Vol. 4, No. 1, 2022

https://doi.org....

УДК 621.121

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INTERACTIVE SYSTEM OF SURFACE WATER MONITORING USING IoT TECHNOLOGIES

The article considers the possibility and priority of using the Internet of Things, especially its implementation in the surface water monitoring system. The feasibility of developing a complex system of interactive monitoring of surface water using IoT technologies has been substantiated, such a system will significantly improve water monitoring in real-time and ensure the gradual implementation of new sensor capabilities, such as collecting data on the deviation of parameters from the specified normative indicators of water quality in natural reservoirs. An interactive system for intelligent monitoring of water quality in natural reservoirs using Internet of Things technologies and tools has been developed, among others, the Node MCU 1.0 Wi-Fi microcontroller based on the ESP8266 microcontroller was used, as well as PH4502s analog sensor, the DHT-11 water and environmental temperature sensor, the DFRobot water turbidity and signal conversion board V2. The results were displayed on a 2.2-inch QVGA TFT LCD. The microcontroller unit (MCU) is connected to the sensors and further processing is performed on the server unit. The choice of a cloud server was justified, and the transfer of received data was transferred to the cloud using IoT-based ThingSpeak open-source software for water quality monitoring. The computer design environment Autodesk was used to increase the efficiency of design, in particular, the arrangement of elements, ensuring functionality, and ergonomics. The software and hardware of the device were designed with open-source software Fritzing and Arduino (IDE). Based on the obtained statistical data about the quality of water in natural reservoirs, a modern network of smart devices was implemented, such a network is a monitoring and notification system, which considers the linking of data to the time and place of positioning. Features of obtaining data on the results of water quality monitoring in natural reservoirs in real time for consumers were presented, with such monitoring, it is possible to predict and take the necessary measures to prevent possible negative impacts.

Key words: surface water, smart system, turbidity, monitoring system, pH sensor, ambient temperature, water quality.

Introduction

Environmental monitoring is one of the most important tools to assess the state of the environment. The changes occurring in the ecosystem are recorded while being observed, and an analysis of their causes, contagion, and anthropogenic influence is carried out based on the monitoring results.

Water monitoring is useful to deal with natural disasters or floods when the system can provide early warning for evacuation, emergency planning, and more to nearby residents. Border areas are the least protected in terms of preventing possible poisoning of natural water bodies. Also, in a period of armed conflict, there is a threat of deliberate poisoning or pollution of the ecosystem. Therefore, it is necessary to ensure the timely determination of changes in water quality indicators in real-time [5, 7, 12, 22].

Production environment control is carried out to study the impact of technogenic factors. The following tasks have been identified:

- daily monitoring and water quality control;
- increased control after daily.

Daily quality control implies monitoring the main parameters of water quality in normal mode. Enhanced control includes conducting analyses on a wider range of parameters and immediate use of response measures [19, 20].

As a rule, research is carried out as follows: water sampling is carried out, and then, based on the current type of control, appropriate analyses are conducted on the content of various substances and bacteria in the water. The data is processed, and based on the obtained results, a conclusion is drawn regarding its quality [15-18, 21].

Processing can be carried out both in manual and automatic modes. While analyzing water parameters, other sensors can be used, for example, sensors for analyzing the air around the water as well as analysis of water vapor for the content of toxic substances [3, 12, 14, 23].

The actuality of the Research

The development of remote monitoring technologies ensures the gradual introduction of new sensor capabilities. Modern developments of sensor networks are crucial for environmental implementation. The Internet of Things (IoT) allows connectivity between different devices with the ability to share and collect data. IoT is also extending its capabilities to environmental issues in addition to automation, benefiting from the perspectives of Industry 4.0 [1, 11].

Since water is one of the basic needs of human life, it is necessary to implement smart water quality monitoring. About 40% of deaths in the world are caused by contaminated water. Therefore, it is necessary to ensure the timely determination of changes in its quality indicators following current norms and requirements.

A full assessment of water quality can be obtained only based on a comprehensive study. It includes [13, 15]:

- a sanitary and topographic survey of the source of water supply and the surrounding area;
- determination of physical properties of water;
- determination of the chemical properties of water;
- determination of bacteriological contamination of water;
- biological analysis of water.

