Study on practical methods for treatment of oil-contaminated and domestic wastewater

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Abstract. The implementation by small innovative enterprises of the LBR technology for household wastewater treatment, which is a complete cycle of urban wastewater treatment (WWTP), is one of the most perspective direction of strategic development of the regional economy, improving the parameters of its investment, environmental and social components. Each technological stage of technology is carried out on separate devices located indoors - a technological process of a closed hardware type. Such a process lends itself to automation, since each of the devices is technologically autonomous and can be replaced by another due to a malfunction or according to technological indications. In this way, high process stability and flexibility are achieved. All devices are of serial factory manufacturing, which ensures high quality, aesthetics and reasonable price parameters, as well as, if necessary, the ability to upgrade each unit individually. The hardware type of the technological process, being high-tech, energy-efficient and environmentally friendly, creates the prerequisites for a significant reduction in sanitary protection zones (2–6 times) and areas allocated directly to sewage treatment plants (7–8 times). In addition, it becomes possible to flexibly change the capacity of WWTP (increase or decrease if necessary), as well as introduce purification stages necessary for specific conditions or remove unnecessary ones, without compromising the integrity of the technology and the efficiency of wastewater treatment. Implementation LBR technology by small innovative enterprises maximum environmental, social and economic efficiency and at prevent the waste of investment resources.

1. Introduction

The escalation of innovative small business is the most effective and fastest way to develop and implement scientific and technical products, as well as new technologies, obtaining competitive advantages at the Federal and regional levels. The technological solution proposed for consideration is the LBR technology for household wastewater treatment implemented by small innovative enterprise, which is a complete cycle of urban wastewater treatment (WWTP). A complex of the wastewater purification is located in a building made of the light metal constructions. The complex has an automated system of control of the technological process, of the sludge dehydration and wasting system, of the heating, ventilation, lighting system [1].

Division of the complex of wastewater purification into separate technological lines allows one to provide the purification of the whole volume of the inflowing waste water to normative requirements in
case of unplugging of up to 25 per cent of equipment for reparation of one or several lines (according to SNiP (construction rules and regulations) 2.04.03-85). Besides it allows one to produce emptying and prophylactic examination of tanks without stopping of treatment facilities [2-4].

2. Solution
For purification of industrial wastewater the following technological scheme of purification has been chosen.

The wastewater passes the stages of mechanical purification (pressure electrocoagulators, primary settling tanks with thin-layer modules), a block of biological purification (bioreactors with anaerobic purification zone, bioreactors with aerobic purification zone), coagulation and sludge settling in the secondary settling tanks, aftertreatment (electromagnetic filters, filters of mechanical and sorption purification), sludge treatment by mechanical dewatering.

The wastewater from the plant comes to the stabilization tank, located near the treatment facilities building. Then from the stabilization tank the drains are delivered by submersible pumps per pressure pipeline to treatment plants into electrocoagulators.

The electrocoagulator is suitable for reagentless coagulation of pollutants during water purification. The electrocoagulation is the reagentless method of water purification that provides effective removal of organic matters, iron and other concomitant pollutions (decrease of BOD, COD happens) due to anodic oxidation and cathodic reduction with formation of insoluble in water compounds that precipitate in the settling tanks [2, 3].

Electrical treatment combines chemical and electrochemical coagulation, destruction by action of direct current. The process of electrolytic water purification proceeds the stages of:
- electrochemical interaction of matters on the electrodes’ surface and proceeding herewith reduction-oxidation processes;
- transformation of matters into insoluble compounds and formation of disperse phases in water. Besides, the sorption of the ions and of the molecules of the dissolved impurities, and of the impurities emulsified in water on the surface of aluminium hydroxides that have a significant sorption capacity, especially at the moment of formation.

The anode metal is ionized by action of direct current and proceeds to purified water. The hydroxides forming in water coagulate the disperse system. The electrocoagulator represents a block of aluminum alloy electrodes, placed into a closed case and connected to a rectifier. The electrocoagulator is compact and easy to use. On the water inlet pipeline to the electrocoagulator, membrane sensors are installed to define pH of the incoming drains connected to digital dosing pumps with a pH control function. Neutralization of waste water occurs in automatic mode to the TLV standards. Neutralization is made with solutions of hydrochloric acid or sodium hydroxide stored in plastic containers.

