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METHODS FOR INTELLIGENT ANALYSIS OF WATER COMPOSITION BASED ON ARTIFICIAL INTELLIGENCE MECHANISMS

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Abstract. This research study analyzed the main factors causing water quality deterioration, criteria for assessing physical, chemical and other parameters of water, and hazardous pollutants that may be found in water. During the study, physical indicators such as pH, turbidity, color, total dissolved solids, electrical conductivity, which are important in assessing the quality of drinking and natural waters, as well as chemical pollutants such as heavy metals and organic compounds, were considered. Also, the capabilities of modern measuring instruments used to determine these substances, including UV–Vis spectrophotometers, ion-selective electrodes, pH meters, and EC meters, were analyzed. Artificial intelligence models for water quality analysis were compared and the LSTM algorithm was considered from them. The results of the article serve as a scientific basis for monitoring water quality, identifying pollution sources, and rational planning of water use.

Keywords: Artificial Intelligence, Artificial Neural Networks, chemical parameters, EC meter, indicator parameters, ion-selective electrode, LSTM, machine learning algorithm, microbiological parameters, pH meter, physical parameters, UV–Vis spectrophotometer, water pollution, water quality.

Sun'iy intellekt mexanizmlari asosida suv tarkibini aqlli tahlil qilish usullari

Annotatsiya. Ushbu tadqiqot ishida suv sifati buzilishiga sabab bo‘luvchi asosiy omillar, suvning fizik va kimyoviy va boshqa parametrlarini baholash mezonlari hamda suv tarkibida uchrashi mumkin bo‘lgan xavfli ifloslantiruvchi moddalar tahlil qilindi. Tadqiqot davomida ichimlik va tabiiy suvlar sifatini baholashda muhim ahamiyatga ega bo‘lgan pH, loyqalilik, rang, umumiy erigan moddalar, elektr o‘tkazuvchanlik kabi fizik ko‘rsatkichlar hamda og’ir metallar, organik birikmalar kabi kimyoviy ifloslantiruvchilar ko‘rib chiqildi. Shuningdek, ushbu moddalarni aniqlashda qo‘llaniladigan zamonaviy o‘lchash asbob-uskunalari, jumladan UV–Vis spektrofotometr, ion-selektiv elektrod va pH-metr, EC metrlarning imkoniyatlari tahlil etildi. Suv sifatini tahlil etishda Sun’iy intellekt modellari o‘zaro taqqoslandi hamda ulardan LSTM algoritmi ko‘rib chiqildi. Maqola natijalari suv sifatini monitoring qilish, ifloslanish manbalarini aniqlash va suvdan foydalanish yo‘nalishlarini oqilona rejalashtirish uchun ilmiy asos bo‘lib xizmat qiladi.

Kalit so‘zlar: sun’iy intellekt, sun’iy neyron tarmoqlari, kimyoviy parametrlar, EC o‘lchagich, indikator parametrlari, ion-selektiv elektrod, LSTM, mashinani o‘rganish algoritmi, mikrobiologik parametrlar, pH o‘lchagich, fizik parametrlar, UV-Vis spektrofotometri, suv ifloslanishi, suv sifati.

Методы интеллектуального анализа состава воды, основанные на механизмах искусственного интеллекта

Аннотация. В данном исследовании проанализированы основные факторы, вызывающие ухудшение качества воды, критерии оценки физических, химических и других параметров воды, а также опасные загрязняющие вещества, которые могут содержаться в воде. В ходе исследования были рассмотрены физические показатели, такие как pH, мутность, цветность, общее содержание растворенных твердых веществ, электропроводность, которые важны для оценки качества питьевой и природной воды, а также химические загрязняющие вещества, такие как тяжелые металлы и органические соединения. Также были проанализированы возможности современных измерительных приборов, используемых для определения этих веществ, включая УФ-спектрофотометры, ионоселективные электроды, pH-метры и EC-метры. Было проведено сравнение моделей искусственного интеллекта для анализа качества воды, и из них был выбран алгоритм LSTM. Результаты статьи служат научной основой для мониторинга качества воды, выявления источников загрязнения и рационального планирования водопользования.

