Innovative technologies and their implementation in the field of sanitation and water supply

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Abstract. Digitalization in the water supply and sanitation system refers to the introduction of modern digital technologies and solutions to enhance the efficiency and productivity of these systems. Numerous innovations and advanced technologies contribute to improving the efficiency, reliability, and environmental sustainability of water supply and sanitation systems. This includes the use of various water-saving technologies, ultrafiltration, remote monitoring and control systems, smart water meters, and more. To maximize the efficiency of the water supply and sanitation system, it is essential to integrate as many different innovative technologies as possible. The article identifies existing problems within the water supply and sanitation system and explores solutions through various innovations. It also discusses the innovative technologies already implemented in the system and how they contribute to its improved operation.

1 Introduction

Urban water supply and sanitation systems are critical components of urban economies. These systems provide the population with high-quality drinking water and maintain sanitary safety by managing wastewater, including its purification and precipitation neutralization [1]. The development of modern cities influences not only the level of social security for the population but also the scale of industrial growth. Human activities introduce significant amounts of solid household waste into the environment, worsening the environmental situation and necessitating new technical solutions.

Currently, the volume of construction and reconstruction of water supply and sanitation systems is increasing, which demands the training of qualified builders capable of addressing both water supply and sanitation tasks and the development of water management complexes and water protection measures [2, 3, 4].

Innovations in water purification and disinfection enable the effective and safe removal of impurities and microorganisms, making water drinkable. Technologies such as reverse osmosis, ultrafiltration, and activated carbon ensure high efficiency in removing harmful substances and pollutants from water [5, 6]. Additionally, innovative disinfection methods, including ultraviolet irradiation and electrochemical treatment, help destroy bacteria and

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viruses present in the water. The use of these technologies improves drinking water quality and ensures human health safety [7, 8].

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Innovative technologies also help save water and enhance the efficiency of water supply use. For instance, rainwater collection and utilization systems allow the use of water that would otherwise be lost for garden irrigation, field irrigation, and industrial needs. Flow metering and control technologies ensure precise control of water consumption, preventing leakage and overuse. Unmanned vehicles and sensor systems optimize water use in agriculture and urban landscaping. The adoption of these innovative technologies reduces water consumption and increases the sustainability of water supply systems [9, 10, 11].

Efficient wastewater disposal is crucial for ensuring the health and preservation of the environment. Innovative wastewater treatment methods can remove impurities and chemicals, making the water safe for discharge into the environment or reuse. Technologies such as biological purification, membrane filters, and UV treatment are employed in modern wastewater treatment systems. These innovative technologies help protect the environment and water reserves, allowing purified water to be used for irrigation and industrial purposes [12].

Additionally, innovative technologies are advancing wastewater disposal methods. Traditional methods are not always effective, making the development of new technologies essential. For instance, biological wastewater treatment systems (biologically active sludge) can more effectively remove pollutants from wastewater, reducing the negative environmental impact. The potential use of ultraviolet irradiation and ozone for additional wastewater treatment is also being actively studied, achieving high-quality purified water [13, 14].

In addition, innovative technologies are also applied in wastewater treatment and reuse. Often, the wastewater treatment process produces water rich in minerals and nutrients, which can be used for crop irrigation or industrial purposes. This approach reduces the consumption of fresh water and alleviates pressure on water resources. Furthermore, such wastewater treatment systems align with the concept of a circular economy, where wastewater is viewed as a resource rather than a problem.

2 Materials and Methods

The use of comprehensive methods allows us to comprehensively explore and evaluate the potential of introducing innovative technologies into water supply and sanitation systems. Analytical methods, such as physico-chemical analysis of water and wastewater, allow for assessing the quality and composition of water and the effectiveness of purification processes. Process modeling and forecasting are used to analyze and optimize the operation of water supply and sanitation systems. Economic analysis of system effectiveness assesses the economic feasibility of introducing innovations. Experimental methods include field studies and measurements carried out at existing water supply and sanitation facilities, laboratory experiments that allow for testing new technologies and materials under controlled conditions, and pilot installations used to test innovative solutions in real-world conditions. Complex methods involve system analysis, which considers water supply and sanitation as a unified system with interrelated elements, life cycle assessment, which evaluates the economic aspects of innovation implementation, and multi-criteria optimization, used to select the most effective innovative solutions, taking various factors into account.

3 Identification of problems and solutions

In our perspective, there are the following problems of water supply and sanitation:

1. Infrastructure deterioration: more than 80% of structures and pipelines of water supply systems are worn out, which leads to increased operating costs and unjustified increase in water tariffs.
2. Insufficient wastewater treatment: violation of the requirements for the quality of wastewater treatment, which worsens the environmental situation and threatens the health of the population.
3. Insufficient availability of high-quality drinking water for all segments of the population.
4. Insufficient awareness of the environmental consequences of inefficient sanitation.

