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APPLICATION OF ARTIFICIAL INTELLIGENCE FOR WATER RESOURCES MANAGEMENT

***Abstract**: The article discusses the application of big data in water resource management, and the use of artificial intelligence for effective water resource management.*

***Key words**: Artificial intelligence, water resources, water quality, ethical standards, and regulatory requirements.*

***Language**: English*

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Introduction

Artificial intelligence (AI) is being actively implemented for water resource management. However, managing these resources is becoming increasingly challenging due to factors such as population growth, climate change, and the complexity of water systems. Traditional water management practices are often insufficient to effectively address these issues. AI, on the other hand, offers a solution for improving efficiency and sustainability in water management.

In the field of water management, AI analyzes large amounts of data in water management. is extensive and covers areas such as water quality monitoring, AI makes water quality monitoring, infrastructure maintenance, and efficient water distribution.

In water quality monitoring, AI-powered devices can continuously monitor water quality parameters such as pH, turbidity, and pollution levels, providing real-time alerts and ensuring the safety of drinking water. AI can predict the need for maintenance of the population's water infrastructure, effectively distributing water among its consumers and ensuring a balanced supply.

AI can analyze data to predict floods, allowing for timely evacuations and better management of water resources during extreme events. While AI has significant potential in water management, there are several challenges that need to be addressed to fully realize its potential, such as managing water resources in accordance with ethical standards and regulatory requirements. New methods for improving neural networks can increase the accuracy of forecasting and the efficiency of decision-making processes. These advancements will enable more accurate modeling of complex water systems, optimize resource allocation, and improve anomaly detection in water supply networks.

The integration of AI with renewable energy systems is a promising trend in the field of water management. AI can help in the development of sustainable water infrastructure that can withstand the increasing frequency and intensity of climate events. It is necessary to develop standards that regulate the implementation of AI technologies in the water sector, taking into account issues such as data privacy, security, and transparency of AI algorithms.

Research methods

When writing this article, we used such methods as induction and deduction of the data and materials used on the issue of water resource management.

Analysis of the results

According to the Decree of the President of the Republic of Uzbekistan dated October 5, 2019, No. PP-4477, measures have been developed to transition the Republic to a green economy by 2030 year [1].

Water management is becoming increasingly effective thanks to the use of AI, which is opening up new avenues in this field by offering sustainable and reliable methods. AI is excellent at suggesting new ways to address various water-related challenges, such as monitoring water quality at any given time, predicting the condition of structures that require repair, optimizing water distribution, and preparing for floods in advance [2].

One of the ways in which AI can be useful in this field is by assessing water needs, designing water systems more efficiently, quickly detecting leaks or anomalies, monitoring water quality at any point within seconds, and suggesting more efficient options based on statistical analysis. AI-powered detectors can analyze data from detectors and meters at any given time to identify any significant deviations that indicate a water leak. Early detection of leak locations can reduce water loss and the cost of necessary repairs [3].

AI can predict the amount of water that people need in a particular region based on past water usage, climate conditions, population growth rates, and the duration of water usage from another source [4]. AI helps to make goal-oriented decisions and use resources more efficiently. The main goal of water management is to provide all sectors of the economy with the necessary amount and quality of water, as well as to meet environmental needs.

Economic regulation of the rational use and protection of water includes: planning and financing measures for the rational use and protection of water; setting limits on water use; setting standards for fees for water use and consumption; setting standards for fees for discharges of pollutants into water bodies; providing tax, credit, and other benefits for the use of low-waste and non-waste technologies, as well as for other measures that have a significant impact on the rational use and protection of water, etc.

The main reserve for increasing the efficiency of water resources is to reduce consumption in the main branches of the water sector, especially in relation to fresh water. It is necessary to eliminate numerous water losses at all stages of its use. Large water losses are observed directly at the level of individual participants in the water sector. The need to manage water resources is determined by the variability of the amount of water resources over time, depending on their source of formation. It is also important to reduce the pollution and salinity of water resources caused by natural and anthropogenic factors.

It is necessary to emphasize the negative impact of water bodies on both nature itself (flooding, waterlogging, etc.) and the national economy. The management of water resources is based on the quantity of water resources, which should be calculated based on the analysis of the average amount of water consumed and the established consumption levels. The water resources of Uzbekistan are part of the overall water resources available in the Aral Sea basin. The largest rivers of Central Asia, the Amu Darya and the Syr Darya, belong to this basin and are the main sources of surface runoff that directly flow into the Aral Sea, as well as those that are hydrographically related to the basin and are located within the Aral Basin.