Ключевые слова: искусственный интеллект, искусственные нейронные сети, химические параметры, EC-метр, параметры индикатора, ионоселективный электрод, LSTM, алгоритм машинного обучения, микробиологические параметры, pH-метр, физические параметры, УФ-спектрофотометр, загрязнение воды, качество воды.

Introduction. Water is an important resource for life, and today providing the population with clean drinking water is considered one of the urgent issues at the international level. Identifying the causes of water pollution and monitoring water quality are considered the most necessary measures. Only 2.5% of the total water on planet Earth is considered suitable for drinking. The growth of the world's population and the improvement of living standards are increasing the demand for water. At the same time, in addition to natural factors such as salinization, wastes generated as a result of human activities such as industrial discharge and mining change the quality of water, including its nature and characteristics, and cause pollution. This, in turn, leads to premature death and diseases; for example, 14,000 people die every day in the world due to the consumption of contaminated water [1]. According to World Bank estimates, 21% of infectious diseases in India are related to contaminated water and lack of hygiene. Every year in the United States, between 8,000 and 18,000 people are hospitalized with Legionnaires' disease, a respiratory infection caused by exposure to contaminated water aerosols spread from artificial water systems. Water pollution causes many types of diarrheal diseases, as well as cholera, dracunculiasis, filarial diseases, dysentery, viral gastroenteritis, and amoebiasis. Therefore, water quality determines the quality of human life, and in short, the survival of humans and other life forms is impossible without water.

Water pollution factors. Pollution factors related to the water source. One of the main factors causing deterioration of drinking water quality is the contamination of the water source as a result of natural and anthropogenic impacts. Due to the geochemical composition of underground rocks, elements such as arsenic, iron, or fluorine may be present in high concentrations in water. In addition, contamination with nitrates, pesticides, and heavy metals as a result of industrial wastewater, agricultural fertilizers, and domestic waste poses a serious threat to drinking water safety.

Deficiencies in the water treatment process. The following errors during the treatment process may pose a risk to human health:

- insufficient disinfection;
- decrease in filtration efficiency;

- incompatibility of the treatment technology with the water source.

Deterioration of quality during water storage. When water is stored in open containers or in containers that do not meet sanitary requirements, microorganisms from the external environment enter and cause the multiplication of Escherichia coli, intestinal enterococci, and other pathogens. According to WHO data, even boiled or treated water can become microbiologically recontaminated within 24–72 hours if stored improperly, especially within the temperature range of 25–45 °C, where bacteria develop rapidly. In addition, low-quality plastic or corroded metal containers negatively affect the smell, taste, and color of water. Therefore, storing drinking water in closed, clean, and cool conditions is an important factor in ensuring its safety.

Pollution factors related to the water distribution (pipeline) system. As a result of pipe aging and internal corrosion, iron, manganese, and other metal ions enter the water, negatively affecting its color, turbidity, smell, and taste. In particular, lead pipes increase the risk of heavy metal contamination, therefore proper selection of pipe material and regular technical maintenance of the system are important.

Human factor. One of the factors often underestimated in the deterioration of drinking water quality is the human factor, where failure to follow sanitary-hygienic rules leads to microbiological contamination of water. Failure to keep containers clean, storing water improperly or openly, and failure to follow disinfection rules increase the risk of waterborne diseases, therefore improving the hygienic knowledge and skills of the population is important.

Factors related to emergencies, natural disasters, and climate change. Floods, earthquakes, heavy rainfall, and technogenic accidents disrupt water supply systems and cause drinking water to mix with sewage, industrial waste, and other pollutants. Climate change, due to rising global temperatures and extreme weather events, worsens the microbiological and chemical quality of water and negatively affects the stability of water supply infrastructure; therefore, enhanced monitoring and adaptive management strategies are necessary under such conditions.

In preventing contamination of drinking water, considering the causes that negatively affect its composition is the most correct and primary measure. By identifying exactly which factor caused the deterioration of water quality, it is possible to select the most optimal treatment method and eliminate the problem.

