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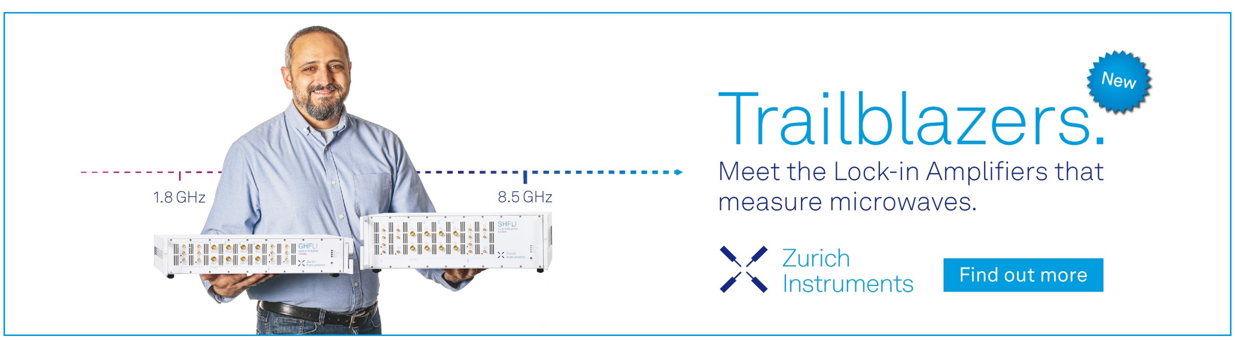

Design of Sewerage and Wastewater Treatment Systems in a Village

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Abstract. The article describes the features of wastewater and water treatment plants in settlements. An example of decentralized wastewater treatment with the presence of two treatment plants in an urban-type settlement with a population of 14.4 thousand people was considered. The composition of buildings and structures for wastewater treatment plants for settlement was proposed. As a result of the research, the most appropriate technological scheme for wastewater treatment, sludge treatment and disposal were developed. The efficiency at each treatment stage was analyzed. It is concluded that the described technological scheme of wastewater treatment for settlement meets the fishery standards for effluent discharging into the river.

INTRODUCTION

Nowadays the treatment and disposal of municipal wastewater generated as a result of human activity is one of the most important environmental problems [1].

Environmental protection and sustainable management of natural resources are now at the forefront of economic and technological activities worldwide [2]. The development tendency should be aimed at achieving a self-sufficient urban water cycle, which is not only a closed cycle in terms of water flows, but also minimizes energy requirements and the volume of waste discharged into the environment [3].

Most small settlements in the Russian Federation do not have modern sewer and wastewater treatment systems. For the well-being of the population and the environment protection, the design of these systems is essential [4]. Water management systems of cities should be equipped with modern complexes of gravity and pressure pipelines and other special facilities that carry out the removal, treatment, neutralization and use of water and sludge [5].

The main objectives of sewer systems are to prevent the flow of poorly treated wastewater into water bodies and to protect the environment from pollution [6]. Due to the material selection, availability of appropriate normative and technical documents, quality design and maintenance, reliability and durability of engineering systems is achieved [7].

The predominant method of wastewater disposal in large cities and towns is the discharge of surface water into a water body. Wastewater must be treated to a certain degree in order to protect public health and preserve the suitable quality of surface water bodies.

The degree of wastewater treatment varies depending on local environmental conditions and state standards [8]. There are state and municipal wastewater standards of maximum permissible concentration (MPC) depending on the conditions of the region (climate, geographical location, landscape, sanitary and epidemiological state of the environment, etc.).

Despite the ongoing process of urbanization around the world, about half of the world's population still lives in rural areas [9]. Effective sanitation and wastewater management is a growing problem in dense urban settlements. Rapid urbanization and, with it, the increasing settlement density in urban and suburban areas emphasize the need

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for reliable and affordable sanitation management technologies and systems that reduce the pollution load on local water sources [10].

In urban areas, including many densely populated cities and some suburban areas, wastewater is usually piped off (i.e., through a "sewer system") to a treatment plant and then effluent is discharged into a water body. This sewer is called centralized. However, in most cases around the world there is no centralized sewer and treatment system. In areas without centralized wastewater disposal systems, wastewater must be disposed of on-site or into adjacent utility systems. They are decentralized treatment systems, sewere and sludge decontamination on site [11].

