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Selecting wastewater treatment filters using local raw materials

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Abstract. Currently, in a situation where there is a shortage of fresh water around the world, there are increasing problems waiting to be solved, such as protection of water resources, effective use, and prevention of changes in their physical and chemical conditions. As one of the solutions to these problems, it is considered to make the treatment of waste water suitable for reuse or to achieve it by carrying out theoretical and practical research aimed at discharging ecologically clean water into nature. The article develops recommendations for water treatment and reuse using local raw materials for filter devices widely used in wastewater treatment by small enterprises. Experimental tests and hydraulic calculations were carried out for the use of local gravel, quartz sand, activated bentonite and coal, as well as industrial waste rubber granules as filter load. Taking into account the substances contained in their wastewater, the cleaning parameters were determined and recommendations were developed for the conditions of use. It was proved that the cleaning efficiency of activated charcoal or bentonite filters can be reached up to 90-96% for enterprises with high content of oil-oil products and surfactants. Using quartz sand, gravel, and rubber granules to clean wastewater from suspended matter has been proven to be 92-98% effective in experiments.

1 Introduction

Water consumption is used for drinking water, technical water, fire fighting, irrigation, landscaping and other purposes. Accordingly, water purification is carried out mainly depending on the purposes for which it is used. Wastewater treatment of industrial enterprises is selected depending on their reuse, discharge to nature or waste water networks, depending on their consumption, concentration of impurities, and they are divided into mechanical, chemical, physicochemical, biological and deep treatment stages and levels. Choosing the right filters for industrial wastewater treatment plants is of particular importance [1, 2, 3, 4, 5, 8, 11, 12, 13].

The process of filtering waste water is a much more effective facility than a clarifier, sand trap and other facilities in cleaning harmful small particles. Creating, constructing, installing, operating, and performing hydraulic calculation of water filters, which is one of

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the facilities widely used in water treatment, is a complex process. When designing wastewater filters, it is necessary to determine its filtration coefficient, filtration speed, porosity of the filter product, structural parameters: height, cross-section, layer thickness of the filter product, pressure loss in the filters, and perform calculation projects based on them [2, 6, 7, 8, 9].

2 Objects and methods of research

Conducting experiments on determining hydraulic calculation and structural parameters in order to improve wastewater treatment facilities in small enterprises, which causes a number of difficulties in practice.

At present, in the stage of development of small enterprises, the widespread use of the share of local raw materials is considered an urgent issue. In most of the leather factories, aviaries, furniture shops, iron shops and car washes located in the territory of our country, filters are supposed to be used in the local cleaning facilities according to the project, but in practice only the strainer is used and it was studied whether the filters are not used. The reason for the lack of use of filters was found to be that filter loads are expensive and manufactured overseas. As a result, wastewater from small enterprises is discharged into urban sewage networks, canals or ditches without complete treatment, which leads to the destruction of nature and creates environmental problems. [2, 8, 10, 14, 15, 16].

The purpose of the article is to conduct a research on filters that can replace imported products using local raw materials, i.e. round quartz, activated carbon, activated bentonite and gravel.

Before conducting the research, the technology, water treatment capacity and treatment levels of local wastewater treatment facilities of small enterprises were studied. During the research, it was found that 70-80% of leather factories, aviaries, furniture shops, iron shops, car washes located in Tashkent city and our regions use imported synthetic products mainly as horizontal strainers and filters. As a result of not replacing the filters of some small enterprises, it was observed that the waste water was discharged into canals or ditches without being completely cleaned. [2, 8, 17, 18, 19, 20]

By using local raw materials instead of imported filters, complete wastewater treatment is the solution to such problems, and economic efficiency is achieved. Local rounded quartz, activated carbon, activated bentonite, gravel (fine-grained) and gravel (large-grained) can be used as filter products. Due to this, in order to use various local raw materials as filter load, their physico-chemical properties were studied, and based on this information, suitable filters for small enterprises were selected. The article provides an account of the experiments conducted on different fractions of the above-mentioned local raw materials for filter loading.