Water composition parameters. When monitoring drinking water quality, it is advisable to study the substances present in water and its parameters. During the research process, the parameters affecting water quality were examined. The results show that water must be free from any microorganisms and parasites, as well as from any substances that may pose a potential risk to human health in terms of their amount or concentration. In particular, drinking water must meet minimum requirements based on the following parameters.

Microbiological parameters. Water must be completely free of the following microbiological indicators:

- Intestinal enterococci;
- E. coli;

Chemical parameters. The amount of chemical substances must not exceed the values given in this table (Table 1): (Note: g/l = grams per liter, mg/l = milligrams per liter, and µg/l = micrograms per liter) [2]

Table 1. Chemical substances present in water composition

T/r	Substance Name	Maximum permissible concentration	Unit of measurement
1	Acrylamide (C_3H_5NO)	0.10	µg/l
2	Antimony (Sb)	10	µg/l
3	Arsenic (As)	10	µg/l
4	Benzene (C_6H_6)	1.0	µg/l
5	Benzo(a)pyrene ($C_{20}H_{12}$)	0.010	µg/l
6	Bisphenol A ($C_{15}H_{16}O_2$)	2.5	µg/l
7	Boron (B)	1.5	mg/l
8	Bromate (BrO_3^-)	10	µg/l
9	Cadmium (Cd)	5.0	µg/l

10	Chlorate (ClO_3^-)	0.25	mg/l
11	Chlorite (ClO_2^-)	0.25	mg/l
12	Chromium (Cr)	25	µg/l
13	Copper (Cu)	2.0	mg/l
14	Cyanide (CN^-)	50	µg/l
15	1,2-Dichloroethane ($C_2H_4Cl_2$)	3.0	µg/l
16	Epichlorohydrin (C_3H_5ClO)	0.10	µg/l
17	Fluoride (F^-)	1.5	mg/l
18	Haloacetic acids (HAA)	60	µg/l
19	Lead (Pb)	5	µg/l
20	Mercury (Hg)	1.0	µg/l
21	Microcystin-LR ($C_{49}H_{74}N_{10}O_{12}$)	1.0	µg/l
22	Nickel (Ni)	20	µg/l
23	Nitrate (NO_3^-)	50	mg/l
24	Nitrite (NO_2^-)	0.50	mg/l
25	Pesticides	0.10	µg/l
26	Total pesticides	0.50	µg/l
27	Total PFAS	0.50	µg/l
28	Sum of PFAS	0.10	µg/l
29	Polycyclic aromatic hydrocarbons	0.10	µg/l
30	Selenium (Se)	20	µg/l
31	Tetrachloroethene (C_2Cl_4) and Trichloroethene (C_2HCl_3)	10	µg/l
32	Total trihalomethanes	100	µg/l
33	Uranium (U)	30	µg/l
34	Vinyl chloride (C_2H_3Cl)	0.50	µg/l

Detection of pollutants and assessment of their concentration in water require testing various chemical parameters. Typically, some of the chemical parameters tested include ammonia, chloride ion, nitrite, nitrate, phosphate, and water hardness [3].

Chloride ion (ClO_2^-). The concentration of chloride ions in water may indicate the level of contamination and the presence of saline water. High levels of chloride ions can cause a salty taste in water and lead to corrosion in water pipes. This can not only negatively affect water quality but also increase maintenance costs.

Ammonia (NH). Ammonia is often a byproduct of the decomposition of organic matter and is commonly found in water sources. The concentration of ammonia increases when chloramine is used in water disinfection processes. High levels of ammonia in drinking water may have negative effects on health, and its presence may cause specific taste and odor.

Nitrite (NO_2^-) and Nitrate (NO_3^-). Nitrite and nitrate are forms of nitrogen that can be found in water due to the decomposition of organic matter and the fixation of atmospheric nitrogen. Nitrite, especially at high concentrations, can be toxic and may cause health problems associated with oxygen deficiency in infants, particularly methemoglobinemia (commonly known as “blue baby syndrome”).

