

## COALESCENCE OF WATER-OIL EMULSIONS ON THIN-LAYERED PVC PLATES

Dinar Dilshatovich Fazullin<sup>1</sup>, Gennady Vitalevich Mavrin<sup>2</sup>

<sup>1</sup> Kazan Federal University, Naberezhnye Chelny Institute, e-mail: denr3@yandex.ru

<sup>2</sup> Kazan Federal University, Naberezhnye Chelny Institute

### ABSTRACT

In this paper, studies have been carried out to determine the parameters of the coalescing separation of oil-water emulsions formed as a result of the activities of machine-building industries, spills of oil products and oils using a laboratory experimental setup. In the process of cleaning the used emulsion, methods of coalescence, magnetic separation of metal particles and inertial-gravitational purification are applied. The novelty of this coalescent plant is thin-layered PVC plates, separated by vertical partitions, to increase the contact surface with the emulsion. The degree of separation of water-oil emulsion from suspended solids - 92 %, from petroleum products – 59 % was determined. The capacity of the water-oil emulsion separation unit was 7 dm<sup>3</sup>/min. Depending on the requirements, the purified liquid can be reused, or in other technological processes. As a result of the removal of free oil products by coalescent purification, the particle size increases and the absolute value of the z potential of the dispersed phase of the emulsion decreases.

**Keywords:** emulsion, oil products, suspended outflows, coalescence, sedimentation, particle size.

### INTRODUCTION

At the enterprises of the metallurgical and chemical industry, one of the main categories of waste water are oil-containing effluents. According to the concentration of basic pollution, the latter are divided into low concentration and concentrated. Low-concentration effluents are formed when washing metal products after their heat treatment and after decompression. In many enterprises, concentrated oil-containing effluents are diluted with a large number of conditionally pure waters and become less concentrated. The content of oils in them usually ranges from 10 to 500 mg / dm<sup>3</sup>.

The main types of concentrated oily wastewater are wastewater cleaning solutions and waste lubricating and cooling liquids, which are 3-10% emulsion solutions containing industrial oils, aspidol, ethylene glycol, sodium nitrite and other substances [1]. At machine-building enterprises are used, as emulsions with a short period of operation, and sufficiently resistant with a period of use of several months.

Emulsions, which after being used as part of sewage enter the treatment plant, is a stable emulsion of the oil-in-water type. In addition to the above components, the composition of emulsions includes various stabilizers, as well as a large number of additives (anticorrosive, bactericidal, extreme pressure, etc.) [2].

Coalescence is a simple and inexpensive process for the separation of water-oil emulsions [3-6]. To intensify the process of cleaning oily effluent as coalescing nozzles, more than 50 types of materials have been proposed: cellulose fibers, stainless steel chips, porcelain, clinker chips, slag, granulated polyester resins, polyurethane, granulated styrene, peat, expanded polystyrene, shell rock, brick rubble and others [7,8]. As coalescing reagents, various oleophilic materials are also used, for example, cord fibers of tires with a diameter of 10-20 µm for sewage treatment from heavy oil fractions [9].

The company "Labko" (Finland) offers the oil separator brand "EuroREK" for the purification of storm sewage. The concentration of oil products at the outlet is 0.3 mg /dm<sup>3</sup>. The efficiency of purification is achieved by using coalescent modules [10].

A device for cleaning oily effluents [11] is known, containing a preliminary settling tank with a heating collector, a thin layer module of corrugated plates, two filtering chambers.

In the purification device [12], the emulsion comes from below under the coalescing element of the device where the particles of oil are coarsened, which are carried out by the flow, float to the upper part of the compartment and are discharged through the branch pipe from the device. In this case, the decreasing cross-section of the coalescing element promotes a favorable distribution of the flow velocities over its entire surface. The disadvantage of such a device is the low degree of purification from emulsified petroleum products, the lack of water purification from solid mechanical particles, organic contaminants, 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 cleaning.

The aim of the work is to determine the parameters of the process of coalescing separation of water-oil emulsions and oily wastewater.

