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Hydraulic Simulation of Local Industrial Wastewater Treatment Facilities

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Abstract. The creation of technologies and equipment for wastewater treatment remains a topical issue for the efficient use of water resources and ensuring environmental sustainability. The article presents the results of research on improving the efficiency of vertical sewer settling tanks for the treatment of urban and industrial wastewater based on hydraulic calculations. The study used hydraulic modeling methods. A laboratory model of vertical settling tanks has been developed. The studies were carried out using real industrial wastewater. The process of achieving a reduction in the amount of suspended solids in industrial and storm drains to 345 mg/l, the amount of oil products to 3-3.5 mg/l in a vertical sump and ways to implement it in nature has been studied and shown.

1 Introduction

Any scientific innovations, developments and inventions are made to achieve certain goals of a person in order to have a positive impact on his future. In the current era of industry and production, service and tourism, science and education, information and communication systems, the main goal of science and technology is to prevent environmental disasters and crises such as climate change, species extinction, air, land and water pollution [9, 11, 12, 15, 16, 17].

The idea of improving the quality and use of natural and drinking water has been developed at all stages of the evolutionary development of the "Nature-Man-Society" system. Nowadays, it is important to send wastewater for treatment and reuse in order to reduce its damage to nature [18, 19, 20]. All existing technological wastewater treatment systems are based on the following groups:

1. Mechanical - cleaning with a grate, sand trap, sump, centrifuge, filter, septic tank [4, 7, 8, 9, 10, 11, 12];
2. Biochemical - treatment with aerobic and anaerobic devices, aerotanks, ultrafiltration membranes [4, 7, 8, 9, 10, 11, 12];
3. Physico-chemical and electrochemical - cleaning using devices such as sorbent, flotation, centrifugation, ion exchange, crystallization [4, 7, 8, 9, 10, 11, 12].

In the treatment of industrial effluents containing petroleum products, the mechanical treatment method is widely used as the most economical and efficient. Taking into account

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the low or high density of suspended solids and oil products in relation to the density of water, the feasibility of using sediments for the purpose of trapping at the water level and sinking to the bottom was studied [4, 7, 8, 9, 10, 11, 12].

Experiments, hydraulic calculations and determination of design parameters for the improvement of industrial wastewater treatment plants in practice pose a number of problems. For example, in a vertical settling tank:

1. variability of water consumption during hours (days, weeks, months, seasons, years);
2. the presence of both oil and oil products, the concentration of suspended particles and differences in the composition of wastewater;
3. economic value of its re-construction and construction, operation until positive results of the experiment are obtained;
4. the duration of sedimentation of suspended particles depends on their size;
5. calculate the duration of precipitation formation and their separation from distilled water;
6. The impossibility of simultaneously finding the values of physical and mathematical functions, such as the correspondence of the calculated parameters of the sump to the marks of the city sewerage (usually 1-7 meters in Uzbekistan), creates a problem in solving the problem [9, 11, 12, 15, 16, 17].

This article provides for the creation of a laboratory model for the construction of vertical sedimentation tanks for the treatment of wastewater from small enterprises (containing a lot of oil and oil products) at local treatment facilities. A technique has been developed for conducting experiments on a simulated vertical rod, taking into account and applying in practice their values and sizes.

2 Methods

When modeling hydraulic processes, geometric, kinematic and dynamic similarities are used [18].

In geometric similarity, the dimensions of the geometric elements of vertical settling tanks used in nature are considered uniform in relation to the dimensions of the geometric elements of the model [18].

Dimensions of the simulated natural (original) settler: working diameter Dset=2 m, height Hset=4 m.

Settler model dimensions: working diameter D'set=0.25 m, height H'set=0.5 m.

