

Geoinformation modelling system of natural technical complexes for simulation modelling and optimization of load distribution

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Abstract. To create a system of environmental management of natural-technical complexes the organization of algorithmic support load quotas for each subject by geoinformation modelling tools is necessary. Proposed structure of geoinformation modelling system allows analysing and processing of data by geoinformation system tools with estimation for each parameter value used in accordance with proposed method. Determined criteria for load distribution between water users include the best available technologies, object social significance, ecological status of water bodies in target water points of territorial natural-engineering complex. Presented results open up new approaches, methods and techniques based on technical and new generation software. Practical relevance: algorithm and method of geoinformation project development on environmental management of territorial natural-engineering complex are able to analyse of characteristics on monitoring results, to distribute load quotes taking into account ecological level of production on the proposed criteria in accordance with developed methodology of enterprise management efficiency increasing.

1. Introduction

The environmental management of the territorial natural-technical complex is connected with the solution of following tasks:

- 1) to determine the limiting factors by basin inter-sectoral approach to management and, on their basis, to develop criteria for quoting the anthropogenic load on water bodies;
- 2) to substantiate standard mathematical models and programs for calculating the transfer of pollutants by the basin natural-technical complex; on the basis of proposed algorithm and quota criteria, redistribute and optimize the load between water users of territorial natural-technical complex (TNTC) in water basin.

For objects of first category according to the classification [1], the permissible discharge should be determined based on the best available technologies, for fourth category the calculation the norms of permissible discharges (NPD) is not provided at all, and for third category the NPD calculations should be made only on the limiting indicators.

The implementation of abovementioned requirements predetermines the need to use system analysis based on basin ecological-technological principles and corresponding algorithms implemented using geo-information technologies.



The originality of presented approach consists in development and implementation of the algorithm for substantiating the individual norms of permissible discharges for each water user based on redistribution of basin permitted impact limits (PIL). The main criteria are criteria for technological and environmental standardization based on modern tools of geoinformational mathematical modeling and management of a basin territorial natural-technical complex [2].

2. Geoinformation modelling system of territorial natural-technical complex

Modern quality management systems of water bodies of natural-technical complexes are based on the results of environmental monitoring, industrial environmental and technical control. The most effective is creation and maintenance of geo-information systems based on a database (DB) online. This system allows estimating the degree of influence of different water users on water quality of water bodies based on ArcGis software products with an ability to analyze data via cartographic services and quota the load for each subject using these results.

All information on environmental standardization and water resources management entered in GIS is implemented within Scheme of Complex Use and Protection of Water Bodies (SCUPWP) and PIL projects on a digital cartographic basis.

Information is divided into separate groups:

1. Geodata base, ecological and technological norms of the territorial natural-technical complex in accordance with the regulatory documents includes: rivers, lakes; enterprises; water outlets; water control points; water resources regions; borders of zoning; calculated water resources regions; pollutant balances; limits and quotas; water quality control points; objects of binding to locality (railways and highways, settlements, etc.).

2. Information on standardization of permitted impact limits includes: "PIL chemicals"; "PIL withdrawal of water resources"; "PIL on addition of radioactive substances"; "PIL on addition of microorganisms"; "PIL on addition of heat"; "PIL of water discharge".

3. Information on development of SCUPWP includes: "Limits of water consumption/drainage"; "Quotas of water intake and wastewater discharge"; "Balance of pollutants for base period"; "Balance of pollutants for prospects"; "Water protection measures". Information of the state water register and state monitoring of water bodies.

The developed geo-information modeling complex is a geo-information on-line TNTC system with implemented pollutant transfer models for different types of water bodies (figure 1).

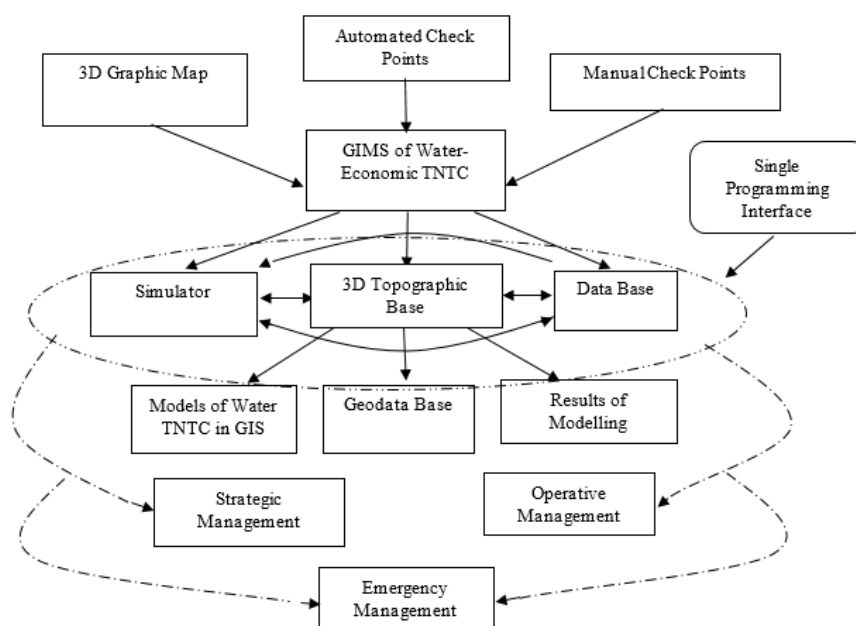


Figure 1. Structure of GIMS-TNTC.

