# **Coalescing Filter for Separation of Water-Oil Emulsions**

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#### Abstract

Today there are a large number of methods for extracting oil products from wastewater, but each of them is effective only in a certain range of concentration of oil products. In this regard, the development of processes for the purification of oily wastewater from enterprises of the machine-building industry is an urgent task. In this work, we carried out the separation of stable water-in-oil emulsions by the coalescence method using filter media made of granular and porous PTFE. According to the results of the study, it was found that after filtration of the emulsion through a filtering load of PTFE, the concentration of oil products in the filtrate decreases. Moreover, with a decrease in the particle size of the filtering load, the concentration of oil products in the filtrate decreases more intensively. The efficiency of removing oil products with porous filter media is higher than with granular filter media. The degree of removal of oil particles from the emulsion and the filtration rate depend on the granule size and porosity of PTFE, the smaller the granule size, the higher the efficiency. Also, the efficiency of removing oil products depends on the size of the particles of the dispersed phase of emulsions, and on the value of the ζ-potential of the emulsion as a measure of repulsion between the particles of the dispersed phase, that is, an indicator of the stability of the system. It has been established that the gradient arrangement of filter media from 0.5 to 3 mm increases the retention capacity and filtration rate. The proposed filter media can be used for efficient separation of oil and oil emulsions with particle sizes from 0.2 to 10 microns and with a concentration of oil products up to 90 g /  $m^3$ .

**Key words:** oil-water emulsion, oil products, filter media, coalescence, filtration, polytetrafluoroethylene.

#### I. INTRODUCTION

Coalescence is a simple and inexpensive process for separating oil-in-water emulsions [1-3]. To intensify the process of purifying oily effluents, more than 50 types of materials have been proposed for use as coalescing nozzles: cellulose fibers, stainless steel shavings, porcelain, clinker crushed stone, slag, granular polyester resins, polyurethane,

granular styrene, peat, foamed polystyrene, washed cotton mass, shell rock, brick rubble and others [4,5]. Various oleophilic materials are also used as coalescing reagents, for example, cord fibers of car tires with a diameter of 10–20  $\mu$ m for purifying wastewater from heavy oil fractions [6].

We all know that oil does not mix with water, but when the two are mixed together, they can not be separated, but with the method recently developed by researchers, this is no longer impossible.

The most efficient way to stain an oil is to use a membrane that can filter small droplets of water. However, the membranes become contaminated immediately and must be cleaned.

An emulsion is a liquid-in-liquid colloid in which droplets of one liquid (such as oil) are dispersed in another liquid (such as water) without mixing. An emulsion consists of two immiscible liquids (usually oil and water), one of which is dispersed in fine droplets in the other. The dispersed liquid is called the dispersed or internal phase and the liquid surrounding the droplets is called continuous, closed or external phase.

During this study, my researchers. IT examined an imaging device that allows the development of a new membrane material that is not contaminated.

"The refining process is almost impossible," said Gregory Rutledge, a professor of chemical engineering and co-author of the paper. The refining membrane usually closes tightly and is difficult to see inside.

To separate the two materials, the researchers used two lasers to scan the material layer by layer. This technique is called "confocal laser scanning microscopy."

When two laser beams pass through, the material is marked with a fluorescent dye. For the experiment, the researchers used two dyes: one on oil in liquid and the other on membrane fibers.

This method is suitable for creating a complete threedimensional image through oil droplets scattered throughout the membrane. This can help to better understand how the separation between oil and water occurs.

The firm "Labko" (Finland) offers an oil separator of the "EuroREK" brand for the treatment of storm sewage. The concentration of oil products at the outlet is  $0.3 \text{ mg} / \text{dm}^3$ . Cleaning efficiency is achieved using coalescence modules [7]. The disadvantages of the device include low efficiency in the separation of stable emulsions such as "oil in water".

Known device for purification of oily effluent [8], containing a preliminary settler with a heating manifold, a thin-layer module of corrugated plates, two filter chambers. Granular polyamide or polyethylene are used as filter media. The disadvantages of the device include the complexity of the device in servicing and in the absence of information on the delay capacity of the filtering load.