The following indicators are distinguished in water quality [10]:

- physical (temperature, turbidity, color, smell, taste);
- chemical (active pH reaction, oxidizability, total salt content, basic ions, soluble gases, biogenic substances, trace elements, radioactive substances, specific pollutants);
- bacteriological.

Surface water monitoring is somewhat difficult due to the location of the city and the topography of the area due to the urbanization and developed infrastructure around large cities. As an example, Fig. 1 shows the locations of water quality measurements in the city of Lviv [11, 23].

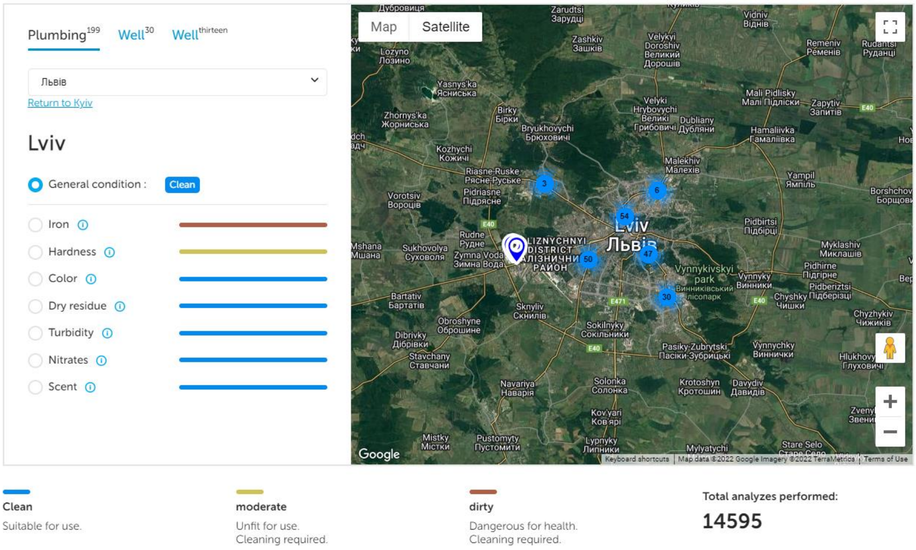

Fig. 1. Water quality index in the city of L'viv

As we can see (see Fig. 1), not all key points of the city of Lviv can receive water indicators. That is why the development of a smart surface water monitoring system using IoT technologies and an app on the mobile device for recording data is quite relevant.

Global environmental problems, such as atmospheric pollution, depletion of mineral resources, and destruction of plants and animals, force us to search for alternative ways to monitor changes or control the state of the environment and reduce negative impacts.

The solution to this problem is IoT, which can be widely used to forecast and monitor the state of the environment [4]:

• Environmental monitoring sensors help measure temperature, humidity, air composition, radiation level, as well as the content of harmful trace elements in water and soil.

• Technologies used in agriculture help farmers carry out sowing, tillage, fertilization, and plant protection treatment, accounting for the heterogeneous composition of the soil according to various indicators, which allows for reducing environmental risks and increasing the quality of products.

The following monitoring architecture system that uses IoT technologies and devices is proposed for surface water analysis (Fig. 2).

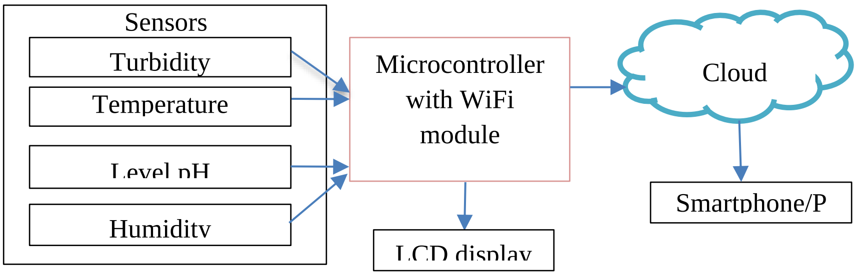

Fig. 2. Surface water monitoring system

As a result of the analysis of the most common devices to test the quality of water in various water resources has been established measured parameters of water quality include: dissolved oxygen, pH, ORP (oxidation-reduction potential), conductivity, salinity, TDS (total dissolved solids), temperature, turbidity, suspended solids and silt layer etc. However, the central part of the analysis of water samples carried out in laboratory conditions. Turbidity, pH level, and temperature have been the most common indicators to determine water quality [7].