This article will apply organization principles of decentralized treatment, completely connect the village population to the sewer system is problematic due to the geological and technical features, as well as economically impractical. Therefore, the optimal solution is decentralized wastewater treatment, which involves the installation of compact treatment plants.

A decentralized system is a viable alternative for wastewater management in existing areas that historically have not had sewer lines. It minimizes the impact on the environment and promotes resource recovery.

The decentralized system makes efficient use of the useful substances contained in the wastewater and allows the water recycling. On-site water treatment and disposal reduces infrastructure costs by reducing the volume of water transported because smaller diameter pipes and equipment with lower capacity can be used. Small wastewater treatment plants generally do not require a large production area, are cheaper and easier to maintain and operate.

Pollutants present in wastewater can be divided into:

- Potentially toxic elements (PTEs) or heavy metals (cadmium (Cd), chromium (Cr III and Cr VI), copper (Cu), mercury (Hg), etc.);
- Organic pollutants. They consist of carbon, hydrogen, oxygen, nitrogen and other elements;
- Inorganic pollutants. Such pollutants include: various garbage, sand, clay particles, salts dissolved in water, acids, alkalis and other substances [12];
- Microbiological contamination. Most waterborne microorganisms that cause human disease come from fecal waste excreted by humans or animals that are carriers of these diseases. Bacterial contaminants include viruses, microorganisms, and various bacteria. Domestic wastewater also contains pathogenic bacteria as well as helminth eggs (worms) [12].

Other pollutants are metalloids, arsenic and selenium, and metallic silver. There are platinum group metals, as well as pharmaceuticals.

MATERIALS AND METHODS

The size and capacity of wastewater treatment systems are determined by the expected volume of wastewater generated by residences, businesses and industries connected to sewer systems. The selection of a particular on-site wastewater treatment plant configuration depends on such factors as the number of customers served, geographic location, sewer connection, average and peak flows, characteristics of incoming wastewater, regulatory effluent limitations, technological feasibility, energy consumption, and operation and maintenance costs [13].

There are four levels of wastewater treatment: primary, secondary, tertiary and quaternary. The primary and secondary treatment process is used to remove most coarse particles and organic matter, respectively. After primary and secondary treatment, there are still various undesirable substances in the treated water, which are removed by tertiary treatment. All treatment stages usually involve a combination of various physical, chemical, and biological processes [14]. Quaternary wastewater treatment is an innovative method that is still under development. The purpose of quaternary treatment is to reduce the spread of drug pollutants (antibiotics, hormones, anticancer drugs, etc.), whose presence in wastewater is regularly increasing, creating problems for human health and aquatic biodiversity [15].

Primary treatment. Mechanical wastewater treatment.

Primary (mechanical) treatment of wastewater includes two consecutive stages - pretreatment and sedimentation process [10]. Pretreatment includes the physical processes of sifting, grinding, sand removal on screens and grit traps. The sedimentation process takes place in primary sedimentation tanks, where the physical treatment process takes place. As a result, organic solids, colloidal and finer suspended solids are removed from the wastewater in the sludge form.

Secondary treatment. Biological wastewater treatment.

Biological treatment methods are used to remove organic and some inorganic (e.g. hydrogen sulfide, sulfides, ammonia, nitrates, etc.) substances from wastewater with protozoan organisms that use these substances for food by breaking them down using cellular processes [16].

There are three variations of biological treatment: anaerobic (phosphorus removal), anoxic (denitrification) and aerobic (nitrification). The combination of these methods makes it possible to achieve the removal of nitrogen groups and phosphorus. Currently in Russia, only aerobic treatment or aerobic treatment in combination with anoxic treatment is used, with phosphorus being removed chemically or not removed at all.

Secondary clarifiers are an integral part of biological wastewater treatment. This process of mechanical treatment is necessary because the activated sludge in the system "aeration tank - secondary clarifier" is constantly growing and excessive activated sludge is formed, which must be separated from the treated water. This solid-liquid separation process is usually achieved by gravity settling in conventional secondary clarifiers.

