ACTA SCIENTIFIC MICROBIOLOGY (ISSN: 2581-3226)

Volume 3 Issue 11 November 2020

Review Article

Information Technologies for Control and Management of Environmental Water Quality

KJ Kachiashvili[1,2,3]*

[1]*Professor of Georgian Technical University, Tbilisi, Georgia*

[2]*Senior Scientific Worker of the I. Vekua Institute of Applied Mathematics of the Tbilisi State University, Tbilisi, Georgia*

[3]*Muskhelishvili Institute of Computational Mathematics, Tbilisi, Georgia*

***Corresponding Author:** KJ Kachiashvili, Professor of Georgian Technical University and Senior Scientific Worker of the I. Vekua Institute of Applied Mathematics of the Tbilisi State University and Muskhelishvili Institute of Computational Mathematics, Tbilisi, Georgia.

Received: June 09, 2020

Published: October 29, 2020

Abstract

The original computer technologies for controlling and managing the ecological condition of the environmental water objects, developed under the guidance and direct participation of the author, are described in the article. In particular, their purpose, capabilities and peculiarities are briefly described. There is also given a short description of problems solved by using them.

Keywords: Information Technologies; Environmental Water Quality; Quality Management; Software; Pollutant Transport

Introduction

For solving the problems of study, analysis and quality management of the environment, there is necessary operatively to treat great amount of measuring information on physical, chemical and biological parameters characteristic for them. To do it in a proper way, in conformity to the modern requirements, is possible only by wide use of modern mathematical methods and computer technics. For this purpose, it is necessary to develop automated systems and universal program packages with developed mathematical methods consisting of self-learning algorithms requiring whenever it is possible minimum a prior information and having capability of adaptation to the most unexpected changes of the character of the investigated objects [1].

One of the important components of the environment is natural water objects. To preserve these objects in proper condition is a markedly topical problem for safe and healthy living of humanity. Monitoring of the environmental objects' pollutions is effective only when it is realized by means of automatic systems and devices. Among the most topical problems of monitoring of a natural water environment, it is necessary to single out the following issues: assessment of the ecological state of a controlled object in current moment, prognosis of the change of the pollution levels of the environmental water objects in the space and in the time, simulation of transportation of pollutants in water objects, making optimal decisions concerning developing processes taking place in them, identification of emergency pollution sources to take measures for their elimination, yielding and sending recommendations to the appropriate destinations, for making optimal decisions for the improving the ecological objects conditions. With the purpose of overcoming of the mentioned problems, the following systems and softwares are developed under guidance and direct participation of the author of the present work: automated water quality control system, mathematical models of pollutants transport in rivers, identification of river water excessive pollution sources and software for making optimal decisions [1-5]. These packages are used for solving many real problems concerning monitoring environmental water objects [4,6,7].

The remainder of this article is organized as follows. Brief descriptions of the developed softwares are presented in next Item, some examples of the application of mentioned softwares for different environmental problems are given in Item 3 and short conclusion is offered in Item 4.

Software's for solving environmental problems

Automated water quality control system

General structure of developed automated water quality control system is given in figure 1 [4].

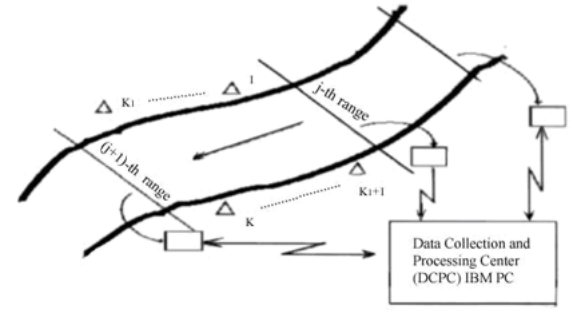

Figure 1: General structure of developed automated water quality control system.

△ j - ($j = 1,....,k_1, k_1, l,.....,k$) river pollution sources;

□ - Automated station for measurement of physical-chemical parameters of the controlled river;

→ - Telephone or radio communication;

DCPC - Data collection and processing center.

