Use of different types of reagents before wastewater treatment by biofiltration technology

Pavel Starostin *, *Andrey* Shatalov

Peoples Friendship University of Russia (RUDN University), Departement of Environmental Safety and Product Quality Management, 6 Miklukho-Maklaya st., Moskow, Russia

Abstract. Biofilters are used for biological wastewater treatment and refer to facilities in which the process of water treatment is carried out with the help of biofilm attached to the load. The use of these filters is becoming more and more relevant in the modern world due to the growing pollution of the environment. This method is effective in treating wastewater from organic matter. It is more environmentally friendly and sustainable. The purpose of this work is to perform a set of analyses of incoming raw sewage treatment and obtain technological parameters of the process of reagent treatment to reduce pollution before the use of biofiltration. The research was carried out by laboratory tests, the direction of which was to determine: the optimal types of reagents, points and sequence of their dosing, correlation of sedimentation/removal of compounds of pollutants depending on the change in doses of reagents, the effectiveness of using different coagulants and flocculants, the optimal combination of reagents. As a result of the laboratory tests conducted, the study of pretreatment issues before the main stage of treatment on biofilters was carried out, the initial data obtained by sampling from the industrial site were analyzed, and a feasibility study of the choice of biofiltration technology was given.

1 Introduction

The use of biofilters is becoming more and more relevant in the modern world due to the growing environmental pollution and threat to human health. Biofilters are devices based on the use of living organisms to purify water, air and soil from various pollutants.

One of the main advantages of biofilters is their efficiency in cleaning the environment from harmful substances. Thanks to specialized microorganisms, biofilters are able to break down pollutants into safe products, which reduces pollution and the risk of disease. [1]

In addition, biofilters are a more environmentally friendly and sustainable way of cleaning the environment compared to chemical methods. They are not only efficient but also cost-effective as they require less energy and resources to operate.

* Corresponding author: 1142220943@rudn.ru

Thus, the use of biofilters has a huge potential to protect the environment and human health. They can significantly improve the quality of air, water and soil, making them one of the key tools in fighting pollution and preserving nature for future generations.
Biofilters, or bioreactors with fixed and movable load, are used for biological wastewater treatment and refer to facilities in which the water treatment process is carried out by means of biofilm attached to the load. Biofilters with a fixed load are divided into irrigated biofilters, in which the incoming water is distributed over the surface of the load and passes through it in separate jets or drops, and flooded biofilters, through the load of which water flows in a continuous stream.

In bioreactors (filters) with a movable load, the process of biological treatment is carried out by moving the load with biofilm in the flow of treated water. These bioreactors can be divided into the following groups: submerged rotating biofilters; bioreactors with floating backfill and bioreactors with fluidized fine-grained load.
This is a sewage treatment plant filled with a feed material through which wastewater is filtered and on the surface of which a biological film consisting mainly of aerobic microorganisms develops. Wastewater treatment is carried out due to the vital activity of these microorganisms.

Biofilters can be of different types and designs, including suspended, chamber, drip filters and others. Each type of filter has its own advantages and disadvantages, and the choice of a particular type depends on the specific conditions of operation. [2-4] The external of the filter is shown in Figure 1.

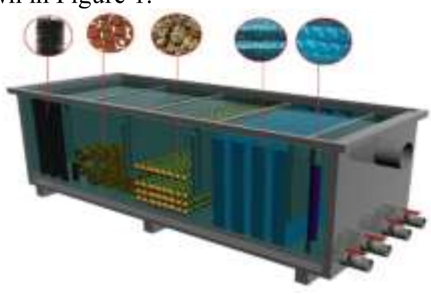

Fig. 1. Biofilter model [3]

The reagent types given in this article are tools that allow technologists, operating engineers and chemical engineers to carry out technological start-up and further technological control of wastewater treatment plants under real operating conditions. The operation of sewage treatment plants is a rather complex and expensive process, taking into account the non-stationarity of quantitative and qualitative characteristics of incoming wastewater. To ensure maximum efficiency of the existing facilities, operating services should regularly monitor the technological parameters and characteristics of biological facilities [5,6], compare them with the optimal (design) parameters and determine the best ways to achieve in each specific situation the maximum efficiency of treatment facilities, in particular biological filters. This article summarizes the main technological parameters and selection principles for different types of reagents.

2 Materials and methods

The purpose of the study was to carry out a set of analyses of raw sewage coming to treatment and to obtain technological parameters of the reagent treatment process to reduce pollution before using biofilters.

