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SOME PROBLEMS DESIGN SOLUTIONS OF SEWAGE TREATMENT PLANTS IN ASTANA

For the majority of Kazakhstan sewage treatment plants, the issues of modernization and construction of new blocks of wastewater treatment facilities are very relevant, the solution of which involves a comprehensive engineering and technological approach.

This article analyzes the level of automation and disadvantages of the project of the second stage of sewage treatment plants (STP) of the State Enterprise «Astana SU Arnasy». The project of biological treatment on the aeration tanks of the second stage of (STP) does not provide for deep cleaning for biogenic pollutants, namely the internal recycling of activated sludge. The volume of the anoxic zone is 18 %, which is not enough for the process of biological dephosphotation. Thus, in order to more effectively achieve high-quality cleaning indicators, it is necessary to provide for a denitrification zone of at least 30 % of the total volume of the aeration tank.

Analysis of the main causes of inefficient removal of phosphates at the stage of biological purification showed: insufficient concentration of biological oxygen consumption in incoming wastewater, absence of denitrification process, dephosphotation in the design of the second stage aerotanks and insufficient volume of the anaerobic zone, which is 18 % of the volume of the aerotank.

The problems of inefficiency of technological wastewater treatment from phosphates at (STP) in Astana are primarily related to design errors and the impossibility of effective operation of wastewater treatment facilities associated with insufficient automation.

Thus, in order to increase the efficiency of the biological treatment facilities of the second stage, it is necessary to carry out a new calculation of the facilities taking into account the processes of nitri-denitrification and biological removal of phosphates, additionally equip with equipment to ensure internal recycling with the allocation of intermediate zones and in the process of retrofitting to provide greater automation to minimize manual labor.

Keywords: sewage treatment plants, wastewater, biological treatment, reconstruction, aerotanks.

Introduction

Sewage treatment is relevant not only for Kazakhstan, but also for the whole world. In such a way, according to the UN World Report, the amount of waste water produced and its total pollution is constantly growing all over the world, while the bulk of wastewater is discharged directly into the environment without appropriate treatment.

In Kazakhstan, sewage treatment plants (hereinafter referred to as STP) appeared in the middle of the last century, when mechanical treatment facilities were built and put into operation in large cities. Prior to this, urban wastewater was diverted to absorption fields or containment ponds without pre-treatment. Today, the main problem is the wear of these sewage plants, for example, in the Kokshetau, Shalkar, Kapshagai, Semey, Ridder, Karatau, Saran, Arkalyk, Ekibastuz cities, the degree of wear is more than 90%. In addition, there is an extremely low efficiency of plants, outdated technologies and equipment, which together has an extremely negative impact on the environment. In some cities, for example, in Taraz, there are no sewage treatment plants at all, urban wastewater is discharged through temporary settling tanks to absorption fields. In this regard, for the majority of Kazakhstan water utilities, the issues of reconstruction, modernization and construction of new wastewater treatment facilities are very relevant, the solution of which involves a comprehensive engineering and technological approach.

Methods and materials. STP SME «Astana suarnasy» of Astana city with a total capacity of 254 thousand m^3 / day consists of two stages: the first stage is the existing station: with a capacity of 136,000 m^3/day (facilities built in 1964, which passed several stages of reconstruction), the second stage is new facilities with a capacity of 118 thousand m^3/day, commissioned in 2017 [1].

The second stage of the STP includes: a block of grates with aerated grit chambers, preliminary sedimentation tanks and gas treatment facilities, aerotanks, secondary sedimentation tanks, a block of blowers, sludge pumping station, a mechanical sludge dewatering shop № 3, a block for compacting sludge thickening sludge and filtrates treatment.

From the moment of commissioning operations, the main task was to achieve the quality indicators of wastewater laid down in the project for each stage of treatment. After the launch of biological treatment facilities, in order to accelerate the process of building up activated sludge, its supply was organized from the functioning facilities of the first stage of the STP [2]. 4 aerotanks are placed on the second stage of the STP according to the project. The scheme of the aerotank is shown in Figure-1.Aerotanks of the second stage are structurally different from aerotanks of the first stage: corridor type, length–166 m, depth–7.5 m, corridor width–15 m. The total volume of one aerotank is 18675 m^3, the volume of the oxygen-free zone is 3375 m^3.The anaerobic zone occupies 18 % of the total volume of the aerotank. Aerotanks in the anoxic zone are equipped with mixing devices in the amount of 4 pieces in each of the aerotanks. The aeration system consists of tubular diffusers installed along the length of the entire aerotank.