Phosphate (PO_4^{3-}). Phosphate exists in water in various forms, including dihydrogen phosphate ($H_2PO_4^-$), polyphosphate, and organic phosphate. Phosphate mainly originates from agricultural waste, sewage, and industrial waste. Although phosphate itself is not toxic, high concentrations can lead to eutrophication of water.

Hardness. Water hardness is determined by the presence of calcium (Ca^{2+}) and magnesium (Mg^{2+}) salts in water. Temporary hardness occurs due to carbonate and bicarbonate ions, while permanent hardness is associated with chloride and sulfate ions. Hard water may be beneficial to some extent as drinking water, but excessive amounts of certain ions can cause inconvenience due to the formation of deposits.

Relevant parameters for assessing the risks of domestic distribution systems (pipes, reservoirs). These include:

- Legionella (a bacterium that multiplies in natural and artificial water systems) < 1000 CFU/l
- Lead < 10 μg/l.

Indicator parameters. These parameters include substances in water that have aggressive or corrosive properties. Substances with aggressive or corrosive properties cause deterioration of materials in water supply systems, which leads to indirect deterioration of drinking water quality. The main substances with aggressive or corrosive properties include:

- acids and acid-forming substances
- substances with alkaline (corrosive) effects
- salts (the most dangerous corrosive group)
- dissolved gases
- low mineralized water composition
- conditions leading to the release of metal ions

Dissolved carbon dioxide, chloride and sulfate ions in drinking water, as well as pH exceeding the norm, have aggressive or corrosive properties and cause deterioration of materials in water supply systems.

Physical parameters of water. These indicators include the assessment of various physical properties such as temperature, color, turbidity, and conductivity. Physical parameters provide valuable information about the clarity and suitability of water for various purposes.

Table 2. Physical parameters of water

Physical parameter	Permissible limit	Description
Turbidity	≤ 5 NTU (Nephelometric Turbidity Unit)	Affects the efficiency of the disinfection process and may hide microorganisms
Color	≤ 15 TCU (True Color Unit)	Aesthetic indicator of the presence of organic substances and iron compounds
Odor and taste	No foreign odor or taste	Indicator for assessing water quality using sensory (organoleptic) method
Temperature	≤ 25 °C (recommended)	High temperature may increase microbiological activity
Total dissolved solids (TDS)	≤ 1000 mg/L	Determines the salinity level and taste characteristics of water
Electrical conductivity (EC)	≤ 2500 μS/cm	Indirect indicator of the total amount of dissolved ions in water

Turbidity. It indicates the absorption or scattering of light caused by suspended particles in water (soil, algae, organic matter) and is measured using a turbidity meter. High turbidity worsens the appearance of water and negatively affects disinfection processes.

Color. The color of water depends on suspended or dissolved substances; apparent color originates from suspended substances, while true color comes from dissolved substances. Excessive color is aesthetically unpleasant and may indicate the presence of organic compounds.

Temperature. Water temperature affects the amount of dissolved oxygen, the solubility of gases, and the development of aquatic organisms. Although it is simple to measure, it is important in assessing the state of the ecosystem.

Electrical conductivity. It indicates the ability of water to conduct electric current and depends on the amount of dissolved salts and ions. Conductivity provides information about the mineral composition, salinity, and practical use of water.

Studying the composition of water based on various parameters is of great importance, as these parameters help determine the suitability of water for drinking, domestic, or industrial purposes. Each parameter represents a specific aspect of water quality and makes it possible to assess its safety and stability. Comprehensive analysis based on parameters serves to identify hidden risks in water composition and prevent them. Therefore, considering several parameters together in the water assessment process is scientifically and practically important.

Measurement equipment and technologies. Devices used in the study of water composition. Due to the increasing pollution of water and the growing demand for it, accurate and reliable water analysis is of great importance. Water analysis instruments play an important role in monitoring and

ensuring water safety and quality. Just as water has its own various parameters, the instruments and technologies used to analyze it are also diverse.

