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DEVELOPMENT OF THE SOFTWARE COMPLEX FOR MODELING POLLUTION TRANSFER IN THE ILI-BALKHASH BASIN

ABSTRACT

dissertation of J.K. Jamalov for the degree of Doctor of Philosophy (PhD) in the specialty 6D070400-Computer Science and Software

Actuality of the research

The problem of economical, rational use of water resources, the fight against their depletion and pollution, is attributed to the national environmental problems. To solve this problem, a number of legislative acts and Resolutions of the Government of the Republic of Kazakhstan were adopted. In the context of implementation of the Strategy for the Formation and Development of the Republic of Kazakhstan "Kazakhstan - 2030" as a sovereign state and the formation of market relations, the basis for solving economic, technical, environmental, international and other tasks is the rational use of natural resources, among which a special place in the system of water supply to the population and sustainable development of productive forces in the region is occupied by water resources. However, their limitedness is one of the main factors hindering the development of the richest natural potential in the region, for the development of the economy, and the negative impact on the environment.

The Ili- Balkhash basin is located in the southeast of the territory of the Republic of Kazakhstan and includes the Almaty region, the southern part of the East Kazakhstan region, the southeast of Karaganda, the eastern part of Zhambyl regions, as well as the northwest of Xinjiang province within the People's Republic of China. The Ili River is one of the largest transboundary rivers connecting the Republic of Kazakhstan and China, and is also one of the most important sources of fresh water for the Republic of Kazakhstan.

The object of research is the Kazakhstani section of the Ili River from the border with the People's Republic of China to the delta, including the Kapshagai reservoir. The Ili River takes its beginning in the Tien Shan mountain system in the PRC (Xinjiang Uygur Autonomous Okrug) and flows into the western part of Lake Balkhash. The length of the river is 1439 km, of which 815 km (56.6%) in the territory of the Almaty region of Kazakhstan. The basin area on the territory of the Republic of Kazakhstan is 82488.53 square kilometers. The Ili River gives about 80% of the total water flow of Lake Balkhash, of which 70% is formed in China.

Transboundary rivers passing through the territory of China bring not only organic matter, but also selenium and heavy metal ions to the lake, the main sources of which are sewage from the tanneries of the PRC. State monitoring of surface and groundwater pollution must, in accordance with the Law of the Republic of Kazakhstan "On Environmental Protection", obtain data on the quality of surface

and groundwater and provide information on the level of their pollution to management bodies, interested organizations and the population.

The purpose of surface water quality monitoring is to identify the most important pollutants and establish their sources in order to develop measures to eliminate them. This is possible if in the course of observations a sufficiently wide range of ingredients is tracked, and observation points are located along a hydrographic network, which allows us to make the most accurate determination of the location of the sources of a particular pollutant.

When performing research work related to the description of complex natural systems, which include hydrological and ecological studies of such a complex and versatile region as the Ili-Balkhash basin, it is necessary to carry out mathematical modeling of complex hydrological, hydraulic and hydrochemical processes.

The results of modeling are intended for use in planning social and economic development of the given region. According to the principle applied in this work, at the initial stage, all available information about the factors influencing the natural and anthropogenic processes occurring in the Ili-Balkhash basin in the modern period is collected. The paper presents advanced computer technologies, modern technologies for processing space images, and direct instrumental observations on the water bodies of interest.

The subject of research. The subject of research is a software package as a means of solving problems of assessing and analyzing the quality of surface waters.

Methodological basis of research. The author uses theoretical developments of domestic and foreign authors on assessing the quality of surface waters, assessing changes in water inflow, geoinformation systems, geoinformation mapping, modeling, geoecology and hydrology. The author uses the model that is a modification of the classical Streeter – Phelps model, as well as methods for optimizing the concentration of dissolved organic matter and the rate coefficient of biochemical oxygen consumption. Methods of system analysis, storage and processing of information, statistical methods of data processing and models of visualization of spatial information are also used.

Scientific novelty of the research:

- Creation of a hydraulic model of the Ili River;
- Development of the algorithm for predicting the transfer of pollution in the water basin;
- Development of the algorithm for calculations for diffusion sources of pollution;
- Development of the automated web-oriented system for scenario modeling;
- Comparison of the results obtained with factual data.

The main provisions for the defense:

- The software package for modeling pollution transfer in the Ili-Balkhash basin;

- The automated algorithm for parallel processing of digital elevation models using a supercomputer;

- The simulation model adapted for the Kazakh part of the Ili River, which allows the calculation of various scenarios for the Ili River basin;

- The results of model and experimental studies of the process of modeling transport in water, confirming the adequacy of the developed model;

- The results of computer modeling of scenarios for the development of the Ili-Balkhash basin in the case of a decrease in water inflow in the territory of the Republic of Kazakhstan.