Laboratory tests were carried out on wastewater from the existing site of the Leningrad region water and wastewater treatment complex. Wastewater is divided by the nature of contamination into industrial and domestic wastewater. It is planned to construct treatment facilities using standard biological treatment technology in aerotanks and additional treatment technology in biological filters.

At present at the stage of commissioning there are problems with debugging of pre-reagent treatment. Therefore, the study will be divided in stages.

As part of the study, samples were taken from different points of the industrial site and a model combined effluent was produced with a percentage of 80% domestic effluent, 15% concentrate from RO plants, and 5% regeneration effluent.

The list of reagents used in laboratory tests is given in Table 1.

The list of measuring instruments and laboratory utensils is given in Table 2.

Table 1. List and characteristics of reagents

Reagent grade	Assignment
Aluminium sulphate, 18-aqueous	Coagulant: separation of dispersed phase substances from the medium, reduction of COD level
Azimut-D, composite coagulant	Coagulant: separation of dispersed phase matter from the medium, reduction of COD level
Sodium hydroxide	Alkaline: pH correction, reduction of hardness salt concentration
Fe sulfuric acid	Coagulant: separation of dispersed phase substances from the medium, reduction of COD level
Fe III chlorine	Coagulant: separation of dispersed phase substances from the medium, reduction of COD level
Sodium hypochlorite	Pre-oxidation of organic substances, disinfection
Hydrochloric acid	Adjustment of pH
Anionic non-ionogenic flocculants	Coagulation intensification
Ferrous sulphate 3	Coagulant: separation of dispersed phase matter from the medium, reduction of COD level
EXTRASORB coconut active charcoal, GAC-12X40	Sorption of organic substances, removal of residual chlorine

Table 2. List of measuring instruments and laboratory glassware

Name	Model
pH-meter-millivoltmeter	pH-420
Liquid chromatograph	“Jetchrome.”
Fluid Analyzer	“Fluorat-02-3M”
UNICO spectrophotometer	S2100
Inductively coupled plasma emission spectrometer	OPTIMA 2100 DV
Laboratory electronic scales	CE-224C
Electric stove	SOKOL 1.0 kW/220V/50 Hz, TEN 70-0101
Laboratory magnetic stirrer	Tugler MM-135

3 Results and Discussion

3.1 Analysis of initial runoff and pooled runoff (Stage 1)

The combined wastewater in the ratio 80/15/5 was submitted for analysis to the laboratory. Quality indicators of the investigated wastewater are given in Table 3.

Table 3. Indicators of the composition of the wastewater under study are presented

Indicator	Unit of measurement	Combined effluent
TSS	mg/l	6.81
pH	unit pH	7.663
Ca	mg-eq/l	7.6
Mg	mg-eq/l	4.6
Mineralization	mg/l	1 113
SO4	mg/l	374.6
COD	mgO/l	2356.15
NH4	mg/l	14.04
NO3	mg/l	28.026
NO2	mg/l	1.564
Cl	mg/l	99.152
HCO3	mg-eq/l	5.1
BOD	mgO/l	567.29

Based on the results of the analysis of the composition of the combined effluent, taking into account the requirements for wastewater treatment, the priority groups of pollutants to be removed at the stage of reagent treatment were determined: Hardness salts, COD, BOD, and Ammonium ions.

3.2 Reagent treatment of wastewater with various coagulants and flocculants (Stage No. 2)

Investigation of the effect of different coagulants and flocculants, as well as their combination on the degree of removal of a group of contaminants. The sequence of reagents introduction: coagulant, flocculant. The effluent treated with reagents was sedimented, clarified water was filtered through a paper filter White Tape. The results of the experiments are summarized in Table 4.

In this series of experiments such reagents as FeCl3, FeSO4, Superfloc A-130, Superfloc N-100, Azimut D, DX, DR were tested.

Table 4. Addition of organic coagulants and flocculants

Indicator	Unit of measurement	Initial flow	Filtered	% efficiency
TSS	mg/l	6.81	2.72	40
pH	unit pH	7.663	8.1	-
Ca	mg-eq/l	7.6	3.8	50
Mg	mg-eq/l	4.6	4.6	0
Mineralization	mg/l	1 113	1477	0
SO4	mg/l	374.6	374.6	0
COD	mgO/l	2356.15	1531.5	35
NH4	mg/l	14.04	11.01	22
NO3	mg/l	28.026	28.026	0

Indicator	Unit of measurement	Initial flow	Filtered	% efficiency
NO2	mg/l	1.564	1.564	0
Cl	mg/l	99.152	99.152	0
HCO3	mg-eq/l	5.1	5.1	0
BOD	mgO/l	567.29	510.56	10

According to the results of the experiments the following conclusions were made - the best result was shown by oragnic coagulant Azimut DR in the dosage of 0.3 mg/l, the sludge is quickly formed, settles well and is quickly filtered.