Filters studied in the experiment allow cleaning from suspended substances, surfactants, and oil-oil products. Suspended substances - sand, dry substances, iron substances, wood residues and similar substances; surfactants - soda, gel, soap, shampoo; petroleum products - kerosene, gasoline, lubricants and others.

Fig. 1. Overview of the experimental device.

The experimental device was implemented in the "Water filtration" device in the "HYDRAULIC" laboratory of the "Engineering Communications and Systems" department of the Tashkent State Transport University (Fig. 1). The device is equipped with reservoirs of primary wastewater and treated water, a centrifugal pump, and eight filters for different loads. The filter load of 6 of them was changed to local raw materials and experiments were conducted. A scale for visual control of the amount of filled water (from 0-100 liters) is installed. A shut-off check valve is installed on each filter and is designed to be used in pilot applications at the desired load. The filter device itself consists of inlet and outlet pipes, shut-off control valves, water consumption and pressure meters before and after the filter. It was possible to monitor the measured quantities through the control panel, and to keep the pressure constant during the experiment, a switch was used to control the rotation speed of the pump shaft [14, 15, 16].

Fig. 2. Tested filter device

In order to fill the filter with a new filler, it is necessary to turn off the device, ensure that the water flows out of the filters, and unscrew the nut of the intake nozzle (at the top of the filter) and push it towards the "G"-shaped pipe connection (it is provided with a flexible hose that allows movement). It is important that the necessary filler is poured into the filter hole using a funnel, and the pipe is assembled in the reverse order.

The round quartz in filter 1 is not replaced in the above manner. If necessary, the faucet is flushed with the flow of water from 1, and the control throttle 2 must be closed.

The approximate volume of each filter is not more than 5 liters.

The experimental device works in the following order. Water is delivered from the tank to the pump through the pipes using a round tap 19, then delivered to the flow controller using the pressure controller 18 and the reverse valve, the control throttle 1 and the block of 8 filters connected in series. When the water leaves the filter 8, it is poured into the reservoir through the control throttle 2. At the time of manufacture, the filters are supplied with the following fillers (numbered from left to right):

The filter raw materials in the first five cylinders in the pilot plant were replaced with the following raw materials.

1 - round quartz filter;
2 - filter activated carbon;
3 - filter activated bentanite;
4 - filter gravel (fine-grained);
5 - filter gravel (large grain);
6 - the filter is filled with industrial waste rubber granules.

The passage of water through the filter device is carried out in the following order - water enters the inlet of the filter 1 (the inlet of this filter, along with other filters, is located above it), fills its internal capacity. After that, samples are taken to check the purity of the filtered water through faucets 1-6, and it is discharged into the sewer through faucets 9-14 and 17. The pressure and temperature of the water at the outlet of the filter 1 are monitored using sensors D1 and T1, respectively. Water flows through the second and subsequent filters in the same way as above. Each filter is equipped with screens (Fig. 2) at the outlet of the water to prevent the filler from flowing to the next filters. [17, 18, 19, 20]

The stand is started using the switch on the control panel (Fig. 3). In this case, the "Network" indicator light will turn on and the data on the control panel (Fig. 4) will be loaded.

Fig. 3. Stand control panel

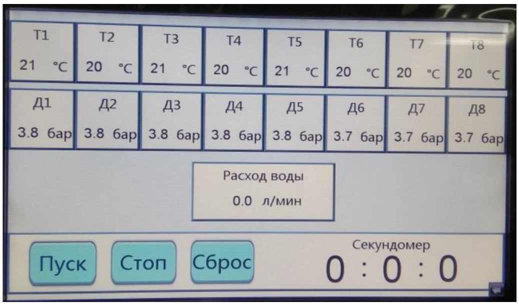

Fig. 4. Control panel

The consumption value is displayed in the corresponding window of the control panel. (Fig. 5).

