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EXPERT REVIEW

Modern technologies used in compact installations of complex treatment of household wastewater, and their sanitary protection zone

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The purpose is a scientific substantiation of the criteria for evaluating compact sewage systems for domestic wastewater treatment and the size of sanitary protection zones for them. Materials of more than 30 manufacturers (Ukraine, Lithuania, the Czech Republic, Poland, Germany) of compact sewage plants for biological treatment of domestic wastewater, in particular, those designed for wastewater treatment of infectious diseases hospitals and TB dispensaries are studied. The results of the conducted instrumental researches on the efficiency of their work, air pollution and noise at the border of the sanitary protection zone are analyzed. It is noted that the characteristic feature of such structures is the factory production of tanks, tightness and lack of specific odor in the area of their location. It is revealed that the manufacturers of compact installations of complex domestic wastewater treatment offer different: methods for purification, disinfection and additional treatment of wastewater and their sediments; measures to prevent air pollution; design features and materials of tanks that make them resistant to corrosion processes and different temperatures; technologies for the manufacture of tanks; aeration systems; characteristics of automatic equipment, etc. Based on the research, the criteria for assessing such facilities and the size of sanitary protection zones for them are substantiated. A comparative analysis of current regulations of Ukraine and Lithuania revealed significant differences in the regulated requirements for the size of sanitary protection zones and the composition of treated wastewater.

Keywords: Sewage installations, Cleaning efficiency, Cleaning methods, Sanitary protection zones.

Introduction

Today, anthropogenic human intervention leads to man-made pollution of water basin ecosystems (Netrobchuk, 2011; Laskov, et al., 2013; Shakhman and Bystriantseva, 2021), which prevents the use of reservoirs and watercourses in recreational, fishery activities and as sources of drinking water (El-Shehawy, et al., 2012; Kovalchuk, et al., 2014; Pichura, et al., 2018). One of the main reasons for the deterioration of surface water quality is insufficient treatment of domestic wastewater (Muñoz, 2014; Ivanova, et al., 2017). For example, almost 40% of untreated domestic wastewater is discharged into the Dnieper River (Denis, 2018). Discharging untreated or dirty sewage to water receivers undoubtedly poses a threat to their entire ecosystems (Policht-Latawiec and Kanownik, 2013; Młyński, et al., 2016). Untreated or insufficiently treated wastewater enriches the surface water with organic and biogenic substances, which first leads to biological imbalance and suppression of self-purification of the reservoir, and then the change of type of its ecosystem into eutrophic, oxygen deficiency and create favorable conditions for pathogenic microflora, pathogenic agents and carcinogenic N-nitrosamines (Policht-Latawiec, et al., 2017). Due to the above, it is recommended to control the content of basic biogenic substances (total nitrogen and total phosphorus) that promote "water bloom" in surface and treated wastewater (Kurek, et al., 2019). Despite the creation of new and modernization of existing sewage treatment plants, the condition of surface water even in some European countries is still unsatisfactory and the problem of their eutrophication remains unsolved (Makowska, 2015, Neverowa Dziobak and Preisner, 2016). The problem of wastewater treatment is acute in the presence of a large number of water users who are close to the water source, but are located at considerable distances from each other. In particular, in the case of placement of sewerage facilities far outside the settlement (sanatoriums, specialized hospitals, separate military units), sewerage of rural settlements, country settlements, temporary sewerage of certain facilities for the period before the commissioning of centralized drainage, and also complex terrain (Chmielowski, et al., 2011; Cossio, 2017). There are no cost-effective standard projects for such facilities. Unfortunately, traditional artificial biological treatment plants operating in large cities cannot be mechanically copied and transferred for treatment and disinfection of effluents in small settlements (Ivanko, et al., 2012), because small treatment plants are characterized by high uneven hydraulic and organic loads and changes in composition and properties of wastewater (Khoruzhiy and Mosiychuk, 2019). In such cases, cesspools and septic tanks are used (Chmielowski, et al., 2011;

Gizińska-Górna and Mariusz, 2020). It needs to be emphasized that objects of this type are often leaky, which poses a threat to the surface and underground waters. Them should be regularly emptied, which entails high costs (Pryszcz and Mrowiec, 2015). Various designs of small sewage treatment plants can also be used: hydrophyte treatment plants, treatment plants with a biofilter, and treatment plants with activated sludge (Bryszewski, et al., 2020). Some of them are prefabricated and are called compact installations. Nowadays it is important to systematize such installations and scientifically substantiate the criteria for their evaluation and determination of the size of their sanitary-hygienic zones.