Linear simulation scale [18].:

$$K_1 = \frac{D_{set}}{D'_{set}} = \frac{H_{set}}{H'_{set}} = 8 \tag{1}$$

The ratio of the original vertical settler of the working surface to the working surface of the model is equal to the square of the linear scale of the model [18].:

$$K_1{}^2 = \frac{F_{set}}{F'_{set}} = 64 \tag{2}$$

The ratio of the working volume original vertical settler to the working volume of the model is equal to the cube of the linear scale of the model [18].:

$$K_1{}^3 = \frac{W_{set}}{W'_{set}} = 512 \tag{3}$$

The kinematic characteristics of the simulated mechanical process in kinematic similarity must correspond to the kinematic characteristics of the model, i.e. time parameters are introduced while maintaining geometric similarity [18]:

$$K_2 = \frac{T}{T\prime} = 1 \tag{4}$$

where: K2 – time modeling scale;
Tn, Tm - time in "nature" and "model", respectively
With dynamic similarity, the ratio of forces acting on the simulated mechanical process and the model must be the same, that is, the ratio of densities, for example, density, which again represents the “mass” while maintaining the geometric, kinematic similarity [18]:

$$K_3 = \frac{\rho}{\rho\prime} \tag{5}$$

Due to the use of industrial effluents in the experiments conducted in this laboratory, the densities in nature and in the model are equal, therefore K3 = 1.

After determining the geometric parameters of the model based on the laws of similarity in the laboratory of the Department of Hydraulics and Hydroinformatics of the "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" of the National Research University, a model of a local treatment plant with a vertical sump was created (Fig. 1)

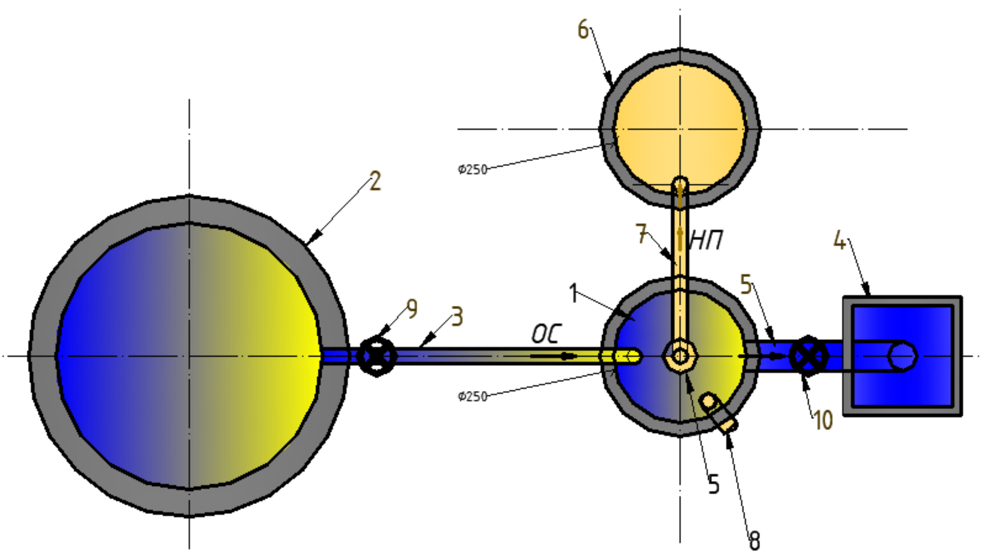

Fig. 1. Top view of the layout of local treatment facilities with a vertical sump for industrial wastewater treatment

1 - a vertical sump made of transparent material (plexiglass) with a diameter of 25 cm, a height of 50 (working height 45) cm, the upper part is open, the lower is closed; 2 - sewer tank with a capacity of 80 liters; 3 - a pipe (bell) with a diameter of 25 mm, which discharges wastewater into a vertical sump; 4 - filter; 5 - branch pipe with a diameter of 20 mm, through which purified water is discharged from the vertical sump to the filter; 6 - tank for collecting oil and oil products; 7 - socket with a diameter of 20 mm, separating flakes and oil products in a vertical sump; 8 - branch pipe with a diameter of 25 mm, through which the precipitated precipitation flows; 9 - valve for regulating the flow of primary wastewater; 10 - valve that regulates the flow of settled water.

