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Araştırma Makalesi

Treatment Of Oil-Containing Industrial Wastewater In Thin-Layer Oil Traps

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Abstract: In this article, oil production facilities and refineries are essentially the facilities where the most chemical processes are carried out and pollution is high. While oil is obtained in these facilities, the pollutants mixed with the water containing the oil are of great importance. While these waters contaminated during the production of petroleum and petroleum products are discharged to the receiving environment through different channels and collectors, this situation can cause serious problems in channels and collectors. Studies are carried out to prevent the pollution in these waters contaminated with oil and its derivatives from damaging the system. It is aimed to reveal the advantages and disadvantages of the newly designed soft layer oil trap, which is different from the previously used ones, by performing experimental studies for the application. The description of the new design of the thin layer oil trap and the results of production tests at different operating flow rates in the inter-plate gap are presented. As a result of the experiments and analytical evaluations, the new system is found to be very successful in oil refining. Its advantages over existing horizontal oil traps are proved. A detailed analysis of available patent materials and information in technical literature shows that it is possible to create a more complete and compact construction of thin mud oil tanks. The facility created by us differs from other similar ones due to its compactness, simplicity of operation and higher cleaning efficiency. The device received invention patents of the Republic of Azerbaijan.

Keywords *Hydrocarbons, Industrial plants***,** *Mechanical particles, Oil refinery, Oil trap, Processed water, Thin layer, , Water treatment plant.*

İnce Katmanlı Yağ Tuzaklarında Yağ İçeren Endüstriyel Atık Suların Arıtılması

Öz. Bu makale, petrol üretiminin gerçekleştirildiği tesisler ve rafineriler esasen en fazla kimyasal işlemin yapıldığı ve kirliliğin yüksek olduğu tesislerdir. Bu tesislerde petrol elde edilirken, petrolün içerdiği suya karışan kirlilikler büyük önem taşımaktadır. Petrol ve petrol ürünlerinin üretimi sırasında kirlenen bu sular farklı kanal ve kolektörler vasıtasıyla alıcı ortama deşarj edilirken bu durum kanal ve kolektörlerde ciddi sorunlara yol açabilmektedir. Petrol ve türevleri ile kirlenen bu sulardaki kirliliklerin sisteme zarar vermemesi için çalışmalar yürütülmektedir. Daha önce kullanılanlardan farklı olarak yeni tasarlanan yumuşak tabakalı yağ tutucunun uygulamaya yönelik deneysel çalışmalar yapılarak avantaj ve dezavantajlarının ortaya konulması amaçlanmaktadır. İnce tabaka yağ tutucunun yeni tasarımının tanımı ve plakalar arası boşlukta farklı çalışma debilerinde üretim testlerinin sonuçları sunulmuştur. Yapılan deneyler ve analitik değerlendirmeler sonucunda yeni sistemin petrol rafinasyonunda oldukça başarılı olduğu ortaya çıkmıştır. Mevcut yatay yağ tutuculara göre avantajları kanıtlanmıştır.

Anahtar kelimeler: *Petrol rafinerisi, İşlenmiş su, İnce tabaka, Endüstriyel tesisler, Su arıtma tesisi, Yağ tutucu, Mekanik partiküller, Hidrokarbonlar.*

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1. Introduction

Oil refineries and petrochemical plants are are among the most water-intensive industrial plants. In these plants, water is mainly used for cooling production products and process equipment. The water used at such production sites is usually contaminated with oil and petroleum products. In refinery production water, oil products are 3-5 g/l, mechanical impurities are up to 100-500 g/l [1]. To purify water from these impurities, devices called oil traps are used at operating industrial plants. The oil traps used in production are horizontal sedimentation tanks, rectangular in plan, 36 m long, 6 m wide and 2 m deep (at the beginning) to 1.2 m deep (at the end). The capacity of such sedimentation tanks is 198 m^3/hour, and the water to be treated must remain in it for 2 hours [2]. Operational experience shows that only 90-95% of oil and oil products are trapped in treated produced water [3]. According to A. V. Ponomarev and other authors [2], the amount of petroleum products in treated water in active oil traps operating at CIS refineries ranges from 50-450 mg/l. However, according to current regulations this amount should not exceed 100 mg/l. In order to improve the purification efficiency of oil traps, improvements are required in their design. From this point of view, it is more appropriate to treat oil-containing production water in oil traps equipped with thin-layer blocks. At present, there are various designs of such oil traps [4], and each of them has one or another shortcoming. The thin-layer oil trap proposed by the authors [5] is superior to others in terms of its purification efficiency and takes up less production space. The distinctive feature of this oil trap is the combined treatment of water in the thin-layered blocks housed in its casing, using the countercurrent and direct-flow principles. The process flowchart of the device is shown in Figure 1.