## METHODS

In this paper, studies have been carried out to determine the parameters of coalescing separation of water-oil emulsions formed as a result of the activities of petrochemical, oil-producing and machine-building industries using a laboratory installation with thin-layered PVC plates.

The laboratory installation for wastewater treatment, waste emulsions from oil products, organic pollutants, suspended solids was collected in the laboratory of the Department of Chemistry and Ecology of the Naberezhnye Chelny Institute of KFU [13]. The unit is designed for initial cleaning of used emulsions and is the first stage of purification in the complex technology of emulsion cleaning.

The device consists of three compartments (Figure 1). In the first compartment, the effluents are subjected to liquid coalescent purification.

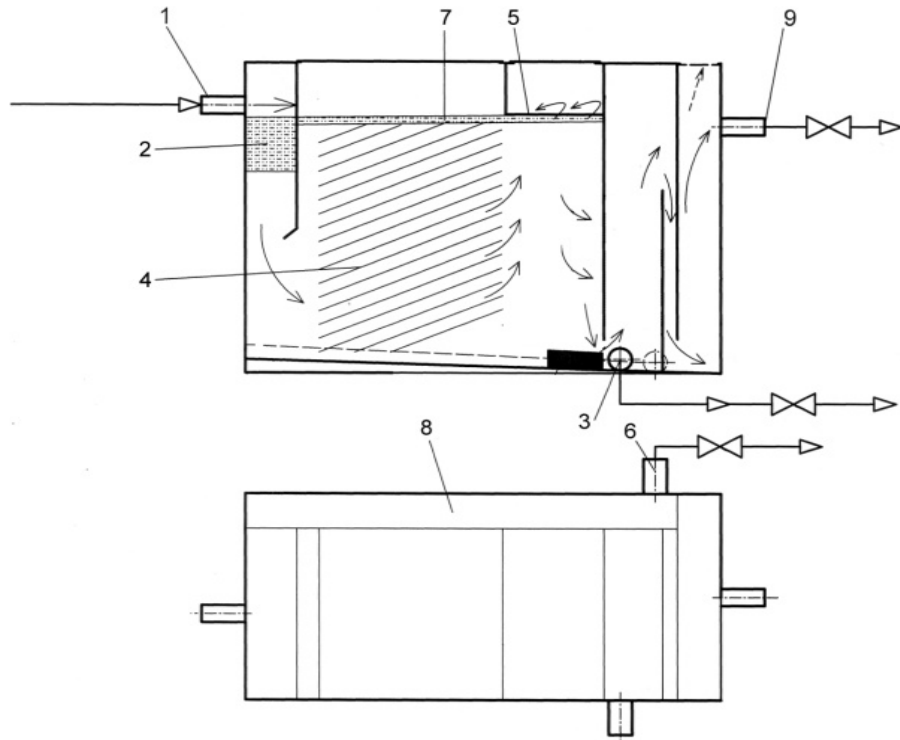
In the second compartment, thin-layer liquid separation takes place on a detachable module of inclined thin-layered plates with the possibility of electroflotation cleaning with non-consumable electrodes, as well as magnetic cleaning from metal particles. Separated pollutants are discharged from the liquid continuously through the overflow partition into a collection of surfaced contaminants. Coalescent module is removable and universal, can be replaced if necessary by another module. The gap between the plates of the coalescent module is 10 mm, and the slope of the plates to the flow of liquid can be set in the range from 22 ° to 45 °. With thin-layer settling, particles with an equivalent diameter of 1 20 µm are separated. When these particles reach the surface of the thin-layer element, a coalescence process takes place. Coalescing filter plates are made of materials with high wettability oils and oil products. Unlike other coalescent plants, thin-layered plates are separated and vertical partitions to increase the contact surface with the emulsion. In the third compartment, if necessary, additional purification of the liquid is carried out with the help of adsorbents.

In the process of cleaning the used emulsion, methods of coalescence, magnetic separation of metal particles and inertial-gravitational purification are applied. Depending on the requirements, the purified liquid can be reused, or in other technological processes. The average capacity of the plant is 5-7 dm<sup>3</sup>/min [14].