Disinfection. The disinfection process is carried out in the following ways:

- Chlorine treatment: Chlorine is one of the most commonly used disinfectants in wastewater treatment because it is economical, easy to use and effective [17].
- Ultraviolet light treatment: Ultraviolet (UV) light is a common disinfectant in tertiary treatment. Wastewater flows under UV light and the light sterilizes the water, damaging the genetic structures of microorganisms.
- Ozone Treatment: An alternative method is to use ozone, a compound formed by means of electrical energy to add a third oxygen atom to the standard two-atom (O_2), as a disinfectant. Ozone is highly reactive and can destroy most microorganisms with which it comes into contact [17].

RESULTS

Consider an example of decentralized wastewater treatment on the example of an urban village with a population of 14.4 thousand people.

We plan to arrange a decentralized wastewater treatment system with the presence of two treatment plants in the urban village. Stations are located on the edges of the village (north and south), downstream and upstream. The effluent will be treated to fishery standards for water use and discharged into the river after treatment. Conventionally: wastewater from half the area of the village will go to treatment plant number 1 and from the other half of the village - to the treatment plant number 2. The street sewer network from private homes and establishments will be built and reconstructed. Wastewater treatment plants number 1 and number 2 are identical by load and composition of plants. The design of sewage treatment plants is developed for a capacity of 700 m^3/day.

TABLE 1. Pollutants concentration of in wastewater arriving at wastewater treatment plant number 1.

Indicators	Unit of measure	Parameters before treatment, mg/dm^3	MPC for water bodies for fishery purposes, mg/dm^3	Excess rate
BOD-5	mg/l	267.73	-	-
Suspended matter	mg/l	242.5	10	24.25
COD	mg/l	273.35	-	-
Nitrates	mg/l	0.874	40 (in terms of nitrate nitrogen 9)	-
Nitrites	mg/l	0.079	0.08 (in terms of nitrite nitrogen 0.02)	-
Chlorides	mg/l	236.6	300	-
Sulfates	mg/l	37.5	100	-
Phosphates	mg/l	5.5	1-2	2.75-5.5
Synthetic surfactants (SPAs)	mg/l	2.83	0.5	5.66
Ammonium nitrogen	mg/l	136	0.4	340
Dry residue	mg/l	157.8	-	-

The urban village is the district center. The area of the district is 2,434.7 square kilometers. The Region includes 17 rural settlements. The population on January 1, 2021 was 29263 people. The population density per square kilometer is 12.0 people. Within the district, 14 of the 16 rural settlements are connected to the district center by paved roads [18].

There are 14.4 thousand people living in the district center, an urban-type settlement. It occupies an area of 1,046 hectares and is the administrative and economic center. The territory of the municipality is predominantly homestead, low- and mid-rise buildings. Some neighborhoods are built up with five-story houses. In the village there are health care and social protection, educational establishments, sports facilities, industrial plants, etc. In the western part of the village there is a distillery and a residential sector. In the northern part is a former flax factory with adjoining private residences. Most of the population lives in the central district. There are public buildings, cultural and household establishments, the central district hospital (CRH), school, administration, bus station, post office, central stadium, stores, etc. [18].

The sewerage in the village is poorly developed. Capital construction is partially sewered with the release of effluents into cesspools with subsequent removal to the inoperative wastewater treatment plant (WTP). Yard latrines with pits are provided for individual sector.

For sludge treatment, the proposal is to install mechanical sludge dewatering equipment (decanters) to help reduce the volume generated. As well as equipment for drying sludge to produce organic-mineral fertilizer. Sand drying beds are available for the treatment of mineral sludge. Emergency sludge drying beds are also provided.

DISCUSSION

The authors proposed the following scheme of urban wastewater treatment (fig.1).