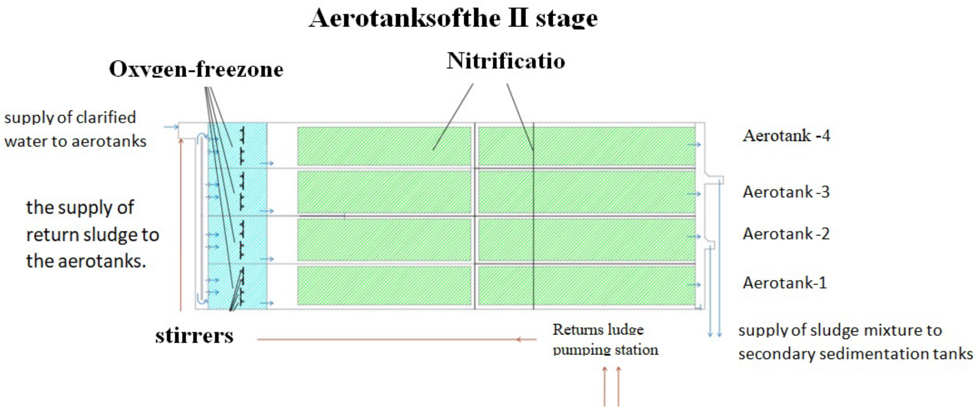

Figure1 – Scheme of the aerotank of the second stage of the STP

Mixing of the flow of clarified wastewater after the preliminary sedimentation tanks with the return activated sludge is carried out in a gravitycanal sewage regulator. The mixing of wastewater with activated sludge is achieved due to the length of the canal. In order to prevent sludge settling, the canals at the bottom are equipped with a large-bubble aeration system, where air bubbling is carried out. In addition, sensors are installed in this canal that measure the concentration of ammonium and nitrate nitrogen in the incoming mixture of return activated sludge and clarified water.

After passing through the overflow stoplog, the flow enters the oxygen-free zone of the aerotank, in which, in accordance with the implementation of the project: «Liquidation of the Taldykolholding pond with reclamation in Astana», the processes of nitrate nitrogen denitrification are carried out.

However, the design of aerotanks does not provide for an internal recycling of nitrates, namely, there are no pumps and associated pumblingsfor this task. The anaerobic zone at the beginning of each aerotank is 30 m long, does not perform its function. The small volume of the zone and the residence time of the mixture of clarified liquid and return activated sludge in it does not allow the processes of denitrification and biological dephosphorization to proceed. Also, there are no control and measuring devices in this zone, such as: a sensor for measuring temperature, dissolved oxygen, ammonium nitrogen, nitrates, phosphates, etc.

From the oxygen-free zone of the aerotank, the flow of the sludge mixture enters the aeration zone. To implement the process, a system of fine-bubble aeration was used. Sensors for measuring dissolved oxygen, ammonium nitrogen and nitrates are installed at the end of each aeration tank.

An important point in the operation of any biological treatment system is the process automation system. In this case, the project does not provide for full automation of the process. The signals from the dissolved oxygen sensors in the aeration tanks do not participate in the processes of regulating the air supply and controlling the operation of the blowers. The air supply is carried out through the main pipeline, from which there is one common air duct for every two aerotanks.

This design solution does not allow to regulate the air supply to each aerotank individually, to regulate the air supply, 18 manual valves are installed in each aerotank. In this regard, during operation, the adjustment of the air supply in the aerotanks takes a huge amount of time and effort, which involves two blower drivers who control the operation of the blowers depending on the readings of the dissolved oxygen sensors, and a locksmith for servicing the aerotanks, who controls the manual valves on the spot.

No less important in the design was the choice of the layout and design of the aerotanks carrying out biological treatment. Unfortunately, it should be noted that in this case, the design of the aerotanks does not allow achieving the design values for the indicators «phosphates» and «nitrates». During the commissioning operations from April to November 2017, the following indicators of the quality of biologically treated wastewater were recorded, presented in Table 1.