Expansion of surface technology and creation of surfaces with selective wettability to water and oil in order to increase the efficiency and create anti-fouling properties of membranes is one of the most important solutions to the existing challenges. In this regard, acquiring technical knowledge and developing it in the manufacture of superhydrophobic or super-oil-repellent coatings underwater using metal oxides on a porous stainless steel base due to good compatibility with many materials, cost-effectiveness. Non-toxicity, high thermal stability, high mechanical strength, suitable ductility, adjustable pore size (selection of mesh with different mesh number), direct application in industry and also due to having a regular and uniform texture are among the topics to be studied in this field. Is.

In the purification device [9], the emulsion enters from the bottom under the coalescing element of the device, where the oil particles are enlarged, which are carried away by the flow, float to the upper part of the compartment and are discharged through the branch pipe from the device. At the same time, the decreasing cross-section of the coalescing element contributes to a favorable distribution of flow rates over its entire surface. The disadvantages of such a device are the low degree of purification from emulsified oil products, the lack of water purification from solid mechanical particles, organic pollutants, the absence of a post-treatment module, the need for periodic regeneration or replacement of coalescing elements, which significantly complicates and increases the cost of the purification process.

Polymer wheel loading in the form of granules was used in the following works. In [10], polymer hydrolyzed polyacrylamide was used to separate model oil emulsions with a concentration of oil products of 790 mg / dm<sup>3</sup>.

When using a granular material with a closed porous structure (for example, granular polystyrene and polypropylene), the placement of oil is possible only between the granules in the sorbent layer due to capillary forces and oleophilicity. The liquid between the granules is retained by adhesion and capillary forces [11-13].

The work [14] describes the device "Coalescing cartridge" for cleaning from fine liquid droplets, their separation, filtration or coalescence from gas or liquid streams. The device contains a frame with a coalescing material and flexible drainage elements fixed on it, and the flexible drainage elements are made of a porous bundle with a free volume greater than the free volume of the coalescing (filtering) material and are located in front of the layers and / or between the layers. The porous harnesses are made of metal knitted sleeve mesh. The technical result is to increase the productivity and efficiency of the coalescing cartridge and reduce its hydraulic resistance. The disadvantage of the device is the low efficiency of separation of the emulsion of the "oil-in-water" type, since the metal tubular mesh used as a filter-coalescer has low porosity and large pore size, which allows cutting off only coarsely dispersed particles of oils and petroleum products. Also the used filter mesh is susceptible to corrosive processes.

All presented works have disadvantages: low retention power, or a complex device, therefore, the development of an effective caolescing filter is an urgent task.

The purpose of the work is to develop a coalescing filter made of polytetrafluoroethylene for removing emulsified oil products from wastewater and waste water-oil emulsion.

# II. METHODS

Granular PTFE was obtained by grinding PTFE sheet of the "fluoroplast-4" grade, after grinding using laboratory sieves, the grains were distributed according to the particle size distribution into particles: <0.5, 0.5-1, 1-2, 2-3 mm. Porous PTFE was obtained by sintering a fluoroplastic powder grade "F-4PN" with a particle size of 20 microns at a temperature of 380 ° C for 2 hours. After sintering, PTFE was crushed with a mill and sieved into granules with a size of 0.5 to 3 mm.

The separation of the model water-oil emulsion by the coalescence method was carried out on a laboratory filtration unit. A model 3% emulsion was prepared from distilled water and industrial oil of the I-20 brand by dispersion using a laboratory stirrer at a speed of 2500 rpm; sodium dodecyl sulfate was used as a surfactant. The concentration of oil products in the original model emulsion was more than 93 g / dm3. Emulsions were passed through columns filled with granules and grains of different fractions (from 0.5 to 3 mm) of PTFE at a given flow rate. Filtration of emulsions through a layer of granular loading occurs in two stages: delivery of oil particles to the loading grains and their adhesion to the surface. The working area during filtration is the surface of the material and the space between the grains of the load. And when used as a load of granular porous PTFE, oil particles will be retained in the pores of the polymer. The height of the layer of polymer grains is 100 mm in a column with an inner diameter of 10 mm and a length of 150 mm, the weight of the coalescing filler was 2 grams. The concentration of oil products in the model emulsion was 93 g /  $dm^3$ .

Regeneration of the filter media was carried out by washing with carbon tetrachloride.