In the system, in closed buildings located at different points of the waterfront, there are multi-channel analyzers for measuring the concentrations of water pollution parameters, from which the information measured in automatic mode is transmitted to the data collection and processing center by phone or radio lines. In the center, the received information is decoded and is distributed to the relevant databases for further processing. The information received from each analyzer at the discrete moments of time is the realization of a multidimensional time series, which is processed by appropriate methods of mathematical statistics [1,4]. The purpose of the information processing is: objective assessment of the ecological condition of the water object at the moment, the forecast of the possible development of the pollution process in the time and the space, objective detection of emergency pollution sources, if any, to make recommendations to the relevant administrative bodies to improve the ecological condition of the water object. For all these problems, the system automatically forms the appropriate notifications and transfers them to the destination.

In order to optimize this technology, the author has developed a system analysis methodology, which involves the simultaneous optimization of technical, informational, software, mathematical and organizational support of the technology by solving the problem of multi-purpose optimization [1,8-11]. Using this methodology, systems for the implementation of these technologies were developed, which were introduced in the cities of Moscow, Odessa, Kemerovo and Riga. According to ISO standards, introduction in the exploitation of such complex technologies (systems) are realized using both real and simulated data, because due to the limited duration of the tests by the real data cannot be fully tested the quality of the work of the systems. Because of this, imitation models for modeling the process of pollution of natural water objects have been developed, which have been successfully used both in the creation of systems and in the stages of their testing [12].

Mathematical models of pollutants transport in rivers

In softwares "Application Package of Realization of Mathematical Models of Pollutants Transport in Rivers (MMPT)", Version 2.0 and "Automatic Detection of River Water Excessive Pollution Sources (ADrweps)", Version 2.0 are implemented of one-, two- and three-dimensional convective-diffusion models. The novelty of these models lies in the originality of the boundary conditions in the partial diffusion equations of the appropriate dimension. Instead of the traditionally used boundary condition, according to which the variability of a substance's concentration is equal to zero in a cross-section infinitely distanced from a given cross-section, we have introduced a boundary condition in which the concentrations of a substance in two finite distanced cross-sections are related to each other by coefficients. The existence and values of such coefficients are known in ecology and they are called self-purification coefficients of ecological objects. This novelty of the models significantly increased the accuracy and reliability of the description and calculation of the real process through them.

In addition, a number of innovations have been introduced in the implementation of the models. In particular, optimization is made by selecting time and spatial discretization steps for the finite-difference schemes of the differential equation for the given value of the nodal points (which determines the time and accuracy required for the calculations), which significantly increases the accuracy of the calculations. In addition, in order to increase the accuracy of the calculations with a finite-difference scheme, the approx-

imation of the Dirac's delta functions[1)] (which model the actions of the point sources of pollution) in the non-uniform part of the diffusion equation is carried out by smooth, so called quasi-point functions, which significantly increase the accuracy of calculating the concentrations of pollutants in a different scheme in the vicinity of the point sources of pollution [13].

General look of the software and the results of computation realized by this software are presented in figure 2 and 3, accordingly. More detailed information about this software can be found in [2].

Because this is explanation of the expression "the Dirac's delta functions" given on the left side column.