Table 1 – Comparative table of the efficiency of the aerotanks of the first and second stages of the STP in 2017

Name of indicators, mg/ dm3	I stage entrance to the aerotanks	I stage biologically treated WW	II stage entrance to the aerotanks	II stage biologically treated WW
Phosphorusofphosphates	6,5	1,10	3,72	3,76
Ammoniumnitrogen,	41,92	2,24	27,09	2,64
Nitrates	9,1	34,24	31,65	79,72

According to the results, it is clear that biologically treated wastewater from the second stage does not reach the treatment parameters according to the indicators: nitrates and phosphorus of phosphates, therefore, reagent treatment at the post-treatment stage is used to bring the quality of treated wastewater to standard indicators [3].

For comparison, the aerotanks of the first stage are classic four-corridor aerotanks with regeneration. During the reconstruction, the biological treatment process was modernized with the introduction of nitri-denitrification for deep treatment from biogenic pollutants.Aerotanks are technologically divided into several zones: anoxic, denitrification and nitrification zones. Each aerotank is equipped with four mixing devices, nitrate recycling pumps, bottom turboaerators, sensors of dissolved oxygen, ammonium nitrogen and nitrates, as well as hydrostatic level meters for uniform distribution of flows. The scheme of the aerotank is shown in Figure 2.

As can be seen in the figure below, the number of aeration tanks is 6 pieces, there are 4 aeration tanks in constant operation. The length is 118 m, the depth is 4 m, the width of one corridor is 8 m. The total volume of one aeration tank is 15370 m3, the total volume of the oxygen – free zone is 4393 m3. The oxygen-free zone occupies 28 % of the total volume of the aeration tank. The aeration system in the first stage consists of tubular diffusers installed in the second, third and fourth corridors. The operation of the aeration tanks is automated, the start and speed of operation of the nitrate recycling pumps, turboaerators depends on the indicators of the nitrate and ammonium nitrogen sensors.

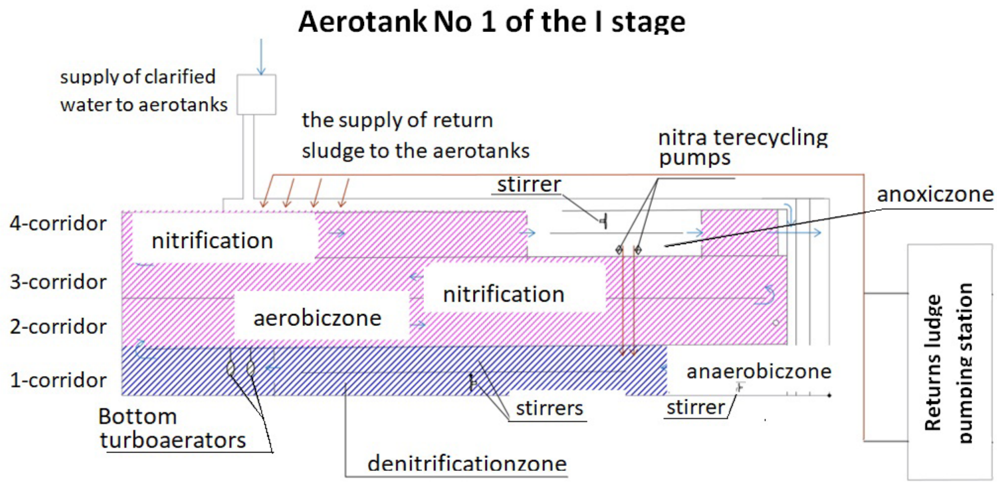

Figure 2 – Scheme of the aerotank of the first stage of the STP

However, the air-supply system and the operation of the blowers are not interconnected and are carried out manually by the service personnel.

The project of biological treatment on the aerotanks of the second stage of the STP does not provide for deep treatment for biogenic pollutants, namely, in this case, an internal recycling of activated sludge is not provided. The volume of the anoxic zone is 18 % and this is extremely insufficient for the process of biological dephosphorization [4].

For comparison, biological treatment of the first stage takes place on aerotanks, the anoxic zone of which is 28 % of the total volume, also in the fourth corridor there is a small compartment with a stirrer and pumps for internal recycling. At the end of the first corridor, a transition zone is provided, which, if necessary, operates in the nitrifier mode, saturating the aerator solids with oxygen, and in the case of an increase in nitrates at the outlet, it operates in the continuation mode of the denitrification zone where mixing takes place. This kind of transition is achieved by using the speed of the turboaerators, to start a particular mode, signals are sent to the controller from sensors of ammonium nitrogen and nitrates installed at the output of each aerotank.

