

# Prevention of environmental risks when designing wastewater treatment facilities

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**Abstract.** Economic development leads to increased negative impacts on the environment, including water resources. Domestic wastewater treatment plants are an integral part of the sustainable development of the infrastructure of settlements and cities. Treatment facilities are a multifunctional complex and are engineering and environmental protection structures, the activities of which are aimed at protecting surface water bodies. At the same time, this activity is associated with environmental risks and negative impacts on the environment. It is most effective to predict risks and develop effective engineering measures to prevent them at the design stage of technical systems. The purpose of the work is to identify possible environmental risks during the implementation of the life cycle and to propose the necessary engineering measures to prevent them when developing a wastewater treatment plant project. The article is the first to identify and systematize the main environmental risks at the stages of design, construction, operation and reconstruction of wastewater treatment facilities. A classification of environmental risks according to other criteria (frequency, predictability, degree of damage) is presented. Research has been carried out to model possible events at wastewater treatment plants and their connection with negative consequences for the environment. Recommendations have been developed for the prevention of environmental risks, including technological, production and operational, and organizational aspects of environmental protection.

## 1 Introduction

Wastewater treatment facilities play a key role in the sustainable development of the infrastructure of settlements and urban districts and are an integral part of the sustainable development of urban infrastructure [1-2]. The resulting effect of wastewater treatment plants helps keep the environment clean, ensures the efficient use of natural resources, and makes settlements more prosperous and comfortable for life.

By treating household wastewater (HWW) to established quality standards, they also ensure the preservation of the ecological balance in surface water bodies, maintaining the habitat of aquatic organisms. Modern wastewater treatment technologies make it possible

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not only to remove contaminants, but also to return water to the natural cycle, which contributes to resource conservation [3]. At the same time, wastewater treatment plants are environmental protection structures; they implement wastewater treatment technologies, and this activity is associated with environmental risks. Within the framework of this work, environmental risk will be understood as the probability of an event occurring that has adverse consequences for the natural environment. Currently, many researchers are working on the problem of environmental risks. Research has been carried out on the analysis of environmental risks by financial institutions [4, 5], assessment of environmental risks at the stage of investment projects [6] -these works are more of an economic nature. Less research is focused on environmental engineering - modeling in the assessment of environmental risks due to the impact of global warming on complex ecological networks [7], an analysis of risks during the operation of wastewater treatment facilities of small-scale sewerage in the Far North [8], and contamination of soil and water bodies with wastewater from airfields [9], research to assess the impact of treatment facilities on atmospheric air and the appearance of unpleasant odors [10, 11]. However, these works have not solved the problem of identifying environmental risks at all stages of the life cycle of HWW treatment facilities and there are no solutions to engineering problems to prevent environmental risks in the life cycle at the design stage.

At the same time, reducing environmental risks is most effective at the stage of development of complex technical systems [12, 13]. When developing a wastewater treatment plant project, it is important to assess all possible risks taking into account the life cycle, their impact on the environment and develop effective measures to prevent environmental risks. A complete picture of environmental risks makes it possible to provide developers with the necessary information to make engineering decisions about the advisability of choosing one or another technology, technical and organizational measures to reduce the negative impact on the environment.

The purpose of this study is to identify possible environmental risks during the operation of treatment facilities for the treatment of domestic wastewater, taking into account the life cycle and to develop recommendations for engineering environmental protection and reducing environmental risks at the design stage of treatment facilities.

To achieve this, the following tasks were solved:

- identification of environmental risks in the life cycle of wastewater treatment facilities;
- development of recommendations for engineering environmental protection and the prevention of environmental risks at the design stage.

## **2 Research methods and results**

The methodological and theoretical basis of this study was made up of domestic and foreign scientific sources of information, reference books on the best available technologies. When conducting research, methods of analysis, generalization, comparison, synthesis and modeling were used.

The generalized data of the analytical review and the available practical experience in the design, construction, maintenance and reconstruction of wastewater treatment facilities of the HWW have shown that the environmental risks of treatment facilities are associated primarily with insufficient wastewater treatment associated with reasons of a design, technological, and organizational nature.

The work simulates possible events at wastewater treatment plants in their life cycle (design, construction, operation, reconstruction), which are associated with environmental risk and can cause negative consequences in the environment. The simulation results are presented in the Table 1.