UV–Vis spectrophotometer is an analytical device that measures the amount of ultraviolet and visible light absorbed by a sample and is widely used to determine the concentration of substances such as nitrate, nitrite, iron, and manganese in water. It operates based on the absorption principle, where photon energy is transferred to an atom or molecule, causing a change in the electron energy level, and this change is measured. The instrument typically operates at wavelengths of 190–900 nm (up to 3200 nm in some models) and allows identification of molecules, determination of concentration, and evaluation of absorption and transmission in liquid and solid samples [4].



Figure 1. UV–Vis spectrophotometer

Ion-selective electrodes (ISE) are important sensor devices in the study of liquid composition, enabling the evaluation of the physicochemical properties of a liquid by determining the activity of specific ions. They are widely used to determine the concentration of ions such as sodium, potassium, chloride, calcium, ammonium, nitrate, nitrite, and fluoride, and play an important role in assessing drinking and wastewater quality, the level of mineralization, and environmental safety. Due to their portability, rapid results, and the possibility of use in real-time monitoring systems, ISEs effectively support continuous monitoring of liquid composition and prompt decision-making processes [5].



Figure 2. Ion-selective electrode (ISE)

pH meter is a scientific instrument used to measure the activity of hydrogen ions in water-based solutions and expresses the acidity or alkalinity level of the solution through the pH value. The difference in electrical potential is directly related to the acidity level of the solution, that is, its pH value. pH is a scale used to measure the acidity or alkalinity of a solution, ranging from 0 to 14:

- pH = 7: Neutral (for example, pure water)
- pH < 7: Acidic (for example, lemon juice, stomach acid)
- pH > 7: Alkaline (for example, soapy water, bleach)



Figure 3. pH meter

Basically, pH reflects the concentration of hydrogen ions (H^+) in a solution — the lower the pH, the more acidic it is; the higher the pH, the more alkaline it is. The device converts the activity of hydrogen ions in the solution into an electrical signal, usually allowing measurement with an accuracy of ±0.01 pH, and can be used in real time in both laboratory and field conditions.

At the same time, the pH meter has some limitations: the electrode requires regular calibration, contamination may affect the results, and it provides only the pH value and does not fully characterize the water composition. However, the pH meter is important for controlling the acidity or alkalinity level of water and assessing its suitability.

Methodology for determining water composition. In assessing water quality, determining its physical and chemical indicators is of great importance. For this purpose, water sampling, preparation, and analysis using modern analytical instruments are carried out based on specific stages.

The general stages of water composition analysis are carried out as follows:

1. Sampling. At this stage, the water sample is taken from sources such as the drinking water supply network, well, river, lake, or reservoir. In order to ensure the representativeness of the sample and preserve its original composition, the rules of sampling, transportation, and storage are strictly followed. Errors in sampling may negatively affect the accuracy of subsequent analysis results.

2. Sample preparation. The collected water sample is prepared for analysis. This process includes filtration to remove mechanical particles, dilution if necessary, and the addition of chemical reagents to determine certain parameters. This stage serves to increase measurement accuracy and ensure the reliability of the results.

3. Instrument setup and calibration. Before analysis, the measuring instrument is prepared for operation. In this process, the instrument is calibrated, measurement parameters are set, and the appropriate operating mode corresponding to the parameter to be analyzed is selected. Proper setup ensures the accuracy of measurement results.

4. Measurement process. The prepared water sample is analyzed using the appropriate instrument. The instrument measures physical or chemical parameters of the water composition, such as pH, electrical conductivity, ion concentration, or optical properties. Each parameter is determined using the corresponding sensor or analytical method.

5. Data processing and analysis. The measurement results are processed, and the quantity or quality indicators of substances in the water are determined. The obtained data serve as a basis for assessing water quality, monitoring, and, if necessary, performing in-depth analysis using artificial intelligence algorithms.

Proper sampling, preparation, and analysis of water samples using analytical instruments make it possible to reliably assess water quality and obtain important information for further monitoring and analysis.