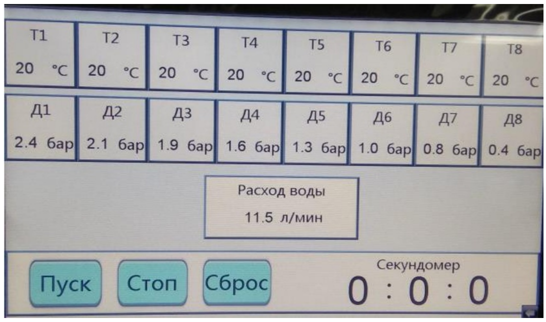

Fig. 5. Indicators of sensors when the consumption is maximum and the filters are not filled.

Using the results found in the experiment, the values of filtration coefficient, pressure gradient, water consumption, filter cross-sectional area, pressure lost in the layers of the filter product, hydraulic slope and filtration speed were found. The treatment levels of each filter load were determined by chemical analysis of the sampled waters.

Dimensionless complexes and simplicities used as similarity criteria (to ensure geometric and dynamic similarity) are called independent dimensionless parameters. In addition to them, dependent (required) dimensionless parameters are used in hydromechanics [4, 5].

The filtration coefficient is considered as a dependent parameter in the process of experimental deviceization of filters.

$$k_n = k_m$$

According to Darcy's law, the filtration coefficient is the ratio of the filtration rate to the pressure gradient:

$$k_f = \frac{v_f}{\mathrm{i}}$$

Napore gradient is defined as:

$$i = \frac{\Delta h_f}{l}$$

From the equality of filtration coefficients in the experimental device and in nature (k_n=k_m), the velocity scale is equal to:

$$\frac{v_n}{v_m} = 1, ie\ v_n = v_m$$

3 Results and their discussion

After determining the geometric parameters of the experimental device based on the laws of similarity, a number of experiments were carried out in the "HYDRAULICS" laboratory of the Department of Engineering Communications and Systems of the Tashkent State Transport University using the filter experimental device.

During the experiments, the filtration coefficient of the filter product, filtration speeds, cleaning efficiency, and pressure losses for different heights of the filter layers were determined [19, 20].

Formulas and quantities used in the implementation of hydraulic calculation in experiments:

1. The volume of water flowed during each experiment (W=100 l) was poured into measuring containers and measured separately;
2. Water consumption was found as follows (automatically determined on the control panel):

$$Q = \frac{W}{t}$$

3. The cross-sectional area of the filter did not change during the experiments and is equal to:

$$\omega = \pi r^2$$

4. Pressures lost in the layers of the filter product were determined separately for each layer using pressure gauges (sensors):

$$h_{f(i)}=D_i-D_{i+1}$$

where: $h_{f(i)}$ is the pressure lost in the filter layers, D_i and D_{i+1} are indicators of piezometers installed at the beginning and end of the layer, respectively.

5. The hydraulic slope was found based on the following formula:

$$i_i = \frac{h_{f(i)}}{l_i}$$

6. The filtration coefficients of local raw materials of medium and small grain size, rubber granule, coarse gravel, fine gravel and quartz sand, as well as activated carbon and bentonite were determined in experiments using Darcy's law (Table 1).
7. In the experiment, the values of the speed of wastewater (filtration speed) in each layer of the filter were determined according to the following formula:

$$v_i = k_i i_i$$

On the basis of the conducted experiments, the parameters of the proposed local treatment facility were calculated, and the parameters of the design parameters of the in-kind treatment facility were recommended through the created pilot device [17, 18].

In order to determine the change in the quality of the treated water, the composition of the initial wastewater and the chemical analysis after filtration were taken, and the treatment levels of the loads were compared.

The results of chemical analysis are presented in figures 6-8.

