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Optimization of the Technological Treatment Process of Waste Water of Finishing Enterprises.

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ABSTRACT

By the physical state of contamination and its origin, wastewater of the finishing enterprise represents a complex physical and chemical multicomponent system. For a rational treatment technology, wastewater of the enterprise was divided into two streams. On the basis of this division, an optimal scheme of the water balance was developed, which took into account the flow rate of water for various types of losses, discharge and the addition of fresh process water to compensate for its costs in the system of re-circulating water supply. Based on the compiled water balance scheme, the physical and chemical composition, type and concentration of specific contaminants, as well as with regard to the volume of slightly and highly contaminated streams, there was developed a complex technology of treatment and re-circulating water supply of finishing enterprises, where the functionalities and specific loads onindividualtreatmentfacilitieswere distributed. The efficiency of the developed complex treatment technology was tested in experimental-industrial conditions by the example of real wastewater. Theoperatingefficiency andtechnological parameters for the calculation of individual facilitieswere given.It was proved that the implementation of the developed environmentally friendly treatment technology in the finishing enterprisewoulddecrease theflow rate by 60%, reduce the discharge of wastewater into water bodies and ensure the ecological safety of the environment.
Keywords: water balance, treatment technology, parameters, ecological safety.

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INTRODUCTION

The relevance of this research area is based on the need to further develop and improve the re-circulating systems of water supply of finishing enterprises. The existing systems do not have a clear comprehensive approach to solving this problem and do not provide the ecological safety of the environment.

The present paper proposes an integrated approach with the use of system analysis, mathematical and functional modeling, allowing to select the most efficient and environmentally friendly technology of re-circulating water supply at the very stage of project developments.

The practical implementation of the proposed technology will significantly reduce the consumption of fresh water, decreasethe environmental damage caused by enterprises, and will provide an opportunity to assess and manage the environmental situation in the regions with finishing enterprises.

The purpose of this work is to optimize the technological process of treatment and the creation of re-circulating water supply in finishing enterprises of the light industry, providing the ecological safety of the environment.

The research includes the following main objectives:

- the analysis of the technical and technological characteristics of water consumers and the quantitative and qualitative composition of slightly and highly contaminated wastewater, and the development of an optimal scheme of the water balance of finishing enterprises;

- based on the results of experimental-industrial studies, the selection of the rational technology of wastewater treatment was made and the optimal operating parameters of the basic facilities and devices were defined.

The treatment of industrial wastewater and the introduction of the re-circulating water system in enterprises is one of the most important elements to ensure the ecological safety of the environment. To date, there is a number of works by Russian and foreign scientists [Shamyan1997; Laskov, Trunova and Alekseev 1995; Dittrich 1981] on the development of rational systems and water disposal schemes, the improvement of treatment methods and the systems of recycling water supply, the development of requirements for the quality of water used in the technological processes of finishing enterprises. There is limited research on the development of technical and environmental bases of the complex technology of treatment and re-circulating water supply ensuring the environmental safety and the study of the extent of impact of their ecological and economic damage both at the local-regional and national levels. Mathematical and functional modeling of the treatment technology [Toibayev2005; Toibayev, Omarbekuly and Rysbaiuly 2006]allowing to optimize the process by changing the control parameters of purification at the very stage of project developments and the selection of the most rational scheme of local treatment in each case also remain poorly explored in the well-known works.

METHODS

The methodological basis for the development of the technology of treatment and re-circulating water supply of finishing enterprises is the concept, which recommends the comprehensive elaboration of a water supply technology of finishing enterprises, including the optimization and ecologization of water use in all operations and processes. The development of research methods, first of all, took into account the conditions for obtaining the reliable results that served as the basis for selecting the performance rate of the experimental setup. The experimental research was conducted in the experimental-industrial facility, built in the "Almaty Cotton Plant" finishing enterprise. Studies were carried out on real wastewater. The monitoring of physical and chemical parameters of wastewater was implemented using uniform methods and standard techniques of measurement with the help of colorimetric, potentiometric, ionometric and other instruments. To determine the concentration of colorants in wastewater and circulating water, there was used the developed certified method of determining the total content of colorants, approved by the State Standard of the Republic of Kazakhstan.

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The optimal scheme of the water balance in the finishing enterprise

The water balance scheme and the complex technology of treatment and re-circulating water supply of the finishing enterprise have been developed with regard to all the changes associated with the transition to a market economy, the opportunity of the re-use of treated water in the technological process and the assurance of the environmental safety.

In view of the above, wastewater of the finishing enterprise and textile mill "Almaty Cotton Plant" (ACP) was divided into two streams. This division of industrial wastewater is technically possible under the current system and the scheme of water disposal in the enterprise. An optimal scheme of the water balance of the ACP finishing enterpriseis shown in Figure 1. This scheme takes into account the various types of water loss and discharge and the addition of fresh process water to compensate for its costs in the system of re-circulating water supply.

