Smart farming: monitoring and management of wastewater system

Olga Kireeva[1] and *Galina* Boikova[2*]

[1]Russian State Social University, 129226 Moscow, Russia
[2]Moscow Polytechnic University, 107023 Moscow, Russia

Abstract. The paper substantiates the need to develop an information system that enables the monitoring of all processes related to the collection, transport, filtration and use of wastewater from farms of any profile. Such farms use water to carry out their activities, which subsequently becomes polluted and dangerous for the environment. Depending on the degree of pollution, the rules and means of utilization of such water are determined. The developed concept of the information system allows to monitor the condition of the equipment, the level of pollution, to make recommendations on the current maintenance. The application of the methods of analysis and synthesis allowed to define the requirements to the functional capabilities and categories of users of the information system. Application of the object-oriented design method to the obtained results allowed to create a prototype of the graphical user interface of the software product.

1 Introduction

Wastewater discharged from industrial and agricultural facilities, settlements through sewerage or gravity flow, negatively affect the natural objects in contact with [1]. The composition and quantity of industrial wastewater depends on the type of production and may not require special treatment (when entering a water body it does not lead to changes in its physical and chemical composition), undergo treatment (the level of pollution does not exceed the established normative indicators) and discharged in unchanged form (the concentration of substances is higher than the established standards and is designed for dilution and self-purification within the water body). Agricultural wastewater, depending on the type of activity, may contain crop residues, vegetable juices, soil particles, antiseptics, mineral or organic fertilizers and other substances. Fecal (associated with human biological activity) and household (associated with relevant wastes and detergents) types of pollution are characteristic of domestic wastewater. Such waters are highly polluted (pollution is of animal and plant origin) and their inflow with the process of subsequent treatment is relatively constant in time and volume [2].

Separately, it is necessary to note waters that are formed as a result of runoff during atmospheric precipitation. In addition, they can be formed as a result of flushing of impurities by irrigation water. Their pollutants include solid (suspended) particles and petroleum

*Corresponding author: boykovagv@mail.ru

products. Such wastewaters have episodic nature of appearance and are characterized by heterogeneity in volume and concentration of pollutants [3].

Modern treatment facilities are based on different principles of separation (mechanical, physical-chemical, biological), which is associated with objective reasons for the peculiarities of pollutants [4]. For instance, treatment of effluents from pig farms is technologically different from treatment of effluents from greenhouse complexes, as they contain a lot of pesticides, dissolved minerals and organic fertilizers [1, 2].

The legal framework regulates the composition, treatment and utilization of wastewater. When dirty wastewater is collected in a large sewage system, the regulations on the composition of the liquid may differ, since the centralized system has powerful equipment capable of destroying complex contaminants [3]. Farms, most often, are located far away from large settlements and may not have access to centralized water runoff systems, which places additional responsibility for the disposal of this type of waste on the farmer. For this purpose, autonomous treatment systems with specialized equipment may be used or waste may be transported to appropriate landfills. Monitoring of the condition of such systems and management of the utilization of this class of waste can be carried out with the help of information systems.

An information system is able to offer the user reasonable solutions to a narrow problem domain that is difficult to formalize based on established knowledge and data obtained from different sources [5]. Such data can be obtained from sensors that are installed on the object of observation in automatic or manual mode, from control actions by the users of the system, etc.

Thus, the purpose of the research is to develop the concept of an information system that monitors the condition of the wastewater collection system.

The object of research is small and medium-sized farms located in the territory of settlements without centralized sewerage system. The subject of the research is the process of wastewater utilization.

The theoretical significance of the research lies in structuring the processes of wastewater utilization and establishing all the objects that affect the change of their states. The practical significance of the research lies in the creation of a digital aggregator of services related to the utilization or processing of wastewater, control of the state of wastewater disposal of farms. Thus, it provides a unified digital environment for consumers and service operators, as well as controlling authorities of municipal and regional significance.

2 Methods and Materials

Synthesis and analysis methods were used to determine the functionality of the information system under development. With their help, all the key elements of the research subject affecting the change of its states were established. In works in which the object of research is formalized, the use of a set of the above methods allows to establish its structure with qualitative and quantitative description of elements of the appropriate level of detail [6-8]. Based on this, models describing the behavior of the system from different points of view are created to fully cover all the work envisaged at the stage of software product development.

The object-oriented design method was used to create a prototype of the user graphical interface of the information system under development. It was used to classify all objects according to the model of their behavior and properties. This approach is used in the works to provide unified methods of object-oriented programming and to create a modular system of the software product [9, 10].

3 Results

The analysis of the research subject has shown that the facilities designed for wastewater collection at pig farms, poultry complexes, greenhouses operate according to the same principle scheme with certain differences [1]. This difference lies in the composition of treatment equipment, determined by the specificity of wastewater. For instance, from crop and livestock facilities, the sewage system discharges wastewater to complexes of treatment facilities for sequential mechanical, biological treatment, filtration and disinfection. Upon completion of all stages, the already treated wastewater is discharged into the environment.