The database contains following basic information about this TNTC:

- data of the State Hydrometeorological Service and Rospotrebnadzor;
- data of regional (basin) TNTC;
- boundaries of a basin and calculated water resources regions, location of tributaries, hydrological and morphological parameters;
- information on the actual state of water quality in water bodies:
 - background characteristics of water bodies by hydrochemical and hydrobiological indicators, integral indicators and indices;
 - information on water users and outlets;
 - quantity and characteristics of water outlets;
 - mass discharge of pollutants;
 - discharged wastewater flows.

The model of a water body in GIS is presented as polygons with homogeneous hydrological and morphological characteristics and implemented in accordance with calculating scheme of catchment and characteristics of water quality formation. A set of software modules allows to implement the appropriate mathematical models for calculating the concentration fields for a given boundary conditions and export the result to a topographic base. The simulation is carried out using the GIMS-TNTC program, which is based on finite difference method with a preliminary approximation of computational domain, within which the concentrations of pollutants are constant.

As a result of program module work, a shape-file consisting of polygons set is formed, each of which is assigned the number m_x and n_y recorded in the attribute table. A shape-file is required for addition the values of concentration field obtained as a result of modeling and constructing thematic maps in GIS.

In case of operational load redistribution between water users in accordance with the established quotas, the GIS provides a possibility of providing information to a remote user via Internet for the most number of TNTC. At the same time, a remote user, using a standard Internet browser, is able to view not only static images, but also navigate interactively, approaching objects of interest, analyze subject layers, label objects, etc. It should be particularly emphasized the ability to view and evaluate cartographic services with the presentation in the form of a web-resource on the Internet.

The developed program GIMS-TNTC allows you to:

1. Redistribute the load between individual water users (NDP), on the basis of quotas, within the basin PILs by controlled or potentially controlled introduction of pollutants.
2. Substantiate the possibility of building new enterprises and reconstructing existing ones with heterogeneous characteristics within TNTC.
3. Model the processes of pollutant transfer during actual, emergency and planned parameters of water body and discharge composition, as well as taking into account natural changes (change of hydrological phase, flood, etc.). For each calculating variant, zones of influence and zones subject to maximum contamination are determined.
4. Optimize the load from a number of water users to minimize the negative impact on the basin's water resources with a minimum of total reduced costs of achieving NDP by all water users of water resources region or TNTC.

The developed algorithm, methodology and software were tested on the example of GIMS-TNTC "Neva", used for management of domestic water supply, industrial needs, recreation, discharge of waste, storm and drainage water (figure 2) [5].