Materials and Methods

Materials of more than 30 manufacturers (Ukraine, Lithuania, the Czech Republic, Poland, Germany) of compact sewage installations of biological treatment of household sewage are considered. The methods used for wastewater treatment in such plants and their sediments, materials, design features of these plants and equipment to them, the efficiency of wastewater treatment, the size of sanitary protection zones (SPZ) and air pollution at their borders, prevention measures its pollution, etc. The results of the conducted instrumental researches of air pollution and noise on the border of the sanitary protection zone of compact installations for domestic wastewater treatment are considered. The requirements of the current normative documents of Ukraine and Lithuania regarding sewerage are analyzed. Regulations of Ukraine (Resolution of the Cabinet of Ministers of Ukraine No. 465 "On approval of the Rules for the protection of surface waters from pollution by return waters" (March 25, 1999), DSP 173-96 "State sanitary rules of planning and construction of settlements", DBN B. 2.5-75: 2013 "Sewerage. External networks and structures. Basic design regulations»); regulations of Lithuania on wastewater treatment (order of the Ministry of Environmental Protection No. D1-236 (September 17, 2006) and the size of the sanitary protection zone (order of the Ministry of Health No. V-586 (August 19, 2004). Methods: bibliosemantical, sanitary-epidemiological, comparative-descriptive, expert assessments, sanitary-chemical, full-scale measurements of pollutants and noise in the air.

Results and Discussion

In compact sewage systems for complex treatment of domestic sewage the biological method of treatment by means of microorganisms is used. The intensity and depth of the relevant treatment process depends on the quality, the variety of forms and types of microorganisms, their ability to adapt to the specific composition of pollutants in the wastewater and the conditions of the process (Davydenko and Arakel, 2017). Compact sewage treatment plants are manufactured with a flow circuit or with serial-variable reactors (SBR).

Preferably, the first technology for biological treatment of domestic wastewater with a flow scheme is based on a modified biological treatment process with preliminary denitrification according to the German standard ATV-131E. This technology is more common and simple in construction and operation, but requires a high degree of internal recirculation to effectively remove nitrogen from wastewater.

The second technology is based on the process of biological treatment in batch reactors according to the German standard ATV-M210. The complete cleaning cycle is about eight hours. This technology allows to reduce the total volume of treatment facilities for a full cycle of deep biological treatment compared to traditional aeration tanks. This technology is more complex than the technology of the ATV-131E standard, due to the cyclical nature of the units has increased technological risks and requires the use of a wider range of automatic control equipment during operation, which increases the cost of units. However, the results of the analysis of the microbial population (Han Xiangxiang, et al., 2019) showed that reactors with periodic aeration are suitable for water treatment with low characteristics of the C/N ratio.

The results of the research show that biological wastewater treatment in compact plants is traditionally carried out with free-floating (aerotanks), fixed (biofilters) or mixed (aerotanks with nozzle, biotanks) microflora. A large number of manufacturers of compact plants for biological wastewater treatment use a flow-through treatment scheme with biofilters, which allows to increase the number of stages of treatment with the minimum size of the area of treatment facilities. However, installations are also made with a combined block-modular cleaning system with zones of suspended and immobilized cultures of microorganisms on bulk free-floating plastic elements of factory production of different spatial configuration ("OPET", "TVK", "BFZ-30.22", "Piccobell"), which are in continuous motion due to the aeration system. Also used textile fiber type "POLITEX", stretched on the frames. These polymer elements intensify the cleaning process, in particular, contribute to the maximum exclusion of places in the tank, where anaerobic conditions lead to uncontrolled bacterial growth. Dzherelo plants use the patented principle of biological filtration of wastewater previously clarified in the primary settling tanks through a synthetic fibrous nozzle of the "VIYA" type. In such installations, wastewater is treated in a flow mode, passing successively first anaerobic and then aerobic biotanks, each of which develops its own specific biocenosis, which includes, in addition to destructive bacteria, even more complex forms of aquatic filters, sedimentators, predators. This technology allows you to minimize the side effects that accompany biocleaning (secondary bacterial contamination, sludge formation) (Ryl's'kiy, et al., 2018).