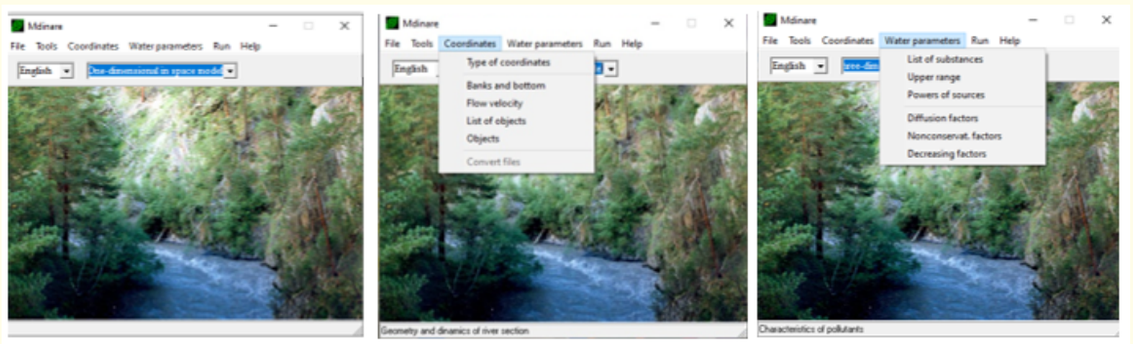

Figure 2: General look of the software of mathematical models of pollutants transport in rivers.

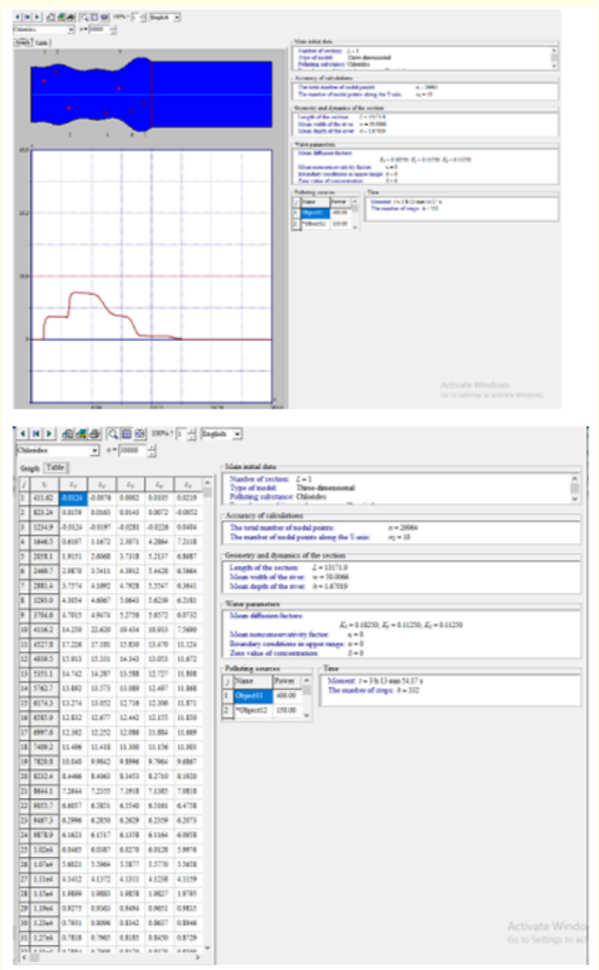

Figure 3: Computation results realized by the software.

Identification of river water excessive pollution sources

One of the urgent problems of environmental monitoring is the problem of identification of excessive pollution sources in order to take measures to eliminate them [1,4]. This problem is especially urgent for city conditions where the large number of pollution sources do not allow to control all of them. Solution of this problem has not only an ecological effect, but a considerable economic effect that can be achieved by minimization of technical facilities, in particular, measurement equipment needed for separate control of each pollution source. This problem is also urgent for large factories and plants with biochemical waste-water purification, in order to identify those sections or shops that are guilty of waste-water pollution over the norm.

A generalized diagram of the unique method, developed by us, to solve this problem is given in figure 4.

There are used the following denotations: DVMV - decorrelation of the vector of measured values; FDCPS - formation of different combinations of pollution sources; CHCP - calculation of hypothetical concentrations of pollutants in the lower controlled cross-section according to mathematical models; FH - formation of hypotheses concerning excessive pollution sources; CPP - calculation of a prior probabilities of the formed hypotheses; MD - making a decision on the guiltiness of sources in the excessive pollution.

