

INFORMATION SYSTEM FOR OPERATIONAL
MONITORING OF THE CITY'S WATER ENVIRONMENT
BASED ON IOT TECHNOLOGIES

Yue Zheng¹, Chenjian Dong², Jianjun Wang³,
Andrii Topalov^{4✉}, Oksana Nechai⁵, Alexander Klymenko⁶,
Sergey Nekrasov⁷, Vladyslav Knysh⁵

Received on February 18, 2025

Presented by Ch. Roumenin, Member of BAS, on March 25, 2025

Abstract

This work deals with the issue of operational environmental monitoring of the urban water environment. The specified general provisions regarding the functioning of monitoring methods and the monitoring programme of water bodies. Maximum permissible concentrations of various water quality indicators are set. The main sources of pollution and the main requirements for water quality control systems are defined. On the basis of the above, an industrial parameter control system based on the principles of the Internet of Things technology for remote monitoring and operator control was developed. In the process of performing the work, structural and functional schemes of the operational monitoring system were created and local and remote level work algorithms were compiled. The analysis of measurements of a large number of parameters of the water environment was carried out. The proposed approach proved the possibility of ensuring high accuracy and reliability of measurement results obtained using the developed computer monitoring system.

Key words: Internet of Things, monitoring, computer system, sensor, water environment

This study is financially supported by the National High-Level Foreign Experts Introduction Project, China (G2022014116L).

<https://doi.org/10.7546/CRABS.2025.05.09>

Introduction. Under urbanization, the demand for water is continuously rising, as are wastewater emissions.

This process is accompanied by a continual deterioration in water quality, water sources, and the potential for their use in drinking, cultural, domestic, recreational, aquaculture, irrigation, and even industrial applications [1–3]. Freshwater, essential for human life, is heavily utilized by modern industry.

Currently, the urban water environment, namely the river, is, on the one hand, a source of water consumption for economic and technical needs, and on the other, a reservoir for dumping domestic and industrial effluents [4,5], of various chemical compositions [6,7], as well as agricultural waste [8]. Currently, with the rapid development of automation technologies using innovative microprocessor systems, SCADA software and Internet of Things technologies, monitoring and control systems are actively developing in such areas of environmental activities as agriculture, industry, etc. [9–12]. These technologies are integral components of Industry 4.0 [13–15].

Today, there are many types of water environment control systems [16,17]. There is a growing need to simplify the control process through gradual automation of multi-sensor systems. The well-known foreign companies “HANNA”, “NASN” and others operate among the water environment monitoring systems. Imported automated laboratories (systems) based on flow-injection type measuring devices also began to appear. Examples include the automated system WATERLAB 2000 M/S: SERES 2000 (SERES, France), and the portable multi-parameter water quality monitor Series 900 (SYRUS SYSTEMS), which can measure eight parameters. Known examples of the application of systems at the local level are SCADA-like systems; with the presence of a cloud environment – IoT systems. These systems are more universal and are mainly intended for real-time analysis of the parameters of the urban water environment in order to detect the fact and place of exceeding the maximum permissible concentration (MPC) as per natural components (for example, dissolved iron, hardness salts, etc.), as well as by anthropogenic pollution (primarily, artificially synthesized organic substances, water-soluble forms of toxic heavy metals, etc.).

Therefore, the question of building a universal, highly efficient system with decentralized control components remains open. This study aims to enhance monitoring quality and adaptive ecological balance control in the urban water environment through the development of a microprocessor-based system using ICP DAS digital modules and IoT technology.

Regulation of water quality in reservoirs. Water quality standards of water bodies include: general requirements for the composition and properties of water in watercourses and reservoirs for various types of water use; the list of MPCs of standardized substances in the water of water bodies, which are used for economic and drinking and communal and household needs of the population; the list of MPCs of standardized substances in the water of water bodies used for

fishery purposes [18–20].