**Table 1.** Events at wastewater treatment plants associated with environmental risks.

Life cycle stage	Description of events leading to environmental risks	Environmental Consequences
Design	Inaccuracies in methods for calculating contaminants entering water treatment [13] Design errors	Insufficient wastewater treatment
	Inaccurate determination of the class of soil contamination at a construction site (which goes to solid waste landfills, but could be used on a designated site or on the territory of a populated area[13])	Unreasonable load on solid waste landfills Disposal of uncontaminated soil
	Errors in the justification of used wastewater treatment technologies	Insufficient wastewater treatment
	Lack of dendrological research and assessment (inventory of green spaces) at the construction site [13]	Damage to the flora of a populated area
Construction	Violation of construction regulations	Negative impacts in the form of noise, dust and air pollution, soil compaction, waste generation
	Errors in construction	Negative impact on landscapes Insufficient wastewater treatment
Exploitation	Process failure Equipment defects/breakdown Inadequate control of the composition of water entering treatment Inadequate control of wastewater composition Personnel errors Inadequate control over the technical condition of equipment Power outage The flow of wastewater in excess of the standard volume, and with a deviation from the design in chemical composition. Impact of external man-made factors and emergency situations	Intake of wastewater of inadequate quality into surface water bodies
	Processes of decay of the organic component of wastewater pollution [10-11]	Air pollution, the appearance of an unpleasant odor
Reconstruction	Decommissioning of some facilities (treatment stages) for the period of reconstruction/repair	Intake of wastewater of inadequate quality into surface water bodies
	Completion of some facilities (e.g. sludge beds)	The need for land reclamation

All of the listed risks can be conditionally qualified as risks of the internal environment (related to activities), but the stable operation of treatment facilities according to the design regime is also influenced by the external environment. Environmental risk factors include:

- sudden change in climatic conditions;
- unevenness in volume and chemical composition of wastewater generated in populated areas;
- external power outage;
- destructive technogenic influences of the external environment;
- natural disasters.

Environmental risks can also be classified as follows:

- in terms of repeatability (systematic and non-systematic);
- in terms of predictability (predictable and random);
- according to the degree of influence on surface waters:
- catastrophic, leading to emergency situations;
- accidents that do not cause a deterioration in the sanitary and epidemiological situation in urban and rural settlements, for example, leading to a decrease in the productivity of treatment facilities.

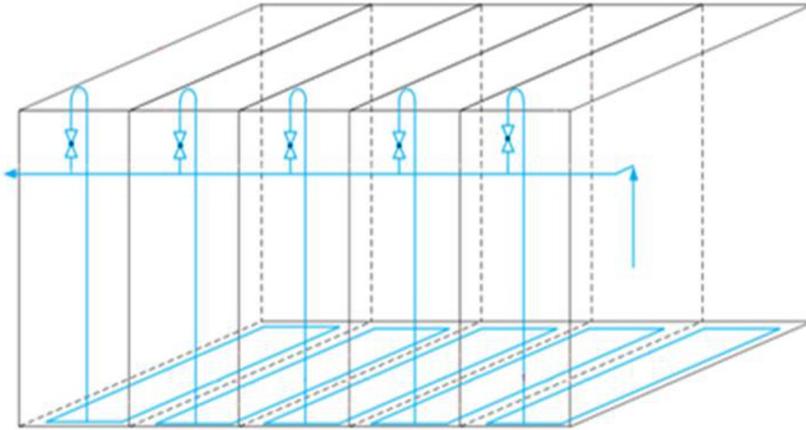
To reduce the consequences of environmental risks when developing wastewater treatment facilities, the following is proposed:

At the design stage:

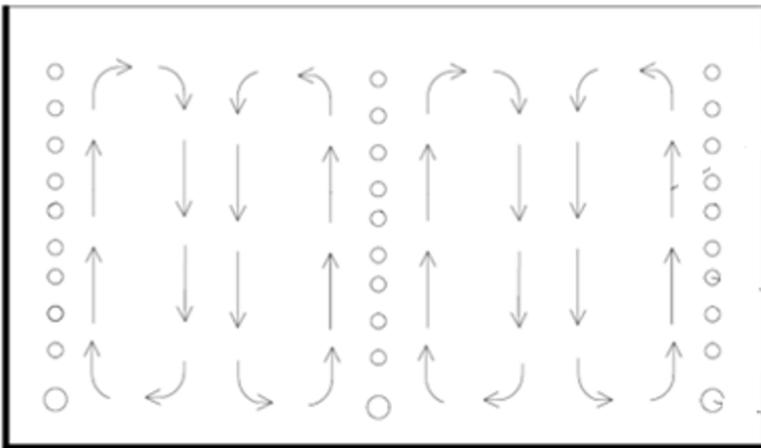
- apply calculations of wastewater pollution taking into account possible burst emissions and changes in the chemical composition of wastewater (introduction of correction factors);
- determine more accurately the class of soil contamination;
- provide for the prevention of water hammer on the hydraulic equipment of wastewater treatment plants in the event of a sudden power outage;
- eliminate accidents during power outages;
- provide for the creation of capacity reserves;
- prepare structures for operation in abnormal climatic conditions;
- conduct dendrological research and assessment (inventory of green spaces) at the construction site;
- carry out environmental impact assessments and examinations of wastewater treatment plant projects, taking into account identified environmental risks.

