TAMPEREEN AMMATTIKORKEAKOULU

COMMISSIONING OF A SMALL-SCALE WASTEWATER TREATMENT PLANT

Kristina Shunova

Bachelor's Thesis
February 2016
Environmental Engineering

ABSTRACT

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
Environmental Engineering

KRISTINA SHUNOVA:
Commissioning of a small-scale wastewater treatment plant

Bachelor's thesis 30 pages, appendices 2 pages
February 2016

The thesis is dedicated to the wastewater treatment process study, while providing commissioning of a small-scale wastewater treatment plant on the territory of a national park in Sochi, Russia.

The objective of the study was to conduct a commissioning as well as research ways to increase the oxidation capacity of the wastewater treatment facility. The effluent quality from the treatment facility was to correspond with standards issued by Russian authorities.

Research was based on previous studies and Russian legislation. Chemical and microbiological analyses have been conducted by local laboratory according to Russian standards. Field work was carried out during summer 2015 in Sochi as part of practical training.

By the end of the commissioning works, the effluent quality was approved to be in accordance with Russian standards by a local laboratory. Maintenance plan was established along with guidelines on improvement of possible malfunctions. Recommendations for further improvements have been given to the company.

The research indicates one more possible way to improve oxidation capacity of the treatment facility. Biorotors could be implemented in the future. Also, zero-waste cycle can be considered in order to improve the efficiency of wastewater treatment.

Key words: wastewater treatment ; aeration; annamox bacteria; oxidation capacity

CONTENTS

ABBREVIATION AND TERMS

Annamox	Anaerobic ammonium oxidation
STP	Sewage treatment plant
MPC	Maximum permissible concentration
AOPs	Advanced oxidation processes
GHGs	Greenhouse gases

1. INTRODUCTION

1.1. General concept of wastewater management

Wastewater treatment process and its characteristics is an issue of various literature sources (Kulikov et al. 2015; Tchobanoglous, G., Schroeder, E. D. 1987). Those two literature sourced mentioned above attempt to introduce theoretical concepts of wastewater treatment process along with its practical applications.

Book written by a Russian professor Kulikov et al. (2015) is dedicated to advanced wastewater treatment technologies and is based on technologies introduced by a group of Russian scientists. It also gives basic theoretical information on wastewater treatment process and describes ways of boosting quality of treatment facilities. Hereby, this particular source of literature helps to understand basics of wastewater treatment process and do not describe every related concept in details. However, it gives a possibility to study a number of feasible ways that can improve effluent quality.

As for another literature source that was written in 1987 by Tchobanoglous, G. and Schroeder, E. D., it gives a wider view on theory of wastewater treatment process. Authors gave perfect description of each concept that is related to treatment process. This particular book helps to understand the wastewater treatment process in details. Moreover, the first part of the book is dedicated to the role of water and its properties attracting reader's attention by introducing analytical methods for water quality management.

The above mentioned literature sources are both worth reading for environmental engineer. There is a clear difference between two sources presented before. Book written by Kulikov et al. (2015) has less theory on the treatment process, however, gives perfect examples on boosting effluent quality with practical examples. Meanwhile, book written by Tchobanoglous, G. and Schroeder, E. D. in 1987 gives a wider view on theoretical concept of wastewater treatment process describing all the related approaches in details.

Water in a crucial part of every living organism being essential for maintenance of all forms of life. There is a candid relation in between of abundance of water and quality of life. Therefore, water available need to possess to certain characteristics that determine the quality of water. (Tchobanoglous, G., Schroeder, E. D., 1987)

Totally pure water H_2O is colorless, tasteless and odorless. However, the existence of entirely pure water in nature is impossible due to its exceptional solvent properties. Water represents a complicated system that consists of gases, mineral and organic matter. Impurities that are present in natural and waste waters can be classified based on their origin into 3 groups: mineral, organic and biological. (Kulikov et. at., 2015) These impurities can be extremely dangerous for human health. Therefore, water is always treated before getting to municipal use.

According to Tchobanoglous and Schroeder (1987) water used for municipal needs can be divided into 4 categories: domestic, commercial and industrial, public services and leakages. Domestic water comprises 36,7 percent out of total water usage in USA. It is used for such household needs as drinking, cooking, washing, bathing and waste removal. Water consumption level varies from country to country depending on climatic, social and economical characteristics. For instance, in Russia average annual consumption of water for household needs per capita per day is about 230-250 liters (according to Russian building regulations «Water supply. External water networks and facilities»). Meanwhile, an average citizen of the United States uses about 220 L/day. This value is given by Tchobanoglous, G. and Schroeder, E. D. in their book which was published in 1987. Assuming that water consumption level is constantly rising, average water used by capita can be up to 300 liters per day. Therefore, amount of wastewater produced is dramatically high. (Tchobanoglous, G., Schroeder, E. D., 1987)

Water discharged as wastewater from households includes a wide range of impurities: fats, oils, proteins, volatile organic compounds, phosphorous, sulfur etc. The list of all possible impurities that are present in household wastewater is rather long and include variety of chemicals, pathogens and heavy metals that are dangerous for both human and environment. Pathogens and majority of decease-causing organisms are coming from feces, while chemicals, including endocrine disrupting chemicals are coming from detergents and medicine. Thereby, wastewater carries a number of impurities that should be eliminated before discharging it to the environment in order to avoid pollution and possible infections.