Development of a system prototype

The proposed system uses pH and turbidity sensors, and the microcontroller unit as the main processing and data transmission module ESP8266 Wi-Fi module (NodeMCU). The microcontroller is an important part of the system designed to measure water quality because the ESP8266 Wi-Fi has low power consumption and small overall size, which is quite an important and decisive criterion for usage in a smart monitoring system. Sensors for water turbidity, pH, and ambient temperature have been used to obtain data on water quality indicators. The NodeMCU has a built-in ADC that converts analog transducer signals into digital format for further analysis [2, 6, 9, 13]. The structural diagram of the proposed smart surface water monitoring system is shown in Fig. 3.

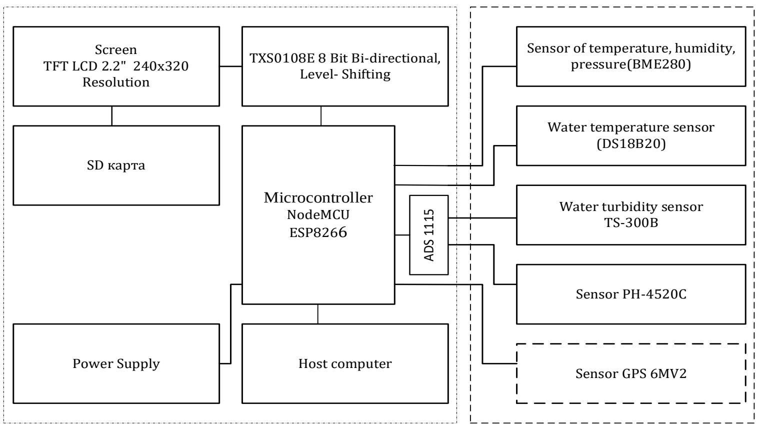

Fig. 3. Structural diagram of the device

The analog encoder output is connected to the analog pins of the NodeMCU to receive an analog signal from the encoder. In turn, the output of the other two sensors is connected directly to the digital contacts of the MCU unit. All sensor data is processed by the MCU and updated on the ThingSpeak server via an ESP8266 Wi-Fi data transfer module (NodeMCU) on the central server.

Autodesk's computer design environment has been used to increase the efficiency of the design, in particular, the arrangement of elements, ensuring functionality and ergonomics (Fig. 4)