The efficiency of cleaning the installation was determined by the degree of removal of oil products and suspended solids by the formula:

$$\varphi = (C_f - C_p) / C_f, \quad (2.1)$$

where  $C_f$  and  $C_p$  are the concentration of the contaminant in the initial and purified solution, respectively.



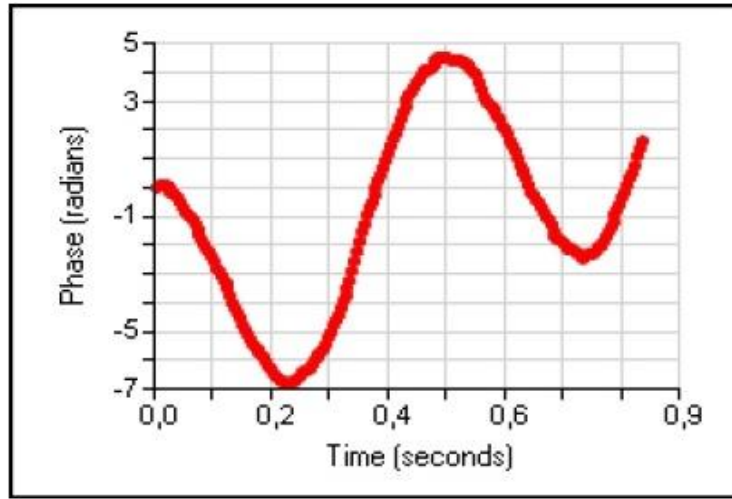
**Figure 1.** Scheme of coalescing purification of used emulsion: 1 - branch pipe; 2 - layer of oil products; 3 - a branch for the discharge of solid particles; 4 - coalescent module, 5 - channel of transfusion of oil products; 6 - branch pipe of oil products discharge; 7 - layer of floating oil products; 8 - oil receiver; 9 - outlet branch of purified liquid;

The particle size of the dispersed phase of oil-in-water emulsions was determined by the method of dynamic light scattering (DLS), and the  $\zeta$  potential by the light scattering method with phase analysis (PALS) using the NanoBrook Omni analyzer.

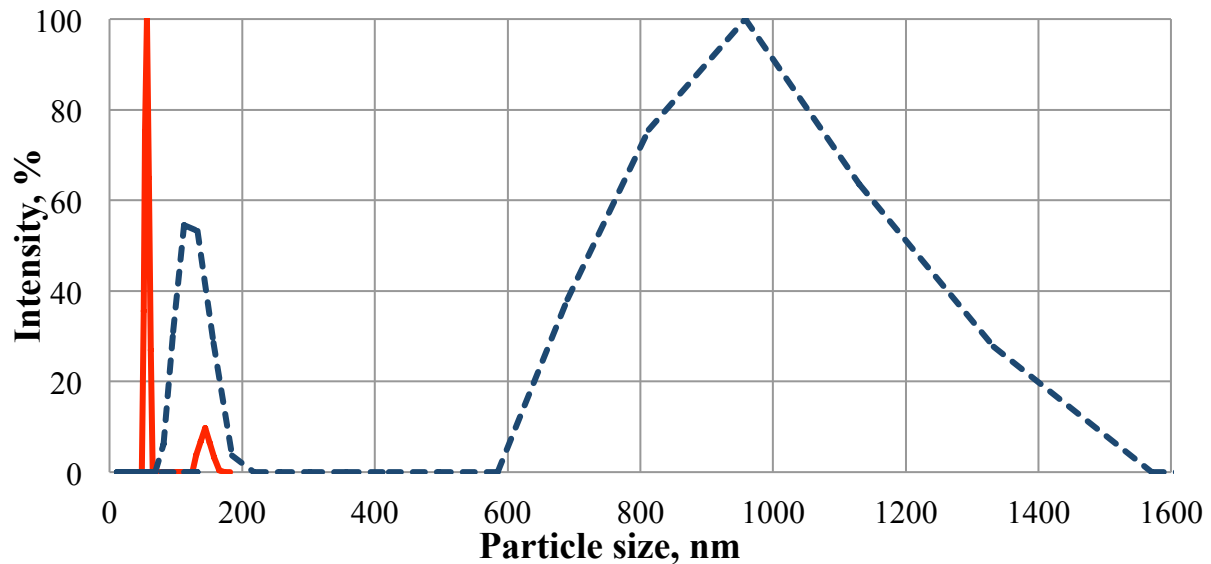
The productivity and the degree of separation of the water-oil emulsion, which was calculated as the ratio of the oil content in the emulsion before and after the separation, determined with the help of the KH-3 concentrate meter, were considered as the main indicators of coalescing emulsion separation. The efficiency of separation of suspended solids was also determined.