The contaminants in wastewater are removed by physical, chemical and biological treatment processes. Each phase include a range of unit operations and processes that have a certain valuable function. Table 1 represents a list of impurities that are eliminated during corresponding unit operations and processes. The following table helps to understand that each phase is significant and has its own value. For instance, pathogenic organisms that cause diseases can be eliminated only during disinfection phase.

TABLE 1. Wastewater treatment unit operations

	Unit operation	**Contaminant**
Physical	Screening	Turbidity, suspended solids
	Mixing and gas transfer	Tastes and odors, dissolved gases
	Sedimentation	Turbidity, suspended matter
	Filtration	Turbidity, suspended matter, iron and manganese
Chemical	Chemical precipitation	Turbidity, uspended matter, color, organic matter, hardness, heavy metals, iron and manganese, phosphorous,
	Disinfection	Pathogenic organisms, organic matter, dissolved gases
	Advanced oxidation processes	Tastes and odors, iron and manganese
Biological	Activated sludge	Biodegradable organics, nitrogen
	Anaerobic digestion	Nitrogen

Nowadays, wastewater is most commonly treated in conventional wastewater treatment plants. However, decentralized system is argued to be more efficient due to separation of black water, wastewater from industries and rainwater. As an example of decentralized wastewater treatment management, small-scale treatment plants can be took into consideration. This type of wastewater treatment facility is applicable for small communities, individual residences, commercial establishments.

In Russia this type of wastewater management is getting more and more popular. One issue that always has to be taken into consideration and should not be underestimated is commissioning of the plant. Commissioning is a process of inspecting and testing every component of a wastewater treatment plant once the construction was finished. It requires specific engineering techniques to ensure that that problems and risks during plant's operation are minimized and all malfunctions are eliminated.

1.2. Background of this thesis work

The following thesis work is based on practical training in Sochi (southern part of Russia, coast of the Black sea) for a local «Persey» group of companies. The practical training period took 4 months (from the beginning of may till the end of august). Company's activity is focused on design, facility installation and its maintenance. «Persey» group is one of the leading companies in the region that provides a range of services in environmental protection area of business.

One of the duties as for a trainee was commissioning and star-up activities of a small-scale wastewater treatment plants. All the activities performed by a trainee have been done under supervision of certified engineer. One of the commissioned treatment facility was installed on the territory of the national park couple of years ago. However, due to economical situation in the region, it was not in use for the whole period.

In summer 2015 national park requested the company to commission the facility and sign a maintenance agreement. Therefore, the company has started to plan commissioning works and start-up activities.

Also, as part of the thesis work, ways to improve oxidation capacity in the treatment plant and efficiency of the wastewater treatment facility have been researched. All the recommendations and suggestions to the company are presented below in Results.

1.3. Water quality requirements in Russia

Sanitary regulations № 4630–88 «Protection of surface water bodies from pollution» give a list of maximum permissible concentrations of harmful substances in water bodies that are assigned for community water use (represented in Table 2).

TABLE 2. Water quality characteristics

Parameters	Water usage category	
	Drinking water	Recreation water use
Suspended solids	0,25 mg/dm^3	0,75 mg/dm^3
Scummings	None are permitted on the water surface	
Color	Should be not observed within:	
	20 cm	10 cm
Odor	Should not exceed 2nd level according to table 6	
Temperature	Should not be increased by more than 3°C	
pH	6,5—8,5	
TDS	No more than 1000 mg/dm^3 : Cl^- - 350 mg/dm^3; SO_4^{2-} - 500 mg/dm^3	
Dissolved oxygen	More than 4 mg/dm3	
BOD(5)	Not more than (when the temperature is 20 °C)	
	2 mg O_2/dm^3	4 mg O_2/dm^3
COD	No more than:	
	15 mg O_2/dm^3	30 mg O_2/dm^3
Intestinal flukes	Not permitted	
Helminth ova	None are permitted in 25 liters of water sample	
Thermotolerant coliform organisms	No more than 100 CFU/100 ml	No more than 100 CFU/100 ml
Total coliform bacteria	No more than:	
	1000 CFU/100 ml	500 CFU/100 ml
Coliphages	No more than:	
	10 PFU/100 ml	10 PFU/100 ml

Therefore, when treating wastewater, the above mentioned concentrations are to be taken into account. Also, a report on allowable discharge standards including calculated amount of discharged pollutants into water body should be created. It is to define the permissible amount of pollutants entering the water body to ensure the composition of the water is at the level that was formed under natural conditions.

1.4. Ways to increase oxidation capacity

Ways to increase oxidation capacity in wastewater treatment plants is an issue of various researchers. Litter and Quici (2010) studied photochemical advanced oxidation processes which represent a set of chemical processes for remediation of contaminated wastewaters. There is a variety of AOPs : photochemical-based processes (PAOPs), as UV/hydrogen peroxide, heterogeneous photocatalysis (HP), photo-Fenton (PF), UV plus ozone and combination of mentioned technologies. (Litter, M., Quici, N. , 2010)

All the above mentioned processes are based on the production of powerful oxidative substances that are able to degrade or transform chemical pollutants, causing total mineralization. It was studied that advanced oxidation processes are able to inactivate even pathogens in wastewater. However, AOPs are rarely implemented in disinfection due to its short half-life. When applied for wastewater treatment, AOPs destruct organic and inorganic pollutants transforming them into non-toxic compounds. Thereby, advanced oxidation processes provide an ultimate solution for wastewater treatment process. However, high operational costs are considered to be major drawbacks. Basically, this technology is best applied when very recalcitrant compounds (those that can not be treated by conventional technologies) are present in wastewater. (Litter, M., Quici, N. , 2010)