The sanitary condition of the reservoir meets the requirements of the norms during the implementation of the unevenness:

$$(1) \quad \sum_{i=1}^n \frac{C_i}{MPC_i^m} \leq 1,$$

where n is the number of harmful substances in the reservoir belonging, for example, to the “sanitary-toxicological” group of harmful substances; C_i is the concentration of the i -th substance from this group of harmful substances; m is the number of the group of harmful substances, for example, $m = 1$ – for the “sanitary-toxicological” group of harmful substances, $m = 2$ – for the “general sanitary” group of harmful substances, etc.

This inequality is used for each of the three (for water bodies of the second type – for each of the five) groups of harmful substances, the MPCs of which are set, respectively, according to the sanitary-toxicological limiting indicator of harmfulness (LIH), the general sanitary LIH, the organoleptic LIH, and for fish farms – also according to toxicological LIH and fish. At the same time, the background concentrations of C_f of harmful substances contained in the water of the reservoir before the discharge of wastewater should be taken into account. In case of predominance of one harmful substance with a concentration of C of the group of harmful substances of this LIH, the following requirement must be met:

$$(2) \quad C + C_f \leq MPC.$$

MPCs have been established for more than 400 harmful main substances in water bodies for drinking and cultural and household purposes, as well as for more than 100 harmful main substances in water bodies for fishing purposes. The equation for the balance of dissolved impurities when they are discharged into a watercourse (river) taking into account the initial dilution in the outlet is as follows:

$$(3) \quad C_{cm} = [n_{pc}(C_{pc} - C_f) + C_f],$$

where C_{cm} , C_{pc} , C_f represent the concentrations of impurities in wastewater before discharge into the reservoir, in the calculated structure and the background concentration of impurities, respectively, mg/kg; n_0 and n_{pc} – the dilution ratio of wastewater in the outlet (initial dilution) and in the calculated outlet, respectively.

Initial dilution of wastewater at the point of its release:

$$(4) \quad n_0 = \frac{Q_0 + q}{q},$$

where $Q_0 = LHV$ is the part of the drain flow flowing over the dispersing outlet, which has, for example, the form of a perforated pipe laid on the bottom, m³/s;

q is the waste water consumption, m^3/s ; L is the length of the dispersing outlet (perforated pipe), m ; H , V are the average depth and velocity of flow above the outlet, m and m/s .

$$(5) \quad C_{cm} = \frac{LHV + q}{q} [n_{pc}(C_{pc} - C_f) + C_f]$$

at $LHV \gg q$

$$(6) \quad C_{cm} = \frac{LHV}{q} [n_{pc}(C_{pc} - C_f) + C_f].$$

Software and hardware implementation of a computer system for controlling water environment parameters based on Internet of Things technology. The implementation of a computer system for controlling the parameters of the water environment with the details of the monitoring system and operator control is presented in Fig. 1.

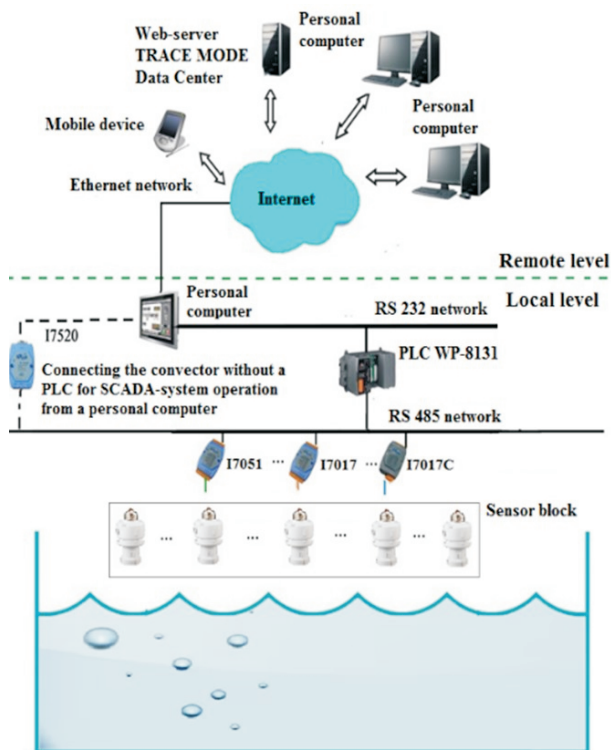


Fig. 1. The functional structure for controlling water parameters based on the IoT technology