The particle size of the dispersed phase of the model emulsions and their filtrates was determined by dynamic light scattering (DLS), and the  $\zeta$ -potential was determined by the method of light scattering with phase analysis (PALS) using a Nano Brook Omni analyzer.

As the main indicators of the coalescence separation of the emulsion, the filtration rate and the degree of separation of the water-oil emulsion were considered, which was calculated as the ratio of the content of oil products in the emulsion before and after separation, determined using a KN-3 concentrometer.

The content of petroleum products in the model emulsion and in the filtrates was determined by IR spectrometry using a KN-3 concentrometer.

#### **III. RESULTS AND DISCUSSION**

Figure 1 shows a photograph of a porous filter media of different particle size distribution.



Figure 1. Granulometric composition of the porous PTFE filter media.

The filter cartridge in the central part is filled with granular PTFE, and the subsequent layers, separated by a polymer mesh, are filled with porous PTFE granules shown in Figure 1 with sizes from 0.5 mm to 4 mm in order of increasing particle size towards the center of the cartridge.

Figure 2 shows a micrograph of a porous PTFE granule.



Figure 2. Micrograph of a porous PTFE granule at a magnification of 503.

The micrograph shows that the PTFE granule consists of particles with a size of less than 20 microns between which there are pores.

Grain size of filter Filtra	Filtration time,	Productivity (filtration rate), cm <sup>3</sup> / sec			
media, mm	seconds	by distilled water	oil emulsion		
<0,5	20	5,4	1,8		
0,5-1	7	9,3	3,1		
1-2	6	17,2	5,8		
2-3	5	23,4	7,8		
>3	3	33,5	11,3		

**Table 1.** Performance of filter media made of granular PTFE for distilled water and water-oil emulsion

As the grain size of the PTFE filter media increases, the filtration rate increases. The filtration rate through granular PTFE increases by 4 times with an increase in the grain size from 0.5 to 3 mm. Also, the filtration rate for water-oil emulsion is 3 times lower than for distilled water.

The performance of filter media made of porous PTFE with granule sizes from 0.5 to 3 mm in distilled water and 3% water-oil emulsion is shown in Table 2.

Grain size of filter	Filtration time,	Productivity (filtration rate), cm <sup>3</sup> / sec			
media, mm seconds		by distilled water	oil emulsion		
<0,5	19	7,8	2,6		
0,5-1	15	9,9	3,3		
1-2	8	18,8	6,3		
2-3	7	21,3	7,1		
>3	6	24,9	8,3		

Table 2. Performance of filter media made of porous granular PTFE for distilled water and water-oil emulsion

As the grain size of the PTFE filter media increases, the filtration rate increases. The filtration rate through porous PTFE increases by a factor of 4 with an increase in the grain size from 0.5 to 3 mm. Also, the filtration rate for water-oil emulsion is 3 times lower than for distilled water.

With porous PTFE filter media, the filtration rate is 8% lower than with granular media.

To establish the effectiveness of PTFE filter media, the retention capacity with grain sizes from 0.5 to 3 mm for oil products from a 3% water-oil emulsion was established. The results are shown in Tables 3 and 4.

Table 3. Retention capacity of filtering media from granular PTFE for petroleum products

Grain giza of filter modia mm	Concentration of oi	Retention capacity,%	
Gram size of finter media, min	initial	in filtrate	
<0,5		9,9±0,9	89,2
0,5-1		15,2±1,5	81,3
1-2	93 <u>+</u> 9,3	19,6± 1,9	72,1
2-3		25,8±2,5	70,6
>3		40,1±4,0	56,8

After filtration of VME through a filtering load made of PTFE, the concentration of oil products in the filtrate decreases. Moreover, with a decrease in the particle size of the filtering load, the concentration of oil products in the filtrate decreases. The maximum retention capacity for oil products is 89% for filter media with grain sizes <0.5 mm at a filtration rate of 1.8 cm<sup>3</sup> / sec and at a pressure of 0.05 MPa.