Another way to increase oxidation capacity in a wastewater treatment plant is to utilize anammox bacteria that removes ammonium in absence of oxygen. Anaerobic ammonium-oxidizing bacteria convert both CO_2 and N_2O to nitrogen gas decreasing amount of greenhouse gasses by 90%. Also, this technology allows to decrease costs and energy. However, bioreactors with annamox bacteria are designed to treat wastewater at mesophilic temperatures. Due to climatic characteristics of Sochi region, this technology can be implemented. (Hu, et. al. 2013)

Another way to increase oxidation capacity is to increase aeration efficiency. Biorotors with polyamide units can be introduced. The principle is based on providing a larger amount of bacteria to be in contact with influent wastewater. Basically, the biorotor is submerged inside a treatment tank through which the influent passes through. The facility rotates to mix the wastewater and to transfer oxygen. Therefore, aeration efficiency is increased. Speed of rotation depends on the diameter of the tank as well as on the hydraulic load. Moreover, polyamide units retain anammox bacteria that are able to remove ammonia in the absence of oxygen. Therefore, oxidation capacity can be increased. (Kulikov et al, 2015)

2. OBJECTIVES

This thesis is focused on commissioning of a small scale wastewater treatment plant as a part of practical training and dedicated to increasing oxidation capacity in order to improve effluent quality. Also, some recommendations on making wastewater treatment process more efficient are to be suggested.

3. MATERIALS AND METHODS

3.1. Facility description

The following chapter is dedicated to the detailed description of the wastewater treatment facility with its characteristics. «STP 5m^3 Persey» is designed for wastewater treatment of black and grey water. It is used on sites with no connection to centralized sewerage system or as its alternative. This modification of the treatment facility is applicable for the specific climatic conditions: seismicity (magnitude of 9), seasonal temperature changes (up to -35 degrees Celsius). Performance characteristics of the facility are demonstrated in the table 3 below. It represents maximum efficiency of wastewater treatment plant during operation. Technical parameters of the treatment plant (dimensions, mass, electric power etc.) are given in table 4.

TABLE 3. Performance characteristics of the wastewater treatment facility

Parameter	Unit	Value
Effluent quality:		
BOD	mgO_2/l	3,0
TSS	mg/l	< 5.0
NH_4-N	mgN/l	< 0.39
NO_2 -N	mgN/l	0.02
NO_3-N	mgN/l	< 9.1
P_2O_5-P	mgP/l	< 1,1

Performance characteristics of a wastewater plant meet sanitary regulations of Russian Federation. That means that effluent quality needs to be in correspondence with given standards that are discussed above in the introduction section.

TABLE 4. Parameters of the wastewater treatment facility

Parameter	Unit	Value
Mass	tons	0,9
Dimensions (diameter/length (septic tank + treatment tank)	mm	2000/3000+3000
Electric power	kW	0,2
Performance	m^3/day	5
Wastewater flow	m^3/h	0,2

Technical scheme of the facility is presented below. It gives an understanding to the working principle of the treatment facility.