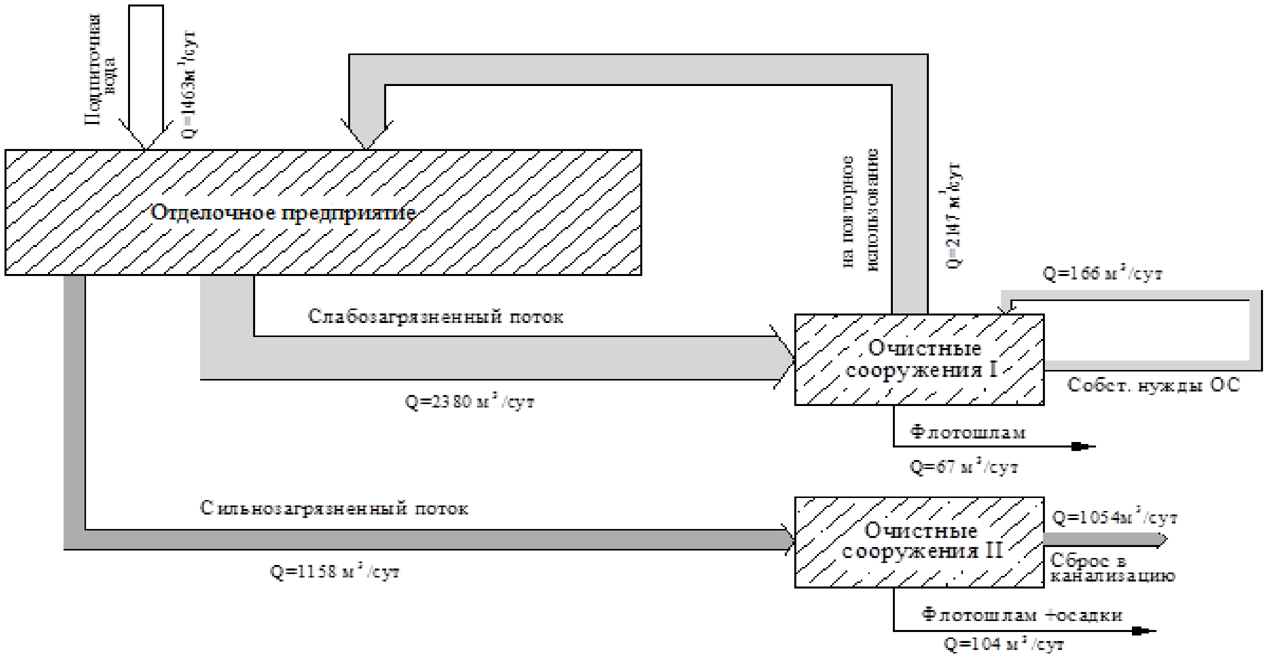

Figure 1: Water balance scheme of the finishing enterprise. Translation of terms: Отделочноепредприятие – Finishing enterprise; Подпиточнаявода – Make-up water; Слабозагрязненныйпоток – Slightly contaminated stream; Сильнозагрязненныйпоток – Highly contaminated stream; м^3/сутки -m^3/day; Очистныесооружения - Treatment facilities; Флотошлам - Flotation sludge; Флотошлам+ осадки - Flotation sludge + sediments; Наповторноеиспользование – For re-use; СобственныенуждыОС – Auxiliaries of treatment facilities; Сбросвканализацию – Discharge to sewers.

In accordance with the water balance scheme of the enterprise, the slightly contaminated stream includes industrial wastewater of the bleaching shop (without first dirty flushing) and water from soap washing ranges and machines with a total expenditure of about 2,380 m^3 / day.

The highly contaminated (colored) stream includes industrial wastewater of the dyeing-printing and finishing shops and certain chemical plants, as well as the generated first dirty washing water of the bleaching shop with a total expenditure of about 1,158 m^3 / day.

The physico-chemical composition of wastewater of the mentioned streams is presented in Table 1.

Table 1: The average physico-chemical composition of slightly and highly contaminated wastewater streams

Key indicators of wastewater	Wastewater streams	
	slightly contaminated	highly contaminated
Suspended substances, mg/dm^3	85-210	160-395
Cotton plant, mgO_2/dm^3	195-520	350-810
Dry residue, mg/dm^3	940-2200	2015-3120
Synthetic surfactants, mg/dm^3	7,3-37,0	17,5-65,5
Colorants, mg/dm^3	2,5-9,45	25-58,5
pH	7-11	5,7-10
Sulfides, mg/dm^3	Absent	5,5-11,5
Ammoniacal nitrogen, mg/dm^3	1,5-3	10-15
Total chromium, mg/dm^3	Absent	trace amount

The elaboration of an experimental-industrial facility of the complex technology of waste water treatment in finishing enterprises

On the basis of the developed water balance scheme, the physical and chemical composition, type and concentration of specific contaminants, as well as with regard to the volume of the mentioned streams, there was developed a complex technology of water treatment of the ACP finishing enterprise:

- The slightly contaminated stream: equalization - reagent pressure flotation - filtration - ozonation - filtration – ion exchange (30% Q day), then the treated water from the reservoir tank is supplied to the system of re-circulating water supply of the enterprise. The adjustment of the stream treatment scheme is possible, and it is under definition in the pre-commissioning period of treatment facilities;

- The highly contaminated (colored) stream: equalization - coagulating - thin-layer sedimentation - pressure flotation, then the treated water in compliance with the permissible concentration of harmful substances (maximum permissible discharge) is discharged into the municipal sewage system.

The developed complex technology of treatment and re-circulating water supply of the ACP finishing enterprise is shown in Figure 2.

According to Toibayev [2008] and Toibayev, Taubaldiyeva and Kasabekova [2015], the functional loads by the facilities of the complex technological scheme are distributed as follows:

- a preparatory stage –equalization, preliminary reduction of high concentrations of contaminants;

- binding (combination) into the dispersive part of the basic mass of colorants, synthetic surfactants and other impurities - coagulation;

- separation of the dispersive part - sedimentation, pressure flotation;

- advanced treatment of suspended substances - filtration;

- removal of residual concentrations of colorants, synthetic surfactants and disinfection of process water - ozonation;

- adjustment of the salt content - ion exchange.

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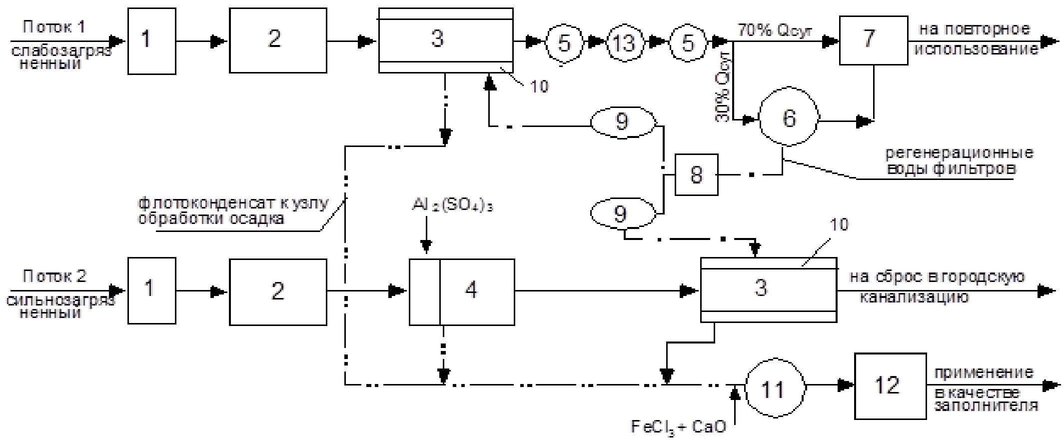


Figure 2: The complex technology of treatment and re-circulating water supply of the finishing enterprise.*Note.*1- fiber collector; 2-equalizing tank; 3 - pressure flotator; 4- thin-layer sinker; 5- granular filter; 6 – ion-exchange filter; 7 -treated water tank; 8 – reservoir-tank; 9-supply tank; 10 – foam-receiving flotator section; 11 -sludge consolidation tank; 12–filter-press; 13 - ozonator (reactor).Translation of terms: Поток 1, 2 – Stream 1, 2; Слабозагрязненный - slightly contaminated; Сильнозагрязненный - highly contaminated; Флотоконденсаткузлуобработкиосадка – Flotation condensate to the node of sludge treatment; Qсут – Q day; Наповторноеиспользование – For re-use; Регенерационныеводыфильтров - Reclaimed filter water; Насбросвканализацию – For discharge to sewers; Применениевкачествезаполнителя - Use as a filler.

Based on the results of laboratory studies [Toibayev2008; Toibayev and Myrzakhmetov 1990], we have developed the experimental-industrial facility of the complex wastewater treatment technology of finishing enterprises, which was operating in a flow mode with the capacity from 0.5 to 1.0 m^3/h.