Artificial intelligence models in water composition analysis. Many types of artificial intelligence are used in monitoring and forecasting water quality, especially machine learning and deep learning algorithms, which are among the widely used methods. These include regression, classification, clustering, and neural network models.

Regression is a method of quantitatively predicting the dependent variable *(y)* using one or more independent variables *(x_1, x_2, ...)*, and in water analysis, regression is used to determine the concentration of pollutants, calculate the Water Quality Index (WQI), optimize laboratory measurements, and predict changes over time.

Classification belongs to the supervised learning category of machine learning, in which the task of assigning data into predefined categories is performed [6]. In water quality monitoring, classification determines whether water is suitable for drinking, whether the water quality falls into the category of “good,” “acceptable,” or “polluted,” and whether the source of pollution is natural or anthropogenic.

Clustering is an unsupervised learning method that groups data based on their similarity without predefined labels. In water analysis, clustering makes it possible to identify groups of similar water samples, distinguish pollution zones, optimize monitoring points, and identify hidden patterns.

Artificial neural networks (ANN) are algorithms based on the functioning of the human brain and are used to model complex patterns and predict solutions to problems. Since ecological systems, including the water environment, are multi-factorial, nonlinear, and time-varying, neural networks show high efficiency in this field. Using neural networks, the concentrations of NO_3^-, NH_4^+, and PO_4^{3-} are predicted with high accuracy.

Artificial neural networks (ANN) are distinguished by their ability to identify complex and nonlinear relationships in assessing water composition, which makes it possible to determine hidden relationships between various physicochemical parameters and to predict water quality indicators with high accuracy. The most common types of artificial neural networks include the following:

- **Feedforward networks** — the simplest type, used in classification and prediction tasks.
- **Recurrent neural networks (RNN)** — designed for processing sequential data and used in speech recognition and natural language processing.
- **Convolutional neural networks (CNN)** — used for analyzing image and audio data and designed to identify spatial or temporal local patterns [7].

Long Short-Term Memory networks (LSTM). LSTM is a specialized type of RNN that solves the vanishing gradient problem that occurs when training standard RNNs over long sequences. They have a memory state and control mechanisms that allow learning and retaining long-term dependencies in sequential data [8].

In traditional RNNs, when the error gradient becomes very small during the backpropagation process, the network has difficulty learning long-term dependencies. To solve this problem, the LSTM model includes a memory cell. This memory cell controls the storage or forgetting of information based on the input data.

LSTM architecture is expressed as follows (Figure 4):

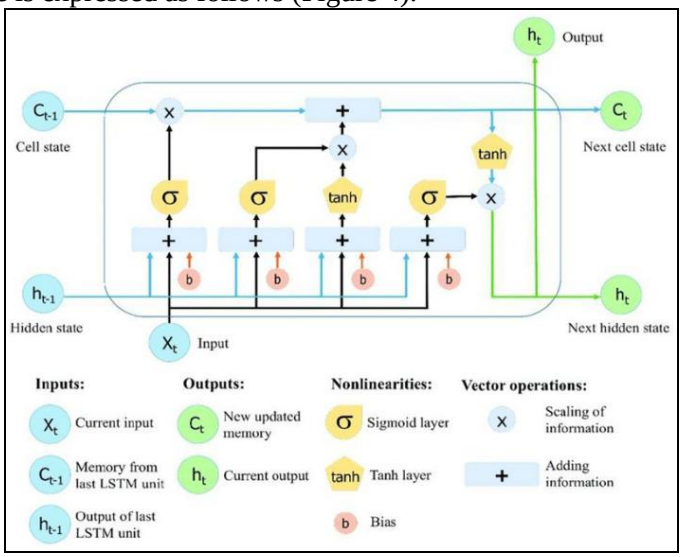


Figure 3. LSTM architecture

For each time step t, the following values are calculated:

- x_t – input vector
- h_{t-1} – previous hidden state
- C_{t-1} – previous memory state

Input Gate. The input gate controls how much new information is added to the memory state:

$$i_t = \sigma\left(W_i\left[h_{t-1}, x_t\right] + b_i\right) \quad (1)$$

here, the value of i_t ranges between 0 and 1 and determines the extent to which new information is added to the memory state.