In such a way, in order to more effectively achieve high-quality treatment indicators, it is necessary to provide for a denitrification zone of at least 30% of the total volume of the aerotank [5–7].

Results and discussion. Upon completion of the commissioning operations, the management of the second stage treatment process was transferred to the staff of the STP SME «Astana suarnasy», who carried out a number of measures to achieve the quality indicators of biologically treated wastewater, as a result of which the problem with excessive formation of nitrates in the process of biological treatment on the aerotanks of the second stage of the STP was solved. However, it was not possible to achieve the design indicators for treatment from phosphates.

All the work carried out by the specialists of the SME on REM "Astana suarnasy" did not allow to reduce the concentration of phosphates after biological treatment to standard indicators, in the second stage aerotanks, a decrease in the concentration of phosphates is achieved by no more than 1–1.5 mg/dm3. According to the design calculations, the biological removal of phosphates should be at least 50 %. In such a way, the issue of biological removal of phosphates at the second stage of the STP remains relevant.

Table 2 – Results of studies of samples of incoming and biologically treated wastewater of the 1st stage of the STP (the average value of concentrations of pollutants for the first half of 2020)

s/p No	Indicators	Unit of measurement	Incoming WW for the 1st stage	Biologically treated WW 1st stage	The norm for the project
1	B O D (biological oxygen demand)	mg/dm3	162,2	7,9	8
2	C O D (chemical oxygen demand)	mg/dm3	445,5	54,9	70
3	Suspended substances	mg/dm3	320,4	15,0	20
4	Chlorides	mg/dm3	300,0	294,0	350
5	Sulfates	mg/dm3	302,0	291,0	290
6	Phosphates	mg/dm3	10,79	1,47	4,91
7	Ammoniumnitrogen	mg/dm3	42,79	2,01	2,0
8	Nitrates	mg/dm3	0,85	25,15	45,0
9	Nitrites	mg/dm3	0,227	0,617	3,3
10	Iron	mg/dm3	3,90	0,38	-
11	Manganese	mg/dm3	0,079	0,038	-
12	Fluorides	mg/dm3	0,446	0,411	-
13	Petroleumproducts	mg/dm3	2,227	0,042	0,35
14	SAS (surface active substances)	mg/dm3	4,26	0,17	-

Table 3 – Results of studies of samples of incoming and biologically treated wastewater of the 2nd stage of the STP (the average value of concentrations of pollutants for the first half of 2020)

s/p No	Indicators	Unit of measurement	Incoming WW for the 2nd stage	Biologically treated WW 2nd stage	The norm for the project
1	B O D (biological oxygen demand)	mg/dm3	153,1	9,2	6
2	C O D (chemical oxygen demand)	mg/dm3	476,0	41,9	40
3	Suspended substances	mg/dm3	268,7	17,8	9
4	Chlorides	mg/dm3	303,0	293,0	350
5	Sulfates	mg/dm3	305,0	299,0	290
6	Phosphates	mg/dm3	8,84	7,27	4,91
7	Ammoniumnitrogen	mg/dm3	42,48	1,43	2,0
8	Nitrates	mg/dm3	0,84	34,15	45
9	Nitrites	mg/dm3	0,196	0,284	3,3
10	Iron	mg/dm3	3,31	0,63	-
11	Manganese	mg/dm3	0,150	0,126	-
12	Fluorides	mg/dm3	0,433	0,399	-
13	Petroleumproducts	mg/dm3	2,102	0,045	0,35
14	SAS (surface active substances)	mg/dm3	4,64	0,19	-

Table 4 shows data on the quality of treated wastewater of the first and second stages of the STP after post-treatment on flotation filters with quartz sand loading. Further, the treated wastewater passes through all the disinfection processes in the ultraviolet disinfection shop and then is discharged into the Yessil River.