This system has two levels: local level and remote level. The system implementation involved various digital devices. Digital components of the ICP DAS

company were used among software and hardware tools. ICP DAS I-7017 modules are used as analogue data collection modules from sensors of voltage converters. ICP DAS I-7017C modules with current input are used to collect information from sensors with current output. Sensors, in turn, are analogue and digital. Analogue sensors are convenient and easy to implement, while digital sensors offer high accuracy but require additional equipment for converting analogue signals into digital formats.

The ICP DAS I-7051 module with 16 inputs is used as a data acquisition module for discrete input signals. The system is additionally equipped with the ICP

City water environment monitoring point No. 5		Powering the system ☒	The water meets the standards ☒
Update indicators U		Sensor power supply ☒	The water does not meet the standards ☐
Temperature	deg C	Saturated O2	%
pH	units, pH	Chemical consumption oxygen	mg O2/dm cube
Transparency	cm	Biochemical consumption oxygen in 5 days	mg O2/dm cube
Turbidity	mg/dm cube	Alkalinity	mg eq/dm cube
Scent	balls	Hardness in general	mg eq/dm cube
Color	deg	Dry residue	mg/dm cube
Suspended substances	mg/dm cube	Sulfates	mg/dm cube
Ammonium salt	mg/dm cube	Chlorides	mg/dm cube
Nitrites(NO2-)	mg/dm cube	Calcium	mg/dm cube
Nitrates(NO3-)	mg/dm cube	Magnesium	mg/dm cube
Dissolved oxygen	mg O2/dm cube	Sodium	mg/dm cube
		Potassium	mg/dm cube
		Phosphates	mg/dm cube
		Common iron	mg/dm cube
		Chromium (VI)	mg/dm cube
		Chromium (III)	mg/dm cube
		Copper	mg/dm cube
		Zinc	mg/dm cube
		Nickel	mg/dm cube
		Manganese	mg/dm cube
		Oil products	mg/dm cube

a)

City water environment monitoring point No. 5 Online	
Characteristic indicators Temperature deg. C pH units, pH Transparency cm Turbidity mg/dm cube Scent balls Color deg. Suspended substances mg/dm cube Biochem. consumption oxygen in 5 days mg O2/dm cube Nitrites(NO2-) mg/dm cube Nitrates(NO3-) mg/dm cube Dissolved oxygen mg O2/dm cube	
Specific pollutants Common iron mg/dm cube Chromium (VI) mg/dm cube Chromium (III) mg/dm cube Copper mg/dm cube Zinc mg/dm cube Nickel mg/dm cube Manganese mg/dm cube Oil products mg/dm cube	
The water meets the standards ☒ The water does not meet the standards ☐	

b)

Fig. 2. Human machine interface: a) local level; b) remote level

DAS I7520 interface converter module, which performs the functions of converting RS485 bus signals into the RS232 interface. PLC ICP DAS WP-8131 is used in the current control and measurement system as the main executive module.

Algorithms for measurement and calculation of operational parameters in the PLC are implemented using tools provided by the TRACE MODE 6 SCADA system, which is a universal and compact SCADA system (all system editors are called from one program). The necessary data processing algorithms (for checking the range, coefficient values, etc.) are implemented in SCADA TRACE MODE 6 in the “RTM_1” node using ST and FBD language programs.