In the model of a local treatment plant with a vertical sump, experiments and calculations for car wash wastewater were carried out in the following order (Fig. 2):

1. Waste water tank 2 is filled with waste water from car washes;

2. The valve 9 is opened in the socket 3, which discharges wastewater into the vertical sump and the start time of the test is set;
3. In the vertical sump 1, we control the level of the drain until it reaches the height of the drain socket 7 and open the control valve 10;
4. It is observed how much liquid passed during the experiment from the socket 7;
5. The experiment continued until the end of the runoff in tank 2 and this time was determined, i.e. the duration of the experiment.
6. The amount of flakes and oil products extracted during the experiment was determined by volume;
7. During the experiment, the amount of purified water that passed to the post-treatment stage was determined by the volumetric method;
8. The amount of liquid and sediment remaining in the sump was also determined by the volumetric method;
9. Samples of flakes and oil products, liquid precipitation, water were taken for the next stage of purification in liter containers, each separately, for chemical analysis;

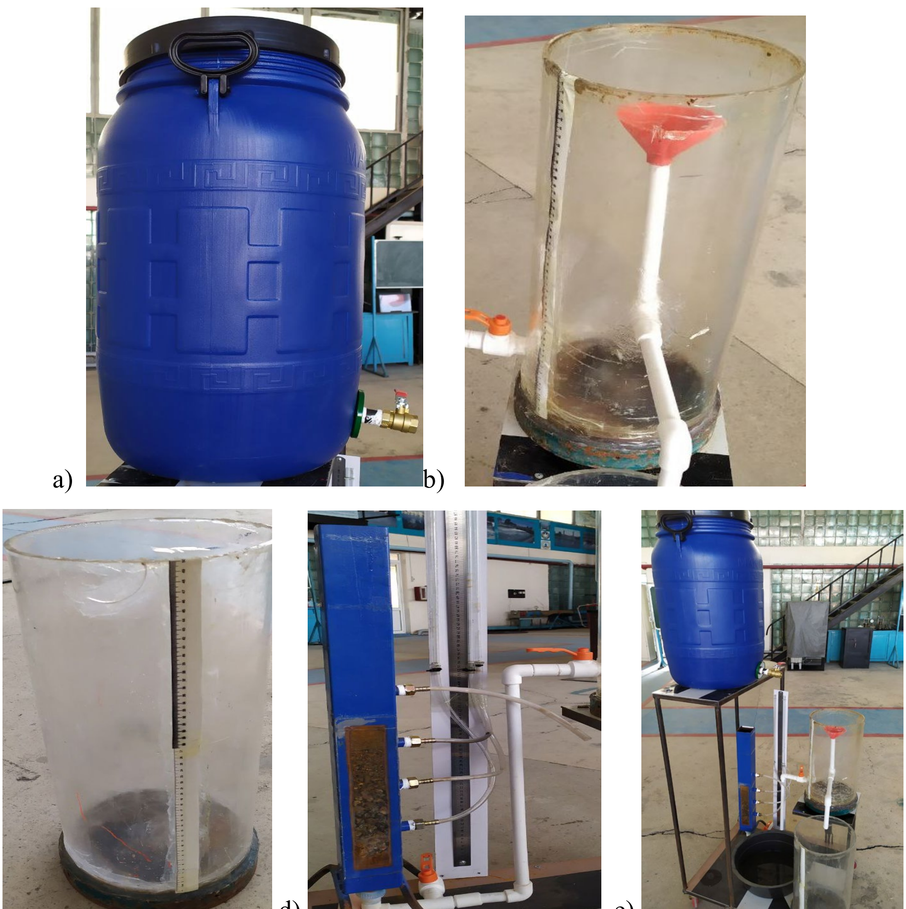

Fig. 2. Model of laboratory local treatment facilities with vertical settling tanks: a) wastewater tank; b) vertical sump; c) flakes and oil storages; d) filter e) model of local treatment facilities with vertical settling tanks.

