Types of wastewater treatment technologies for facilities with a capacity up to 1000 m$^3$/day

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Abstract. The article presents an algorithm of making a decision for choosing a technological scheme of wastewater treatment for facilities with a capacity up to 1000 m$^3$/day. There are factors, which help to determine the scheme: plant performance, amount of suspended solids and indicator of wastewater pollution with organic compounds - biological oxygen demand. The best solution according to these parameters can be one or more from 14 considered options of technological schemes, that simplifies and speeds up the process of selecting and designing the main structures of a wastewater treatment plant.

1. Introduction
One of the urgent tasks at the design stage of domestic wastewater treatment plants with a capacity up to 1000 m$^3$/day is the development of technological processes approach with stage-by-stage wastewater and sludge treatment, as well as a brief design methodology. To complete this aim, it is required to establish a methodology of selection wastewater treatment technologies, which would take into account not only the quality of wastewater in a settlement and the requirements for the degree of its treatment, but also a possibility of combining methods and facilities with their technical and economic characteristics and the optimum control mode in special conditions [1-5].

The types of wastewater treatment technologies developed and presented in this article for plants with a capacity up to 1000 m$^3$/day are the best choices. According to them, designers at the stage of feasibility study of wastewater disposal facilities in settlements and during implementation of a working project can analyze possible technological schemes, select structures and methods for treating waste water and sludge, perform a technological calculation of structures and select their quantity and area.

2. Theoretical basis
To compile the classifiers, the classification of domestic wastewater was used [6]. According to the concentration of pollution, domestic wastewater can be divided into three main groups [6], presented in table 1.
Table 1. Wastewater classification by pollution concentration [6].

| Factor                          | I – low concentrated | II – medium concentrated | III – highly concentrated |
|--------------------------------|----------------------|--------------------------|--------------------------|
| BOD$_{\text{full}}$, mg O$_2$/l | 150                  | 230                      | 530                      |
| BOD$_{5}$, mg O$_2$/l           | 100                  | 150                      | 350                      |
| total suspended solids (TSS), mg/l | 150               | 300                      | > 300                    |
| COD, mg O$_2$/l                 | 210                  | 320                      | 740                      |
| Total nitrogen, mg N/l          | 20                   | 30                       | 80                       |
| Ammonium nitrogen NH$_4$, mg NH$_4$/l | 12              | 18                       | 50                       |
| Nitrites NO$_2$, mg NO$_2$/l    | 0.1                  | 0.1                      | 0.1                      |
| Nitrates NO$_3$, mg NO$_3$/l    | 0.5                  | 0.5                      | 0.5                      |
| Total phosphorus, mg P/l        | 4-6                  | 6-10                     | 14-23                    |

To compile a classifier of treatment technological schemes, domestic wastewater by flow rate Q, m$^3$/day, can be divided into three groups [7]:
- A – Q till 100;
- B – Q from 100 to 500;
- C – Q from 500 to 1000.

The combined groups of wastewater by consumption and concentration of pollutants are summarized in table 2.

Table 2. Groups of wastewater by consumption and concentration [8-9].

| Wastewater consumption, m$^3$/day | Wastewater group by pollution with concentration of pollution, mg/l: |
|----------------------------------|---------------------------------------------------------------|
|                                  | BOD$_{\text{full}} < 150$;  BOD$_{\text{full}} = 150-230$;  BOD$_{\text{full}} = 230-530$; |
| up to 100                        | TSS < 150; TSS = 150-300; TSS > 300; | A-I | A-II | A-III |
| 100-500                          | B-I | B-II | B-III |
| 500-1000                         | C-I | C-II | C-III |

According to [6-11], the treatment facilities include:
- equipment for the retention of coarse impurities;
- sand traps with a wastewater flow rate more than 100 m$^3$/day, or with total suspended solids more than 150 mg/l;
- facilities for wastewater clarification with a wastewater flow rate more than 1000 m$^3$/day, or with a suspended solids content more than 150 mg/l;
- facilities for biological wastewater treatment, with an equivalent number of inhabitants (ECH) of more than 500 conventional inhabitants, deep purification from nitrogen compounds should be carried out.