A comprehensive research of the technology of treatment and re-circulating water supply of finishing enterprises was carried out, i.e. for all the facilities of the technological treatment scheme as a whole, not for its individual structures and devices. Therefore, in those facilities in which the technological operating parameters and modes were investigated in earlier studies [Toibayev and Myrzakhmetov1990; Toibayev 1997], these parameters have been rechecked and corrected in whole by the scheme, and for the individual facilities of the technological scheme (flotator, sinker, etc.) the operating modes and parameters have been determined again as a result of experimental-industrial studies. This is due to the change in the structural treatment scheme of slightly and highly contaminated streams, the functional purpose and the specific load on the individual treatment facilities and the technology of finishing of textile materials related to the upgrading of the technological equipment and devices, the nomenclature of the used colorants, synthetic surfactants and suspended substances.

The scheme of the experimental-industrial facility is shown in Figure 3.

The operating experience of the water treatment facilities of "YUZHTEKS" JSC (Shymkent) has shown the complexity of the operation and the low efficiency of the combined filter design –a thin-layer sinker [Toibayev 2005; 4, 9]. Therefore, this paper proposes the design of a thin-layer sinker, combined with a flocculation tank, and changes its location in the structural treatment scheme.

As a result of experimental-industrial studies, there have been re-established the design parameters and operating modes of the thin-layer sinker: coagulant dose, hydraulic size of particles, the slope of the flanges. In the process of ozonation and flotation wastewater treatment, the modes and parameters of these treatment facilities have also been re-set.

Given the changes in the technological process of finishing production and in other facilities of the technological wastewater treatment scheme, the optimal operating modes of facilities have been refined (granular, ion-exchange filters, etc.).

The experimental results have showed that the basic operating modes and parameters of facilities, as well as the efficiency of wastewater treatment in granular and ion-exchange filters are slightly different from those presented in the earlier works of the author and the literature [Shamyan1997; Toibayev 1997]. In this regard, we consider that there is no need to present a full description of the treatment process and the efficiency graphs of slightly or highly contaminated wastewater treatment. Therefore, the basic operating parameters and modes in the calculation and instrumentation of granular and ion-exchange filters are recommended to be taken according to these earlier works of Toibayev[2008], [1997].

As it is known, the effective operation of a complex of water treatment facilities is provided in the first place by their qualitative design. The design load on the treatment technology as a whole and on each element of treatment facilities should be at least correctly calculated with regard to the received contamination values of source, treated and re-circulating water and the operating technological parameters of each facility. The determination of these loads on facilities is of paramount importance for solving the problem of design optimization and rationalization as well. The most rational way to solve it would be to obtain a universal method for calculating the loads on treatment facilities, regardless of the diversity of technological schemes and initial wastewater values. This is possible only on the basis of formulating and solving the equations of material balances of re-circulating technological systems.

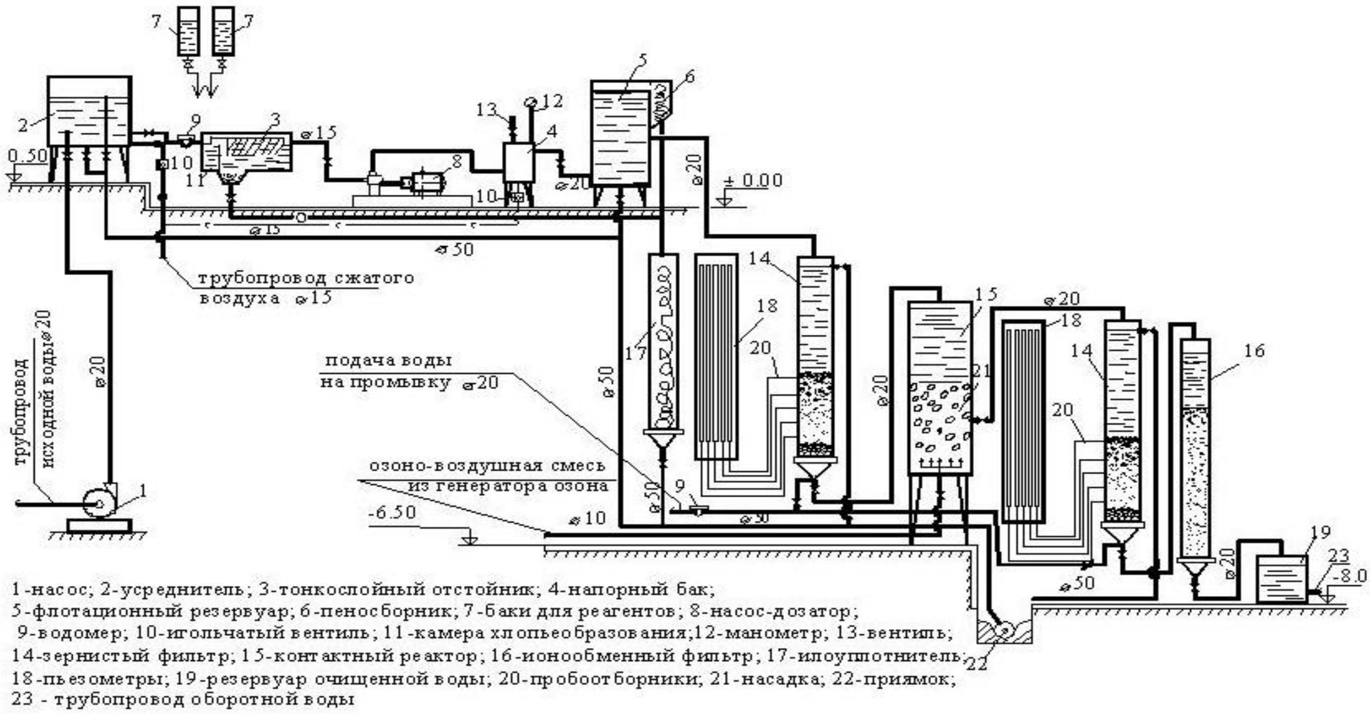


Figure 3: The experimental-industrial facility scheme. ***Note: 1 – pump, 2 - equalizing tank, 3 - thin-layer sinker, 4 - pressure tank, 5 - flotation tank, 6 – foam tank, 7 - tanks for reagents, 8 - metering pump, 9 - water meter, 10 - needle valve, 11 - flocculation tank, 12 - manometer, 13 - valve, 14 - granular filter, 15 - contact reactor, 16 – ion-exchange filter, 17 – sludge consolidation tank, 18 - piezometers, 19 - treated water tank, 20 - samplers, 21 – cap, 22 - pit, 23 - circulating water pipe.*** **Translation of terms: Трубопроводсжатоговоздуха – Compressed air pipe; Подачаводынапромывку – Water supply for flushing; Трубопроводисходнойводы – Source water pipe; Озоно-воздушнаясмесьизгенератораозона - Ozone-air mixture from the ozone generator.**

The wastewater treatment process is characterized by a system of quality indicators. The contaminated water, discharged after the use in the technological cycle, contains various components. The basic indicators are suspended substances, dry residue, synthetic surfactants, colorants and chemical oxygen demand (COD). The quantitative and qualitative composition of these components determines the physical and chemical state of wastewater – whether the given water stream is slightly or highly contaminated. To evaluate the physical and chemical state of the wastewater contamination, we have developed a mathematical and functional model of wastewater treatment in finishing enterprises.