3.3 Reagent treatment of wastewater with various coagulants and flocculants with the addition of sodium hypochlorite (Stage No. 3)

At this stage, the effect of adding sodium hypochlorite to the experimental samples to further reduce COD, BOD, and ammonium oxidation was investigated. Table 5 shows the results of the analyses of the experiments with the addition of sodium hypochlorite.

Table 5. Analytical results of experiments with the addition of sodium hypochlorite

Indicator	Unit of measurement	Initial flow	Filtered	% efficiency
pH	unit pH	7.66	8.1	-
COD	mgO/l	2356.15	1460.8	38
NH4	mg/l	14.04	9.126	35
NO3	mg/l	28.026	23.82	15
NO2	mg/l	1.564	1.85	0
BOD	mgO/l	567.29	510.56	10

According to the results of the conducted experiments the following conclusions were made - the use of sodium hypochlorite has an insignificant effect on the efficiency of purification of the analyzed water. However, due to the addition of own domestic wastewater to the initial effluent, it is necessary to use sodium hypochlorite for disinfection.

3.4 Settling kinetics of suspended solids and calculation of sludge thickening (Step 4)

The results of sedimentation kinetics of suspended solids after addition of reagents are given in Table 6. The sludge volume reduction factor is given in Table 7.

Table 6. Experimental data and calculation results of sedimentation kinetics

Settling time, min.	Suspended solids concentration, mg/l	Height of sedimentation layer, mm	Eff, %	Hydraulic coarseness, mm/s
0	471	0	0	-
2	86	16	81.74	0.13
5	77	18	83.65	0.06
15	52	15	88.96	0.02
30	28	18	94.06	0.01

Table 7. Experimental data and calculation results of sedimentation kinetics

Sludge moisture. W	Settling time. min	Sludge layer height. m	Sludge volume. m3	Sludge weight. kg	% dry matter	Volume reduction ratio
99.34	15	0.0019	5.40E-05	5.37E-02	6.61E-01	1
98.95	45	0.012	3.39E-05	3.39E-02	1.05E+00	0.63
98.74	60	0.01	2.83E-05	2.83E-02	1.26E+00	0.53
98.43	120	0.008	2.83E-05	2.26E-02	1.57E+00	0.42

According to the results of the experiments, the following conclusions were made - Suspended matter has well-formed, heavy flakes, The amount of suspended matter (flakes) having hydraulic coarseness more than 0.13 mm/sec is about 80% and can be detained in the sedimentation tank, The sludge falling to the bottom is compacted within 1 hour almost 2 times, The initial moisture content of the sludge is 99.3%, after 2 hours of compaction, the moisture content of the sludge is 98.4%.

3.5 Technical and economic evaluation of wastewater treatment using biofilter

In order to effectively calculate the feasibility study of biofilter use, a comparison between the standard biological treatment technology is given, namely: raw sewage collection, reagent treatment, primary sedimentation, aeration tank, secondary sedimentation, pressure filtration (sand filter) as a step of additional treatment of suspended solids and sludge removal.

Table 8 summarizes the feasibility study for the supply of sand filters and biofilters. Based on these data, it can be said that the supply of biological filters is predominantly favorable compared to FOV. But in case of application of clarifier-vertical filters with sand loading it is possible to save in occupied area.

Table 8. Sludge volume reduction factor

Name	Sand filter	Biofilter
Water supply pump to the filter with VFD	>50,000 rub.	-
Filter material	>5 000 rub.	<3 000 rub.
Cost of treated water 1 m^3	30 000 rub.	20 000 rub.
Purification efficiency	90%	80%
Number of people for manual operation	>2 per.	1 per.
Filter cost	> 200 000 rub.	50 000 - 100 000 rub.
Total, rub.:	> 285 000	> 123 000

4 Conclusions

Preliminary, on the basis of laboratory tests, it is proposed to use the following doses and the following technological sequence of reagent introduction for treatment of combined wastewater:

- Ferrix Coagulant - 30 mg/l,
- Aquifol flocculant, - 1 mg/l,

- Adjusting the pH to a value 7,0,
- Sodium hypochlorite dosing 2 - 3 mg/l,
- The temperature of the effluent fed to coagulation should be between 20 and 25^{0}C,
- Use carbon filter to remove residual suspended solids, free chlorine and reduce COD value,
- Based on the results of laboratory tests, a test program was developed to optimize biological wastewater treatment processes and operating costs.

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