The idea of automatic detection of a river excessive pollution sources lies in the following. By mathematical models of the transportation of pollutants in rivers, the values of all the hypothetical concentrations of the pollutants in all possible

combinations of pollution regimes are calculated, under conditions of possible discharges into the river. When emergency pollution is detected, using optimal decision-making methods, hypotheses about the level of current pollution, i.e. the result of the measurement, are attributed to the concentration of pollutants, stipulated due to this or that combination. Excessive pollutants are the set of pollutants to corresponding hypothetical concentrations of which belong the measurement result [4,14,15].

General look of the software and information about made decision are shown in figure 5 and 6.

Detailed information about the methods realized in the software and directly about the software, can be found in [4,7,14,15].

Software for making optimal decisions

One of important problem of the control and management of the environmental objects' pollution levels is making optimal decisions concerning their ecological conditions and the actions for their quality improvement. For making optimal decision in real time on the basis of a set of measurement results, the existence of the suitable software with advanced methods is necessary. One of such software with classical and new decision making methods is realized by us [15].

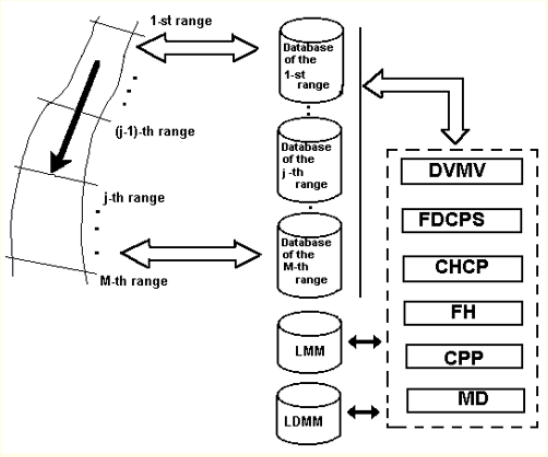

Figure 4: Generalized diagram for solving the problem of identification of excessive pollution sources.

LMM - Library of mathematical models of pollutants transfer in rivers;

LDMM - Library of methods of making decision;

⇒ - Direction of information flow;

→ - Direction of execution sequence of problems.

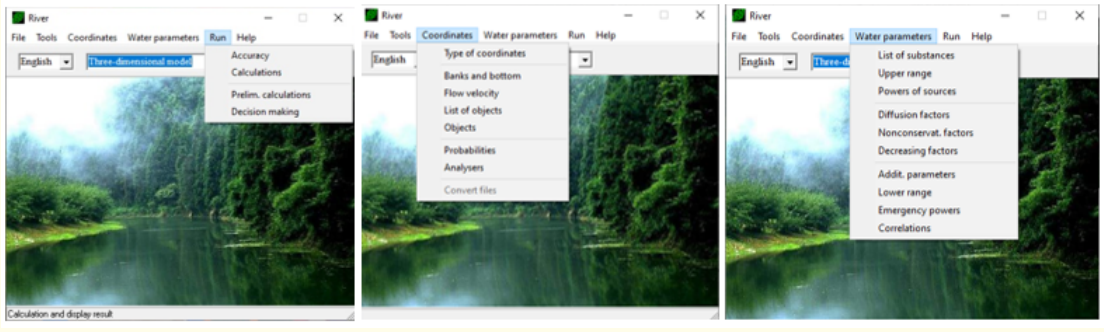

Figure 5: General view of the software.

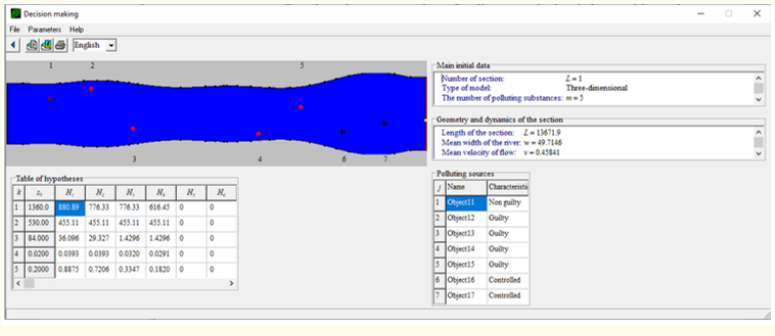

Figure 6: Information about made decision.