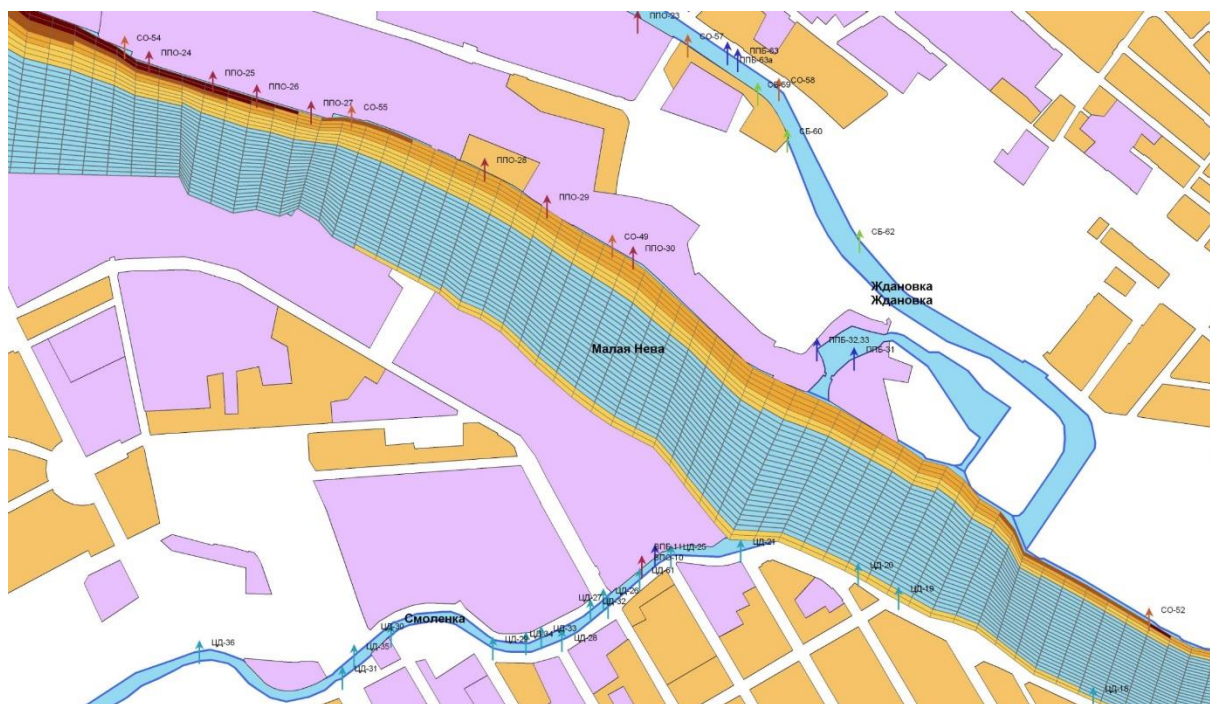


Figure 2. GIMS-TNTC for modelling concentration field distribution in Malaya Neva river.

3. Criteria for redistribution of technogenic load for TNTC and simulation modelling

The key problem of calculating the NDP for each of water users group on basis of PIL in TNTC basin is the substantiation of criteria for load distribution among water users [6].

The authors [1,7] proposed a load distribution criterion (K_{tech}) taking into account: actual mass and mode of wastewater discharge; degree of compliance of main production technology and wastewater treatment systems according to requirements of the best available technologies; the social relevance of each subject in territorial natural-technical complex.

The target function of the algorithm for optimizing the load distribution in TNTC is to ensure the interests of each water user with the need to ensure a certain quota for level of pollutants discharges and to achieve a given ecological state of water basin while minimizing total costs.

The optimization task is reduced to the form:

$$\sum_{i=1}^n S_i^{tr}(P_i) \rightarrow \min,$$

under restrictions:

$$\sum_{i=1}^n C_i^{tr}(P_i) \rightarrow C_{CP}, P_{i,\min} \leq P_i \leq P_{i,\max},$$

where S_i^{tr} – reduced treatment costs in i point;

C_{CP} – decrease of pollutant concentration in control point of a water body according to NDP;

C_i^{tr} – decrease of pollutant concentration in control point as a result of treatment by i water user;

$P_{i,\min}$ и $P_{i,\max}$ – respectively *min* and *max* acceptable degrees of wastewater treatment.

4. Conclusion

A structure and algorithm for the regulation of anthropogenic load for territorial natural-technical complexes has been developed on basis of geoinformation technologies.

To implement the developed algorithm, a geo-information modeling system GIMS-TNTC was created to control the distribution of load quotas among water users according to environmental and technological criteria.

On the basis of new generation software, a method for calculating an integrated indicator of enterprise management efficiency in TNTC has been proposed and implemented, provided that a given level of environmental friendliness is ensured.

The criteria for load distribution among water users are defined, which include: the use of the best available technologies, the social relevance of an object, the ecological state of water bodies in the specified areas of TNTC.

The considered methods and software have been tested in engineering practice and can be recommended for use by the Agency of Water Resources of the Russian Federation in solving both regional and local problems of justifying the load for individual water users (NDP) within basin PIL for an unlimited number and type of water users with databases on a geographic information base [7].

References

- [1] Epifanov A V, Shishkin A I, Antonov I V 2012 Rationing of Wastewater Discharge in Production of Pulp and its Products Using GIS Technology *Celljuloza. Bumaga. Karton [Pulp, Paper, Cardboard]* **1** 66-73
- [2] Zhil'nikova N A, Alekseev V V, Shishkin I A 2015 Geoinformational Information-Measuring System for Flood Protection Monitoring of Fuel-Power Complex Territory. *Informacionno-upravljajushhie sistemy [Information Management Systems]* **6** 93-7
- [3] Alekseev V V 2001 Information Measuring Systems. Comprehensive Assessment of State of Environmental Objects on Basis of GIS-technologies. *Vestnik obrazovaniya i razvitiya nauki Rossijskoj akademii estestvennyh nauk [Bulletin of education and development of science of the Russian Academy of Natural Sciences]* **5(3)** 230-40
- [4] Epifanov A V, Shishkin A I, Antonov I V 2011 Geoinformation Modeling System of Rationing of Permissible Discharges for Pulp and Paper Complexes *Vodnoe hozjajstvo Rossii [Water Economy of Russia]* **1** 66-80
- [5] Shishkin I, Antonov I, Epifanov A 2013 Geoinformation Modeling Complex for Rationing of Technogenic Loading. *XVII Int. Eco-conf. «Environmental protection of urban and suburban settlements»Proc. (Novosad, Serbia)* pp 299-306
- [6] Alekseev V V, Kurakina N I, Zheltov E V 2009 *System for Calculating Standards for Permissible Impact on Water Bodies in GIS* **4** 10-1
- [7] Antohina Ju A, Zhil'nikova N A, Semenova E G 2017 *Jekologicheskoe upravlenie territorial'nyimi arkticheskimi prirodno-tehnicheskimi kompleksami na osnove geoinformacionnyh tehnologij [Environmental Management of Territorial Arctic Natural-Technical Complexes Based on Geoinformation Technologies]* (Saint-Petersburg: SUAI) p 237