According to the proposed mathematical and functional model of wastewater treatment [Toibayev, Omarbekuly and Rysbaiuly2006], during the development of the experimental-industrial research in the technological scheme the following control parameters were changed: wastewater rate, pressure in the pressure tank, the ozone dose, the duration of sedimentation, a coagulant dose, filtration rate and others.

The basic indicators in the source and treated water were pH, suspended substances, dry residue, synthetic surfactants, colorants, COD, etc. The pH value of wastewater was determined by a pH- meter, suspended substances–by the M-101turbidimeter, synthetic surfactants– by a photoelectric colorimeter.

The wastewater analysis was carried out in accordance with the collection of industrial methods of the chemical analysis of substances used in the light industry[Sectoral compilation of techniques for the chemical analysis of substances used in the light industry, contained in wastewater1988]. The total concentration of colorants in wastewater and treated water was determined on the SF-26 by the working method of determining the total content of colorants in wastewater, developed by the author Toibayev[2008].

The functional purpose and loads by individual treatment facilities and the experimental results

Depending on the physical and chemical contamination state, the functional loads by facilities of technological treatment scheme are distributed as follows.

Equalization. It is used to regulate the composition and consumption of wastewater. Equalization is achieved either by differentiating the incoming wastewater stream or by an intensive mixing of separate streams. According to [Toibayev2005], in the proposed technological scheme of wastewater treatment of the finishing mill, the equalization time of wastewater in these facilities is 4-6 hours.

Sedimentation. By the functional purpose the most efficient and cost-effective construction for the subsidence of suspended substances from wastewater of finishing enterprises is thin-layer sinkers.

As noted in the works of Toibayev [2008], [1997]and Toibayev, Elagin, Myrzakhmetov and Vetlugin[1990], the above sinker does not have those disadvantages that are inherent in other types of sinkers, i.e. those eddy and dead zones that reduce the residence time of water in the facility, increasing its rate of flow, and thus worsening the effectiveness of sinkers. This paper presents the design of a thin-layer sinker with a flocculation tank, which greatly simplifies the construction by combining a sinker and a flocculation tank in one device. The flocculation tank is combined with the settling zone in order to avoid the destruction of flakes when transferring water from the tank to the sinker. Figure 4 shows a thin-layer sinker, combined with a flocculation tank.

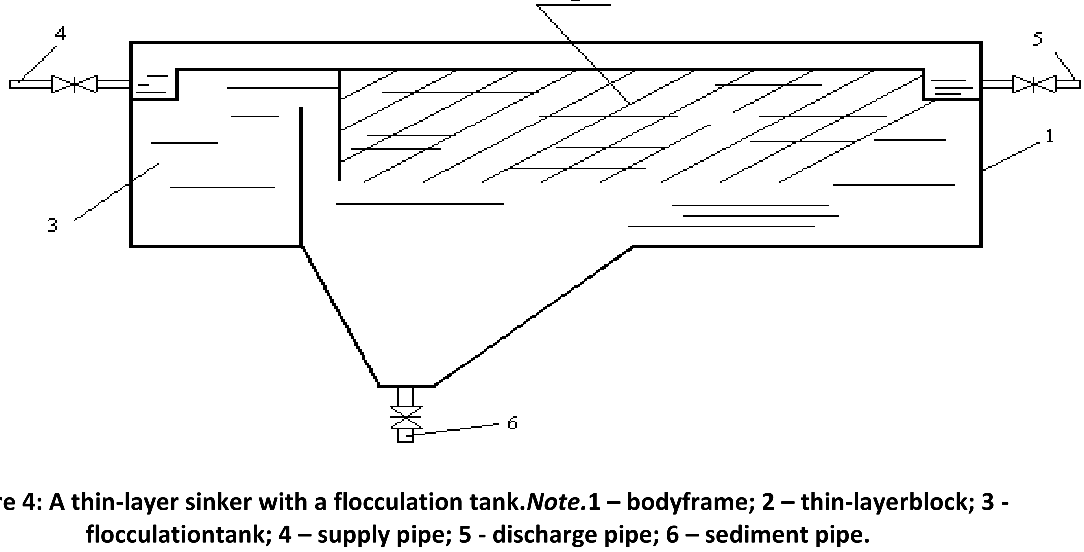


Figure 4: A thin-layer sinker with a flocculation tank.*Note.*1 – bodyframe; 2 – thin-layerblock; 3 - flocculationtank; 4 – supply pipe; 5 - discharge pipe; 6 – sediment pipe.

The compactness of the installation significantly reduces (in 4-6 times) the industrial areas. The construction of the installation allows it to operate, if necessary, in the automatic mode.

Multilayer blocks are installed with a slope to the foundation. The sediment, sliding on the block flanges, is falling to the bottom of the installation and then it is removed by a scraper mechanism. As shown by hydraulic and technological studies in the experimental-industrial facility of the ACP finishing enterprise, multilayer blocks facilitate the uniform (on perimeter and in depth) distribution of water in the sinker. Block flanges were made of stainless steel. The angle of slope to the horizontal flanges was taken in the range of43^0 to 50^0. The required slope angle of the flanges was made with special guiding devices made of steel sections and stretch-bolts. According to the experimental results, the optimal slope angle of the flanges for sliding sediments was 47^0. At a small slope angle, the sediment was sliding badly, and at a large slope, the sedimentation modes were violated. Given the nature of wastewater contamination (up to 70-80% of organic substances), the height of the flanges was taken more than 150-200 mm. The initial parameters for calculating the experimental-industrial model of a thin-layer sinker were the flow rate (m^3/h), the concentration of suspended matters in the source and treated water (mg/dm^3), the hydraulic size of holding particles (mm/s), the duration of sediment accumulation (h),sediment moisture (%), sediment density (kg/m^3).

The test efficiency modes of operation of the thin-layer sinker at the initial concentration of suspended substances are given in Table 2.

Table 2: The efficiency of removal of suspended substances by thin-layer sedimentation

Aluminum sulfate dose (byAl_2O_3)	Suspended substances concentration, mg/dm^3		Treatment efficiency, %
	Source water	Treated water	
100	270	132	51
125	295	133,6	54,7
150	320	138	57
175	330	139,3	57,8
200	340	140,4	58,7

As shown by the experiment, the highest efficiency of removal of suspended substances is achieved at the low speed (a hydraulic size) of holding particles (up to 5-7 mm/sec). This is due to the fact that thin-layer sinkers are effective for the separation of finely dispersed impurities from wastewater, which is typical for wastewater of finishing enterprises.

The dispersed impurities of wastewater of these enterprises are mostly of an organic nature, finely dispersed with a uniform hydraulic size. Therefore, as one would expect, in the application of thin-layer sinks for the treatment of wastewater of finishing enterprises, the higher efficiency to hold the dispersed impurities is achieved at low speeds (up to 7 mm/sec).

Based on the experimental results, the optimal dose of coagulant is established at 125-150 mg/dm^3, for which the efficiency of wastewater by suspended substances amounted to 57%.