There are currently a large number of statistical software packages available (both universal and special) that use statistical hypotheses testing methods. Despite the large number of such packages, there is no package in which original methods similar to the current software package are implemented. In the offered package, there are realized except of well known, classical methods, such as the Bayes method with general and step-wise loss functions, sign test, Mann-Whitney Test, Wilcoxon Test, Wilcoxon Signed-Rank Sum Test and sequential methods of Wald, purely new, original methods, developed by author. Among them are Constrained Bayesian Methods (CBM) with restrictions put on the Type-I and Type-II error rates, quasi-optimal methods, sequential methods of the CBM type for testing any number of hypotheses [16]; also, simple, convenient and reliable methods based on the information distances (Euclidean and Makhalanobis) between hypotheses [17].

The general look of the package and the results obtained by Bayes-type sequential method are shown in figure 7 and 8 respectively.

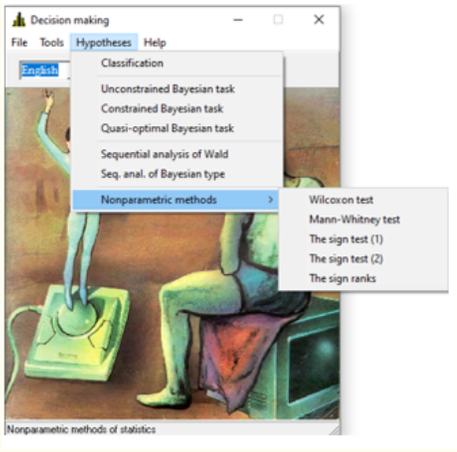

Figure 7: The general look of the package.

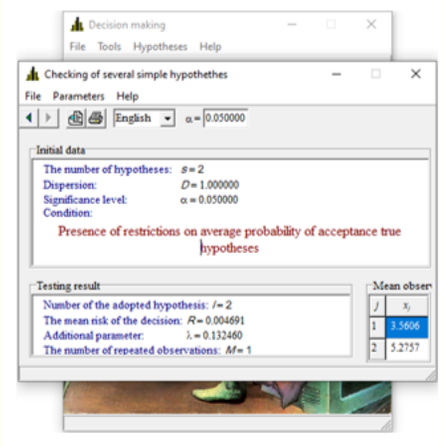

Figure 8: The results obtained by sequential methods of the CBM type.

The examples of application of the developed sofwares

Unique technologies for controlling and managing the pollution level of the environmental water objects were developed using our system analysis methodology and were practically implemented in the end of last century in the cities: Moscow (Moscow River), Odessa (wastewater from Odessa Nitrogen Plant), Kemerovo (Tommy River) and Riga (city wastewater).

Described above packages were used many times for solving different problems of the monitoring of the environmental water objects. For example: 1) Simulation of pollutants transport in the rivers. For example, rivers Choga and Khobistskali from Western Georgia, flowing into the Black Sea. The polluting substances were NO3 and PO4. The modeling results ware used to estimate the degree of influence of agricultural activities along the river banks on the pollution of Choga and Khobistskali in a particular interval. The obtained results have shown the good quality of the applied mathematical models and the software package for its practical application for simulation of the pollution processes in rivers due to multiple sources [17]. 2) For the rivers Choga, Ochkhomuri, Chanistskali and Khobistskali, we have computed the mean annual volumes of pollution components NO_3 and PO_4 that were brought in the Black sea with these rivers [6]. Comparison of computation results obtained as by directly results of measurement, so by direct summation of the computed by models, confirmed high quality of the developed models, methods and software of their realization. 3) Decision making software was many times used for testing different suppositions at processing data not only ecological but also medical and agricultural [18].

Conclusion

The information technologies of the monitoring of the environmental objects, considered in the paper, are much needed to solve many problems at the appropriate level. They allow us to solve many aspects of these very important problems and significantly increase the reliability and authenticity of the results obtained.