Table 1. Hydraulic calculation of filter loads

Designation		*d*	*l*	*W*	*Q*	*T*	*ω*
Unit of measure		*m*	*m*	*l*	*l/s*	*s*	m^2
Value in the model	Large gravel	0.1	0.4	15	0.214	70	0.0079
	Fine gravel	0.1	0.4	15	0.15	100	0.0079
	Rubber granule	0.1	0.4	15	0.23	65	0.0079
	Activated carbon	0.1	0.4	15	0.158	95	0.0079
	Active bentonite	0.1	0.4	15	0.153	98	0.0079
	Quartz sand	0.1	0.4	15	0.167	90	0.0079

Continuation of table № 1

Designation		D_1	D_2	h_f	i_i	k_i	V_i
Unit of measure		*m*	*m*	*m*		*m/s*	*m/s*
Value in the model	Large gravel	30	26	4	10	0.0017	0.017
	Fine gravel	30	21	9	22.5	0.0008	0.018
	Rubber granule	30	27	3	7.5	0.0023	0.0173
	Activated carbon	30	22.5	7.5	18.75	0.00091	0.0171
	Active bentonite	30	22	8	20	0.00088	0.0176
	Quartz sand	30	21.5	8.5	21.25	0.00085	0.0181

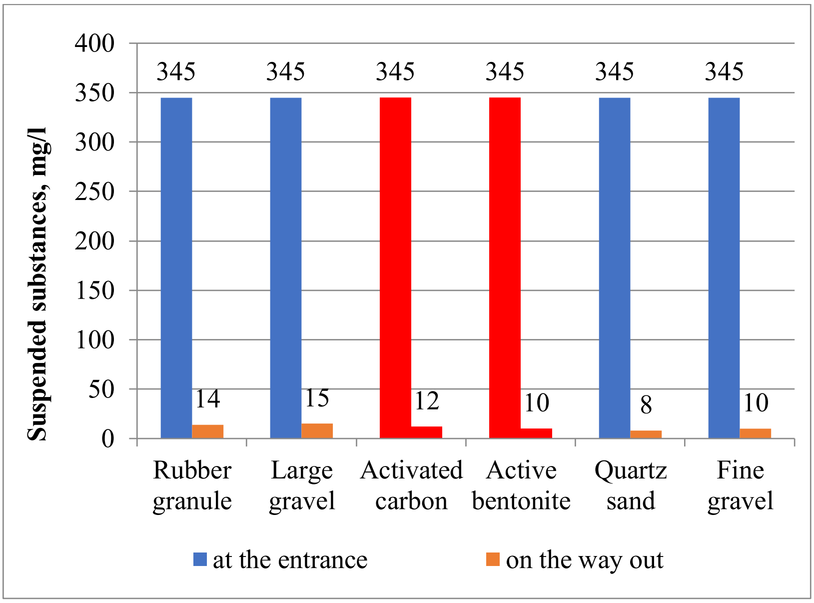

Fig. 6. Degrees of purification of wastewater from suspended matter in filter loadings

Fig. 7 shows the degree of purification of wastewater from suspended matter in the filter loads. It can be seen from the experiment that the degree of purification of the local raw materials used is approximately the same. Due to the high cost of activated carbon and activated bentonite, as filter raw materials, industrial waste rubber granule, large gravel, the use of small gravel and quartz sand is economically beneficial.

Fig. 8 shows the degree of purification of wastewater from surface folate substances in filter loadings. It can be seen from the experiment that activated carbon and activated bentonite have a high purification index. Therefore, these filter loads are recommended for practical use in car washes, aviaries, laundries and chemical processing plants.

Fig. 9 shows the degree of purification of wastewater from oil-oil products in filter loadings, as it can be seen in the experiment, the purification index of activated carbon and activated bentonite is high. Therefore, these filter loads are recommended for practical use in car washes, aviaries, laundries and chemical processing plants.