Pressure flotation. The pressure flotation method is widely used for the treatment of wastewater of finishing enterprise from synthetic surfactants, colorants and other specific contaminants. The papers[Toibayev2008; Toibayev and Myrzakhmetov 1990;Ibadullayev 2001] show the technological capabilities of applicability of the pneumatic pressure and electrical flotation of wastewater treatment from these contaminants. They also prove the expediency of application of the pneumatic flotation devices, when the content of synthetic surfactants in the treated water is within 200-1000 mg/dm^3 and up to 200 mg/dm^3– in pressure and electrical flotation devices. At the same time, the efficiency of removal of synthetic surfactants by the pneumatic flotation devices is 20-70%, while by the pressure and electrical flotation devices - 20-60%. It should be noted that with an increase in the content of synthetic surfactants and colorants in wastewater, the efficiency of their removal increases with the pneumatic flotation and decreases with the pressure and electrical flotation. This is most likely due to the different dispersed composition of the gas-liquid mixture.

If the efficiency of removal of these contaminants is insufficient, the use of reagents is provided. The intensification of flotation is achieved by hydrophobization of the surface of the extracted impurities by reagents that, being selectively sorbed on the surface of particles, decrease their wettability, which improves the adhesion of dispersions and colloids to air bubbles. The author of the paper Toibayev[1997] applies the conventional coagulants and flocculants as hydrophobic reagents. The floatability of particles of various size depends on the size of air bubbles, which are determined by the surface of tension at the interface of "water - air". By reducing the surface tension and preliminary coagulation of impurities, the efficiency of water treatment by flotation is improved.

As known, one of the most common and effective methods of wastewater treatment of dyeing and finishing industries is pressure flotation. The research on the flotation treatment of wastewater of the finishing enterprise was carried out in the pressure flotator. The flotation installation was operated as part of the experimental-industrial installation and made of steel sheets 2 mm thick in the mechanical workshop of the plant. The installation consisted of the pressure tank for water saturation with air, the flotation tank, the foam tank, equipped with the manometer for measurement and the valve for the regulation of pressure in the pressure tank (Figure 3). In addition, the installation was provided with supply pipelines of the compressed air and the water under treatment, and the pipeline for the diversion of the treated water. Slightly contaminated (washed) and highly contaminated (colored) wastewater streams were subjected to flotation treatment.

In the preliminary coagulation with an aluminum sulfate (Al_2O_3 - 35 mg/dm^3) and the pressure flotation of slightly contaminated wastewater, synthetic surfactants and suspended substances were effectively removed, and the concentration of colorants was significantly reduced. In accordance with Figure 5, the efficiency of wastewater treatment by synthetic surfactants amounted to 30-67% (depending on the type of surfactants), colorants - up to 65-71%, suspended substances - up to 75-80%, COD - up to 33% with an accepted duration of flotation of 20-30 minutes. A further increase in the duration of flotation contributed not to a significant increase in the efficiency of wastewater treatment, but to additional energy costs. Therefore, the set duration of flotation of up to 30 minutes is considered sufficient for the treatment of slightly contaminated wastewater. The same treatment indicators in the non-reagent pressure flotation of slightly contaminated wastewater are significantly lower. The kinetics of removal of contaminants from slightly contaminated wastewater by the reagent pressure flotation is shown in Figure 5.

Highly (colored) contaminated wastewater was treated with the reagent pressure flotation method. From the operating experience in treatment facilities of "YUZHTEKS" JSC (Shymkent),as compared to Toibayev and Myrzakhmetov [1990]and Toibayev [1997],the flotation installation in the scheme was located after the thin-layer sinker, which provided a more efficient operation of the technological treatment process in general.

At the aluminum sulfate dose of Al_2O_3 at 150 mg/dm^{3}and the flotation duration of 30-40 minutes, the efficiency of wastewater treatment by synthetic surfactants was 52-63%, suspended substances - 78%, COD - 39-45% and colorants - up to 66-75%. As can be seen from Figure 6, the treatment efficiency curve of colored wastewater almost reaches the maximum value with the duration of flotation of 35-40 minutes. A further increase in the duration of flotation leads to an unnecessary growth in the cost of wastewater treatment because of the high energy costs.

The saturation of water with air in the pressure flotation installation was carried out by dissolving it under pressure in the pressure tanks - saturators. By varying the amount of pressure in the saturator, it is possible to control the amount of the dissolved air and its dispersed composition, i.e. to manage the process of pressure flotation.

It is known that two critical processes take place in the working area of the flotation tank:

- Formation of floto complexes "bubble - particle";
- Sloughing of flotocomplexes.

The greatest impact on the efficiency of wastewater treatment is made by a ratio of sizes of particles and bubbles. It is known that decreasing the size of bubbles leads to reducing their release rate.

Consequently, the bubbles, which have the largest specific surface area, are hardly ever separated from the water. They are carried with it from the flotator along with the particles firmly fixed on their surface. To separate these particles, it is necessary to increase the duration of flotation.

Therefore, in the design of the experimental-industrial flotator model and determination of its size, the conditions for separating the bubbles with the most likely (average) size were taken into account.

The experimental research on the treatment of slightly and highly contaminated wastewater streams from synthetic surfactants and colorants was carried out in the pressure flotation installation in order to study the dependence of treatment efficiency on the degree of primary water saturation with air at a pressure in the pressure tank from 0.2 to 0.5 mPa. The duration of water saturation with air was from 3 to 5 minutes. The throttling of the water-and-air mixture was performed with a needle valve immediately before the supply of water to the flotation tank.

Figures 5 and 6, respectively, show the dependence of the efficiency of wastewater treatment of slightly contaminated (with an aluminum sulfate dose of 35 mg/dm^3) and highly contaminated (with an aluminum sulfate dose of 150 mg/dm^3) streams by the reagent pressure flotation on the pressure of water saturation with air. As seen from these curves, the dependence of the efficiency of wastewater treatment on pressure in the pressure tank has the greatest value, corresponding to the pressure of air dissolving in the range of 0.25-0.4 mPa.