Forget Gate. It determines how much information from the previous memory state is retained:

$$f_t = \sigma\left(W_f\left[h_{t-1}, x_t\right] + b_f\right) \quad (2)$$

here, the value of f_t controls which part of the memory state is retained and which part is forgotten.

Output Gate. The output gate controls how much information from the updated memory state is transmitted as output:

$$o_t = \sigma\left(W_o\left[h_{t-1}, x_t\right] + b_o\right) \quad (3)$$

Candidate Memory. The new memory value is calculated based on the current input data and the previous hidden state:

$$\tilde{C}_t = \tanh\left(W_C\left[h_{t-1}, x_t\right] + b_C\right) \quad (4)$$

Memory State Update. The memory state is updated using the forget gate and the input gate:

$$C_t = f_t \times C_{t-1} + i_t \times \tilde{C}_t \quad (5)$$

Hidden State. The hidden state represents the current output value of the LSTM model:

$$h_t = o_t \times \tanh\left(C_t\right) \quad (2)$$

where:

σ — sigmoid function

tanh — hyperbolic tangent function

The LSTM model is designed to process time series data and makes it possible to identify complex and long-term dependencies in the temporal changes of water quality parameters. This model is effective in predicting future values based on previous measurement results and in assessing water quality conditions in advance. These features of the LSTM algorithm make it an important tool for water quality monitoring, early detection of pollution conditions, and the development of real-time monitoring systems. The use of LSTM and similar models reduces the time and cost required for laboratory analysis and enables real-time monitoring of water quality. In the future, based on this model, it is possible to develop practical systems that automatically assess water quality by analyzing data obtained from sensor devices.

Table 3. Comparison of the performance of machine learning models

Model	Purpose	Dataset requirement (average number of samples)	Accuracy	Advantage
Regression (Linear, Polynomial regression)	Predict quantitative values of water quality parameters	Small and medium 50–1000	Medium	Has a simple structure, works fast, and the results are easy to interpret
Classification (SVM, Decision Tree, Random Forest)	Classify water quality into categories (good, moderate, polluted)	Medium 200–5000	High	Effective and provides high accuracy in determining water quality categories
Clustering (K-means, Hierarchical clustering)	Group water samples based on similarity	Medium and large 200–10000	Medium	Enables automatic grouping of unlabeled data and identification of hidden structures
ANN — Artificial Neural Network	Predict water quality parameters and perform complex analysis	Medium and large 1000–50000+	Very high	Enables identification of complex nonlinear relationships and high-accuracy prediction

The comparative evaluation of the performance, accuracy, and advantages of machine learning models used for water quality assessment and prediction is of significant importance (Table 3). These models enable the identification of complex and nonlinear relationships among water quality indicators, improve prediction accuracy, and facilitate the automation of analysis processes. At the same time, the effectiveness of the model depends on the size, structure, and characteristics of the dataset, and the selection of an appropriate algorithm is a critical factor in ensuring the reliability and accuracy of intelligent water quality assessment systems.

Conclusion. In this article, the main factors causing water pollution, microbiological, indicator, physical, and chemical parameters describing water quality, as well as modern measuring instruments used to determine these indicators were analyzed. The research results showed that the deterioration of water quality is associated with many anthropogenic and natural factors and highlighted the importance of accurate and reliable measurement methods in determining the

concentration of pollutants. In assessing water composition, pH, turbidity, total dissolved solids, electrical conductivity, heavy metals, and microbiological indicators were identified as the main parameters. The use of technologies such as UV–Vis spectrophotometer, ion-selective electrode, and pH meter in determining these parameters was scientifically justified. Analyzing the data obtained from such devices using artificial intelligence models is considered a modern and effective method for monitoring water quality. During the research, artificial neural networks (ANN) and LSTM algorithms of machine learning were analyzed. These methods are important for improving water quality monitoring, identifying pollution sources, and rational planning of water use, and serve as a scientific basis for the future implementation of intelligent analysis and automated monitoring systems.

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