Table 4 – Results of studies of samples of treated wastewater after post-treatment (average value of concentrations of pollutants in the first half of 2020)

s/p No	Indicators	Unit of measurement	TWW output after post-treatment	The norm for the project	Permissible concentration for water outlet
1	B O D(biological oxygen demand)	mg/dm^3	2,8	6,0	6,0
2	C O D (chemical oxygen demand)	mg/dm^3	25,9	40	30,0
3	Suspendedsubstances	mg/dm^3	5,4	<10	13,35
4	Chlorides	mg/dm^3	292	350	346,33
5	Sulfates	mg/dm^3	292	-	406,33
6	Phosphates	mg/dm^3	2,67	3,07	-
7	Ammoniumnitrogen	mg/dm^3	1,05	2,0	1,92

8	Nitrates	mg/dm^3	30,63	45,0	43,65
9	Nitrites	mg/dm^3	0,057	3,3	3,07
10	Iron	mg/dm^3	0,27	-	0,28
11	Manganese	mg/dm^3	0,037	-	0,1
12	Fluorides	mg/dm^3	0,404	-	1,2
13	Petroleumproducts	mg/dm^3	0,021	0,3	0,1
14	SAS (surface active substances)	mg/dm^3	0,13	0,5	0,37

To achieve the normative indicators in emergency and emergency situations, a process of reducing the residual concentration of phosphates on the post-treatment unit using a coagulant is provided [8–13]. However, due to the fact that there is no decrease in the concentration of phosphates at the biological treatment, the use of the coagulant is carried out all year round [14]. Taking into account the volume of 118 thousand m3 / day of wastewater at the second stage of the STP, the process of removing phosphates, with a coagulant consumption of about 5-6 tons per day, is very expensive, and makes up a significant part of the company's expenses.

The analysis of the main reasons for the inefficient removal of phosphates at the stage of biological purification showed: insufficient concentration of biological oxygen demand (Hereinafter-BOD) in incoming wastewater, the absence of a denitrification process, dephosphorization in the design of the second stage aerotanks and insufficient volume of the anaerobic zone, which is 18 % of the volume of the aerotank [14].

Conclusion. As a result, all the problems of inefficiency of technological wastewater treatment from phosphates at the STP of Astana city are associated with:

errors in design decisions, in particular, an erroneous technological scheme for specific wastewater was adopted, there were miscalculations in the facilities for biological wastewater treatment from phosphates, as a result of which an inefficient design was implemented;

the impossibility of effective operation of treatment facilities associated with insufficient automation, especially when regulating the air supply and its distribution on aerotanks, as well as when starting structures and equipment into operation in emergency and emergency situations;

3) an extremely cost-intensive process of the annual consumption of a coagulant for the chemical removal of phosphates of biologically treated wastewater of the second stage of the STP, the consumption of which is about 2 thousand tons per year.

At the same time, all responsibility is assigned to the operational services of treatment facilities, which are forced to use cost-intensive cleaning methods to level out the mistakes made during the design.

In such a way, the problem of phosphate removal within the framework of already implemented engineering and technological solutions requires its own solution. To increase the efficiency of the biological treatment facilities of the second stage, it is necessary to re-calculate the facilities taking into account the processes of nitri-denitrification and biological removal of phosphates, additionally equip them with equipment to ensure internal recycling with the allocation of intermediate zones that will serve for the transition from one mode to another. In the process of re-equipment, provide for greater automation, which will minimize manual labor and generally increase the efficiency and cost-effectiveness of biological treatment facilities.

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КЕЙБІР МӘСЕЛЕЛЕР АСТАНАДАҒЫ КӘРІЗДІК ТАЗАРТУ ҚҰРЫЛЫСТАРЫНЫҢ ЖОБАЛЫҚ ШЕШІМДЕРІ

Көптеген қазақстандық кәріздік тазарту құрылыстары үшін сарқынды суларды тазарту жөніндегі құрылыстардың жаңа блоктарын қайта құрылымдау, жаңғырту және салу мәселелері өте өзекті және қажетті болып табылады, оларды шешу кешенді инженерлік-технологиялық тәсілді көздейді.