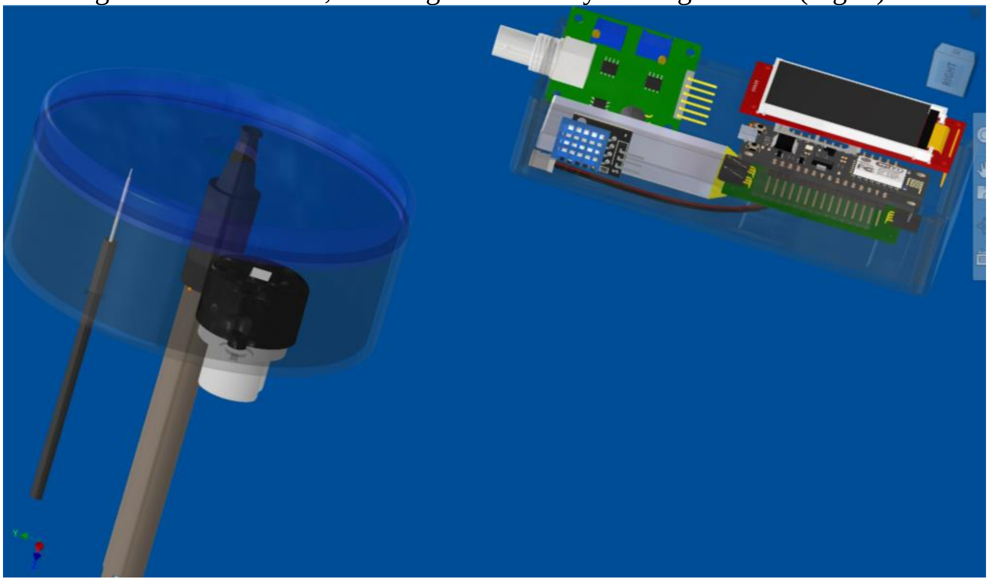

Fig. 4. 3D prototype system model

A working model prototype was developed for the practical implementation of the tasks after designing the elements of the surface water monitoring system, (Fig. 5).

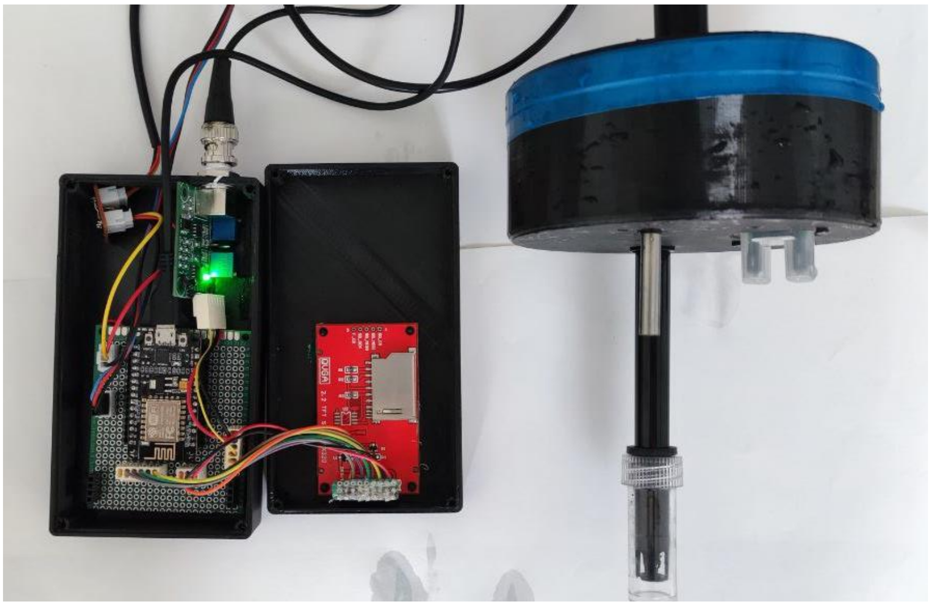

Fig. 5. General view of the developed prototype

We adjusted all sensors, starting with the pH level sensor by coordinating the hardware and software according to the developed connection scheme of the device elements. A TFT LCD is connected to show the received quality data in real-time.

We calibrate the sensors regarding changes in the water pollution level, pH level, and ambient temperature for proper adequacy of the received data. In the next stage, we adjust the received data (both raw and processed) on the website using a cloud server for their pilot demonstration in the free ThingSpeak service. We connect the mobile version of this ThingViewer environment and test the system as a whole.

We have developed a software interface for an interactive surface water monitoring system to display received data (Fig. 6).