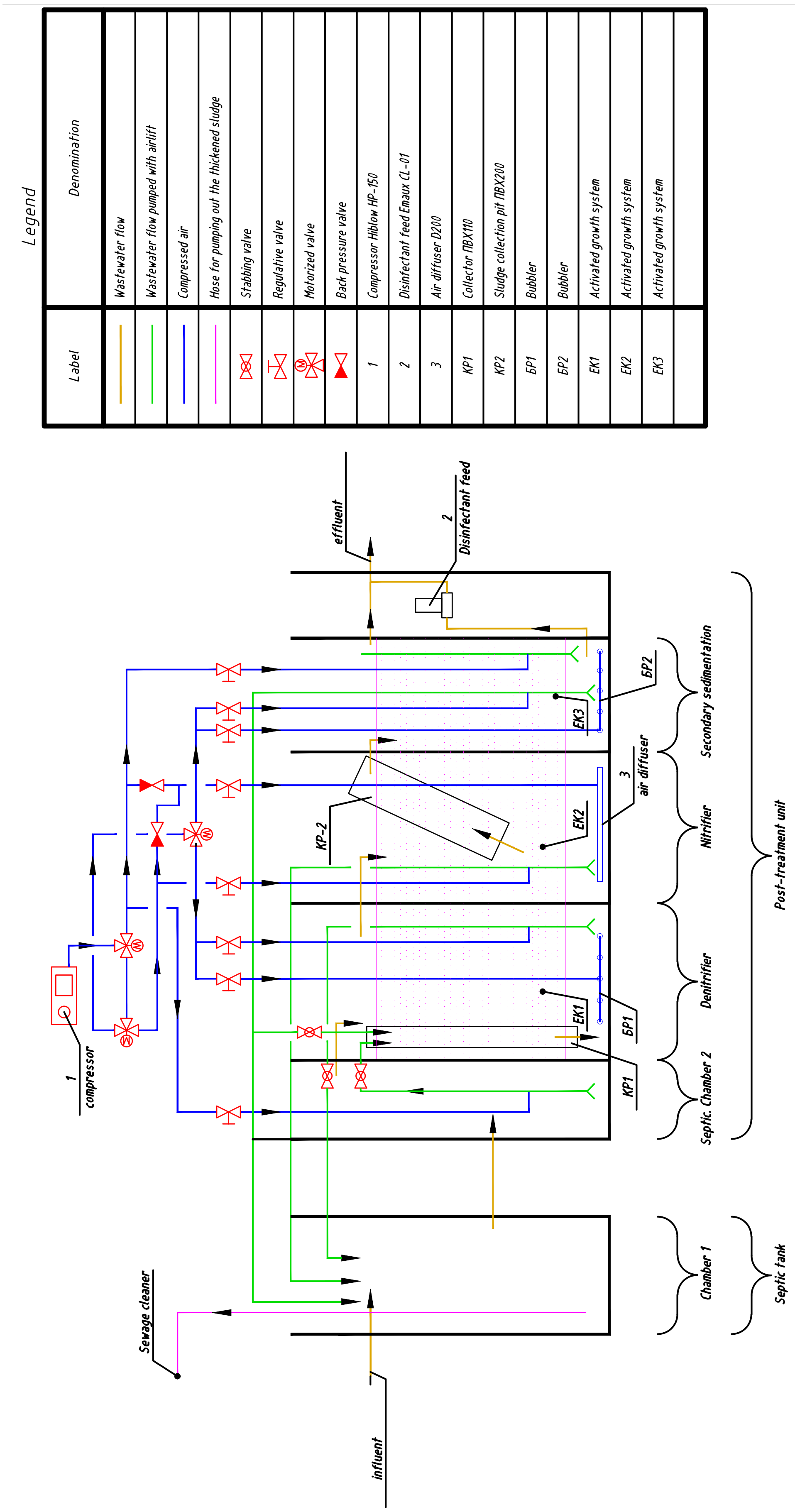

FIGURE 1. Technical scheme of the treatment facility

Wastewater treatment plant includes a septic tank that consists of 2 chambers and a post-purification unit that is comprised of biological (denitrification and nitrification) and chemical (disinfection) treatment units.

The wastewater flow enters the first chamber of the septic tank through a pipeline by gravity force. It is made of concrete and serves as an anaerobic digester. Suspended solids with density higher than 1000 kg/m^3 settle and form a sludge layer at the bottom of the chamber. Lighter materials float to the surface accumulating a scum layer. Since the influent wastewater remains in the first chamber of the septic tank for about three days, such processes as ammonification of protein substances (bacterial decomposition of organic matter producing ammonia as a by-product), fermentation of fats and carbohydrates decomposition occur due to anaerobic digestion. Sludge layer that accumulated in the septic tank is pumped out with sewage pipe cleaner (approximately once a year).

Liquid wastewater flow enters the second chamber of the septic tank through a pipeline by gravity force. As a result of anaerobic processes, which are undergoing in the second chamber of a septic tank, BOD level is reduced by half, amount of suspended solids is reduced by 80%. However, total amount of NH_4-N and total amount of phosphorous is increased.

From the second chamber of the septic tank, wastewater flows to the biological treatment chamber, where denitrification process takes place. Activated sludge is represented by immobilized bacteria that is attached to the polymeric units, it utilizes organic matter to support growth in anaerobic conditions. BOD is reduced up to 30 mg O_2/l during this stage.

Wastewater flow enters the second chamber of biological treatment facility (nitrifier) by gravity force. Aeration (compressed air) is introduced through diffuser at the bottom of the chamber to ensure aerobic conditions for nitrification process. As a result of biological treatment, wastewater quality achieves the following parameters: BOD less that 10 mg O_2/l; concentration of NH_4-N less than 0,5 mg/l; NO_2-N about 0,1 mg N/l ; NO_3 -N about 5 mg N/l.

Once influent was biologically treated, mixed liquor is recycled to the first chamber of biological treatment, while the clarified liquid is forwarded to the secondary sedimentation tank for separation of microbial mass and treated wastewater. The post treatment process increases quality of wastewater to the following parameters: BOD about 3-5 mg O2/l; concentration of NH_4-N less than 0,4 mg/l; NO_2-N about 0,05 mg N/l ; NO_3 -N less than5 mg N/l; PO_4-P 5 mg P/l.

From the secondary sedimentation tank, flow is forwarder to disinfection, where the total amount of microbial organisms is reduced from 10^7 to 10^2 cell/l. Also, BOD is reduced to 2 mg O_2/l and NO_2-N concentration to 0,02 mg N/l.

3.2. Commissioning plan

According to the methodology established by the housing and communal services in Russia, trial operation of a wastewater treatment plant precedes its commissioning. All treatment facilities and their elements are to be examined properly. Facilities with biological treatment are to be introduced into trial operation during summer in order to ensure certain temperature. The temperature of influent should be in the range of 10-12 degrees Celsius, so that microbial organisms can be cultivated. In case the above mentioned temperature range is unattainable, biomass from nearby wastewater treatment plant can be utilized. The following steps are required to start the trial operation of the facility: (Methodological documents in the housing and communal services, 2000)

a) Train personnel;

b) Provide a backup equipment;

c) The laboratory is supposed to be ready to operate, no malfunctions are acceptable;

d) Apply serial numbers onto all pieces of equipment.