2. The Purpose of This Study

Azerbaijan is a major oil producer. Serious environmental pollution occurs in oil production areas, wells, oil refineries and other production facilities. It is aimed to separate the mixture of crude oil derivatives, other petroleum ingredients and water in the best possible way without causing environmental pollution and to purify contaminated crude oil wastewater. For this purpose;

It is aimed to reveal the advantages and disadvantages of the newly designed gentle layer grease trap, which is designed differently from the previously used ones, by carrying out experimental studies for application.

2.1. Scope and Hypothesis:

This new design (gentle layer grease trap), with its experimental results for application, is aimed to be directly implemented in many places in the country if these results are advantageous. In the area between the plates of the system and at different flow rates; Efficiency tests were carried out and the system was examined based on collapse and floating.

This study was carried out in the "central laboratory of Neft Union" in the area where crude oil production takes place. The unit is concentrated in thin muddy blocks with high and low currents. The water injection depth in the blocks was 100 mm, the working flow distance between the plates was 1000 mm, the total length was 1880 mm, the width was 200 mm, and the height was 1620 mm. The blocks are placed in 600-grain gold, which allows the compacted silt to slide continuously along the surface of the racks forming the blocks and remove them to the silt collection zone, eliminating the need for frequent washing. Flowing in several directions lengthens its path and creates conditions for increasing the degree of water purification.

2.2. Hypothesis:

Test samples for analysis were taken from pipes equipped with special valves placed at the entrance and exit of the facility to sterilized glass jars. The analyzes were carried out on the day of sampling. During the study, the amount of oil and oil products in the production water supplied to the water tank was 275-860 mg/l, and the amount of mechanical impurities was 48-150 mg/l.

3. Experimental and Application Studies Conducted

3.1. System and Experimental Application

The treated production water, containing oil, oil products and mechanical mixtures, is fed into trough 2 with pipe 1. As the trough has 20 mm diameter holes arranged in a staggered pattern it ensure even distribution of the treated water over the cross-sectional area of the primary rinsing chamber (3). The water is guided down the chamber and into a thin layered block (4) positioned at an angle of 60° to the horizontal. In this case, the coarse oil and petroleum products separate from the water and float to the surface of the flow, where they are collected and discharged into trough 5. Water, together with relatively low-dispersed oil and petroleum products, enters the channels between the plates of the block.

The distance between the plates in the block is 100 mm. Moving upwards in the channels between the plates, the low-dispersed oil and petroleum products in the water float to the upper shelves and rise in the same direction as the flow, accumulate on the water surface in chamber 6 and then pour out into trough 5. The heavier mechanical particles settle on the surface of the lower shelf, slide in the opposite direction to the flow and accumulate on depression 9. The water enters block 7 and is routed to the bottom of the final rinsing chamber (8). In this case, the low-dispersed oil and petroleum products, separated from the water, are directed against the flow and accumulate on the water surface in chamber 6 and then discharged into trough 5. Heavy mechanical particles settle on the surface of the bottom shelf, slide in the flow direction and accumulate on depression 9. The sludge accumulated in the depressions is periodically removed through pipes 10 and 11. While the water from the block in the final rinsing chamber moves from the bottom upwards, the remaining oil and petroleum product particles are separated and accumulate on the water surface and flow into trough 12 and from there into the separator chamber (13).

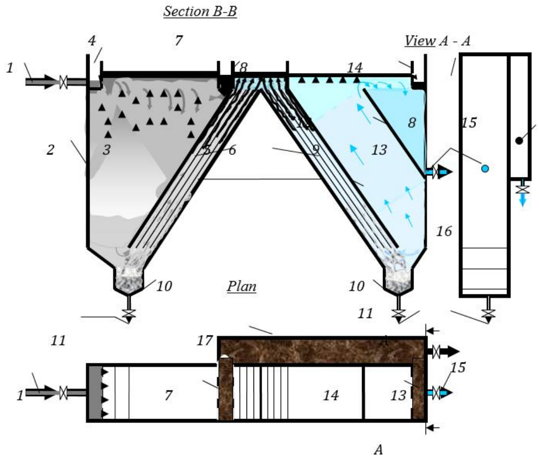


Figure 1. *Process flowchart of a thin-layer oil trap.*

In order to prevent the separated product from being re-mixed with the treated water in the final rinsing chamber, a baffle (14) is installed parallel to block 7. The treated water is discharged from the device via pipe 15.

The water separated from the oil and petroleum products temporarily accumulated in the separator chamber is removed through pipe 16 located in the lower part of the chamber, and the dewatered oil and petroleum products through pipe 17.