We especially believe it is necessary to include innovative approaches when designing technological processes for cleaning waste water treatment plants:

- supply activated sludge to primary settling tanks to speed up the biological treatment process and the presence of mixers based on a “large bubble” to prevent caking of activated sludge;
- in aeration tanks, ensure water circulation and air supply in such a way as to prevent activated sludge from settling in “quiet zones”. The scheme of aerators and the water movement diagram are shown in Figures 1-2).



**Fig. 1.** Scheme of aerators.



**Fig. 2.** Scheme of water movement in the aeration tank.

- use in secondary sedimentation tanks, a thin-layer module block to improve sedimentation of sludge and lower it to the bottom more slowly to improve denitrification;
- create additional aeration in the wastewater receiving area to prevent unpleasant odors.

During construction

- follow construction regulations

During the operation stage, provide:

- development of technical regulations for the maintenance of treatment facilities to maintain design parameters for the treatment of domestic wastewater;

- development of an industrial environmental control program, including control of the composition of water entering treatment, control of the composition of wastewater after treatment

- development of a system for managing the environmental safety of treatment facilities, which includes requirements for personnel, personnel work regulations, composition and content of regulatory documents.

At the reconstruction stage:

- provide reserve capacity and an additional stage of treatment in the form of biological ponds, which are constructed on the site of sludge beds during the reconstruction of treatment facilities. The authors have already conducted a full-scale experiment on the construction of biological ponds on the site of sludge beds, where deep post-treatment of wastewater takes place using the phyto-purification method, which ensures wastewater treatment to levels significantly lower than those established by standards.

### **3 The discussion of the results**

The simulated relationship between possible events at the HWW in the life cycle of treatment facilities and the associated negative consequences for the environment allows developers, even at the design stage, to incorporate into the project, first of all, engineering and technological solutions to prevent environmental risks. Supplying activated sludge to primary settling tanks, ensuring the circulation of water and air in aeration tanks to exclude “quiet zones” contribute to the acceleration and quality of the biological treatment process of cold water treatment plants. The use of a thin-layer module in secondary settling tanks to improve the sedimentation of sludge and lower it to the bottom more slowly helps to improve the processes occurring under anaerobic conditions for the reduction of oxidized nitrogen compounds (nitrates and nitrites) to molecular nitrogen, thus ensuring the necessary indicators of wastewater for nitrates and nitrites before release into fishery reservoirs.

The use of additional aeration devices in wastewater reception areas prevents the formation of unpleasant odors from wastewater treatment plants.

In the case of reconstruction of the treatment facilities of HWW, where sludge platforms were operated, which, as a result of modernization, were replaced by a mechanized method of sludge dewatering and were subject to reclamation, it is proposed to construct biological ponds in their place. Biological ponds, where deep post-treatment of wastewater will take place using the phyto-purification method, are another step in the treatment of cold waste water treatment plants, which provide water quality indicators for many pollutants significantly lower than the established standards. In addition, they can be used as reserve structures for the period of repair/reconstruction of treatment facilities, which eliminates the entry of untreated wastewater into surface water bodies.

All engineering measures proposed by the authors at the stages of the life cycle of treatment facilities (design, construction, operation, reconstruction) are aimed at preventing and minimizing environmental risks associated with wastewater treatment.

### **4 Conclusions**

In this work, for the first time, studies were carried out to model possible events at wastewater treatment plants and their connection with negative consequences in the environment. A classification of environmental risks is presented. The results of this study allow developers, at the design stage, to include, first of all, technological solutions to prevent environmental risks in the design of treatment facilities for the treatment of cold waste water.

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