## RESULTS AND DISCUSSION

Dynamic light scattering method (DLS), and  $\zeta$ -potential by light scattering method, the particle size and  $\zeta$  potential of the disperse phase of the spent emulsion and the emulsion after the destruction are determined. Figure 2 and Table 1 show the results of measurements of the  $\zeta$  potential and mobility of the particles in the dispersed phase of the emulsions studied.



**Figure 2.**  $\zeta$ -potential of dispersed phase of water-oil emulsion.



**Figure 3.** Comparative graphs of particle size distribution of the dispersed phase of emulsions: (solid line) water-oil emulsion and (dashed line) oily waste water.

**Table 1.** The values of the particle size and the z potential of the dispersed phase of the emulsions

Emulsion	Particle size, nm	$\zeta$ -potential, mV
Water-oil emulsion	52-184	$-58 \pm 6$
Oil-containing sewage	81-1600	$-3,8 \pm 0,4$

Based on the data presented in Figure 3, the emulsion is a polydisperse system with particle sizes of 52 to

184 nm. The  $\zeta$ -potential for all emulsions studied is negative. As a rule, with increasing particle size, the  $\zeta$ -potential between particles decreases; the smaller the  $\zeta$ -potential of the particles, the stronger the particles stick together, coalesce with each other, precipitation occurs. Data on the particle size and  $\zeta$  potential make it possible to select membranes, coagulants for processes of purification of waste emulsion.

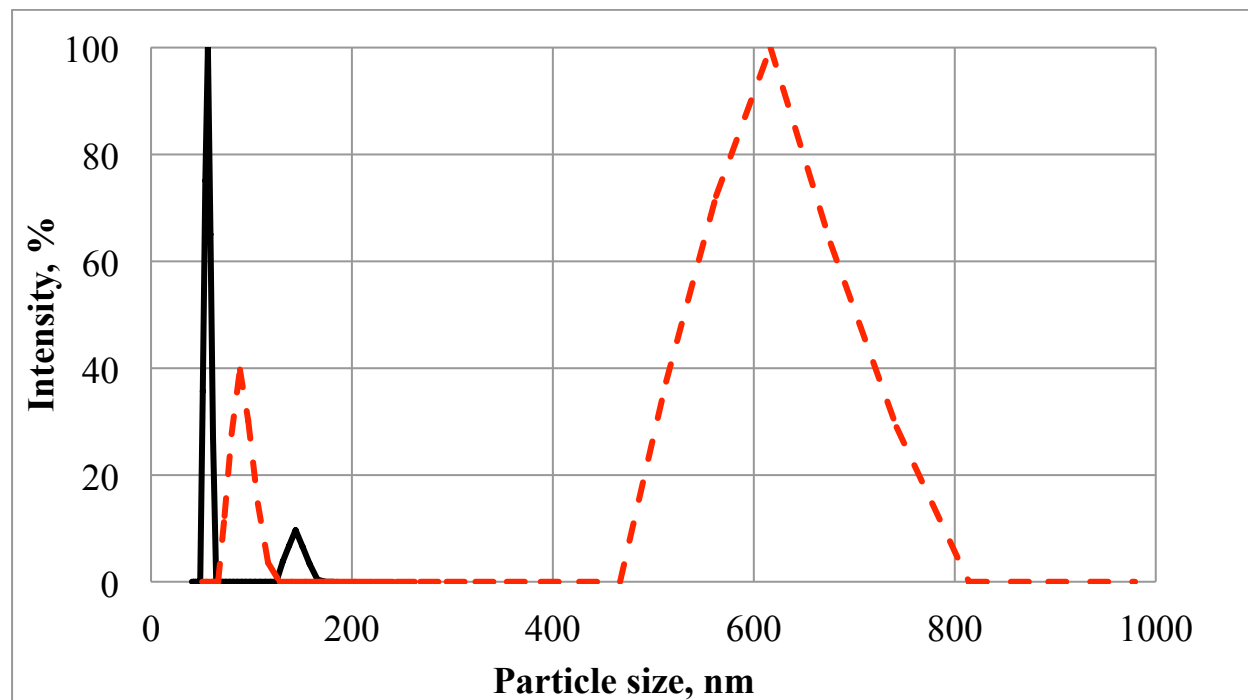
The degree of purification from petroleum products, oils, suspended solids is confirmed by the results of chemical analysis of samples of the initial and purified liquid. The results of cleaning the water-oil emulsion on a coalescent plant are shown in Table 2.