The multi-directional flow reversal in the device lengthens the flow path and increases the efficiency of the water treatment.

The oil droplets in the inter-plate channels are subject to two main forces: hydrodynamic forces tending to remove the droplets from the rinsing area and gravitational forces guiding them towards the upper channel plate. These forces determine the trajectory of the oil droplets in the inter-plate channels.

The threshold hydraulic size of oil droplets trapped in the channels varies with the flow rate and is calculated according to formulae (1) for counter-flow blocks and (2) for straight-flow blocks [7]:

$$u=(v \cdot h)/(L+h \cdot \sin\alpha) \quad (1)$$

$$u=(v \cdot h)/(L-h \cdot \sin\alpha) \quad (2)$$

In the formulas, v is the velocity of the working flow in the inter-plate channels, m/s; h is the vertical distance between the plates, m; L is the channel length, m; α is the angle formed by the channel with the horizon.

The dependence of the hydraulic size of the smallest oil droplets that can be trapped in the device on the flow rate in the channel is shown in Figure 2.

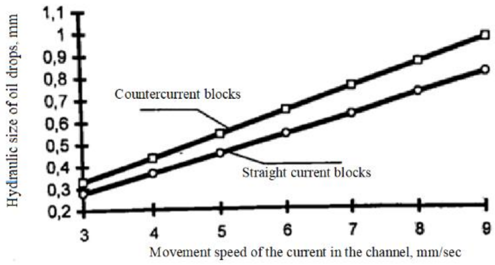


Figure 2. *Flow rate in the channel*

The graphs in Figure 2 show that oil droplets with a smaller hydraulic size are trapped by straight-flow blocks with parallel plates. The positioning of the two blocks - straight and counter flow - makes it possible to free the water from coarse and fine oil droplets more quickly.

The device was tested at Azerneftyag Production Union. The studies were conducted at different work flow rates in the space between the block plates.

3.2. Analysis of Experimental Studies

According to analyses conducted by the Union's central laboratory, the amount of oil and petroleum products in the treated production water was 147-374 mg/l, and the amount of mechanical impurities was 133-165 mg/l.

Table 1. Treated water results of thin layerm oil trap

Flow rate in the inter-plate channels, mm/s	Device productivity, l/h	Quantity of mechanical impurities, mg/l			Quantity of hydrocarbons,mg/l		
		At the input	On the output	Average	At the input	On the output	Average
3.0	432	164	25 17	21.0	374	30 18	24.0
		147	26 14	20.0	256	28 19	23.5
		144	24 11	17.5	261	27 30	23.5
		137	19 13	16.0	368	30 17	23.5
4.0	576	135	31 23	27.0	363	30 18	24.0
		133	21 12	16.5	250	24 18	21.0
		141	24 15	19.5	191	20 12	16.0
		143	21 18	19.5	182	27 18	22.5
5.0	720	133	18 12	15.0	171	22 18	20.0
		137	20 16	18.0	189	20 14	17.0
		158	21 13	17.0	147	26 15	20.5
		165	21 10	15.5	197	25 18	21.5

The efficiency of the device was investigated at working flow rates of 3-5 mm/s in the inter-plate channels. For the analysis of the treated water, samples were taken 15 and 30 minutes after the start-up of the device and its complete filling of the working volume. Some of the results obtained are shown in the Table above.

The results in the Table 1 show that the residual concentrations of oil products and mechanical impurities in the samples taken after the first 15 minutes at different concentrations of oil, oil products and mechanical impurities in the water to be treated and at different working flow rates in the channels, do not differ significantly. Residual quantity for oil and petroleum products is 29-40 mg/l, for mechanical impurities is 24-40 mg/l. In the samples taken within the second 15 minutes, the residual quantity of both contaminants is significantly reduced and the optimum mode of operation of the device has been established. The residual quantity of the specified contaminants in the samples taken after this period is virtually the same as the residual quantity in the samples taken after 1.5 hours.

A variation in the working flow in the inter-plate space within 3-5 mm/sec has no tangible effect on the efficiency of the water treatment. Changes in water temperature prove to be a more active factor in this process. Thus, after treatment with a water temperature of 16°C and a hydrocarbon content of 144 mg/l, the residual hydrocarbons are 40 mg/l, while at a water temperature of 25°C the residual quantity is reduced to 20 mg/l. This can be explained by the effect of changes in water temperature on water density, i.e. on increasing or decreasing the resistance of oil and petroleum product particles to float to the water surface. An increase in water temperature results in a reduction of the dynamic viscosity coefficient as well as the resistance, which is reflected in an increase in purification efficiency and in the thickness of the oil film formed on the flow surface in the channel.