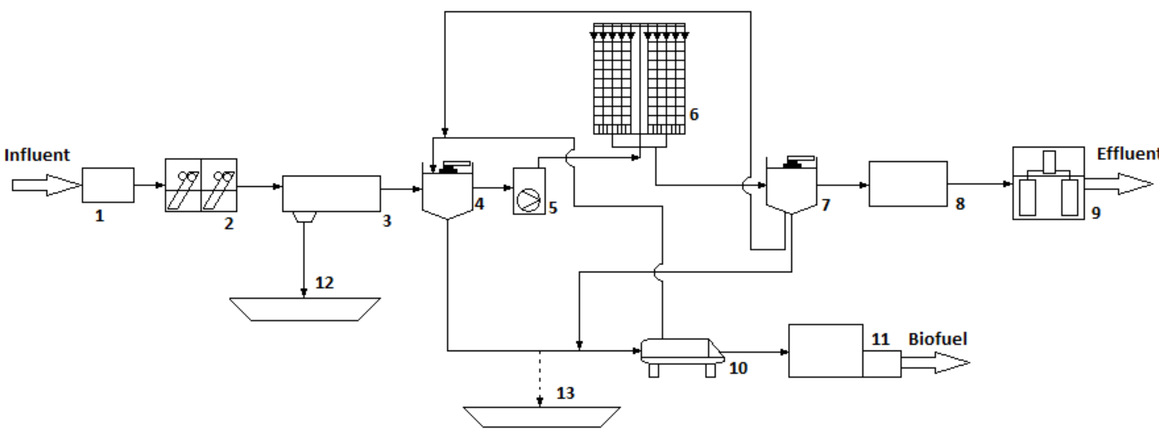

FIGURE 1. Wastewater treatment techological scheme for the urban village: 1 - Inlet chamber, 2 - Screens; 3 - Grit chamber; 4 - Primary settling tank ; 5 - Biofilter pumping station; 6 - Biofilters; 7 - Secondary clarifier; 8 - bioreactor for post-treatment; 9 - ultraviolet disinfection; 10 - Decanter; 11 - Drum drying; 12 - Sand drying beds; 13 - Emergency sludge drying beds.

Wastewater enters the inlet chamber, and then goes to the mechanical treatment.

Mechanical wastewater treatment includes cleaning on screens, grit chamber and primary settling tank. Water from the inlet chamber enters the screens, where large insoluble impurities are detained. The water then enters the grit chamber, where inorganic pollutants (0.25 or larger) are deposited – this technology allows up to 90% of the sand to be deposited, while possible organic pollutants do not precipitate out. Removal of sand from grit chamber is done mechanically, the sludge is taken for further dewatering on sand drying beds. After grids and grit chambers, suspended solids are reduced by 7%, BOD-5 – 7%, the number of bacteria – 10% [19]. The water is then sent to the primary settling tank, where the physical treatment process (the sedimentation process due to gravity) takes place. The sedimentation effect of suspended solids is 60% (organic solids, colloidal and finer suspended solids in the form of sediment are removed), BOD-5 is reduced by 25%, the number of bacteria by 25%, helminths by 70% [19].

After the primary settling tanks, wastewater is pumped for biological treatment in the biofilters. The treatment efficiency for suspended solids is 70%, BOD-5 is 70%, the number of bacteria is reduced by 80% [19]. The water then enters the secondary clarifier. At this stage, the activated sludge is separated from the treated wastewater. There is a reduction of pollutants by suspended solids by 80%, BOD-5 – by 85%, the number of bacteria is reduced by 90% [20]. Sludge settles inside the clarifier, and treated water flows for further treatment - post-treatment in the bioreactor, where the content of suspended solids is reduced by 25%. After post-treatment, the water enters ultraviolet disinfection, where 100% of bacteria and helminthes are removed. This treatment allows the water to be reused or discharged into the river.

Raw sludge from the primary settling tanks is sent to decanters for dewatering. The decanter feeds the primary settling tanks for treatment. The activated sludge separated from the treated water in the secondary clarifiers is sent to the decanter for further treatment. The decanter also transfers the feed from the decanter to the primary settling tank for treatment. The dewatered sludge from the decanter is sent to a drum dryer, after which we get solid biofuel (briquetted).

Emergency sludge drying beds are also provided for in case of emergency situations.

The described technological scheme of wastewater treatment for the urban settlement brings the indicators of water composition to fishery standards for discharge into the river, makes it possible to reuse treated water for the needs of enterprises and the population, reduces energy and process losses, operating costs, offers the use of waste after sewage treatment for commercial purposes, ensures the safety and reliability of this treatment, which ultimately reduces the harmful effects on the environment.

CONCLUSION

As a result of the analysis of wastewater disposal in the urban village and drawing up a technological scheme of treatment, the selection of equipment at the sewage treatment plant, we can say that the implementation of this project, the construction of new sewer upgrading existing treatment plants, equipment replacement will significantly improve the environmental condition of the area, water resources, increase the level and quality of life of the population.

It is proposed to use this project and send it for further refinement, calculation and construction.

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