Once trial operation is completed, wastewater treatment plant is introduced into a temporary operation. The following actions need to be taken. First of all, technical facilities are to be adjusted. Then, dose of the reagent for disinfection is to be determined. Also, testing of the wastewater treatment plant performance should be performed (emergency accidents should be taken into account). All possible malfunctions are to be identified and eliminated. (Methodological documents in the housing and communal services, 2000)

3.3. Analytical methods

Water quality analyses have been performed by a local laboratory that is established by sanitary-epidemiological center of Sochi city. «Persey» group of companies has an agreement for provision of laboratory services.

3.3.1.Quantitative chemical analysis

Odor of the effluent was measured according to Russian standard 12.16.1-10. Odor is caused by presence of volatile particles. First of all, the type of the odor is detected based on table 5. Then, the intensity of the smell is determined (usually according to five-grade scale that is presented below in table 6). Hydrogen sulfide and chlorine presence in water sample often disturb odor indication test. Therefore, few drops of 10% cadmium acetate solution may be added to water sample to get rid of hydrogen sulfide odor. 10% sodium thiosulfate solution may be also added to neutralize odor coming from chlorine.

TABLE 5. Odor type

Type of the odor	*Smell*
Aromatic	Cucumber-like, floral
Marshy	Oozy
Putrefactive	Fecal
Wood	Wooden
Earthy	Rotten

Fish-like	Fish-like, fish fat-like
Hydrogen sulfide	Rotten eggs
Herbal	Hay
Unknown	

Table 6. Odor intensity

Grade	*Intensity*
0	No odor observed
1	Very light
2	Light
3	Noticeable
4	Strong
5	Very strong

According to Russian standard 12.16.1-10, color of the water sample is detected by description of the color and shade (light-green, for example). Color of the water sample is necessary in order to know the dilution factor that has to be achieved before discharging the wastewater to the water body.

Chlorides are determined within the concentration range 10,0-250 mg/dm^3 by titrating the water sample. In case the chloride concentration exceeds the range limit values, water sample can be diluted. Silver nitrate is usually added to the water sample in order to produce hardly soluble sediment. Once chlorides have been settled on the bottom of the beaker, excess of silver ions reacts with potassium chromate, which serves as an indicator chemical. The procedure is standardized by Russian authorities (standard 01.1:1.2.4.41-06).

Quantitative determination of suspended solids is performed by implementation of gravimetric method. It is based on water filtration through a 0,45 micro km membrane filter. Once filtered, residue is weight after drying under 105^{o}C. The method is also standardized by Russian legislation (standard 52.24.468-2005).

According to standard 52.24.420-2006, biochemical oxygen demand analysis is based on ability of microorganisms to consume dissolved oxygen. It is measured as an amount of oxygen used for oxidation of organic matter in anaerobic conditions as a result of biochemical processes. Basically, dissolved water sample with special dissolving solution is placed into glass container under anaerobic conditions. Mass difference of the dissolved oxygen in water sample is measures after the incubation period, so the reduced amount of dissolved oxygen is multiplied by the dissolving factor in order to obtain BOD value in O_2/dm^3.

Chemical oxygen demand is monitored according to standard 52.24.421-2012 by titration of water sample. The following method is based on the oxidation of organic matter by potassium dichromate in the sulfuric acid solution in presence of the catalysis - silver sulphate.while heating. The excess of potassium dichromate is determined by titration with Ammonium iron(II) sulfate. The difference detects the amount of $K_2Cr_2O_7$ used for oxidation of organic matter.

Such parameters as pH, total iron concentration, sulphates and fats present in effluent have been analyzed according to international standards and do not require further description.

3.3.2.Microbiological analyses

Total coliform bacteria was measured by enumeration of coliform in water. Standard 2.1.5.800-99 states that m-Endo agar is to be used in total coliform bacteria analysis with the membrane filtration method. Samples are incubated aerobically under 37 ° C for 18-24 hours. Then, all colonies formed (red colored and have a metallic sheen) are counted.

Determination of coliphages in the waste water is carried out by seeding in the Petri dishes with nutrient agar. Fecal streptococci and pathogenic organisms analyses are performed in accordance with standard 2.1.5.800-99 issued by Russian Federation.

4. RESULTS AND DISCUSSION

4.1. Water analysis

The influent water quality was analyzed before the commissioning of the treatment facility. Table below gives a detailed information of the influent quality. As it may be noticed from the data presented, the influent quality is quite poor.

TABLE 7. Influent quality

Parameter	Unit	Value
Influent quality:		
BOD	mgO_2/l	180
TSS	mg/l	60
NH_4-N	mgN/l	46
P_2O_5-P	mgP/l	2,25

Water quality analysis was also performed after the commissioning of the wastewater treatment plant in order to complete trial operation of the plant and start up real operation of the facility. Water samples have been taken by a trainee. However, according to Russian legislation, water samples are to be taken by a certified person,. Therefore, water samples were also taken by laboratory personal. Protocol from the laboratory with all the parameters examined is disclosed as appendix 1. The Protocol includes both results for chemical and biological analysis.

The following tables give data on major parameters of water quality indication. Table 8 represents quantitative chemical analysis results, while Table 9 include biological analysis of effluent water quality.