In the long term, the problem of water use in the Central Asian region will become more acute due to the high rate of population growth. According to the United Nations, the population of Uzbekistan is 34.2 million people. Experts estimate that the demographic growth in these countries will inevitably increase the demand for water by 40% over the next years [5]. Additionally, economic growth in Afghanistan may create additional challenges, as it will increase water consumption in this country, which is located in the upper reaches of the Amu Darya River. According to World Bank experts, Uzbekistan benefits significantly from the use of water resources for irrigation purposes. Uzbekistan is interested in developing its hydropower potential and ensuring sustainable and fair management of transboundary rivers.

For example, in the Syrdarya basin, where the use of water for energy needs does not meet the requirements of the irrigation regime in some cases. As a result of the complete depletion and exhaustion of water resources due to their maximum extraction, the deterioration of their quality, and the disregard for environmental requirements and the problem of the Aral Sea. The abrupt change in the priority use of water resources in Uzbekistan has created a number of problems, primarily of an environmental nature, that require immediate resolution.

If we systematize the problems that have arisen due to the complete depletion of the region's water resources, we can observe a shortage of water resources, which is more pronounced during periods of severe water scarcity due to insufficient irrigation, drying out of crops, and the deterioration of the environmental situation, sometimes reaching the level of ecological disaster in the lower reaches of most rivers. Heavy pollution of river waters with pesticides, herbicides, and other harmful elements, as well as increased water mineralization, flooding of land and economic facilities, destruction of coastal protection structures, and deterioration of the reclamation and fertility of irrigated land, make it unsuitable for agricultural use.

Uzbekistan, in cooperation with other water users, should implement a water management policy that takes a broad perspective on issues (economic, social, and environmental) and promote partnerships between different sectors and authorities at the national and local levels to improve investment in the water and sanitation sectors and increase efficiency. In addition, it is necessary to implement organizational and legal reforms to reduce losses and support the reuse and recycling of excess water.

It is necessary to implement AI in Uzbekistan's water management and develop bilateral and multilateral legal mechanisms to implement Principle 13 of the Rio Declaration, which relates to the duty and compensation for environmental damage caused by activities within the jurisdiction or control of their respective areas of jurisdiction. In this sense, states should be guided by Principle 16 of the Rio Declaration, which supports the approach of polluter-pays, and aims to minimize damage by adjusting the hydrological regime of rivers through the development and implementation of coordinated releases from reservoirs, taking into account the needs of all sectors.

For example, the Spanish multinational company Acciona has launched the PRISTINE project on a pilot water treatment plant. Thanks to this project, a number of virtual sensors collect data in real time, such as water flow, pH, and turbidity, and the AI system estimates the concentrations of pollutants in real time, which was previously only possible in laboratories and certainly not in real time. As a result, the system implemented in the PRISTINE project automatically adjusts the water treatment process to meet regulatory requirements. Severn Trent, a British water supply company, announced in January 2023 year that it had transformed its wastewater management with an "AI-powered pilot project" to "predict weather conditions, schedule maintenance, and control discharge flows."[6].

Oldcastle Infrastructure, a U.S.-based infrastructure solutions provider, collaborated with FIDO Tech Ltd., a British company, to develop an AI technology called Hydro-Logic CivilSense. This AI system can detect leaks in the water distribution network. According to data provided by Oldcastle Infrastructure, there are 240,000 pipe breaks in the United States every year, resulting in the loss of approximately 22.7 billion liters of drinking water and costing municipalities and water utilities an estimated \$7.5 billion. The solution offered by Oldcastle Infrastructure is to map the water infrastructure, install sensors in strategic locations, and collect their parameters. The AI tool then analyzes the data and is able to predict and detect network leaks with an accuracy of 93%.