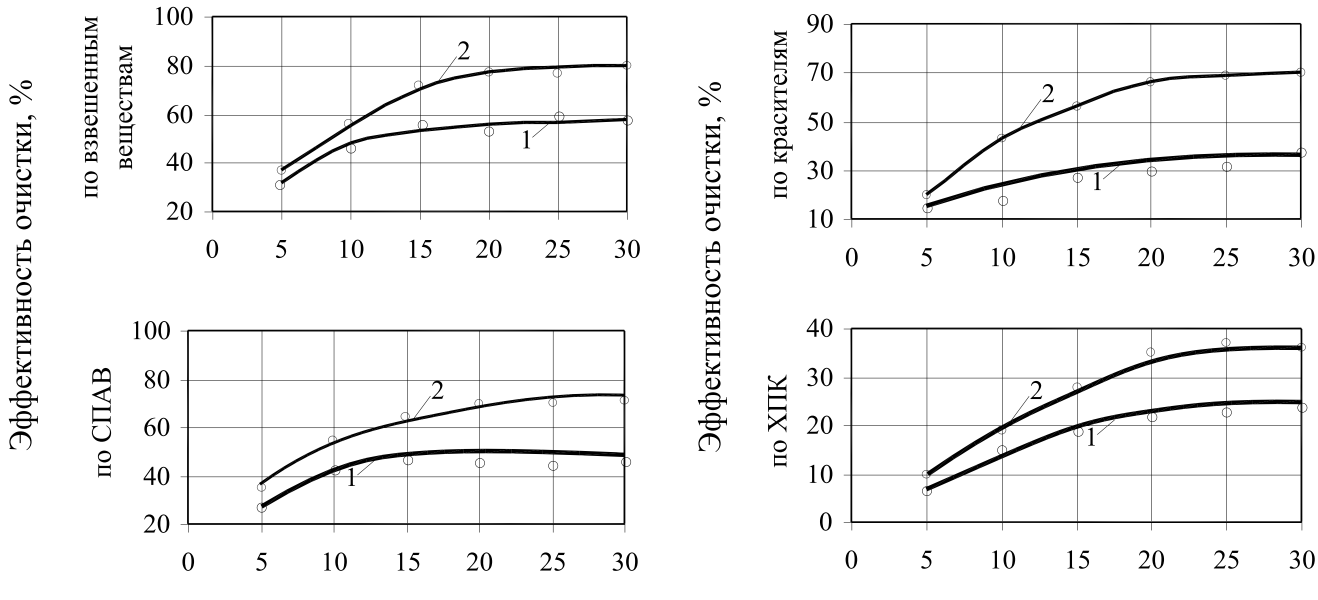


Figure 5: The efficiency of treatment of slightly contaminated wastewater.*Note.* 1 – non-reagent pressure flotation, 2 – reagent pressure flotation, an aluminum sulfate dose (by Al_2O_3) – 35 mg/dm^3. Translation of terms: Эффективностьочистки, % - Treatment efficiency, %; ПоСПАВ – by synthetic surfactants; Повзвешенныммвеществам – by suspended substances; ПоХПК – by COD; Покрасителям – by colorants.

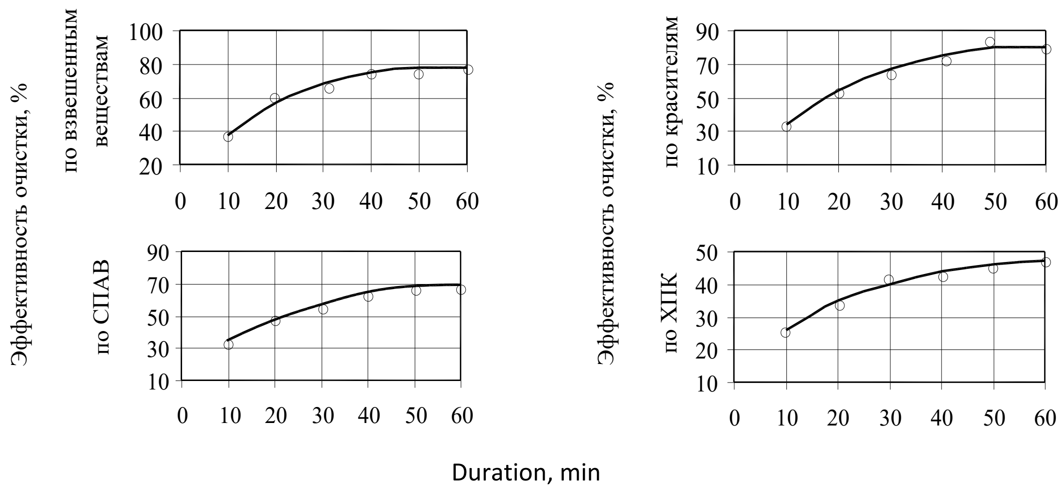


Figure 6: The efficiency of treatment of colored wastewater.*Note.*Reagent pressure flotation, an aluminum sulfate dose (by Al_2O_3) – 150 mg/dm^3. Translation of terms: Эффективностьочистки, % - Treatment efficiency, %; ПоСПАВ – by synthetic surfactants; Повзвешеннымвеществам – by suspended substances; ПоХПК – by COD; Покрасителям – by colorants.

During the experimental research on flotation treatment ofslightly contaminated and highly contaminated wastewater, it was proved that:

-At the saturation pressure of 0.25-0.4 mPa bubbling was ended within 35-40 minutes;

- At the saturation pressure of 0.45-0.5 mPa and more bubbling mainly lasted within 45-60 minutes. But some of the finely dispersed bubbles were hardly ever separated from the water into the foam layer and were carried to the following facilities, reducing the treatment efficiency and disrupting their operating mode. To separate these bubbles from wastewater, it was necessary to increase the duration of flotation to 50 minutes or more, which lead only to an increase in facilities amount, energy consumption and, in general, in the cost of wastewater treatment.

According to the experimental results (Figure 7), the established optimal areas of the pressure of water saturation with air in the pressure tank are:

- For slightly contaminated wastewater - 0.25-0.35 mPa;
- For highly contaminated wastewater - 0.3-0.4 mPa.

The established areas of the optimal saturation pressure of slightly contaminated and highly contaminated wastewater streams are also supported by the recommended values of saturation pressure in a number of works [2,11,12].

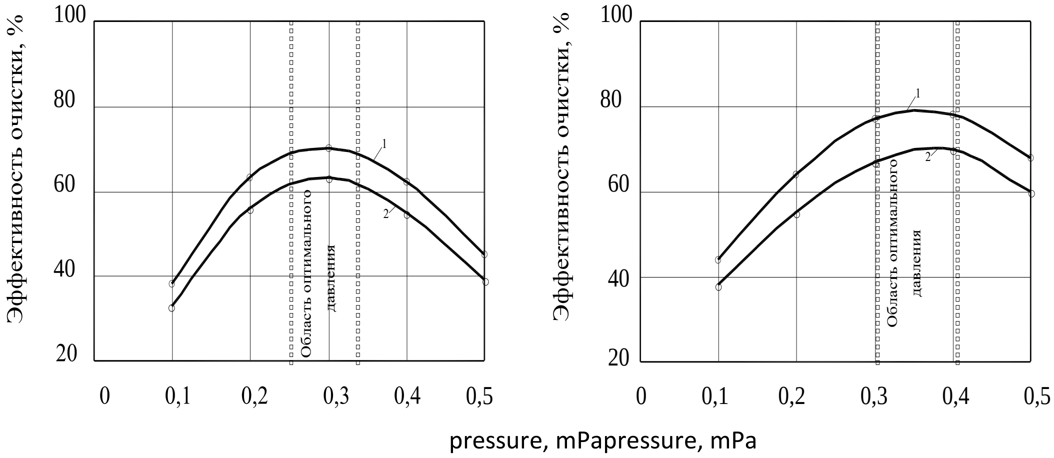
For treatment of the slightly contaminated wastewater stream, where the concentrations of synthetic surfactants are low (7.3-37 mg/dm^3), there was used the direct-flow scheme of pressure flotation with saturation of the total volume of treated water with air.