TABLE 8. Chemical analysis

Parameter	Unit	Maximum permitted value	Result
Color	cm	not permitted	none
Odor	level	-	0
pH		6,5-8,5	6,92
TSS	mg/dm^3	< 0,3	< 5,0
Cl^-	mg/dm^3	< 350	28,05 ± 4,21
SO4	mg/dm^3	< 500	20,19 ± 1,21
BOD	$mg\ O_2/dm^3$	< 4	1,98 ± 0,51
COD	mg/dm^3	< 30	< 4,0
Fats	mg/dm^3	-	1,12±0,2

TABLE 9. Biological analysis

Parameter	Unit	Maximum permitted value	Result
Total coliform bacteria	CFU/100 ml	< 100 CFU in 100 ml	not found
Pathogenic organisms	-	not permitted at all	not found
Faecal streptococci	CFU/100 ml	<10 CFU in 100ml	not found
Coliphage	PFU/100ml	< 100 PFU in 100 ml	not found

4.2. Elimination of malfunctions

All the commissioning activities have been performed by a trainee under supervision of a professional hired by the company. Few problems were identified during the trial operation of the facility.

Insufficient aeration in bioreactor (chamber 2) was observed during the trial operation of the treatment facility. Air diffuser as well as the compressor were monitored. As a result of observation, the reason for defective aeration was overheated compressor.

Also, airlift pump of the returned sludge was not working properly. Basically, there are several reasons that may cause malfunction of the airlift: clog formed due to improper maintenance or compressor malfunction due to overheating. By analyzing the equipment, it was observed that the pump was clogged, so the the backwash was performed in order to eliminate the malfunction.

As a result of the commissioning operations, the list of possible malfunctions and ways of its elimination was created. Table 10 gives also a preferable frequency of maintenance that should be followed afterwards. The data given was confirmed by the engineer from the practical training company. Therefore, the information presented is considered as an official guidelines for further maintenance.

TABLE 10. Malfunctions and its elimination

Facility	Frequency of maintenance	Malfunction	Reason	Maintenance work
Septic	Once a year			Removal of stabilized sludge, cleaning the walls of the sludge adhering layer.
Airlift pump (influent)	Once a week	Feed of influent is insufficient	1. Clogged with large impurities 2. Malfunction of air supply system.	1. Backwash the airlift pump 2. Repair the compressor.
Bioreactors	Once a week	Insufficiently aerated nitrifiers	Malfunction of air supply system.	Repair the compressor.
Airlift pump (returned sludge)	Once a week	Feed of fluid recirculation fluid is insufficient	1. Clogged with large impurities 2. Malfunction of air supply system.	1. Backwash the airlift pump 2. Repair the compressor.

Settler	Once a month	An increased level of activated sludge from the settling tank	1.Hydraulic overloading of the settling tank. 2. Overloading with suspended solids	1. Check the airlift pump (influent) 2. Regenerate the settler
Secondary sedimentation	Once a week	An increased level of suspended solids from the post treatment filter	Dirt holding capacity is exceeded	Regenerate microbial organisms attached to the ruffs
Chlorine feed	Once a month			Check the need for reagent load.
Compressor	Once per 3 months			Change the filter

4.3. Decision taking process

Once the laboratory has released the protocol with effluent quality results, the decision on where it should be discharged is to be taken. According to Russian legislation, hydrological and hydraulic characteristics of the water body are to be determined in order to calculate allowable discharged amounts of effluent into the water body.

Therefore, river, where the effluent was planned to be discharged, has been studied in terms of hydrological and hydraulic characteristics (presented in table 11). Then, allowable discharged amounts and concentrations of the effluent are to be calculated based on river's properties. Afterwards, the report is to be affirmed with sanitary epidemiological center along with center of Hydrometeorology and environmental monitoring of the Black sea.

TABLE 11. Major hydrological and hydraulic characteristics

Parameter	Amount	Units
Minimum water flow rate	0,006	m^3/s
Average depth	0,028	m

Maximum depth	0,046	m
Average flow rate	0,11	m/s
Width of the river	2	m
Water surface slope	0,0038	
Sinuosity coefficient	1	
surface roughness factor	20	

Allowable discharged concentration of effluent into the water body is represented in the table below.

TABLE 12. Allowable discharged concentration of effluent

	Allowable concentration mg/dm^3	Approved concentration mg/dm^3
Suspended solids	3.00	1,58
NH_4-N	0,176	0,0925
NO_3-N	9,1	4,78
NO_2-N	0,0122	0,00641
PO_4-P	0,2	0,0641
BOD	3.00	1,58

4.4. Maintenance plan

Once the commissioning of a treatment facility was conducted successfully, maintenance plan was established in order to keep the facility in a proper condition. The maintenance plan has been created by a trainee. Afterwards, it was adjusted and approved by certified engineer. The table below shows frequency of parameters to be maintained.

TABLE 13. Maintenance plan

Parameter	Frequency
Chemical analysis	once in 4 months
Biological analysis	once in 4 months
Regeneration of the biomass	once per month
Aeration system	once per month
Chlorine feed	once per month
Overall inspection	once per month

4.5. Oxidation capacity

«Persey» group of companies is utilizing Hilblow air pump in all their wastewater treatment plants. Its performance is about 12 m^3/hour performance. Assuming that the depth of the bioreactor is 1 meter and the air pump's oxidative capacity is 1 gO_2/m^3hour, about 12 gO_2/hour is produced. However, the oxygen demand of 1 m^3 of wastewater is 370 gO_2/m^3hour. Therefore, above described pump does not provide sufficient aeration to increase oxidation capacity. (Kulikov et al., 2015)