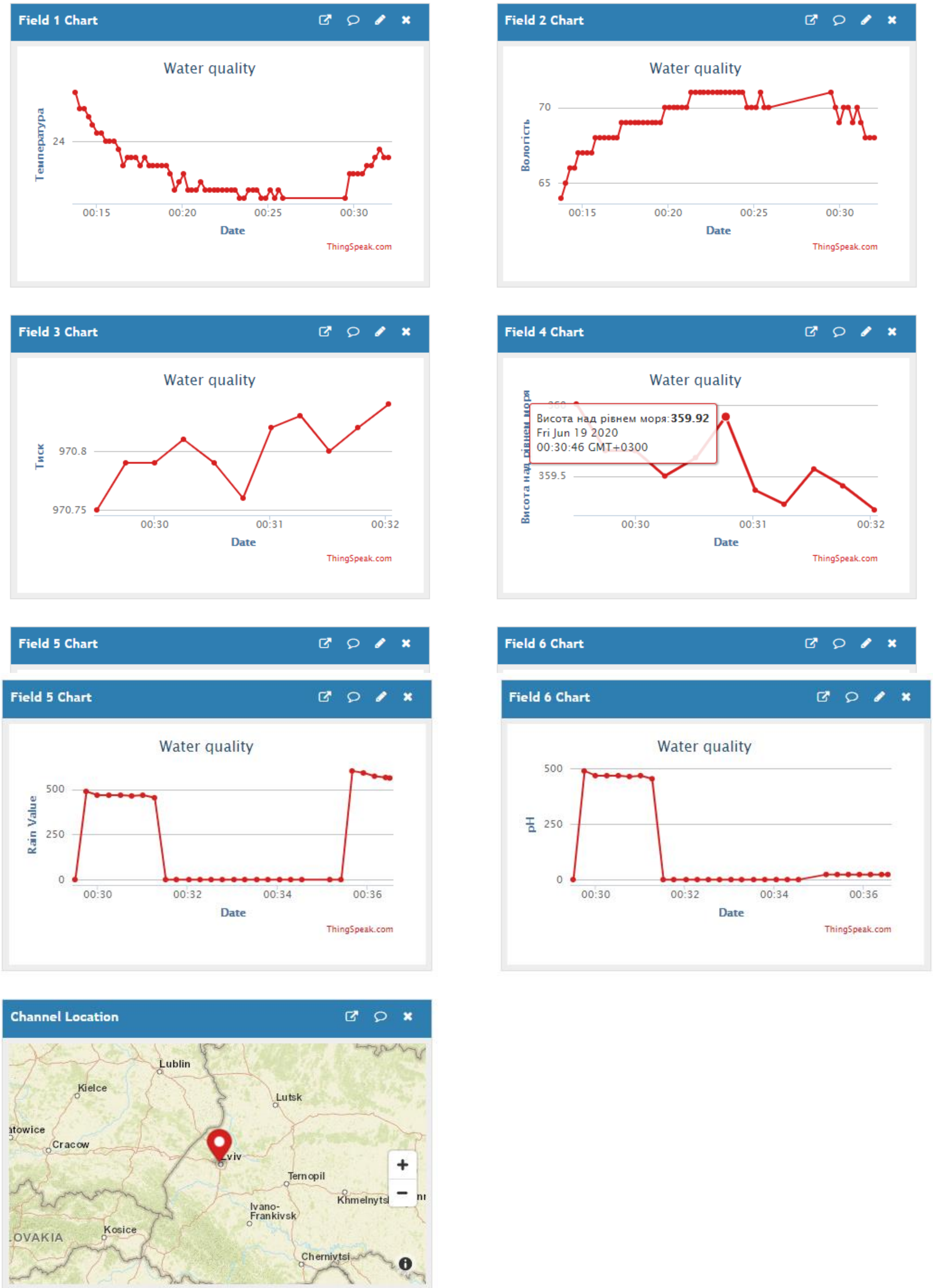

Fig. 6. Thing Speak application interface

We also connect the ThingViewer mobile application to improve informativeness and data display on portable devices, (Fig. 7).