From the electrocoagulator, the treated drains are delivered to the primary settling tank with a thin-layer module. The foam formed in the electrocoagulator is extinguished by the defoamer, from which coagulated foam enters the pit for sludge through the sludge pipelines.

Primary settling tanks are made of polymeric material and are located in a single block of biological purification containers in cases that are identical to bioreactor process tanks and are used for the deposition of undissolved and partially colloidal contaminants of predominantly organic origin. In the process of settling, sedimentation of suspended particles occurs. Settling is the simplest, least energy-consuming and most economical method of separating mechanical impurities from wastewater with a density different from that of water. The relative simplicity of settling facilities makes them widely used on various stages of waste water treatment and the treatment of the resulting sediments. Smaller suspended particles and colloidal impurities are separated during the passage of waste water through the thin-layer modules installed in settling tanks (Patents for invention No. 2398611, No. 2406556). Their separation ability, especially while precipitation of fine impurities, is many times higher. The expediency of applying of thin-layer settling tanks is based on the fact that reducing of the height of the
stream while maintaining the same speed of movement proportionally reduces the time of settling. Splitting the flow height into smaller segments simultaneously increases the settling area and reduces the specific load on it by suspension. The effect of settling is 40–60% with a duration of settling of 1.5-2 hours. The sludge due to hydrostatic pressure from the conical part of the settling tanks through the pipeline enters the pit for sludge.

Primary settling tanks of mechanical wastewater purification are a preliminary stage before biological purification. In mechanical wastewater treatment, the effect of reducing of suspended substances is 40–60%, which also leads to a decrease in the BOD value by 20–40%. Then the drains from the primary settling tanks by gravity flow into the bioreactor. Each bioreactor operating in parallel consists of 4-6 (depending on the parameters of the purified water) cone-shaped communicating tanks, separated by vertical overflow partitions and made of a polymeric material. The process tanks are equipped with an automated sludge discharge system.

Purified drains first enter the anaerobic zone of the bioreactor where destruction of the resistant to oxidation organic matter takes place on the biological carrier with immobilized and free-floating microorganisms. Then the sewage is purified in the aerobic zone of the bioreactor (aerotanks). In addition, nitrification and sulfate reduction processes occur in the anaerobic zone of the bioreactor, as a result of which ammonium compounds are oxidized to nitrates and sulfates to elemental sulfur.

In aerotanks-bioreactors, a mixture of activated sludge and the waste liquid being purified is slowly moving. The mixture of waste liquid with activated sludge is aerated throughout the aerotanks through the system of air supply pipes and microbubble titanium aerators for the oxidation of organic matter and the saturation of water with oxygen that is necessary for the life support of microorganisms and the removal of gaseous decomposition products. The air supply is carried out by means of blower compressors. The compressors are completed with the basic accessories necessary for failure-free operation. The operation of compressors is fully automated. In case of unexpected shutdown of the working compressor, automatic activation of the standby unit is provided.

In order to intensify the work of the treatment plants, an aeration system was used applying pneumatic aerators of sintered titanium powders. The main advantage of porous metal aerators compared with filter plates and tubular aerators is lower resistivity (3-4 times) with a smaller pore size (therefore, with a smaller bubble size - up to 150 micrometres), which allows reducing the air supply by 30-50%, thereby reducing the specific energy consumption for aeration, without degrading the quality of purification. Each bioreactor tank is divided by partitions into two sections. Each section contains biological carrier BPS-140-60 cassettes, (Patent for invention No. 2369564).

An important distinctive feature of the facilities (complex of treatment facilities of daily water) is the use of biotechnologies with the active sludge immobilized on the inert biological carrier (load). The biological carrier has a spatial spiral design and is made of polymeric materials, the advantage of which is a low specific weight, chemical resistance, high specific surface. Due to its rough structure, the loading holds the biofilm well, which is not removed from the facility during the volley flows of the wastewater and other adverse conditions. This allows creating and maintaining stable high concentrations of destructor microorganisms in bioreactors, increases the system's resistance to the uneven supply of drains for purification and the heterogeneity of their qualitative composition [3, 4].

The methods of intensifying of the work of the aerotank, the use of biological carriers for the formation of immobilized forms of microorganisms on them, as well as the use of thin-layer blocks in settling tanks are certified and protected by a patent. As a result of biological purification, water is obtained transparent, not rotting, containing dissolved oxygen and nitrates. The biological purification facilities provide a reduction in pollution indicators for suspended solids and BOD.