A special TRACE MODE Data Center web server is used for remote monitoring of operational parameters of the aquatic environment from the shore post. The TRACE MODE Data Center manages the SCADA system for monitoring operational water environment parameters remotely. TRACE MODE Data Center receives data in real time from a local system based on TRACE MODE 6 via TCP/IP Internet and provides access to data for individual computers and mobile devices (smartphones).

Results. The effectiveness of the computer system hardware and software was confirmed by the results of its testing. All studies were conducted with fully operational sensors and internal digital components, as verified through the operator’s graphical interface. The study included monitoring data of surface water of the river for the period of four quarters of 2021. Some results of the experimental test are shown in Table 1. A more comprehensive list is presented in Fig. 3, where the obtained indicators are compared to the MPC. Determination of water quality was carried out on the basis of previously presented formulas, in the case of meeting the quality requirements, a green LED was lit on the operator’s screen, in the opposite case, a red light was illuminated.

T a b l e 1
Results of the experimental test

Temperature	Transparency	Turbidity	Smell	Suspended substances	Saturated O ₂	Biochemical oxygen consumption for 5 days	Phosphates
degree °C	cm*100	(mg/dm ³)	points	(mg/dm ³)	%*100	(mg O ₂ /dm ³)	(mg/dm ³)
4.00	40.00	0.71	1.0	0.00	122.92	3.85	0.58
23.00	40.00	0.99	1.0	19.20	127.06	1.97	0.36
24.00	40.00	1.54	1.0	11.60	97.05	2.16	1.00
11.00	40.00	1.38	1.0	0.00	83.32	2.31	0.86

Measured and calculated data (Table 1) in the process of researching the urban water environment are combined into a database stored on the server. This

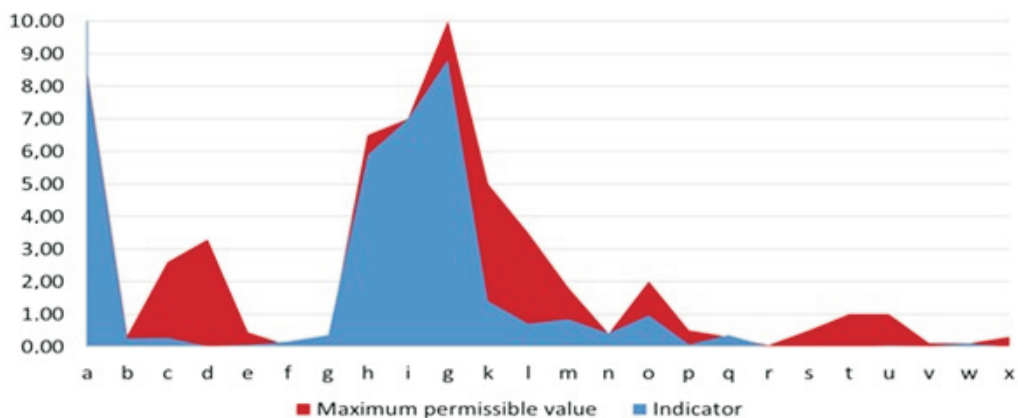


Fig. 3. City river monitoring indicators for 2021: a – Ph units, pH; b – colour, degrees*10²; c – ammonium salt, (mg/dm³); d – nitrite, (mg/dm³); e – nitrate, (mg/dm³)*10²; f – dissolved oxygen, (mgO₂/dm³)*10²; g – chemical oxygen consumption, (mgO₂/dm³)*10²; h – alkalinity, (mg-eq/dm³); i – rigidity is general, (mg-eq/dm³); j – dry residue, (mg/dm³)*10²; k – sulphates, (mg/dm³)*10²; l – chlorides, (mg/dm³)*10²; m – calcium, (mg/dm³)*10²; n – magnesium, (mg/dm³)*10²; o – sodium, (mg/dm³)*10²; p – potassium, (mg/dm³)*10²; q – common iron, (mg/dm³); r – chrome (VI), (mg/dm³); s – chrome (III), (mg/dm³); t – copper (mg/dm³); u – zinc, (mg/dm³); v – nickel, (mg/dm³); w – manganese, (mg/dm³); x – oil products, (mg/dm³)

database provides users with the ability to create, save, update, search for information, and control access to data.