10. Waste water from car washes, i.e. primary samples were taken and sent to a chemical laboratory to study their chemical composition;

11. Chemical-laboratory analysis and hydraulic calculation of treatment facilities were carried out;
12. Based on the results of the experiment, recommendations were developed on the nature of local treatment facilities.

In the experiment, the water consumption was determined by the following formula [1, 2, 3, 5, 6, 8, 9, 10, 13, 14, 18]:

$$Q = \frac{W}{T},\ l/s \tag{6}$$

3 Results and discussion

Based on hydraulic, mathematical and physical formulas, the parameters of the proposed model of the vertical settlement of the local treatment plant were calculated (Table 1). The chemical composition of purified water was analyzed in the developed model (Table 2). Based on the calculations carried out in the experiments and analysis of the chemical composition of the treated water, the measured values of the calculated parameters for the nature of the local treatment facilities were recommended (Table 3)

Table 1. Calculation values of the local treatment plant model

H_s	$H_{w.s}$	D_s	W_s	$W_{v.w.t}$	H_o	$D_{o.}$	$W_{o.}$	T	Q	$H_{o.o}$	$W_{o.o}$	$H_{s.s.}$	$W_{s.s}$	W_p	E
m	m	m	l	l	m	m	l	s	l/s	m	l	m	l	l	%
0.5	0.45	0.25	22	80	0.5	0.25	24.5	2400	0.033	0.03	1.47	0.20	9.8	68.73	60

The efficiency of the vertical settler in the model was determined as follows [1, 2, 3, 5, 6, 8, 9, 10, 13, 14, 18]:

$$C = 100\% \cdot \frac{C_1 - C_2}{C_1} = 60.34\% \tag{7}$$

Table 2. The initial and post-treatment chemical composition of industrial effluents, resented in the vertical settling tank model

Designation	pH_0	$C_{s.s.}$	C_o
Unit of measurement		mg/l	mg/l
Initial composition of water	7.5	870	9.5
The composition of water after settling	7	345	3.5

Table 3. Recommended dimensions for measuring local wastewater treatment plants

$H_{s.}$	$H_{w.s}$	D_s	W_s	H_o	D_o	W_o	T	Q	$H_{o.o}$	$W_{o.o}$	$H_{s.s}$	$W_{s.s}$	W_p	E
m	m	m	l	m	m	l	s	l/s	m	l	m	l	l	%
4	3.6	2	11264	3.6	2	11264	2400	0.033	0.24	1.47	0.20	9.8	68.73	60

The designations given in the table: Hs - sump height; Hw.s. - working sump height; Ds - diameter of the sump; Ws - volume of the sump; Wv.w.t - volume of the waste water tank;

Ho - height of the oil trap tank; Do - diameter of the oil trap tank; Wo - volume oil trap tank; T - duration of the experiment; Q - wastewater consumption during the experiment; Ho.o - the height of the occupied oil product level during the experiment; Wo.o - the volume of the allocated petroleum product during the experiment; Hs.s - height of sediment and liquid in the sump; Ws.s - volume of sediment and liquid in the sump; Wp - volume purified water; Э - the efficiency of the vertical settler.

Typically, the efficiency of wastewater treatment in settling tanks is 40-60%. The fact that the efficiency of the vertical settling tank of this model is 60.34% indicates that the design parameters of the model turned out to be correct and the experiment was successful.

4 Conclusion

In order to prevent problems during the construction, operation and reconstruction of treatment facilities of settlements and industrial enterprises, in order to increase the efficiency of their treatment, first of all, create their models, conduct experiments and calculations on them and make predictions, their nature can be achieved.

Thanks to the vertical settling tank model created in the article and the calculation work, it is possible to develop an economical and efficient sample of a settling tank for industry and small settlements. In addition, with the help of one model, it will be possible to create a catalog of mixers designed for various water consumption and ensure a fast pace of construction work.

The linear scale of modeling makes it possible to create sedimentation tanks of various design parameters, changing K1 = 8, and the model time scale K2 = 1, in which the working activity accelerates or, conversely, slows down to the required degree.

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