Therefore, the company has decided to increase effluent quality by cultivating annamox bacteria in their wastewater treatment technology. This type of bacteria is able to survive is absence of oxygen getting energy from fermentation processes. However, this type of bacteria cannot be cultivated in activated sludge. Polyamide fibers can be used for this purpose, though. (Kulikov et al., 2015)

In order to increase oxidative capacity in the bioreactor, polyamide ruffs are used with fiber diameter of about 15 micro meters to 0,2 milli meters. One polyamide ruff of 1 kilo mass is able to retain 1 kilo of microbial organisms. In order to achieve oxidation capacity of 370 gO_2/m^3hour, total mass of bacteria in bioreactor should be about 10 kilograms and the retention time should be not less than 3 hours. (Kulikov et al., 2015)

However, this oxidation capacity is still unachievable when using the air pumps from the Hilblow brand. It is recommended to use rotating biorotors with polyamide fabrics. (Kulikov et al., 2015)

4.6. Recommendations

During wastewater treatment process, there is a way to make zero waste cycle by introducing some plants and fish to the system. Based on previous studies and article written together with Russian professor Kulikov, zooplankton from bioreactor can be used as food for fish (once per day), feces of which is going back to the septic tank (once per month). (Kulikov et al., 2015)

Also, composting may be introduced to the system to make the zero waste circle completed. Extra sludge that is not utilized nowadays may be used as raw-material for composting. Combination of soil, sludge and composting worms make a perfect material for getting fertilizers.

Then, fertilizers may be used for vegetable plants, which consume CO_2 from the bacterial digestion of organic matter. Basically, by introducing 3 components: composting system, fish and vegetable plants, efficiency of the wastewater treatment facility can be significantly increased in terms of waste reduction. Thereby, human can get clean water, fish and vegetables at the same time. Moreover, methane from anaerobic digestion may be used as an energy material. However, this issue need to be studied more deeply. Also, using methane as energy material, may significantly increase wastewater treatment plant's costs.

5. CONCLUSION

The wastewater treatment plant introduced above is an example of how the wastewater can be treated on site. The technology is not complicated and costly comparatively to conventional wastewater treatment plants. Performance characteristics are in correspondence to local legislation, which is confirmed by the laboratory control. Therefore, this technology could be widely used in location with no connection to centralized sewage system.

Oxidation capacity of the wastewater treatment plant is closely related to wastewater treatment efficiency. As the research represents, oxidation capacity can be increased by introducing anammox bacteria as well as biorotors due to its ability to increase aeration efficiency. Unfortunately, technology studied by Litter and Quici (2010) is not affordable for small-scale wastewater treatment plants. However it could be utilized in a bigger scale.

The wastewater treatment plant described above can be further developed in terms of zero-waste cycle and decreasing greenhouse gasses emissions by introducing modern technologies.

REFERENCES

Building regulations № 2.04.02-84 «Water supply. External water networks and facilities». Ministry of Construction of the Russian Federation. 27/07/1986. 160p.

Building regulations № 23.05.04-85 «External networks and facilities. Water supply and sewage». State Construction Committee (USSR). 25/05/1990. 14p.

Hu, Z., Lotti, T., Kreuk, M., Kleerebezem, R., Loosdrecht, M., Kruit, J., Jetten, M., Kartal, B. (2013) Nitrogen Removal by a Nitritation-Anammox Bioreactor at Low Temperature. American Society for Microbiology 15/02/2013

Kulikov, N.I., Nozhevnikova, A.N., Zubov, M.G., Zubov G.M., Kulikov, D.N., Kulikova, E.N., Litti, U.V., Mamlutov, R.K., Prihodko, L.N. (2015) Municipal wastewater treatment and reuse of treated water and sediments. Theory and practice. Moscow, «Logos», 2015. 400p.

Kulikov, N.I., Kulikova, E.N., Prikhodko, L.N., Shunova, K.S.. 2015. On the specifics of completing low-duty waste water treatment mounts. Volgograd: Science and World, 2015

Litter, M., Quici, N. (2010). Photochemical Advanced Oxidation Processes for Water and Wastewater Treatment. Recent Patents on Engineering . 15/09/2010 241p.

Methodological documents in the housing and communal services. 3-02.2001. "Technical operation of systems and constructions of municipal water supply and sewerage». Federal Agency for Construction, Housing and Utilities. Moscow, 2000. 79p.

Sanitary regulations № 4630–88 Protection of surface water bodies from pollution. Department of health (USSR). Moscow 4/07/1988. 61p.

Tchobanoglous, G., Schroeder, E. D. 1987. Water quality : characteristics, modeling, modification. Addison-Wesley, 1987. 768p.

APPENDICES

Appendix 1. Protocol from the laboratory analysis

Протокол испытаний № 11691 от 14.12.2015 Страница 1 из 2

Федеральная служба по надзору в сфере защиты прав потребителей и благополучия человека

Федеральное бюджетное учреждение здравоохранения

«ЦЕНТР ГИГИЕНЫ И ЭПИДЕМИОЛОГИИ В КРАСНОДАРСКОМ КРАЕ»

Сочинский филиал Федерального бюджетного учреждения здравоохранения

«ЦЕНТР ГИГИЕНЫ И ЭПИДЕМИОЛОГИИ В КРАСНОДАРСКОМ КРАЕ»

Аккредитованный Испытательный лабораторный центр (ИЛЦ)

Аттестат АИЛ № RA.RU 21AB24 от 07.08.15г.