The cleaning efficiency of the rapid filter in the experimental device was equal to:

$$C = 100\% \cdot \frac{C_1 - C_2}{C_1}, \%$$

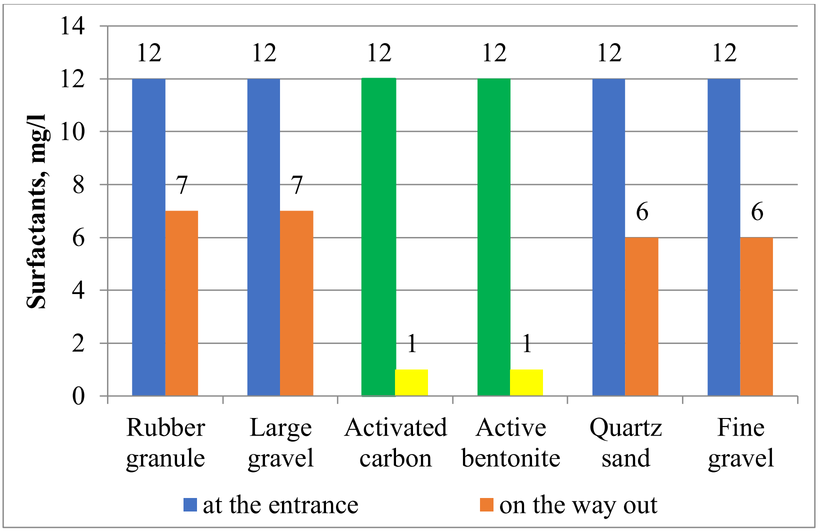

Fig. 7. Levels of purification of wastewater from surfactants in filter loadings

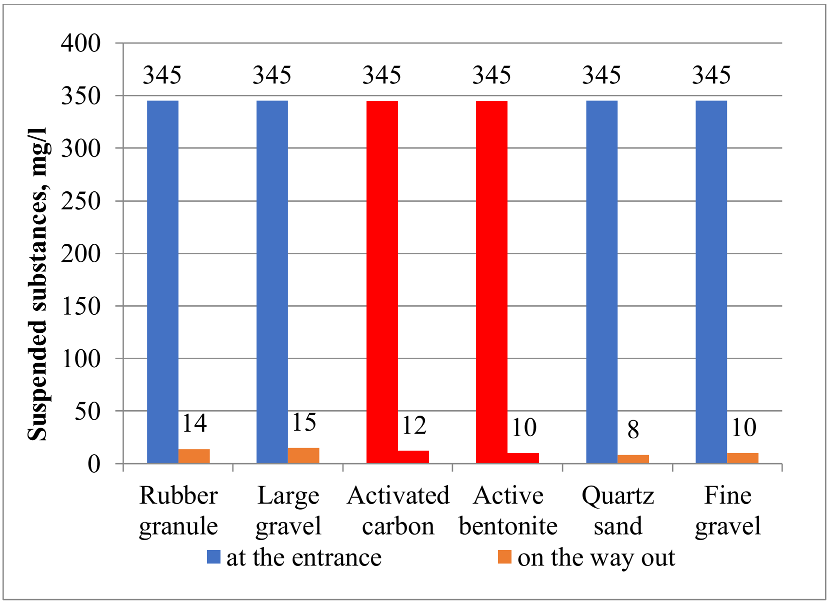

Fig. 8. Levels of purification of waste water from oil-oil products in filter loadings

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Table 2. The cleaning efficiency of the rapid filter

Designation		C_1			C_2			C		
Unit of measure		mg/l			mg/l			%		
		Suspended substances	Surfactants	Petroleum products	Suspended substances	Surfactants	Petroleum products	Suspended substances	Surfactants	Petroleum products
Value in the model	Rubber granule	345	12	5	14	7	4.8	96	42	4
	Large gravel	345	12	5	15	7	4.6	96	42	8
	Activated carbon	345	12	5	12	1	0.3	97	92	94
	Active bentonite	345	12	5	10	1	0.5	97	92	90
	Quartz sand	345	12	5	8	6	4.2	98	50	16
	Fine gravel	345	12	5	10	6	4.2	97	50	16

4 Conclusions

The use of industrial waste rubber granules, gravel and sand as filter raw materials for the purification of suspended substances in water has a high purification index and low cost, and the use of active bentonite and activated carbon as filter raw materials for the purification of surfactants and petroleum products has a high purification index. If the waste water contains all three substances, it is recommended to use a combination of coal and bentonite with gravel, sand, rubber granules as a filter load.

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