In compact wastewater treatment plants, various aeration systems (jet, pneumatic, mechanical, combined) are installed, and one of the three methods (chlorination, UV radiation, ozonation) is used to disinfect biologically treated wastewater. To remove nitrogen and phosphorus from biologically treated wastewater, it is necessary to use additional methods of treatment, such as chemical precipitation, biological processes, electrocoagulation, etc., (Edwar, 2020). Some manufacturers offer additional wastewater treatment-on sand filters without or with anthracite, biofilters, filters with adsorbents, microfilters, membrane plants, bioplates with higher aquatic plants, dephosphatization of effluents by treatment with iron-containing reagent, etc. The parameters of treated wastewater allow their discharge in consultation with local regulators: in existing drainage and reclamation systems; after filtering through filter wells, trenches into the soil stream; after their additional cleaning and obligatory disinfection-on a relief (ditches, ditches, beams, rain gutters, etc.). Some manufacturers offer factory-made equipment for horizontal drainage, used in case of high groundwater, or drainage well, used in case of low groundwater (not more than 2 m above ground level) and sandy soils with good permeability.

The shortage of fresh water in some regions of Ukraine raises the question of the possibility of reuse of treated domestic wastewater. According to research, in the case of compact installations for domestic wastewater treatment of detached residential and public buildings, treated wastewater can be reused for irrigation, for example, in resort areas (rest homes, sanatoriums, entertainment venues, water parks, etc.) on conditions that:

- The microbial composition of wastewater must be in accordance with the following indices: coliform index ≤ 1000, coliphage number ≤ 1000 PFU/l, thus guarantying absence of pathogenic microorganisms in the treated wastewater (Ministry of Health of the USSR, 1988).
- Between garden plots that are irrigated using biologically treated and disinfected wastewater and sources of decentralized water supply (drinking water wells), appropriate sanitary protection zones must be maintained in accordance with the current sanitary norms.
- Sprinkling is not allowed, watering of garden plots must be carried out by the method of intra-soil irrigation; for unfruitful trees and shrubs it is possible to use drip surface watering.
- In areas where it is planned to utilize domestic wastewater after treatment at the cleaning installation, it is allowed to grow grapes, fruit and unfruitful trees and shrubs, flowers, ornamental plants, cereals, industrial and fodder crops.
- It is necessary to provide measures to prevent flooding of the garden plots by surface rain and melt water from the above areas.
- If it is impossible to use wastewater for irrigation (e.g., in winter), it is necessary to provide the discharge of biologically treated wastewater into storm water sewer, filter trench, filter well etc.
- It is necessary to ensure constant control over the quality of treated and disinfected domestic wastewater and their impact on soil and plants.

It is necessary to develop separate project for each specific facility.

Manufacturers of compact plants for complex treatment of domestic wastewater guarantee their complete biological treatment, with the content of: suspended solids ≤ 15 mg/l, chemical oxygen demand ≤ 80 mg/l, biochemical oxygen demand (5 days) ≤ 15 mg/l. The cleaning efficiency of such plants is: suspended solids-95-99%, chemical oxygen demand-82-99%, biochemical oxygen demand (5 days) 94-99%, but very often due to improper operation of the equipment cleaning efficiency is reduced. Unfortunately, the requirements for treated wastewater in Ukraine, in contrast to the requirements of the European Union, do not provide control the composition of nitrogen and phosphorus.

Most often, manufacturers of compact domestic wastewater treatment plants offer sludge and excess activated sludge formed during the operation of the plants, temporarily stored in airtight containers and periodically (1-2 times a year depending on operating conditions) removed from them for further disposal. Some manufacturers recommend filtering excess sludge for dehydration in sludge bags that are easily flushed with running water. In some cases, in order to increase the ability of activated sludge to flake formation before the entry of sludge from the settling tanks into the denitrifier, its regeneration is carried out in an aerobic stabilizer. The stabilized sludge after the aerobic stabilizer is fed to the sludge dehydration complex-dehydrator, filter press or Nutsche-filter (depending on performance).