Юридический адрес: 350000, г. Краснодар, ул. Гоголя / Рашпилевская 56/1 // 61/1
Фактический адрес: 354000, г. Сочи, ул. Роз, 27
Телефон/факс: (8622) 64-77-75
E-mail: sochi_fguz@mail.ru

ПРОТОКОЛ ИСПЫТАНИЙ

ВОДЫ СТОЧНОЙ (ПОСЛЕ ОЧИСТКИ)

№ 11691 от 14.12.2015 к акту отбора № 15834 от 07.12.2015

Заказчик ФГБУ "Кавказский государственный природный биосферныйзаповедник"
Юридический адрес заказчика 354340, г.Сочи, Адлерский район, ул.Карла Маркса, д.8
Наименование предприятия/объекта Тиссо-самшитовая роща Кавказского государственного природного биосферного заповедника
Фактический адрес отбора пробы г.Сочи, Хостинский район, Тиссо-самшитовая роща
Место взятия пробы Сточная вода после очистки на КОС КБ 5м - ПЕРСЕЙ
Количество (масса) пробы на испытания 2,0 л
Температура окружающей среды при отборе, °C 10 **Тип воды** Холодная
Код пробы МХ 15834.07122015 в
Наименование пробы (образца) Вода сточная (после очистки)
Образец направлен ИЛЦ Сочинский филиал ФБУЗ "Центр гигиены и эпидемиологии в Краснодарском крае"
Акт отбора № 15834
Пробы отобраны (Ф.И.О., должность) Ведущий инженер-эколог Сычева Е.П.
Основание Договор № 282 от 01.04.2015г
Дата отбора 07.12.2015 **Время отбора** 13:00
Дата и время доставки 07.12.2015 14:00
НД на методику отбора ГОСТ 31861-2012, ГОСТ 31942-2012, СанПиН 2.1.5.980-00, МУ 2.1.5.800-99
НД, регламентирующие объём и оценку лабораторных испытаний МУ 2.1.5.800-99, СанПиН 2.1.5.980-00
Дополнительные сведения нет
Лицо, ответственное за оформление протокола Куроедова Е. А.

Руководитель ИЛЦ А. М. Шебелян

Частичная перепечатка без разрешения ИЛЦ не допускается.
Воспроизведение протокола разрешается только в форме полного фотографического факсимиле.
Протокол испытаний распространяется только на образцы, подвергнутые испытанию.
Показатели, отмеченные * - аккредитованы в системе DAkkS № D-PL-14354-01-02

Результаты испытаний

Количественный химический анализ

Наименование показателей	**НД на методы**	**Единицы измерения**	**Величина допустимого уровня**	**Результат, погрешность /неопределённость**
Окраска	ПНД Ф 12.16.1-10	см	Не допускается в столбике 20 см	не обн.
Запах	ПНД Ф 12.16.1-10	балл	Не более 2	0
Водородный показатель*	ПНД Ф 14.1:2:3:4.121-97	ед pH	6,5-8,5	6,92
Хлориды*	М 01.1:1.2.4.41-06	мг/дм^3	Не более 350	28,05±4,21
Хлор остаточный активный	М 01.1:1.2.3.4.40-06	мг/дм^3	0,3-0,5	0,15±0,04
Взвешенные вещества	РД 52.24.468-2005	мг/дм^3	-	<5,0
Железо общее*	М 01.1:1.4.2:2.18-05	мг/дм^3	Не более 0,3	менее 0,005
Сульфаты*	ПНД Ф 14.1:2.159-2000	мг/дм^3	Не более 500	20,19±1,21
Биологическое потребление кислорода (БПК-5)	РД 52.24.420-2006	мгО/дм^3	Не более 4,0	1,98±0,51
Химическое потребление кислорода (ХПК)	РД 52.24.421-2012	мг/дм^3	Не более 30,0	<4,0
Жиры	ПНД Ф 14.1:2.122-97	мг/дм^3	-	1,12±0,2

Дата начала и окончания испытаний 07.12.2015 – 14.12.2015 **Зав. лабораторией** Мищенко И. В.

Микробиологические испытания 759

Наименование показателей	**НД на методы**	**Единицы измерения**	**Величина допустимого уровня**	**Результат, погрешность /неопределённость**
Общие колиформные бактерии*	МУ 2.1.5.800-99	КОЕ/100 мл	Не более 100 КОЕ в 100 мл	В 100,0 не обнаружены
Термотолерантные колиформные бактерии*	МУ 2.1.5.800-99	КОЕ/100мл	Не более 100 КОЕ в 100 мл	В 100,0 не обнаружены
Колифаги*	МУ 2.1.5.800-99	БОЕ/100мл	Не более 100 БОЕ в 100 мл	В 100,0 не обнаружены
Патогенные микроорганизмы	МУ 2.1.5.800-99,МУ 4.2.2723-10	-	Отсутствие	Не обнаружены в 1 л
Фекальные стрептококки	МУК 4.2.1884-04	КОЕ/100 мл	Не более 10 КОЕ в 100 мл	В 100,0 не обнаружены

Дата начала и окончания испытаний 07.12.2015 – 10.12.2015 **Зав. лабораторией** Кучук Л. Г.

Мнения и толкования нет

Показатели, отмеченные * - аккредитованы в системе DAkkS № D-PL-14354-01-02