Fig. 3 shows the dependence of the thickness of the oil film formed on the flow surface in channels in blocks on the dynamic viscosity coefficient [7]. The graphs show that the block of both types, placed in the device, is very much involved in water purification.

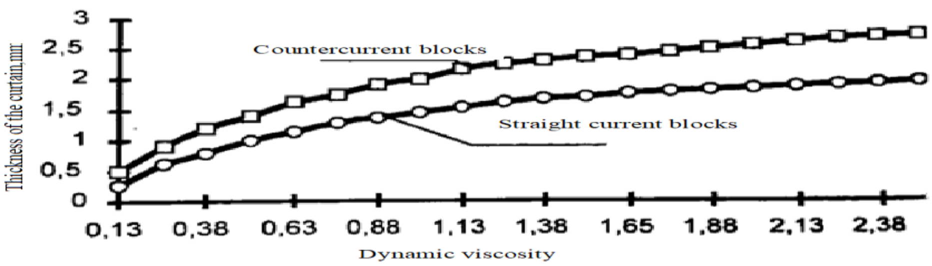
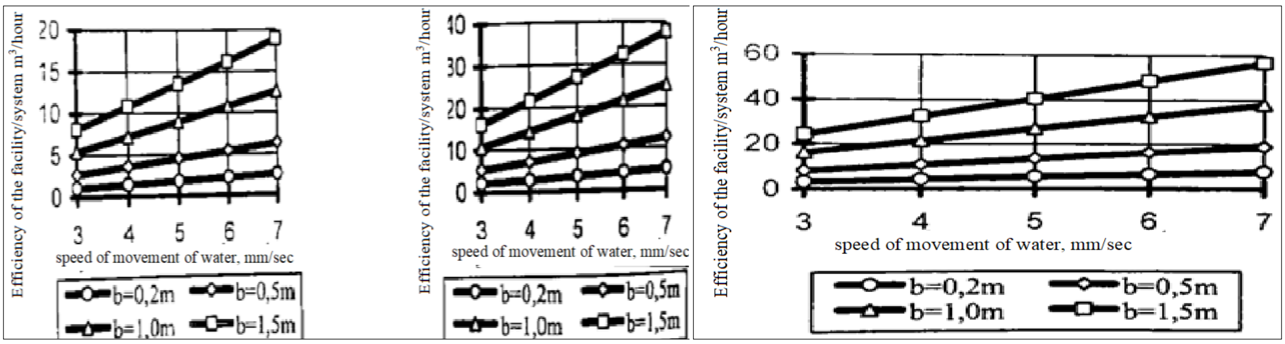


Figure 3. *Dependence of the thickness of the oil film water treatment*

The productivity of a tested oil trap depends on the number of channels and the width of the block, in addition to the working flow rate in the channels in the blocks. Changing these geometric parameters can give the desired productivity with the same water treatment efficiency. The dependence of the productivity of devices with the number of parallel plates in blocks of 5,10 and 15 units on the width of the device for different flow rates in the channels is shown in Figure 4.



(a) (b) (c)

Figure 4. *Variation of device productivity with number of channels in the block: a-5, b-10 and c-15 depending on the rate of working flow in the inter-plate channels.*

4. Results and Conclusion

The graphs in the Figure 4 show that increasing the number of plates and the channel width from 0.2 *m* to 1.5 *m* can increase the productivity of the device by up to 6.5-7.5 times. This possibility is not the final limit. By increasing the number of parallel plates in the block, the capacity can be increased to desired limit.

Increasing the number of channels in the blocks increases the total length of the device by 0.07 - 0.1 *m*, which is practically negligible in terms of production area occupied.

Compared to existing oil traps, the advantages of the proposed device are that it can be made directly in the production facilities, it is inexpensive, easy to operate, requires no energy or chemical reagent consumption, and has a high purification efficiency. The device can be applied to purify oil-containing production waters of industrial plants, as well as wastewater generated in oil fields from oil, oil products and mechanical impurities.

Efficiency tests of the new designed grease trap, which is thought to be more efficient and advantageous than the previously designed and used systems (existing horizontal grease traps), were carried out and it was tried to reveal whether the results support our hypothesis. As a result of the experiments and analytical evaluations, it has been revealed that the new system is quite successful in oil refining.

Author Contribution

Formal analysis –Gülnara Mirza Serdar (GMZ); Investigation – GMZ; Experimental Performance – GMZ; Collection GMZ; Processing – GMZ; Literature review – GMZ; Writing – GMZ; Review and editing – GMZ;

Declaration of Competing Interest

The authors declared no conflicts of interest with respect to the research, authorship, and/or publication of this article.

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