

ABSTRACT

the topic dissertation work:

«Research and development of models and methods for the design of geographic information system (GIS) for monitoring air pollution in a megapolis» submitted for the degree of Doctor of Philosophy (PhD) in the specialty 6D070300 – «Information systems»

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Relevance of the research topic. In Almaty, an increased concentration of contaminated substances in the atmosphere is especially noticeable at any time of the day or year. Analysis and processing of data on the ecological state currently is obtained by air pollution monitoring systems. The main purpose of these systems is to determine the presence and concentration of air pollutants using special instruments and equipment. The effectiveness of monitoring systems largely depends on the devices used to measure harmful emissions, including the use of GIS technologies.

There are three categories of sources of air pollution: industrial, household and transport. Pollution can be primary and secondary. The former immediately enters the atmosphere, while the latter is formed as a result of the transformation and decomposition of primary pollutants. Pyrogenic sources that cause air pollution, those like chemical and metallurgical industries, thermal power plants, boiler plants, pose a hazard to the atmosphere.

In Almaty, according to the sources about CHPPs, there are the following characteristics: Almaty CHPP-1 was converted to gas fuel in 2017, CHPP - 2 and CHPP - 3 operate on coal; in 2020, within the framework of the project to minimize the environmental impact, a decision was made to modernize and switch the Almaty CHPP-2 to natural gas in Almaty, if the environmental and economic efficiency from the introduction of a dust collection module is achieved;

Modern geographic information systems (GIS) are widely used to forecast, monitor, assess and reduce the impact of the spread of pollutants on the ecological situation in cities. With the help of these air monitoring systems, models that visually simulate the processes of emissions and their dispersion are created and analyzed. The developed models used in the air basin monitoring software make it possible to evaluate data interactions and obtain a forecast for decision making.

The ArcGIS system belongs to the family of geoinformation software products of the American company ESRI (Environmental Systems Research Institute) geodatabases and makes it possible to develop and analyze based on spatial data, build interpolation maps and forecasting models in desktop software products, and then publish them online and use in software applications, in web resources, in mobile devices. Therefore, the development of models and methods for designing a geographic information system for monitoring air pollution is always relevant for our city.

The issues of developing models and methods for designing a geographic information system (GIS) for monitoring air pollution in a megalopolis are the

objects of research in many already existing scientific works. Currently, they require further research with the use of modern information technologies, which make it possible to expand the capabilities of the researcher in the analysis of the considered class of systems through the use of modern methods of designing geoinformation systems. At the present stage, the most demanded GIS is the one, which makes it possible to obtain assessments of monitoring and dynamics of the state of the air basin of a megalopolis, taking into account the geographical and climatic features for the city of Almaty. For this reason, the study and development of models and design methods for GIS monitoring of air pollution is relevant.

Combining various kinds of data on a single cartographic base allows to make an objective assessment of the monitoring of the air basin, determine the influence between the factors of emission of harmful substances, assess the risks to public health and make a forecast about the state of the air in different areas of the city, the cleanliness of the air in residential areas, and much more.

Numerical methods for studying atmospheric diffusion were widely used in the works of the following scientists: Zannetti, Paolo (USA), Gang-Jun Liu (Australia), Dr. Anil Kumar Haritash (India), Manju Mohan (India), Kostas Karatzas (Greece), Bruno Sportisse (France), Maria Prodanova (Bulgaria), A.E. Aloyan, M.E. Berlyanda, G.I. Marchuk, V.I. Naatsa, I.E. Naatsa, V.V. Penenko, M.N. Madiyarova, I.P. Gerasimova, Abudujialeli Niyazibieke (Jiang, Zhongying) (People's Republic of China).

The works of the following foreign and domestic scientists are devoted to solving the problem of developing air basin monitoring: L. Brilli (Italy), L. Larsen (Norway), Kolios, Stavros (Greece), Yu.I. Shokin (Russia), V.F. Krapivin, A. M. Shutko, S. L. Belyakova, K. Ya. Kondratyev, O.E. Kondratyev, V. V. Klimova, I. I. Potapova, I.P. Gerasimova, A.A. Goryunkova, T. Omarbekuly, G.N. Nyusupova, A.B. Bigaliev, B.T. Zhakataeva, A.F. Mukhamedkalieva, M.T. Omarbekova, E.A. Zakarina, K.S. Duisebekova, F.N. Abdoldina and others.