**Table 2.** Results of cleaning the water-oil emulsion on a coalescent unit

Indicator	Initial emulsion	After purification	Degree of purification, %
Suspended substances, mg/dm <sup>3</sup>	1554±233	120±18	92,3
Petroleum products, mg/dm <sup>3</sup>	14400±2160	5860±879	59,3

The degree of purification of the installation from suspended solids according to the results of the experiment is more than 92%, of oil products is more than 59%. Depending on the requirements, the purified liquid can be reused, or in other technological processes. The capacity of the unit for the separation of water-oil emulsion is 7 dm<sup>3</sup>/min [13,15].

After purification of the emulsion, the particle size and the  $\zeta$  potential of the dispersed phase of the spent emulsion were studied, the results are shown in Fig. 4 and Table 3.



**Figure 4.** Particle size distribution of the dispersed phase of the emulsion: (solid line) initial water-oil emulsion and (dashed line) emulsion after coalescence purification.

**Table 3.**  $\zeta$ -potential of the dispersed phase of the emulsion

Emulsion	$\zeta$ -potential, mV
Water-oil emulsion	$-58 \pm 6$
After separation into a coalescent plant	$-35 \pm 4$

As a result of the removal of free petroleum products by coalescent purification, the particle size increases and the absolute value of the  $z$  potential of the dispersed phase of the emulsion decreases because of the destruction of the emulsion; The particles instantly become larger due to the loss of charge during the passage through the PVC plates.

## CONCLUSIONS

According to the results of the study, the emulsion is a polydisperse system with particle sizes of  $52 \pm 184$  nm. The  $\zeta$  potential of the emulsion is negative.

The degree of purification of the installation from suspended solids according to the results of the experiment is more than 92%, of oil products is more than 59%. Depending on the requirements, the purified liquid can be reused, or in other technological processes. The capacity of the water-oil emulsion separation unit was  $7 \text{ dm}^3/\text{min}$ .

As a result of the removal of free oil products by coalescent purification, the particle size increases from 52-184 nm to 63-811 nm. And a decrease in the absolute value of the  $z$  potential of the dispersed phase of the emulsion is established because of the destruction of the emulsion; The particles instantly become larger due to the loss of charge during the passage through the PVC plates.

## SUMMARY

In the process of separation of water-oil emulsions, methods of liquid coalescence, coalescence on thin-layer PVC plates, magnetic cleaning from metal particles and inertial-gravitational purification are used.

The efficiency of cleaning the source liquid from such pollutants as petroleum products, oils, organic contaminants, suspended particles is confirmed by the results of quantitative chemical analysis of samples of the initial and purified liquid carried out in the analytical laboratory. The degree of purification of the installation from suspended solids according to the results of the experiment is more than 92%, of oil products is more than 59%. Depending on the requirements, the treated liquid should be reused or in other technological processes, if the plant is used for the purification of sewage from oil products, oils, organic contaminants and suspended solids, then the treated water should be discharged to the sewerage system or into water bodies when environmental regulations and requirements are met.

## ACKNOWLEDGEMENTS

This work was supported by scientific the research grant of Kazan Federal University.

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