For a more complete removal of phosphorus compounds and sludge sedimentation in the secondary settling tank, an aluminum polyoxychloride coagulant solution is supplied. For the preparation of the coagulant solution, a block for the preparation and dosing of reagents is provided, consisting of plastic tanks for preparing and storing the coagulant solution and dosing pumps for supplying the solution. The water for preparing of the coagulant solution is delivered to the tanks through the purified water pipeline. The coagulant solution is supplied to the bioreactor in front of the secondary settling tank [3].
Purified water flows by gravity into secondary settling tanks with thin-layer modules. In the secondary settling tank, sedimentation of spent sludge occurs.

After the secondary settling tank, the purified wastewater flows by gravity into intermediate containers, from where they are delivered by a submersible pump into the aftertreatment unit on filters for mechanical, electromagnetic and sorption purification operating in automatic mode.

The filtering system of mechanical purification consists of:
- fiberglass or stainless steel columns;
- distribution (drainage-distribution) system;
- loading (quartz sand);
- gravel substrate;
- automatic control unit.

During the operation of the filters, the filter material is contaminated. For washing of the filtering material from contamination and restoring its properties, automatic washing is carried out.

The flushing water through the pipeline returns to the reservoir-averager together with the filtrate. When rinsing is complete, the filter is automatically put into operation mode.

### 3. Discussion

Having passed the purification on the electromagnetic filters, the drains by gravity flow to the sorption filters. Sorption purification filters are similar according to the design and operation principle to mechanical purification filters, only activated carbon is used as a filtering load in the sorption purification filters. The treated wastewater passes through the flow meter and is sent for release. In the process of settling of wastewater, large masses of sludge capable of decay are formed in the settling tanks, so the sludge must be further processed. For sludge dewatering after primary, secondary settling tanks and bioreactor, a belt filter press is used.

### Table 1. Specific consumption of materials

| Resource                | Measure unit | Consumption, Measure unit per cubic metre | Cost, ruble per measure unit | Expenses, ruble per cubic metre |
|-------------------------|--------------|-------------------------------------------|------------------------------|---------------------------------|
| Electricity             | kilowatt     | 0.4                                       | 5                            | 2                               |
| Coagulant Aqua Aurat 30 | kilogram     | 0.01                                      | 80                           | 0.8                             |
| Flocculant VPK-402      | kilogram     | 0.000015                                  | 1000                         | 0.015                           |
| Drug "bingsty"          | litre        | 0.00016                                   | 4500                         | 0.72                            |
| Filter gravel           | kilogram     | 0.0012                                    | 41                           | 0.0492                          |
| Activated carbon        | kilogram     | 0.0057                                    | 87                           | 0.4959                          |
| Quartz sand             | kilogram     | 0.0097                                    | 11                           | 0.1067                          |
| UV facility lamps       | piece        | 0.00014                                   | 12000                        | 1.68                            |
| Sand bags               | piece        | 0.0014                                    | 500                          | 0.7                             |
| Oil for blowers         | litre        | 0.0000078                                 | 350                          | 0.00273                         |
| **Total:**              |              |                                           |                              | 6.56953                         |

The sludge from the primary and secondary settling tanks and the bioreactor through the sludge pipeline due to hydrostatic pressure enters the pit for sludge. From the pit, the sludge is delivered by a submersible pump to the sludge dewatering unit (belt filter press with a thickener). The flocculant solution VPK-402, the solution of which is stored in a plastic container and delivered by a dosing pump, is delivered to the thickener together with the sludge. After disinfection, the dehydrated and disinfected
sludge is unloaded onto a dump hermetically sealed trailer, and transported to the landfill of municipal solid waste. Dehydrated sludge belongs to the fourth class of hazard [4, 5].

In case of a filter press breakdown, the possibility of exporting the raw sludge by sewage trucks for further processing is foreseen.

4. Conclusion
When using LBR technology by small innovative enterprises, experts recognize:
• maximum environmental, social and economic efficiency aimed at preventing the waste of investment resources;
• stimulating of innovative development of regional economy due to multiplicative meso-effects;
• a combined approach, taking into account both the technological capabilities of the OS and the capabilities of the water body - to ensure the use of technology that is optimal for the ecological state of the water body.

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