Ways to solve these problems through the introduction of innovative technologies:

1. Introduction of membrane technologies. Membrane technologies are physical methods of water purification in which wastewater or process water is separated into purified water and concentrate using semi-permeable membranes. The main types of membrane technologies used in water treatment include: microfiltration, ultrafiltration, nanofiltration, reverse osmosis. Membrane technologies allow: to provide a high degree of water purification from various pollutants, including organic substances, heavy metals, microorganisms. They also help to carry out deep wastewater treatment and reuse, adjust the salt composition of water by selective extraction of ions. Due to this, it is possible to ensure environmental cleanliness, ease of operation and a high degree of automation of water treatment systems.
2. Energy efficient solutions in the context of water supply and sanitation: the application of technologies and methods aimed at optimizing energy consumption in water supply and sanitation systems. This includes the use of innovative approaches and equipment that reduce energy consumption, improve system efficiency, and ultimately reduce energy costs and reduce negative environmental impacts. This helps to save energy, improve the environmental situation and improve the efficiency of these systems.
3. Development of closed water supply systems. Closed water supply systems are systems in which treated wastewater is returned back to the technological process, ensuring repeated use of water without discharge into natural reservoirs. The main advantages of closed water supply systems are a reduction in the consumption of fresh water and the volume of wastewater discharged, a reduction in the cost of water treatment and wastewater treatment, the possibility of extracting and reusing valuable substances from wastewater, and an increase in environmental safety due to the absence of discharges into natural reservoirs. To implement closed water supply systems, it is necessary: the introduction of effective methods of wastewater treatment, such as membrane technologies, the development of water regeneration technologies taking into account the characteristics of production processes, an integrated approach to the design and organization of closed water consumption systems.
4. Equipment upgrade: upgrading infrastructure and upgrading treatment plant equipment will help improve the efficiency of water supply and sanitation systems.
5. The use of remote monitoring and control to detect leaks and optimize water supply networks. Remote monitoring systems include sensors that continuously measure the parameters of the water supply network, such as pressure and water flow. If there is a leak, the data received from the sensors allows you to identify anomalies in the system (for example, pressure drop) and indicate the possible location of the leak. Prompt detection of leaks allows you to quickly take measures to localize and eliminate them, minimizing water losses and preventing possible damage to the infrastructure. Optimization of water supply networks: Data collected from remote monitoring systems allows you to analyze the operating mode of the system in real time. Algorithms and software solutions can use this

data to optimize the operation of a water supply network, for example, to control pressure, flow rate or direction of water flow. Monitoring and control of the system from a distance allows you to quickly respond to changes in the system, reducing the risks of accidents and increasing the efficiency of water resources use.

6. Implementation of smart water supply systems for data collection and optimization of water consumption. Smart systems are equipped with sensors and flow sensors that continuously collect information about water parameters such as flow, pressure, temperature and quality. The collected data is transferred to a centralized platform where it can be analyzed in real time to monitor the state of the water supply and sanitation network. The analysis of data obtained from smart systems makes it possible to identify patterns of water consumption and identify inefficient flow points. Based on these data, it is possible to optimize the operation of the system, for example, by adjusting the pressure in pipelines, distributing the flow according to needs and preventing water loss. They can use algorithms and artificial intelligence to predict peak loads, optimize consumption, and prevent accidents. Real-time monitoring and management of the system allows you to quickly respond to changes in the scenario, use water resources as efficiently as possible and ensure stable and reliable water supply.

7. Development of digital platforms for monitoring water levels and predicting changes in water resources. Digital platforms allow you to take into account various factors affecting water resources, such as weather conditions, climate change, land use, etc. Analyzing water level data using machine learning and analytics technologies allows you to build predictive models and predict changes in water resources. Based on these forecasts, it is possible to take preventive measures, effectively plan the use of water resources, adapt management strategies and respond to possible extreme situations such as floods or droughts.

8. The use of drones and satellites to assess the state of watersheds and manage water resources. Using satellites and drones, it is possible to regularly monitor changes in water resources, such as the level of reservoirs, the area of irrigation fields, and changes in river flow. Monitoring data allows you to identify changes over time, identify trends and warn about possible problems.

9. Implementation of artificial intelligence systems for monitoring and optimization of water supply networks.

10. The introduction of advanced methods of biological and physico-chemical wastewater treatment. Biological purification: the use of microorganisms or living organisms to decompose pollutants in wastewater. Biological treatment applications may include methods such as active and passive membrane bioreactor, biological filter-based purification, and improved aerobic and anaerobic wastewater treatment plants. Physico-chemical purification: the application of physical and chemical methods to remove contaminants from wastewater. Physico-chemical purification processes may include the use of coagulation, flocculation, precipitation, filtration and other methods to remove toxic substances, heavy metals, pesticides and other contaminants.

4 Conclusion

After examining the current state of urban water supply and sanitation systems and describing the key challenges, the authors argue that the integration of innovative technologies is essential for addressing these issues in the most effective way. In particular, such challenges as infrastructure deterioration, insufficient wastewater treatment, limited access to highquality drinking water, and inadequate awareness of the environmental consequences of inefficient sanitation require comprehensive solutions. The authors propose introducing innovative technologies and implementing remote monitoring and control systems, smart water supply systems, digital platforms for water resource management, and the use of drones and satellites for watershed assessment can further enhance the management and optimization of water resources. In sum, the comprehensive adoption of innovative technologies will mitigate existing challenges and ensure the provision of safe and sustainable water resources for urban populations.

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