According to the scientific literature, when chlorinating biologically treated wastewater with conventional doses, the degree of reduction of bacterial contamination is 98-95%, and virucidal activity of chlorine is absent. Therefore, wastewater treatment of infectious diseases hospitals and TB dispensaries requires the use of more effective disinfection of biologically treated wastewater. The best methods of disinfection may be ultrasound, chlorination with increased doses and heat treatment. The period of inactivation of certain opportunistic and pathogenic microorganisms and viruses (Escherichia coli, typhoid-paratyphoid bacteria, Vibrio cholerae, Mycobacterium tuberculosis), for example, at a temperature of 100°C is up to 5 minutes (Stankevich and Tarabarova, 2014). In general, at the facilities of the local wastewater treatment plants of above-mentioned medical institutions, it is recommended to carry out a complete biological treatment, then effective wastewater disinfection and after that additional treatment by filtration and final disinfection. Unfortunately, only a few manufacturers of compact plants offer technologies for wastewater treatment of infectious diseases hospitals and TB dispensaries.

To treat the relevant wastewater, complete biological treatment according to the German standard ATV-131E is proposed, followed by treatment, as well as their sediments, with high doses of chlorine and contact time with active chlorine, followed by additional treatment of sludge with hot steam using a steam generator. Another technology proposed for the disinfection of wastewater from TB dispensaries is more complex and involves: grease traps for cleaning sewage from the kitchen, tanks with deep aerators, disinfection of waste after sieve with sodium hypochlorite, helmentization with ovicidal preparation and complete biological treatment in an aeration tank-mixer using activated sludge and immobilized microorganisms and clarification of wastewater in two chambers. The first chamber is integral with the aeration zone, and after the second the clarified water is disinfected with sodium hypochlorite (dose-20 mg/l) and enters the filter with quartz sand and anthracite. The efficiency of wastewater treatment for biochemical oxygen demand (5 days)-50-60%, chemical oxygen demand-22-38%, phosphorus-75-80%, suspended solids-75-95%. After treatment, wastewater is disinfected with UV radiation and enters the municipal sewer system. Excess activated sludge and sludge are fed to the sludge (at 100°C for 15 minutes), and then after chlorination are discharged into municipal sewers or dehydrated at the plant using a flocculant and removed for composting to existing sludge sites.

Compact sewage treatment plants have different design features. For example, mostly self-supporting housings for direct installation in the ground without strengthening the walls of the pit, but their polymer tanks can be installed in underground reinforced concrete wells or on concrete platforms. In case of favorable hydrogeological conditions, the installations are located below ground level, at high groundwater levels-above their level in the soil or protected from UV radiation by sunlight and freezing by enclosing structures, equipped with a drainage pump. Individual equipment manufacturers, due to its tightness and design features of housings, guarantee the independence of its location from the groundwater level. Thus, manufacturers of compact installations of complex treatment of household sewage offer special approaches for installation of tanks in adverse soil conditions, and also various:

- Characteristics of functional tanks (geometric shape, vertical or horizontal location, the presence of stiffeners on the body to prevent deformation of the body under the weight of the soil, with a flow scheme or periodic action, etc.);
- Materials for tanks that make them resistant to corrosion processes and different temperature regimes (high density polyethylene, polypropylene and its copolymers, reinforced polypropylene, fiberglass, metal with a special protective coating);
- Technologies for the manufacture of tanks (factory production of solid tanks by different methods or connection of manufactured parts of tanks by seamless or seam welding);
- Characteristics of automatic equipment (absence or presence of more or less of it, as well as location) (Zorina O.V. et al., 2020).
- In order to prevent air pollution in compact sewage treatment plants, watertight covers are used, some manufacturers offer to use deep cleaning of ventilation air from harmful substances using sorption filters, flow ozonizers or synthetic fiber-mounted synthetic nozzles type "VIYA".