Thus, the data recorded every day formed a database for months, which in turn were combined into quarters and years. Fluctuations in the parameters of the urban water environment are presented in Fig. 3.

After analyzing the results of the study of the ecological state of the river, it was confirmed that the main polluter of open water bodies are sewage discharges. From a scientific point of view, it is useful to search for the existence and assessment of the closeness of relationships between the content of certain hydrochemical characteristics in water. This makes it possible to select analytical calculation dependencies, to carry out an operational assessment and forecast of water quality, to automate the calculation of the flow of dissolved chemicals. These relationships do not always exist, which depends on the complexity of the conditions for the formation of the chemical composition of river waters in catchments, the degree of influence of a high level of anthropogenic load, which together can change the natural hydrochemical regime of rivers.

Conclusions. The developed information and measurement system for the control of the water environment measures indicators and summarizes the obtained data into a tabular database, which makes it possible to determine the ecological state of the water body, the nature of the processes of pollution, sedimentation, self-cleaning, coagulation of polluted water-disperse media, etc., and can be used for environmental monitoring of the urban water environment.

Determining the quality of river water is of great importance for assessing the ecological state of the city, the main directions of water protection activities for the improvement of the ecological state of each water body, and establishing ecological water quality standards. Assessment based on hydrochemical indicators revealed that surface water quality in the city's river basin falls significantly below the MPC for most parameters.

REFERENCES

- [1] BEHMEL S., M. DAMOUR, R. LUDWIG, M. J. RODRIGUEZ (2016) Water Quality Monitoring Strategies: A Review and Future Perspectives, *Sci. Total Environ.*, **571**, 1312–1329, <https://doi.org/10.1016/j.scitotenv.2016.06.235>.
- [2] CHAPMAN D. (ed.) (1996) *Water Quality Assessment: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring*, 2nd ed., London, E & FN SPON.
- [3] HUI W., S. SHEVCHENKO, M. KORCHAK et al. (2024) A Study of Mechanical Seal Rings Thermal and Force Deformations in Energy Rotor Machines, *C. R. Acad. Bulg. Sci.*, **78**(1), 109–118, <https://doi.org/10.7546/CRABS.2025.01.13>.
- [4] PETRUK V. G., I. V. VASYLKIIVSKYI, V. A. ISHCHEENKO et al. (2013) Normalization of Anthropogenic Load on the Environment: Part 1, Standardization of Ingredient Pollution, Vinnytsia, VNTU.
- [5] SOLTANI M. (2009) *Quality Based Modelling of Inland Channels*, Master's Thesis, Dept. of Civil Engineering, Sharif University of Technology, Tehran, Iran.
- [6] CHAUDHRY F. N., M. F. MALIK (2017) Factors Affecting Water Pollution: A Review, *J. Ecosyst. Ecography*, **7**(1), 225–231.
- [7] LESKO A., O. KULAKOV, A. MELNICHENKO, A. KATUNIN (2024) Development and Implementation of an Algorithm for Predicting the Intensity of Sorption of Hazardous Gaseous Materials, *Solid State Phenomena*, **364**, 101–112.
- [8] DAIFULLAH A. A. M., B. S. GIRGIS, H. M. H. GAD (2003) Utilization of agro-residues (rice husk) in small waste water treatment plans, *Materials Letters*, **57**(11), 1723–1731.
- [9] TOPALOV A., O. GERASIN, O. KOZLOV et al. (2020) Information System for Automatic Planning of Liquid Ballast Distribution, *Proceedings of the Information-Communication Technologies & Embedded Systems (ICT&ES-2020)*, November 12, 2020, Mykolaiv, Ukraine, 191–200, <https://ceur-ws.org/Vol-2762/paper13.pdf>.
- [10] KONDRATENKO Y., O. KOZLOV, A. TOPALOV et al. (2018) Automation of control processes in specialized pyrolysis complexes based on Industrial Internet of Things, In: *Dependable IoT for Human and Industry*, 367–388.
- [11] MEHTA B. R., Y. J. REDDY (2015) Chapter 7 – SCADA systems. In: *Industrial Process Automation Systems*, 237–300.