For treatment of the highly contaminated wastewater stream, where the concentration of synthetic surfactants reaches 65-70 mg/dm^3 and the concentrations of co-occurring contaminants are higher, it is possible to use the pressure flotation scheme with recirculation.

The optimal recirculation flow rate, defined as a result of the experimental work, amounted to 30% of the flow rate of treated wastewater.

To suppress the flotation foam, the waste products of water treatment facilities are used - eluates (waste regenerant solutions) of ion exchange filters. A component chemical composition of a defoamer, the modes of its processing and instrumentation were suggested [Toibayev, Myrzakhmetov, Alekhin and Egemberdiyeva1989].

Ozonation–an environmentally friendly and efficient method of treatment. In the process of ozonization, synthetic surfactants and colorants are almost completely destroyed. Ozone production is based on a process of "quiet", that is scattered, without sparks, electrical discharge, which allows to convert air oxygen into ozone. At the same time, up to 90% of the electricity is converted into heat, which is removed from the ozonator by the cooling water, circulating in the interbank space of the device.



a) b)

Figure 7: The dependence of the efficiency of treatment of slightly contaminated and colored wastewater on pressure. *Note.* a) of slightly contaminated wastewater; b) of colored wastewater; 1 - colorants removal; 2 - synthetic surfactants removal. Translation of terms: Эффективностьочистки, % - Treatment efficiency, %; Областьоптимальногодавления – Optimal pressure area.

Ozone does not bring any additional impurities in the treated water, which would lead to a deterioration in the salt water composition. The papers of Toibayev [1997] and Bursova [1995]show that the application of the method of ozonation is important for the advanced treatment of wastewater from colorants and synthetic surfactants with the purpose to create a re-circulating water supply in finishing enterprises. In addition, wastewater treatment with this method makes it possible to simultaneously remove the salts of iron and manganese from the water, the presence of which in accordance with the requirements for the process water is limited to 0.1 mg/dm^3 due to a deterioration of the technological parameters of fabrics fineness. These salts are removed from the treated water together with degradation products by filtration through the granular filters.

According toKuznetsova and Palgunov [1997], ozone has an intensive effect on benzene rings. In the interaction of ozone with nonionic synthetic surfactants, there is the oxidation of the chain of surfactants with the formation of low molecular glycols.

During ozonation, the nonionic synthetic surfactants are dissociated and form small amounts of fatty acids, alcohol and acetone. In this case, wastewater has a reduction in the COD value and a simultaneous increase in the COD/BOD (biochemical oxygen demand) ratio, i.e. the occurring substances are oxidized better than the parent compounds. To intensify the ozone oxidation process of organic contaminants present in wastewater, catalysts are used. The experimental work uses the expanded clay and activated carbon as the catalyst (cap).

In wastewater treatment by ozonation, the concentration of the suspended substance in wastewater before supplying to these facilities should not exceed 5-10 mg/dm^3, as the high content of these substances increases the consumption of ozone and the contact time with the water.

Therefore, before supplying to the ozonation facilities, the colored wastewater was subjected to the advanced treatment from suspended substances through the granular filters.

According to the treatment scheme (Figure 3), the colored wastewater after preliminary treatment is supplied to the granular filter for the advanced treatment from suspended substances to the concentration of 10 mg/dm^3, and then the water is supplied to the contact reactor. The ozone-air mixture also enters there from below from the ozone generator. Water, incoming in the contact reactor, has the following characteristics: suspended substances - 5-8 mg/dm^3, colorants - 6-12 mg/dm^3, COD - 210-350 mg/dm^3.

In the contact reactor under the influence of ozone there is the destruction of organic compounds (colorants, synthetic surfactants, suspended substances). The experiment used the direct-flow contact reactor with the granular cap-catalyst. The cap was disposable with periodic replenishment of losses, and its complete replacement takes place 1-2 times a year. The activated carbon AG-3 with a fraction size of 1.5-2.7 mm or the expanded clay with a fraction size of 2-3 mm was taken as a material of the cap.

The experimental ozonator with high frequency, designed for ozone generation from industrial oxygen with a capacity of at least 10 g/h or from air - up to 5 g/h, was taken as the ozone generator. The ozonation facility was made for a special order ofthe "Luch" Special Design Bureau (Russia) for the treatment of colored wastewater of the finishing enterprise with direct involvement in the design and pre-commissioning process of employees of the department of "Water Supply and Sewerage" of Kazakh Leading Academy of Architecture and Civil Engineering and the author [Toibayev 2008;Toibayev, Imanbayev and Zhandauletova 1997].

The experimental ozonator for wastewater treatment of finishing enterprises had the following specifications:

- capacity byozone at the concentration of 10 g/m^{3}no less than 10$\pm$1 g/hour;
- cooling water flow rate of 200 l/hour, temperature of up to 25^{0}C;
- air flow rate of no more than 1 m^3/h, temperature of no higher than 25^{0}C;
- ozone concentration in the ozone-air mixture of up to 20 g/m^3;
- voltage supplied to the ozonized elements is controlled within 6 to 9 kV;
- current frequency - 200-600 Hz;
- air pressure in the ozonized elements - 0.05 mPa;
- power consumed by the ozonator- 400 VA;
- kind of electric current - single-phase alternating;
- voltage - 220 V.

In carrying out the experimental work, the ozone flow rate and the contact time (response rate) with wastewater depended on the chemical structure, the concentration of colorants and synthetic surfactants. Therefore, in determining the optimal ozone dose and the contact time the following parameters were changed: the ozone flow rate, the rate of water supply to the column, the contact time. Based on the results of experimental-industrial studies of Toibayev, Imanbayev and Zhandauletova [1997], the optimal dose of ozone was 10-15 mg/dm^3,and the contact time of wastewater with the ozone-air mixture was up to 8 minutes.

Ozone is explosive, toxic and can affect the respiratory system. The maximum allowable concentration of ozone in the indoor air is no more than 0.0001 mg/dm^3[Toibayev 2008; Bursova 1995]. To neutralize and remove the excessive ozone, there is the degasser of waste gases that are released into the atmosphere after neutralization. In this case, the excessive ozone pipe is connected to the suction side of the compressor delivering the air into the tank of the water-and-air mixture of the pressure flotation system to improve the utilization rate of ozone. This makes it possible to carry out the preliminary ozonation of the source water in the flotator of the waste ozone-air mixture with the residual concentration of 2-3 mg/dm^3. Wastewater after treatment byozonation had the following characteristics: suspended substances - 25-30 mg/dm^{3}at the expense of degradation of organic contaminants, synthetic surfactants – 5-6 mg / dm^3, colorants – up to 1 mg/dm^3.

Considering the secondary coagulation of wastewater after ozonation, prior to wastewater supply (30%

O_{day}) to the ion exchange filters one should provide the granular filters for wastewater treatment from degradation products to the concentration of 3-5 mg/dm^3.