Relationship between the research topic and research programs

The dissertation work was carried out at the National Scientific Laboratory for the Shared Use of Information and Space Technologies of Satpayev KazNRTU within the framework of the scientific project "Modeling the transfer of pollution in the Ili-Balkhash basin using a supercomputer", grant of the Ministry of Education and Science of the Republic of Kazakhstan No. 1049 / GF4 for 2014-2017.

Detailed data on the volume and quality of water resources, as well as a scenario forecast of their change with the expected increase in water withdrawal in the PRC are needed for the implementation of the State Program on Water Resources Management in Kazakhstan. The purpose of this program is to ensure the water security of the Republic of Kazakhstan by improving the management of water consumption and water resources.

Approbation of research results

The main results of the dissertation research were presented at the following scientific and practical conferences in Kazakhstan and abroad:

Title	Conference	Coauthors
The System of Modeling of Transboundary Pollution Transfer for the Kazakhstan Part of the Ili River (article)	11th International Conference on Data Mining, Computers, Communication and Industrial Applications (DMCCIA-2017). Dec.14-15, 2017, pp 261-267., ISBN 978-93-86878-06-9	Daniyar Nurseitov
Numerical solution of the inverse problem of the Streeter – Phelps closed-loop system for two periods of incubation	Water resources of Central Asia and their use. Materials of the International Scientific and Practical Conference dedicated to summing up the results of the decade declared by the United Nations “Water for life”, Book 1, 2016, 56-63	Azimov A.A., Gotovtsev A.V., Nurseitov D.B.

Assessment of the assimilation capacity of the Kazakhstan part of the Ili River Basin using the WPI-RQC model	Water resources of Central Asia and their use. Materials of the International Scientific and Practical Conference dedicated to summing up the results of the decade declared by the United Nations “Water for life”, Book 1, 2016, 80-88	Gotovtsev A.V., Nurseitov D.B., Tursunov E.A., Azimov A.A.
An example of modeling water protection measures in the Kazakhstan part of the Ili River Basin. (scenario calculation)	Collection of articles “Ecology, Economics, Informatics. System analysis and modeling of economic and ecological systems. Mathematical methods and models in environmental studies.”, Volume 1, Rostov-on-Don, 2016, 33-43	Gotovtsev A.V., Nurseitov D.B., Tursunov E.A., Azimov A.A.
Comparison of software systems "BASINS" and "WPI-RQC" at the level of conceptual descriptions and on the example of water quality modeling in the Charyn River	X International Scientific Conference of Young Scientists and Talented Students "Water Resources, Ecology and Hydrological Safety", Moscow, 2016, 104-109	Nurseitov D.B., Gotovtsev A.V.

Practical and theoretical significance of the results obtained

The implementation act was received, indicating that the results obtained within the framework of the dissertation research on the topic "Development of a software package for modeling pollution transfer in the Ili-Balkhash basin", as well as the results of the grant project of the Ministry of Education and Science of the Republic of Kazakhstan No.1049/GF4 "Modeling of pollution transfer in the Ili-Balkhash basin using a supercomputer" were implemented in EcoRisk LLP.

Publications

On the topic of the dissertation, 12 articles have been published, four of which are published in the journals from the list recommended by the CCSON MES RK, two articles – in the international journals included in Scopus and Web of Science database.

5. Nurseitova, A.T., Jamalov, J.K., Azimov, A.A., Nurseitov, D.B., Tursunov, E.A. Comparison of Methods for Assessing the Assimilation Capacity of the Kazakhstani Sector of the Ili River // Modelling and Simulation in Engineering, 2021 (Scopus, percentile 47)

6. Jamalov, J.K., Nurseitov, D.B., Gotovtsev, A.V. Web-oriented quality assessment system for surface waters of River Basin // Periodico Tche Quimica, 2019, 16(33), pp. 457–471 (Scopus, percentile 72)

The certificate of authorship of the Republic of Kazakhstan No. 21159 was obtained Nurseitov D.B., Jamalov J.K., Alimova A.N. «Geographic Information System GSWPM for Modeling Pollution Transport in the Ile-Balkhash Basin».

Structure and volume of the dissertation

The dissertation consists of the introduction, four chapters, general conclusions, the list of references and appendices. The work consists of 109 pages of typewritten text, contains 19 tables, 60 figures, a bibliography of 52 titles, and 3 appendices.

The first section contains a literature review and an analysis of the Ili-Balkhash region, as well as an analysis of existing models for assessing surface water quality.

The second section describes the methodological foundations of research, such as the methods of parallel processing of the DEM, specific features of the simulation model of the Ili River Basin, as well as assessment of the self-cleaning capacity of the Ili River.

The third section describes the formation of the information base of the system and the implementation of software modules.

The fourth section is devoted to describing the structure of the system and the user interface.