- [12] ZAEV E., D. BABUNSKI, A. TUNESKI (2016) SCADA system for real-time measuring and evaluation of river water quality. In: 2016 5th Mediterranean Conference on Embedded Computing IEEE, 83–86.
- [13] YUGHA R., S. CHITHRA, N. BHALAJI, S. KARTHIKA (2022) Privacy Protected IoT-Blockchain using ZKP for Healthcare application, *Control Eng. Appl. Inf. (CEAI)*, **24**(4), 76–87.
- [14] IORDACHE G. V., B. ȚIGĂNOAIA, C. NEGRU, F. POP (2020) Implementing SLA Constraints in Multi-Cloud Environments, *Control Eng. Appl. Inf. (CEAI)*, **22**(4), 71–81.
- [15] AJITH J. B., R. MANIMEGALAI, V. ILAYARAJA (2020) An IoT based smart water quality monitoring system using cloud. In: 2020 International conference on emerging trends in information technology and engineering (ic-ETITE), IEEE, 1–7, <https://doi.org/10.1109/ic-ETITE47903.2020.450>.
- [16] ANCUȚA P. N., A. ATANASESCU, S. SOREA et al. (2019) Bacterial Monitoring of Drinking Water Sources Using Immunofluorescence Technique, Image Processing Software and Web-based Data Visualisation, *Control Eng. Appl. Inf. (CEAI)*, **21**(2), 54–63.
- [17] SIMIĆ M., G. M. STOJANOVIĆ, L. MANJAKKAL, K. ZARASKA (2016) Multi-sensor system for remote environmental (air and water) quality monitoring. In: 2016 24th Telecommunications Forum (TELFOR), IEEE, 1–4.
- [18] SUTADIAN A., N. MUTIL, A. G. YILMAZ, B. PERERA (2016) Development of River Water Quality Indices: A Review, *Environ. Monit. Assess.*, **188**(1), 58, <https://doi.org/10.1007/s10661-015-5050-0>.
- [19] ABBASI T., S. A. ABBASI (2012) *Water Quality Indices*, Amsterdam, Elsevier.
- [20] KHALIL B., T. B. M. J. OUARDA, A. ST-HILAIRE (2011) A statistical approach for the assessment and redesign of the Nile Delta drainage system water-quality-monitoring locations, *J. Environ. Monit.*, **13**(8), 2190–2205, <https://doi.org/10.1039/c0em00727g>.

¹*Department of Science and Technology, Yancheng Polytechnic College, Yancheng, China*
e-mail: and_bsb@126.com

²*School of Automobile and Transportation, Yancheng Polytechnic College, Yancheng, China*
e-mail: 2022210649@yctei.edu.ua

³*Scientific Department, Yunzhou (Yancheng) Innovation Technology Co., Ltd, China*
e-mail: jianjun.wang@yunzhou-tech.com

⁴*Department of Computerized Control Systems, Admiral Makarov National University of Shipbuilding, Mykolaiv, Ukraine*
e-mail: topalov_ua@ukr.net

⁵*Laboratory of Ecology, Institute of Water Problems and Land Reclamation, Kyiv, Ukraine*
e-mails: Water_2019@ukr.net, knysh.vladyslav@igim.org.ua

⁶*Scientific Department, V. N. Karazin Kharkiv National University, Kharkiv, Ukraine*
e-mail: alexanderklmn@gmail.com

⁷*Department of Mechanical Engineering Technology, Machines and Tools,
Sumy State University, Sumy, Ukraine*
e-mail: s.nekrasov@omim.sumdu.edu.ua