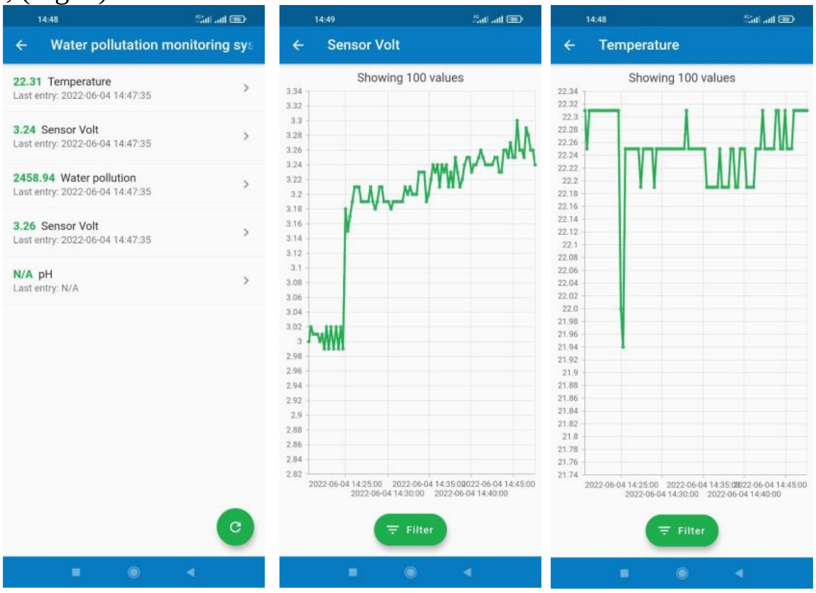

Fig. 7. ThingViewer mobile application interface

Conclusions

The possibility and priority of using the Internet of Things, especially in the water monitoring system, have been discussed. It is important to monitor water in all wells due to rapid population growth and decreasing water resources in high demand. Peculiarities of obtaining data on the results of water quality monitoring in natural reservoirs in real time for consumers who will be able to predict and take the necessary measures to prevent negative impact have been given.

The development of an automated system to determine water quality indicators in natural reservoirs using Internet of Things (IoT) devices will improve the real-time water monitoring system.

Hardware for the development of a smart system to measure water quality is presented, namely, the device can be integrated into a more complex system for monitoring water quality in natural waters in the future.

The choice for the ThingSpeak cloud server is justified, which, based on the obtained statistical data, ensures the implementation of a system for monitoring water quality indicators in natural bodies of water. They consider its connection to time and positioning.

The software implemented can send data on the specified water quality indicators in natural reservoirs concerning the location of the device to the cloud server of the ThingSpeak environment and the ThingViewer mobile application.

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ІНТЕРАКТИВНА СИСТЕМА МОНІТОРИНГУ ПОВЕРХНЕВИХ ВОД ТЕХНОЛОГІЯМИ IoT

У статті розглядається можливість та пріоритетність використання Інтернету речей, особливо їх реалізацію в системі моніторингу поверхневих вод. Обґрунтовано доцільність розробки комплексної системи інтерактивного моніторингу поверхневих вод технологіями IoT, що суттєво покращить систему моніторингу вод в режимі реального часу та забезпечить поступове впровадження нових можливостей давачів за допомогою яких відбуватиметься збір даних щодо відхилення параметрів від заданих нормативних показників якості вод в природних водоймах. Розроблено інтерактивну систему інтелектуального моніторингу якості води в природних водоймах з використанням технологій і засобів Інтернету речей, зокрема мікроконтролера Node MCU 1.0 Wifi на базі мікроконтролера ESP8266, а також низки давачів зокрема, аналоговий давач PH4502c, давач температури води і навколишнього середовища DHT-11, давач каламутності води DFRobot та плати перетворення сигналу V2. Візуалізацію зазначених показників реалізовано через 2,2-дюймовий QVGA TFT LCD-дисплей. Мікроконтролерний блок (MCU) з'єднаний з давачами і подальша обробка виконується на серверному блоці. Обґрунтовано вибір хмарного сервера а також реалізовано передачу отриманих даних в хмару за допомогою програмного забезпечення з відкритим кодом ThingSpeak на основі IoT для моніторингу якості води. Для підвищення ефективності проектування, зокрема компонування елементів, забезпечення функціоналу та ергономічності, застосовано середовище комп'ютерного проектування від компанії Autodesk. Скориставшись програмним забезпеченням з відкритим кодом Fritzing і Arduino (IDE) розроблено програму і апаратну частину пристрою. На основі отриманих статистичних даних щодо заданих показників якості води в природних водоймах реалізовано сучасну мережу розумних пристроїв із системою моніторингу і оповіщення, що враховує прив'язку даних до часу та місця позиціонування. Наведено особливості отримання даних щодо результатів моніторингу якості води в природних водоймах в режимі реального часу для споживачів, що зможуть передбачити та вжити необхідних заходів для запобігання негативного впливу.

Ключові слова: поверхневі води, інтерактивна система, каламутність, система моніторингу, давач рівня pH, температура навколишнього середовища, якість води