For the treatment of domestic wastewater are used autonomous treatment facilities, after which they become ready for discharge into water bodies or the ground. In addition to such systems, transportation of liquid waste from the place of its formation to the place of disposal can be used.

The information system to be developed should fulfill the following main functions:

1. Inform the user of the current status of the wastewater system. The data, on the basis of which such a state is monitored, is carried out by sensors installed at certain points of the system. The sensors determine the level of cesspool filling, leaks, accumulation of suspensions of mineral origin, oil, grease and petroleum products, wear of filters and other elements of the system.

2. Provide the user with information on services and contractors performing installation, routine maintenance, replacement, and removal of treatment systems.

3. Generate a list of recommendations for routine system maintenance based on monitoring results.

The availability of the system functions is determined depending on the user category:

- resident - a user who carries out household activities and is not connected to a unified sewerage system (may have a pit latrine or an autonomous system of wastewater collection and filtration on his/her plot);
- farmer - a user carrying out individual economic activities related to animal husbandry, crop production, etc. (independently carries out these activities with the involvement of a small number of employees);
- principal engineer - user controlling different activities of large agro-industrial complexes.

The information system being developed has a client-server architecture. Both a browser and a mobile application can be used as a client. The use of object-oriented design methods makes it possible to adapt the user interface to the settings of the corresponding client without changing the functionality. It should be noted that depending on the user category, certain functionalities may not be available due to limitations of client versions. For instance, the main functionalities for the Principal Engineer are implemented only at the workplace, and the mobile application allows only monitoring of the system elements for operational management without being bound to a specific location.

Fig. 1 shows fragments of the user interface of the mobile application for Farmer and Resident users.

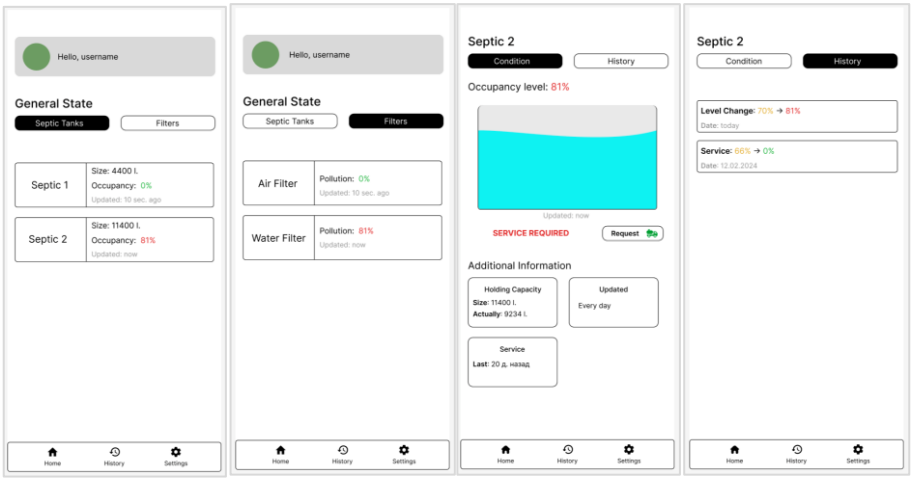

Fig. 1. Interface fragments of a prototype mobile application for wastewater monitoring

A distinctive feature of the interface for Farmer and Resident is a relatively small number of objects, the system "monitors" the condition of which. The screens show the current status of filters and cesspools, dates of maintenance, based on which the system can automatically generate a schedule of preventive maintenance and generate a list of contractors performing such works.

4 Discussion

The development of any information system corresponds to certain stages of the life cycle, each of which has its own purpose, list of works and their corresponding results. The nature of the obtained results corresponds to the results of using the methodologies of requirements analysis, studying the object and subject of research, and creating a prototype of the information system.

The work used well-known methods, which allowed to obtain a formal model of the research subject and make its digital transformation. The analysis of sources related to the modeling of objects and processes of the problem area showed that the result obtained in this way allows us to see not only qualitative and quantitative characteristics, but also to establish the rules of interaction of all objects [11-13]. Based on the obtained information, a set of documents for the development of the information system is formed, the content of which defines the categories of users, their functional capabilities, scope of application, necessary software and hardware, prototypes of the graphical interface, etc. [5, 9, 10].

The concept of the developed information system can be used in the creation of digital educational resources used in the training of specialists in the field of public administration, environmental monitoring and sustainable development of territories of settlements. As it is noted in the research related to the preparation of such resources, the use of models and information systems to study and develop professional competencies for short-term or long-term forecasting of complex ecosystem processes, management decision-making, etc., is a prerequisite for the implementation of the concept of practice-oriented learning [14, 15].

5 Conclusions

The creation of a digital system for monitoring wastewater processes not only makes it possible to control compliance with legal standards in the field of environmental safety and

sustainable development, but also to establish standardized data formats for the consolidation of different systems used, for example, in agriculture.

The use of recommendations based on the analysis of sensor data showing the real technical condition of equipment or other technical means ensures their careful use, timely maintenance or replacement to save consumables and other resources.

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