The works of the following scientists are devoted to the development of GIS using modern information technologies: M.R. Delavar (Iran), Quanyuan Wu (Kytay Khaly Respublikasy), Goodchild, Michael F. (AKIII), I. I. Vasenev, L.A. Solntseva, V.Ya. Tsvetkova, A.I. Lychak, T.A. Trifonova, E.A. Zakarina, R. I. Mukhamedieva, A. K. Mamyrova, J.T. Omirzhanova, K.A. Bostanbekov and others.

The purpose of the dissertation work. It is necessary to research and develop models, methods and algorithms for designing GIS monitoring of the air basin in Almaty, taking the geospatial data into account through simulation modeling.

The main objectives of the study. Solve the following tasks in accordance with the set goal:

1. Conduct a comparative analysis of the methods and models used in the study and monitoring of the state of the air basin.

2. To study a model of a dynamic system for monitoring the air basin of a megalopolis for the development of a functional GIS structure, taking into account the input and processing of data, indicators for assessing the dynamics of the state of the air basin.

3. Develop information support and functional structure of GIS for Almaty, based on the analysis of methods and models used in foreign and domestic GIS for monitoring the air basin.

4. Develop a simulation model and algorithms for the functioning of the GIS monitoring of the air basin, which allows for online assessment of the state of the air basin of pollution depending on natural and climatic factors and industrial activity in a specific territory of Almaty;

5. Develop software for "MESM" GIS with a client-server database structure to assess the dynamics of the state of indicators of the air basin of a megalopolis and, on its basis, to build a map of urban atmosphere pollution by integral indicators.

Object of study. The object of the study are the processes of collecting and processing data for monitoring air pollution in the Almaty city for the design of GIS with the formation of estimates of the dynamics of the state of indicators of the urban atmosphere, obtained from the results of calculations, which is part of the complex for constructing various environmental digital maps of pollution of the megalopolis.

The subject of the research are models and methods for designing GIS monitoring of the air basin, models for studying atmospheric diffusion, business processes in the GIS structure, taking into account the input and processing of data in online mode, indicators of assessing the dynamics of the state of the air basin based on the developed simulation model of the functioning of GIS monitoring air pollution of the megalopolis.

Research methods. In the course of the dissertation, methods of researching information flows for the design and development of geographic information systems, methods of simulation modeling, spatial data analysis, a method for constructing a map of air pollution by integral indicators based on the Gaussian model and by the method of inversely weighted distances were used. A model of the transfer of impurities and an assessment of the influence of air pollution based on the exergy method were used. An object-oriented approach to the construction of an algorithm for a GIS MESM simulation model has been developed.

Scientific novelty of the research

1. The schemes and algorithms of the GIS functional structure which takes the input and processing of geodata, emission indicators and their analysis of the dynamics of the state of the air basin of the megalopolis into account were developed,.

2. A method for calculating the energy characteristics of heat-consuming objects of a megalopolis based on exergy analysis was developed. Equations were obtained for calculating the exergy indicators of the work of megalopolis objects, which are necessary to optimize their functioning.

3. An object-oriented approach to the construction of an algorithm for a GIS MESM simulation model is developed, the efficiency and accuracy of which is reflected in the results of calculations within the framework of the developed GIS software for monitoring the air basin of a megalopolis and makes it possible to build a map of air pollution by integral indicators based on the Gaussian model and inverse distance weighted method.

4. A simulation model of the functioning of the GIS monitoring of the megalopolis air basin was developed.

5. The GIS software was implemented to assess the dynamics of the air basin state in Almaty and on its basis a map of the urban atmosphere pollution was built according to integral indicators, which allows for a comprehensive analysis.

Provisions for Defense. The following provisions are submitted to the defense:

1. The structure of the GIS MESM monitoring and the model of the monitoring process for air pollution monitoring in the city of Almaty have been developed, in which operational information and updating and processing of graphic and descriptive information are taken into account in real time - online, which makes it possible to further use the obtained data in the development of GIS software.

2. Algorithms of functionality and structure of GIS MESM, which take into account the input and processing of geodata, emission indicators and, on their basis, analyzes the dynamics of the state of the megalopolis air basin.

3. A simulation model of the functioning of the GIS MESM for monitoring the air basin, which allows for on-line assessment of the state of the air basin of pollution depending on natural and climatic factors and industrial activity in a specific territory of Almaty;

4. The GIS MESM software product for assessing the dynamics of the state of indicators of the air basin in Almaty and, on its basis, a map of urban air pollution based on integral indicators, allows for a comprehensive analysis of the following indicators:

- a comprehensive assessment of the state of the air basin, depending on the selected urban area, taking into account the terrain, climatic conditions;
- assessments and forecast of measures for making managerial decisions on regulating the environmental situation, obtained from the results of calculations, which is part of the complex for constructing various environmental digital maps of Almaty.