Grain size of filter	Concentration	Retention capacity,%		
media, mm	initial	in filtrate		
<0,5		3,7±0,3	96,2	
0,5-1		43,4 <u>+</u> 4,3	92,3	
1-2	93±9,3	71,5±7,1	86,1	
2-3		12,3±1,2	72,7	
>3		31,0±3,1	66,7	

Table 4.	Retention ca	apacity of	filtering med	a made of porous	PTFE for	petroleum	products
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After filtering the emulsion through a PTFE filter media, the concentration of oil products in the filtrate decreases. As in the case of granular filter media, a decrease in the particle size of the filter media leads to a decrease in the concentration of oil products in the filtrate. The maximum retention capacity for oil products is 96% for filter media with grain sizes <0.5 mm at a filtration rate of 2.6 cm<sup>3</sup> / sec and at a pressure of 0.05 MPa.

It is evident from this table that the efficiency of the porous filter media is higher than that of the granular PTFE filter media when separating the oil-water emulsion.

To increase the retention capacity of the coalescing filter, the PTFE filter media were arranged in gradient layers; the results of the separation of the oil-water emulsion are presented in Tables 5 and 6.

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Grain size of filter media, mm	Concentration	Retention capacity,%	
	initial	in filtrate	
<0,5->3	93±9,3	5,8±0,58	93,7
>3-<0,5		$16,5\pm1,7$	82,2

Table 5. Retention capacity of the filter media located in graded layers of granular PTFE for oil products

When the granular loading is arranged in layers, starting with large particles in the direction of decreasing the particle size along the flow of the emulsion, the retention capacity is higher than with the reverse arrangement of the layers of the filtering loading.

Table 6.	Retention car	pacity of the	filter media	located in	gradient la	vers of	porous PT	FE for oil	products
					L )	./			

Grain size of filter	Concentration of	Retention capacity,%	
incuta, inin	initial	in filtrate	
<0,5->3	93±9,3	3,2±0,32	96,5
>3-<0,5		3,7±0,37	96,2

When the porous loading is arranged in layers, starting with large particles in the direction of decreasing the particle size along the flow of the emulsion, the retention capacity is higher than with the reverse arrangement of the layers of the filtering media. Also, with a gradient arrangement, the retention capacity for petroleum products is higher than the retention capacity of the filter media with a granule size of less than 0.56 mm.

Next, we investigated the particle size of the initial water-oil emulsion and the emulsion filtrates obtained after passing through porous filtering media made of porous PTFE. Figure 3 shows the size of the particles of the emulsion and its filtrates after separation using filter media made of porous PTFE.



Figure 3. The graph of the particle size distribution of the dispersed phase of a 9% model emulsion and its filtrates

After passing the VME through the filter media, an increase in the particle size is observed; the process of coalescence is observed, sticking and aggregation of the particles of the emulsion oil occurs. As a result of passing the emulsion through the coalescer filter, the surface charge of the particles changes and the particle size becomes larger.

## **IV. SUMMARY**

n this work, we carried out the separation of stable water-oil emulsions by the coalescence method using filter media made of granular and porous PTFE. After filtering the emulsion through a PTFE filter media, the concentration of oil products in the filtrate decreases. Moreover, with a decrease in the particle size of the filtering load, the concentration of oil products in the filtrate decreases more intensively. The maximum retention capacity for oil products is 96% for filter media with grain sizes <0.5 mm at a filtration rate of 2.6 cm<sup>3</sup> / sec and at a pressure of 0.05 MPa. The efficiency of removing oil products with porous filter media is higher than with granular filter media. The degree of removal of oil particles from the emulsion and the filtration rate depend on the granule size and porosity of PTFE, the smaller the granule size, the higher the efficiency. Also, the efficiency of removing oil products depends on the size of the particles of the dispersed phase of emulsions, and on the value of the  $\zeta$ -potential of the emulsion as a measure of repulsion between the particles of the dispersed phase, that is, an indicator of the stability of the system. The smaller the size of the filter media granules, the smaller the size of the removed particles of oil products. The retention capacity of oil products with a granular filtering load ranged from 89 to 56.8 %. And the porous filtering load for oil products ranged from 96.2 to 66.7 %. It was also found that the gradient arrangement of filter media from 0.5 to 3 mm increases the retention capacity and filtration rate.

## **V. CONCLUSIONS**

Filter media made of granular and porous PTFE can be used for efficient separation of oil and oil emulsions with particle sizes from 0.2 to 10 microns and oil product content from 1 to 90 g /  $dm^3$  under dynamic conditions.

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