For convenient using of these classifiers, all main technological methods of wastewater treatment are summarized in table 3, facilities and equipment are coded with symbols and conditions of application are assessed.
Table 3. Facilities and equipment used to compile a classifier of wastewater treatment technologies.

| №  | Facilities                                       | Symbol | Conditions of application                                                                 |
|----|-------------------------------------------------|--------|------------------------------------------------------------------------------------------|
| 1.1| Waste bin                                       | WB     | With a wastewater flow rate Q up to 100 m³/day.                                           |
| 1.2| Combined grids-grit traps                       | CGGT   | With a wastewater flow rate Q from 100 m³/day.                                            |
| 2   | Tangential grit traps                           | TGT    | With a wastewater flow rate Q 100-75000 m³/day; BOD

\[
\text{full} > 150 \text{ mg/l; total suspended solids (TSS)} > 150 \text{ mg/l.}
\]
| 3.1 | Thin-layer clarifiers with a direct-flow scheme | TC1    | At any wastewater flow rate; BOD

\[
\text{full} > 150 \text{ mg/l; TSS} > 150 \text{ mg/l.}
\]
| 3.2 | Thin-layer clarifiers with a countercurrent scheme | TC2    | At any wastewater flow rate; BOD

\[
\text{full} > 150 \text{ mg/l; TSS} > 150 \text{ mg/l.}
\]
| 3.3 | Thin-layer clarifiers with a cross scheme       | TC3    | At any wastewater flow rate; BOD

\[
\text{full} > 150 \text{ mg/l; TSS} > 150 \text{ mg/l. They are mainly used for posttreatment of waste water after biological purification.}
\]
| 4   | Biofilters with soft plastic loading            | BFP    | With a wastewater flow rate Q up to 1000 m³/day; BOD

\[
\text{full} < 300 \text{ mg/l; TSS} < 300 \text{ mg/l.}
\]
| 5.1 | Aerotank with attached microflora               | Ae1    | With a low wastewater flow rate; BOD

\[
\text{full} < 150 \text{ mg/l; TSS} < 150 \text{ mg/l.}
\]
| 5.2 | Aerotank with deep removal of nitrogen and phosphorus by technology A2/O | Ae2    | With a wastewater flow rate Q more 100 m³/day. It is used for the treatment of low concentrated wastewater. |
| 5.3 | Aerotank with deep nitrogen and phosphorus removal using Bardenpho technology | Ae3    | With a wastewater flow rate Q more 100 m³/day. It is used for the treatment of low concentrated wastewater. |
| 5.4 | Aerotank with deep removal of nitrogen and phosphorus according to JHB technology | Ae4    | With a wastewater flow rate Q more 100 m³/day. |
| 6   | SBR-reactor                                     | SBR    | With a wastewater flow rate Q 100...1000 m³/day.                                           |
| 7.1 | Sand bunkers                                    | SB     | With a wastewater flow rate Q up to 75000 m³/day.                                           |
| 7.2 | Bag dehydrator                                  | BD     | With a sediment volume up to 20 m³/day with the content of initial dry matter 1%.             |

3. Materials and methods

Choosing the best wastewater treatment system is a difficult task as it requires a lot of experience, knowledge and feasibility studies. This choice was traditionally based on technical and economic factors. Also, it is needed to take into account social, regulatory, governmental and environmental factors, as well as technical and economic factors when making decisions. [12]. Besides, when choosing a specific wastewater treatment system, many related goals and opposite criteria must be considered, which depends on user restrictions, prevailing conditions and intended purposes [13]. Despite the complex decision making, these issues need to be integrated to select a sustainable solution. [14]. To solve this problem, the use of a decision support system is a reliable solution for the appropriate selection of treatment facilities from a number of alternatives. For example, multi-criteria decision making is one
such technique that has been used by previous researchers to make decisions about some environmental issues. [15-21].

To select the necessary technological scheme for wastewater treatment plants with a capacity up to 1000 m$^3$/day, it is possible to use the block scheme, which is shown in figure 1. For different groups of costs presented in table 2, 14 technological schemes were drawn up, which include a model for calculating structures and data on the degree of wastewater treatment.

![Diagram](image)

Figure 1. Block diagram of selection technological scheme for wastewater treatment plants with a capacity up to 1000 m$^3$/day.

The classifier of wastewater treatment technologies for plants with a capacity up to 1000 m$^3$/day consists of the table 4.

Table 4. Classification of wastewater treatment technologies for plants with a capacity up to 1000 m$^3$/day

| Technological scheme number | Wastewater groups | Recommended technological scheme | Wastewater treatment degree |
|----------------------------|-------------------|---------------------------------|-----------------------------|
| №1                         | A-I               | WB → BFP → TC3 (BD)            | BOD $\leq$ 10...15 mg/l, total nitrogen $\leq$ 5...10 mg/l, phosphates $\leq$ 5...9 mg/l, for suspended solids $\leq$ 85%. |
| №2                         | A-I               | WB → Ae1 → TC3 (BD)            | BOD $\leq$ 3...5 mg/l, ammonium nitrogen $\leq$ 0.5 mg/l, for suspended solids $\leq$ 85%. |
| №3                         | A-I               | WB → Ae2 → TC3 (BD)            | BOD $\leq$ 3 to 96...98% (5...8 mg/l), total nitrogen $\leq$ 90%, total phosphorus $\leq$ 90% (up to 70% in low-concentrated wastewater), suspended solids $\leq$ 85%. |
| №4                         | A-I               | WB → Ae3 → TC3 (BD)            | BOD $\leq$ 3...5 mg/l, total nitrogen $\leq$ 2.5...5.0 mg/l, ammonium nitrogen $\leq$ up |
The solids content in the dewatered sludge will be 2%, the moisture content of the sediment will be 60%.