The conducted field researches and experience of operation of underground execution installations of separate manufacturers where various technologies without use of purification of ventilating air were realized, allow to accept for installations of clearing of household sewage of inhabited and public buildings with a productivity from 0.8 to 25 m^3/days level 5 m. According to the results of research on the border of the sanitary protection zone: the equivalent noise level corresponds to DSP 173-96 "State sanitary rules of planning and construction of settlements" and DBN 463-19 "State sanitary norms of permissible noise levels in residential and public premises houses and on the territory of residential development" (up to 50 dBA); maximum permissible emissions of harmful substances into the atmosphere-GR "Maximum permissible concentrations of chemical and biological substances in the air of populated areas", registered in the Ministry of Justice of Ukraine 10.02.2020 No. 156/34439, in particular (mg/m^3): ammonia maximum permissible concentration (MPC) maximum one-time-0.2, average daily-0.04; the maximum amount of hydrogen sulfide maximum concentration limit is 0.008; sulfur dioxide anhydride maximum single time-0.5, daily average-0.05.

The size of SPZ for compact sewerage systems in Ukraine separately from other structures was not regulated until 2018, and today is set in accordance with DBN B.2.2-12:2018 "Planning and development of territories". The principle of establishing SPZ boundaries for such structures in Ukraine is almost in line with the European one. Table 1 presents the size of the SPZ in accordance with the regulations of Ukraine and Lithuania.

Table 1. The size of the SPZ in accordance with the regulations of Ukraine and Lithuania.

Country	SPZ, m, at the estimated productivity of structures, m^3/day				
	up to 50	50-200	200-5000	5000-50000	more than 50 000
Ukraine	15	15	20	20	30
Lithuania	10	25	50	100	-

As can be seen from Table 1, in Ukraine and Lithuania the size of the SPZ depends on the productivity of the facilities. However, in Ukraine, in our opinion, unreasonably smaller SPZs for higher productivity plants (more than 200 m^3/day) and larger SPZ sizes for low productivity plants (less than 50 m^3/day) have been established. In addition, the requirements listed in Table 1 apply in Ukraine, as indicated in the document, to "local treatment facilities", and the Lithuanian document states more accurately-"closed biological treatment plants". In Lithuania, as in Ukraine, the size of the SPZ, if a number of conditions are met, can be increased or decreased by the authorized state body in the country. The Ukrainian document states that in Ukraine, within the sanitary protection zones, the construction of housing, social infrastructure and other facilities related to the permanent stay of people is prohibited. The document in Lithuania, in contrast to the Ukrainian one, states in more detail: residential buildings, hotels or other buildings for short-term residence, medical and medical institutions, wells, as well as recreation areas and open or closed facilities for entertainment activities cannot be built on the territory of the SPZ.

Thus, today the regulatory requirements of Ukraine for sewage treatment plants require significant changes in terminology, requirements for the quality of biologically treated water, the size of sanitary protection zones, which is especially important in terms of European integration.

Conclusion

The use of various technologies used in compact sewage treatment plants of Ukraine, improve the sanitary condition of the territory of sewage facilities. A characteristic feature of such structures is the factory production of tanks, tightness and lack of specific odor in the area of their location. The choice of compact installations for domestic wastewater treatment in each case should be made taking into account: the volume of wastewater; wastewater treatment efficiency; design and functional features of the equipment; materials and technologies for the manufacture of basic tanks; the presence of more or less automation or its absence, the location of automation; methods of sludge treatment and excess activated sludge; conditions of wastewater discharge and their sediments; technological characteristics and risks during operation, which can be a problem at a particular facility; the size of sanitary protection zones for these installations; if necessary-the presence of additional treatment of biologically treated wastewater, the possibility of reuse of treated wastewater and its sediments, the peculiarities of location in adverse soil conditions, etc. Local characteristics, the availability of qualified personnel for the efficient operation of the equipment and the economic component must also be taken into account. The choice of compact sewage treatment plants for biological wastewater treatment should be made taking into account the experience of their use in full-scale sewage facilities. A comparative analysis of current regulations of Ukraine and the European Union revealed significant differences in the regulated requirements for SPZ and the composition of biologically treated wastewater.

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