Бұл мақалада «Астана СУ Арнасы» МКК кәріздік тазарту құрылыстарының екінші кезегі жобасының автоматтандыру деңгейі мен кемшіліктері талданды. КТҚ екінші кезектегі аэротенктерде биологиялық тазарту жобасында биогенді ластанулар бойынша терең тазарту көзделмеген, атап айтқанда бұл жағдайда белсенді тұнбаның ішкі рециклі көзделмеген. Аноксид аймағының көлемі 18 % құрайды, бұл биологиялық дефосфотация үдерісі үшін өте жеткіліксіз. Осылайша, тазартудың барлық сапалық көрсеткіштеріне негұрлым тиімді қол жеткізу үшін жобалау кезінде аэротенктің жалпы көлемінің кемінде 30 % нитритсіздендіру аймағын көздеу қажет.

Биологиялық тазарту сатысында фосфаттарды тиімсіз жоюдың негізгі себептерін талдау мыналарды көрсетті: кіретін сарқынды сулардағы оттегіні биологиялық тұтынудың жеткіліксіз шогырлануы, нитритсіздендіру үдерісінің болмауы, екінші кезектегі аэротенктер құрастырылымындағы дефосфотация және аэротенк көлемінің 18 %-ын құрайтын анаэробты аймақтың жеткіліксіз көлемі.

Астана қаласындағы КТҚ-дағы сарқынды суларды фосфаттардан технологиялық тазартудың тиімсіздігі мәселелері, ең алдымен, жобалық шешімдердің қателіктерімен және автоматтандырудың жеткіліксіздігімен *байланысты тазарту құрылыстарын тиімді пайдаланудың мүмкін еместігімен байланысты. Осылайша, екінші кезектегі биологиялық тазарту құрылыстары жұмысының тиімділігін арттыру үшін нитри нитритсіздендіру және фосфаттарды биологиялық жою үдерістерін ескере отырып, құрылыстардың жаңа есебін жүргізу, аралық аймақтарды бөле отырып, ішкі рециклді қамтамасыз етуге арналган жабдықпен қосымша жарақтандыру және қайта жарақтандыру үдерісінде қол еңбегін барынша азайтуга және жұмыс тиімділігін арттыруга мүмкіндік беретін үлкен автоматтандыруды көздеу қажет.*

Кілтті сөздер: кәріздік тазарту құрылыстары, сарқынды сулар, биологиялық тазарту, қайта құрылымдау, аэротенктер.

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НЕКОТОРЫЕ ПРОБЛЕМЫ ПРОЕКТНЫХ РЕШЕНИЙ КАНАЛИЗАЦИОННЫХ ОЧИСТНЫХ СООРУЖЕНИЙ В АСТАНЕ

Для большинства казахстанских канализационных очистных сооружений, вопросы реконструкции, модернизации и строительства новых блоков сооружений по очистке сточных вод являются весьма актуальными и необходимыми, решение которых предполагает комплексный инженерно-технологический подход.

В данной статье проанализирован уровень автоматизации и недостатки проекта второй очереди канализационных очистных сооружений ГКП «Астана СУ Арнасы». В проекте биологической очистки на аэротенках второй очереди КОС не предусмотрено глубокой очистки по биогенным загрязнениям, а именно в данном случае не предусмотрен внутренний рецикл активного ила. Объем аноксидной зоны составляет 18 %, что крайне недостаточно для процесса биологической дефосфотации. Таким образом, для более эффективного достижения всех качественных показателей очистки при проектировании необходимо предусматривать зону денитрификации не менее 30 % от общего объема аэротенка.

Анализ основных причин неэффективного удаления фосфатов на стадии биологической очистки показал: недостаточную концентрацию биологического потребления кислорода в поступающих сточных водах, отсутствие процесса денитрификации, дефосфотации в конструкции аэротенков второй очереди и недостаточный объем анаэробной зоны, которая составляет 18 % от объема аэротенка.

Проблемы неэффективности технологической очистки сточных вод от фосфатов на КОС г. Астаны связаны, прежде всего, с ошибками проектных решений и невозможностью эффективной эксплуатации очистных сооружений, связанной с недостаточной автоматизацией. Таким образом, для повышения эффективности работы сооружений биологической очистки второй очереди необходимо провести новый расчет сооружений с учетом процессов нитри-денитрификации и биологического удаления фосфатов, дополнительно оснастить оборудованием для обеспечения внутреннего рецикла с выделением промежуточных зон и в процессе переоснащения предусмотреть большую автоматизацию, позволяющую минимизировать ручной труд и повысить эффективность работы.

Ключевые слова: канализационные очистные сооружения, сточные воды, биологическая очистка, реконструкция, аэротенки.

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