Cleaning efficiency for tangential grit traps will be 90%, while the moisture content of the retained sand will be within 20%, and the ash content will be 94%. The amount of retained sand with a particle size of 0.2 mm will be 15...40%. The pumped-out sand will have a humidity of 98...99%.

In case of choosing technological scheme with combined grids, it is possible to reach part dehydration of large waste (up to 45% of dry matter) and sand, while the amount of retained sand will be 90%, with a grain size of 0.20...0.25 mm. The solids content in the dewatered sludge will be 2%, sediment moisture – 50-60%.

4. Results

In the table about choosing a recommended technological scheme, equipment for processing sediments, which are formed during using this type of equipment, is also indicated. In this case, the content of the solid phase in the dewatered sludge after BD will be 2%, the moisture content of the sediment will be 50...60%.

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| №  | A-I, A-II, A-III | WB → TGT (SB) → TC2 (BD) → BFP → TC3 (BD) | to 0.5 mg/l, total phosphorus – up to 70%, suspended solids – up to 85%. BOD_5 → 10...15 mg/l, total nitrogen – 5...10 mg/l, phosphates – 5...9 mg/l, suspended solids – up to 85%. |
| №6 | A-I, A-II, A-III | WB → TGT (SB) → TC2 (BD) → Ae4 → TC3 (BD) | BOD – up to 95% (5...8 mg/l), total nitrogen – up to 90%, total phosphorus – up to 80%, suspended solids – up to 85%. |
| №7 | A-I, A-II, A-III | WB → TGT (SB) → TC2 (BD) → SBR (BD) | BOD – up to 98% (10...15 mg/l), total nitrogen – up to 75%, total phosphorus – up to 70%, suspended solids – up to 95%. BOD – 3...5 mg/l, ammonium nitrogen – up to 0.5 mg/l, suspended solids – up to 85%. |
| №8 | B-I | CGGT (SB) → Ae1 → TC3 (BD) | BOD – up to 96...98% (5...8 mg/l), total nitrogen – up to 90%, total phosphorus - up to 90% (up to 70% in low-concentrated wastewater), suspended solids – up to 85%. |
| №9 | B-I | CGGT (SB) → Ae2 → TC3 (BD) | BOD – 3...5 mg/l, total nitrogen – 2.5...5.0 mg/l, ammonium nitrogen – up to 0.5 mg/l, total phosphorus – up to 70%, suspended solids – up to 85%. |
| №10 | B-I | CGGT (SB) → Ae3 → TC3 (BD) | BOD – up to 95% (5...8 mg/l), total nitrogen - up to 90%, total phosphorus – up to 80%, suspended solids – up to 85%. |
| №11 | B-II, B-II, C-II, C-III | CGGT (SB) → TC2 (BD) → Ae4 → TC3 (BD) | BOD – up to 98% (10...15 mg/l), total nitrogen – up to 75%, total phosphorus – up to 70%, suspended solids – up to 95%. |
| №12 | B-II, B-II, C-II, C-III | CGGT (SB) → TC2 (BD) → SBR (BD) | BOD – up to 96-98% (5...8 mg/l), total nitrogen – up to 90%, total phosphorus – up to 90% (up to 70% in low-concentrated wastewater), suspended solids – up to 85%. |
| №13 | C-I | CGGT (SB) → TC1 (BD) → Ae2 → TC3 (BD) | BOD – 3...5 mg/l, total nitrogen – 2.5...5.0 mg/l, ammonium nitrogen – up to 0.5 mg/l, total phosphorus – up to 70%, suspended solids – up to 85%. |
5. Conclusions
To accelerate the differentiated design of treatment facilities for urban wastewater treatment, you can use algorithms for making technological decisions, taking into account the features of each technological scheme. In this case, the selected or developed models for calculating the main structures of a wastewater treatment plant should consider features of the composition of wastewater, since the composition of wastewater varies for each settlement.

Presented models include technological schemes, brief calculation methods and calculation schemes of structures, which allow to determine their size and quantity, and also simplify and speed up the process of selection and design of the main structures of a wastewater treatment plant.

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