Another example is the UK water company Severn Trent, which announced in January 2023 that it had transformed wastewater management with an "AI-powered pilot." Predictive maintenance of infrastructure is changing the water economy. Instead of reactive repairs after accidents and hard-scheduled maintenance, AI predicts degradation of specific system elements [7]. Vibration sensors on pumps, acoustic sensors on pipelines, and water quality analyzers are all sources of data for algorithms that predict failures 10-45 days in advance. Acoustic monitoring detects leaks by the characteristic sound of water seeping through microcracks. Neural networks are trained to distinguish a useful signal from background noise — transport, industrial facilities, natural sounds. The accuracy of leak localization reaches 2-5 meters even on deep-buried pipelines. The systems work around the clock, detecting problems when the volume of losses is still insignificant — 5-15 liters per minute against 500-2000 in case of obvious breakthroughs. Digital twins of water networks allow you to simulate changes and test solutions without risking the real system, while robotic pipeline inspection with AI video analysis detects corrosion, deposits, and cracks with 94% accuracy. Smart valves with autonomous control isolate emergency areas in 30-90 seconds, minimizing damage. Material science models predict the residual life of pipes based on their age, load, and water chemistry. Upgrading planning becomes a data-driven process rather than an intuitive one. AI ranks network sections based on their priority for replacement, taking into account factors such as failure likelihood, potential damage, repair costs, and social significance. Instead of replacing 3-5% of the network annually, companies focus their resources on the critical 8-12% where the risks are highest. This reduces the number of accidents by 35-40% while maintaining the same capital repair budgets. Singapore, a country with a critical freshwater shortage, has deployed a Smart Water Grid system that integrates 400,000 smart sensors with an AI platform. Results in three years: network losses reduced from 5% to 3.2% (one of the best in the world), demand forecasting reached 96.8% accuracy, the number of emergency shutdowns reduced by 47%. The system paid off in 6.7 years with a calculated term of 12 years, according to the Public Utilities Board Singapore reports. California used machine learning to manage a reservoir system in the conditions of a long-term drought. The algorithms predicted precipitation, snowmelt in the mountains, and groundwater dynamics, optimizing the distribution between agricultural, industrial, and domestic consumers [8]. Over the period of 2015-2019, consumption was reduced by 25% without causing critical damage to the state's economy. The key to success was flexible redistribution rather than simply imposing restrictions. Barcelona implemented an AI-based system for detecting leaks in the city's historical neighborhoods, where pipelines are over 100 years old and dense urban development makes access challenging. Acoustic sensors and neural networks detected leaks based on the propagation of sound in the old infrastructure [9]. Over two years, 3,847 hidden leaks were identified and eliminated, reducing unproductive losses from 24% to 16%. A side effect is a 31% reduction in soil subsidence and damage to building foundations. Copenhagen: Predictive management of stormwater sewage reduced flooding by 42%, the system predicts the intensity of precipitation and preemptively frees up storage tanks. Tokyo: AI water quality monitoring detects micro-pollution in 15-20 minutes, which is 95% faster than laboratory methods, 12 potential incidents were prevented in 2020-2022 years. Dubai: Smart meters with behavioral analytics helped reduce household consumption by 14% through personalized recommendations and gamification of water savings. Amsterdam [10]. A digital twin of the water system is used to test development scenarios, and the necessary upgrades are predicted for the next 30 years. Russian experience is also accumulating, although it lags behind the world leaders. In 2021, the Moscow Water Canal launched a pilot AI monitoring project in the Southern District. Over the course of 18 months, the accuracy of consumption forecasts increased from 73% to 89%, and 127 hidden leaks were detected, resulting in a total loss of 18,400 m³/day. The economic impact amounted to 64 million rubles, with an investment of 41 million, resulting in a payback period of 7.8 months. The project is expanding to other districts with the goal of covering the entire network by 2026 year. AI has transformed water management from a reactive response to problems into a proactive optimization of a limited resource [11]. The numbers speak for themselves: 15-30% water savings, 20-40% reduction in accidents, and 12-25% decrease in energy consumption are not theoretical calculations but the reality of operational systems. Barriers to adoption are decreasing: cloud platforms make it easier to get started, IoT sensors are becoming cheaper, and off-the-shelf AI solutions can be customized in weeks [12].

Conclusions

Modernization planning becomes a proven, rather than an intuitive process. AI ranks network sections by priority of replacement, taking into account the probability of failure, potential damage, repair costs, and social significance of water facilities. Until recently, the natural flow of large rivers in most areas met the requirements of water users and consumers. However, due to increased water use and deteriorating water quality, the shortage of water resources has become increasingly noticeable. A radical, and in many cases the only, way to solve or mitigate water problems is to create water management complexes (WMC), which are groups of industries that are integrated into water management systems of various sizes and structures. When creating a WMC, it is important to consider three interconnected parts: the natural (the ability of the WMC to function and develop), the economic (the interests of all industries), and the technical.Over the past two years, the Ministry of Water Management has been actively developing the digitalization of the water sector. Today, the State Water Cadastre Information System has been established, which collects all information about water resources and their use in various sectors. Additionally, the Water Use Information System has been implemented, and starting from 2024, water usage fees have been introduced in the agricultural sector. A special software is being developed for this system, which allows for the tracking of who used how much water, the collection of water fees, and the monitoring of water distribution and usage efficiency. If elements of artificial intelligence are connected to the water cadastre and water management system, information systems will be able to work more efficiently and rationally. In addition, one of the problems in Uzbekistan is the supply of water through pumping stations. More than half of the irrigated land uses water supplied by pumps rather than gravity. In order for the pumps to work, electricity is needed. In 2017, half of the Ministry of Water Economy's budget was spent on paying for the electricity used for all the pumping systems for irrigation (watering crops), amounting to 8.7 billion kWh, which is about 20% of the total electricity consumption in our country! Since 2019, the Ministry of Water Management has been implementing a special program to replace outdated pumps and equipment and to computerize the management of all pump stations.

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