Bibliography

1. Primak AV., *et al*. "System Analysis of Control and Management of Air and Water Quality". Naukova Dumka, Kiev (1991): 360.

2. Kachiashvili KJ and Melikdzhanian DI. "Software Realization Problems of Mathematical Models of Pollutants Transport in Rivers". *International Journal Advances in Engineering Software* 40(2009): 1063-1073.

3. Kachiashvili KJ and Melikdzhanian DI. "Modern Software for the Environmental Modeling and Statistical Data Analysis". *Procedia Computer Science* WCIT-2010 3(2011): 439-443.

4. Kachiashvili KJ and Melikdzhanian DI. "Advanced Modeling and Computer Technologies for Fluvial Water Quality Research and Control". Nova Science Publishers, Inc., New York (2012): 348.

5. Kachiashvili KJ and Melikdzhanian DI. "Software for statistical hypotheses testing". *International Journal of Modern Sciences and Engineering Technology (IJMSET)* 2.4 (2015):33-52.

6. Kachiashvili KJ., *et al*. "River pollution components mean annual values estimation by computer modeling". *Applied Mathematics and Informatics (AMIM)* 11.1 (2006): 20-30.

7. Kachiashvili KJ and Melikdzhanian DI. "Identification of River Water Excessive Pollution Sources". *International Journal of Information Technology and Decision Making, World Scientific Publishing Company* 5.2(2006a): 397-417.

8. Kachiashvili KJ. "Modeling of analytical devices and environmental water pollution process". Znanie, Kiev (1990): 15.

9. Kachiashvili KJ and Karabegov MA. "General structure selection principles of automated control systems of environmental object pollution". Problems of control and protection of atmosphere from the Pollution 16(1990): 5-8.

10. Kachiashvili KJ., *et al*. "Information-programming and mathematical software of automated control system for natural environment state". Problems of control and protection of atmosphere from the Pollution 15 (1990): 40-43.

11. Primak AV and Kachiashvili KJ. "Optimum structure design of automatic data measurement complexes of environmental pollution control". *Problems of control and protection of atmosphere from the Pollution* 16(1990): 1-5.

12. Kachiashvili KJ. "Software of the automated monitoring systems of a condition of natural water". In book: Multivariate statistical analysis and probability simulation of real processes: Proceeding on statistics, Nauka, Moscow 54(1990): 250-254.

13. Kachiashvili KJ and Melikdzhanian DI. "Parameter optimization algorithms of difference calculation schemes for improving the solution accuracy of diffusion equations describing the pollutants transport in rivers". *International Journal Applied Mathematics and Computation* 183 (2006b): 787-803.

14. Kachiashvili KJ. "Identification of pollution sources ¬by means of automatic stations of river water quality control". In the book: Regulation of the qualities of the environmental waters. Scientific Proceedings of VNIIVO, Kharkov (1984): 114-119.

15. Kachiashvili KJ. "Bayes approach to the identification of environmental objects pollution sources". Problems of control and protection of atmosphere from the Pollution 14 (1988): 21-28.

16. Kachiashvili KJ. "Constrained Bayesian Methods of Hypotheses Testing: A New Philosophy of Hypotheses Testing in Parallel and Sequential Experiments". Nova Science Publishers, Inc., New York (2018).

17. Kachiashvili KJ and Nurani B. "Statistical Models and Simulation by SPSS". Publisher "Alfabeta", Bandung, Indonesia (2013): 353.

18. Kachiashvili KJ., *et al*. "Modeling and simulation of pollutants transport in rivers". *International Journal of Applied Mathematical Modelling (AMM)* 31(2017): 1371-1396.

19. Kachiashvili KJ and Melikdzhanian DI. "Software for Pollutants Transport in Rivers and for Identification of Excessive Pollution Sources". *MOJ Ecology and Environmental Science* 1.1 (2001): 1-8.