,698±1,756	0,506±0,226	71,88±5,44	1,068±0,752	61,48±8,14	0,366±0,222	83,90±2,95
August-November	1,116±0,351	0,245±0,018	66,38±10,60	0,244±0,027	62,58±9,82	0,140±0,029	77,57±7,10
May-November	1,835±0,810	0,364±0,105	68,88±6,06	0,619±0,353	62,08±6,89	0,243±0,101	80,45±4,04

Table 5

Efficiency of treatment of industrial storm waste water from petroleum products using adsorbent "Ecolan" of the plant "Motor Sich JSC" in May-November 2017

Testing period	Content of hydrocarbons, mg/dm^3		Treatment effect, %	Content of hydrocarbons, mg/dm^3	Treatment effect, %
	entering water	at the facility end		at the facility exit	
Control channels with adsorbent "Ecolan"					
May-July	0,498±0,209	3,034±1,870	8,71±6,90	0,398±0,237	38,11±10,32
August-November	0,512±0,133	0,226±0,026	32,48±11,09	0,154±0,014	47,95±9,20
May-November	0,505±0,116	1,503±0,880	21,68±7,15	0,265±0,108	43,48±6,15

The obtained data confirm the efficiency of the fibrous carrier "VIYA" use with immobilized microorganisms-destructors and periphytic organisms for additional treatment of industrial waste water of the plant "Motor Sich JSC".

Thus, the suggested biotechnology, which completely reproduces the natural processes of the trophic chains and does not create any dangerous waste, can be widely used for industrial waste water treatment not only from petroleum products but also from any other toxic pollutants.

Conclusions

1. With the use of the fibrous carrier "VIYA" for additional treatment of industrial waste water of the plant "Motor Sich JSC" from petroleum products, their content in the treated water decreased (in average) after 76 rafts from 1.835±0.810 mg/dm^3 to 0.619±0.353 mg/dm^3, and at the exit, after expanded clay loading from 1.835±0.810 mg/dm^3 to 0.243±0.101 mg/dm^3. The average efficiency of waste water treatment from petroleum products at the end of the experimental tank and the exit of the treatment facility was 62 % and 80 %, respectively.

2. With the use of the adsorbent "Ecolan" for additional treatment of industrial waste water of the plant "Motor Sich JSC" from petroleum products, their average content in the treated water increased at the end of the control tanks from 0.505±0.116 mg/dm^3 to 1.503±0.880 mg/dm^3. At the exit of the treatment facility, the content of petroleum products in the treated water decreased from 0.505±0.116 mg/dm^3 to 0.265±0.108 mg/dm^3. The average efficiency of waste water treatment from petroleum products at the end of the control tanks and at the exit of the treatment facility was at the level of 22 % and 43 %, respectively.

3. The presented experimental data confirm that the use of the fibrous carrier "VIYA" for additional treatment of industrial waste water from petroleum products is almost 2 times more efficient than the same water treatment according to the traditional technology using the adsorbent "Ecolan".

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