Filtration. The main working element of the filter facilities is a filtering load that is why the right choice of its parameters is essential for their normal operation. The selection of the basic filtering material should take into account its cost, availability in the area of construction and compliance with certain technical requirements. The main technical requirements that characterize the suitability of granular materials for their use as a filteringload are: granulometric composition, mechanical strength, chemical resistance, the content of toxic micro-elements and hygienic properties.

In selecting the filtering material and defining the optimal technological operating parameters of filters the previously published works were used Toibayev and Myrzakhmetov [1990] and Toibayev [1997], which enumerated all of the above technical requirements.

The local filtering materials were recommended for loading of the granular filters: expanded clay from Almaty House-Building Plant and sand from the quarry "Novyi". The technological parameters for the calculation of the granular filters are given in the author's works [Toibayev2008; Toibayev and Myrzakhmetov 1990].

Ion exchange. To date, the use of the ion exchange method for wastewater treatment is expanded due to the increasing requirements for the quality of treated water. The wide dissemination of this method contributes to the undeniable advantages: assurance of a high degree of water purification from virtually any ionic compounds, simple instrumentation process, high reliability, selectivity and the possibility of the re-circulating use of treated water in the technological process.

The study of wastewater treatment was carried out in order to remove the residual concentrations of colorants and synthetic surfactants, as well as to correct the mineral composition of treated wastewater by the ion exchange method in the ACP textile mill and the Ridder Knitted Out wear Factory.

In the complex technology of treatment and re-circulating water supply, proposed for implementation in the finishing enterprise, the technological parameters for the calculation of the ion exchange filters weretaken according to Toibayev, Imanbayev and Zhandauletova[1997].

The inclusion of the ion exchange method in the technological scheme of wastewater treatment allowed to remove from wastewater the residual concentrations of colorants almost completely, as well as a significant part of synthetic surfactants. In addition, this method made it possible to reduce the total salt content, which is important in the re-circulating use of treated wastewater in the technological process. Water after treatment had the following characteristics: suspended substances – 1-2 mg/dm^3, synthetic surfactants – 2-3mg/dm^3, colorants –up to 0.5 mg/dm^3, COD - 30-40 mg/dm^3, dry residue –up to 500-600 mg/dm^3. Treated water can be used without limitation in the technological process of textile materials finishing.

Technological parameters for the calculation of basic facilities

By the technological parameters, obtained as a result of experimental-industrial studies, and data from the previously published papers [Toibayev 2005; [6,16], the technological parameters for the calculation of basic facilities are presented as follows:

1) equalizing tanks– of the corridor type, equalization time – 4-6 hours;

2) thin-layer sinkers:

- residence time of water in thin-layer sinkers - 15-20 minutes;
- slope of flanges - 47^0;
- distance between flanges - 150-200 mm;
- coagulant dose - 125-150 mg/dm^{3}byAl_2O_3;
- volume of sediment - 5-7% of the volume of wastewater;

3) pressuren on-reagent flotators:

- air volume – 4-5% of the volume of treated water;
- residence time of water in pressure tanks - 3-4 minutes;
- overpressure in pressure tanks - 0.25-0.35 mPa;
- duration of flotation – up to 30 minutes;

4) pressure reagent flotators:

- air volume – 4-5% of the volume of treated water;
- residence time of water in pressure tanks - 4 minutes;
- overpressure in pressure tanks - 0.3-0.4mPa;
- duration of flotation – 35-40 minutes;

5) granularfilters:

- loading from expanded clay with a fraction size of 0.8-3 mm;
- height of the filtering layer - 1.3-1.5 m;
- filtration rate - 10-12 m/h;
- filter cycle duration - 16-18 hours;

6) ozonationfacility:

- ozonedose - 10-15 mg/dm^3;
- ozone contact time with water – up to 7 minutes;
- cap from AG-3 carbon with a fraction size of 1.5-2.7 mm or from expanded clay - 2-3 mm.

7) ionexchange filters:

- loading from sulfonated carbon SC-3 with a grain size of 0.3-1.6 mm;
- loading height - 2.0-2.2 m;
- filtration speed - 5 m/h;
- filter cycle duration - 12 hours.

The operating efficiency of individual facilities of the developed complex treatment technology of slightly contaminated and highly contaminated wastewater streams of the finishing enterprise is shown in Table 3.

Table 3: The operating efficiency of individual facilities of the developed technological treatment scheme

Facility name	Suspended substances		COD		Colorants		Syntheticsurfactants	
	mg/dm^3	%	mg/dm^3	%	mg/dm^3	%	mg/dm^3	%
Slightly contaminated stream								
Equalizing tank	180	-	340	-	3,2	-	20	-
Pressure flotator	63	65	269	21	1,47	54	7,4	63
Granularfilter	7,2	96	245	28	1,2	62	7	65
Ozonator (reator)	35,7 (at the expense of secondary contamination)	79.2	40	88	0,05	98	3	85
Granularfilter	2	99	34	90	trace amount	-	3	85
Ionexchangefilter	2	99	34	90	trace amount	-	3	85

Highly contaminated stream								
Equalizing tank	315	-	680	-	41,6	-	42,5	-
Thin-layer sinker	134	57,5	551	19	27,2	35	36,6	14
Pressure flotator	69,3	78	354	48	9,2	78	14	67

CONCLUSIONS

- The physico-chemical composition and the volume of discharged wastewater depend on the nature of fibers used in the production, the product range, the type, quantity and mode of operation of the installed technological equipment. The basis of wastewater contamination is formed by organic compounds, persistent to biochemical oxidation - synthetic surfactants, colorants and suspended substances.

- Process water is suggested to be divided into two categories depending on the purpose and the required quality: fresh process (make-up) and circulating (treated). Based on the proposed classification of process water, the measurement of water consumption and water disposal costs, water losses and water balance calculations, there was developed the optimal scheme of the water balance, which allows to create 60% of the circulating water supply system in the enterprise.

- The experimental-industrial studies of wastewater treatment by reagent coagulation allowed to specify the optimal doses of coagulants. For slightly contaminated wastewater they amount to 35 $mg/dm^{3,}$ and for highly contaminated wastewater – 150 mg/dm^3 (byAl_2O_3).

- There was developed the complex technology of treatment and re-circulating water supply of finishing enterprises. In this technology, in order to reduce costs, to simplify the treatment process and to increase the degree of purification and stability of circulating water composition, 26-32% of the total flow rate of slightly contaminated water after filtration through the granular filter is fed to the ion exchange filter for the adjustment of circulating water hardness. The proposed complex treatment technology allows to use the treated slightly contaminated water in the circulating water supply system of the finishing production, while highly contaminated water after preliminary treatment is discharged in compliance with the maximum permissible discharge in the city sewer system.

- The complex treatment technology ensures the efficiency of treatment of slightly contaminated wastewater by suspended substances up to 97-99%, colorants - 95-98%, COD - 80-90%, synthetic surfactants - 85-90%, and of highly contaminated wastewater by suspended substances up to 72-80%, colorants - 70-78%, and synthetic surfactants - 60-70%. Based on the experimental results, the optimal operating parameters of the basic facilities and devices of the technological water treatment scheme were defined.

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