The practical significance of the results obtained:

1. The GIS developed for monitoring the air basin of a megalopolis makes it possible to integrate and analyze cartographic monitoring data, and, on the basis of the integral indicator, build an interpolation map of atmospheric air pollution.

2. The constructed maps of urban atmosphere pollution can be used in the design of residential buildings, industrial enterprises, recreation areas and similar facilities. It is important to determine the direction of the possible spread of pollution, their intensity and settling in the area. This makes it possible to reduce the degree of environmental safety, improve the level of comfort of living and recreation of the population, and optimize the costs of environmental measures.

3. Developed on the basis of a GIS simulation model, it will make it possible to make timely informed decisions in Almaty as an effective tool for information support and support for management decisions on the regulation of the air basin in the city.

4. The international author's certificate was received The computer's program "The GIS - geographic information monitoring system of the air basin of the metropolis" No. EC-01-001325 dated September 26, 2017. The research results in the form of models and algorithms were introduced into the educational process at the Department of Computers and Information Systems of the Kazakh Academy of Transport and Communications named after M. Tynyshpayev in 2017. Acts of implementation of the dissertation results into the production process of UTG "Almaty" LLP "Asian Gas Pipeline" and LLP "Taraz Gas-Terminal" were received. It is also recommended to use the results of the dissertation work on the special course "Geographic Information Systems" for the training of technical specialists.

Structure and scope of the work. The dissertation work consists of an introduction, four chapters, a conclusion, a list of sources used. It is presented on 105 pages of the main text, contains 39 figures, 75 formulas, 8 tables, a list of used sources of 122 titles and applications: listing of software codes, copyright certificates and the acts of software implementations.

The introduction reveals the relevance, identifies the problems associated with the topic under study. The idea of work, the purpose and objectives of the research, scientific novelty and practical value of the work, research methods are stated.

In the first chapter, a comparative analysis of methods and models is, based on a review of scientific papers and web resources used in the study and monitoring of the state of the air basin is conducted; the analysis of systems and software tools for research and monitoring of the state of the air basin of megalopolises was carried out; the structure of the model of the geographic information system (GIS) for monitoring the environmental situation in Almaty is analyzed; on the basis of the analysis of the problems of research and development of models and methods for designing a geographic information system (GIS) for monitoring air pollution in a megalopolis, a goal is formulated and tasks are defined.

The second chapter focuses on the following studies and results:

- based on the analysis of assessments of the impact of air pollution on the basis of the exergy method, the calculation of emissions of pollutants from a thermal power plant was obtained;

- a model for the design of GIS monitoring and a model of the control process for monitoring air pollution in the air basin in Almaty was developed, which takes into account the prompt updating and processing of graphic and descriptive information in real time - on-line, which makes it possible to further use the obtained data in software development GIS

- the method of numerical calculation of the dispersion of pollutants in the atmosphere of a megalopolis for the compilation of a digital map is developed;

- a model for the analysis of GIS monitoring of air pollution on the example of the Zhetysu district of Almaty is developed;

- a simulation model for the design of GIS monitoring of air pollution in Almaty was developed. This method of displaying pollution data, implemented in this simulation model, showed that it allows creating a map of air pollution in the

atmosphere, closer to the results of real monitoring. This is interpreted as a clear reflection of the dynamics of such processes as the formation, movement and settling of pollutants.

In the third chapter, a subsystem of information support for the "MESM" GIS was developed. It includes the entire set of information circulating in the GIS, ensures the process of collecting, receiving, processing and transmitting it, and also serves as the basis for information communication with the external environment. Based on the selected data and the ability to integrate with GIS, a database has been implemented, including the characteristics of pollution sources, the volumes of explosive emissions and their properties. The developed specialized GIS modules make it possible to differentiate the anthropogenic influence on the quality of atmospheric air by superimposing pollution fields in territorial operational units and combining them into zones with the same level of atmospheric condition; to reveal the territorial dynamics of changes in the quality of the atmosphere in different periods of the year; identify areas of the city that are subject to maximum and minimum pollution; identify areas for the rational placement of new enterprises; select points for environmental monitoring; to create a basis for the development of a model of the dynamics of the quality of the atmosphere of an urban area.

GIS "MESM" automates the processes of processing and analysis of data received as a result of monitoring measurements at points of observation of the state of the physical field, phenomenon, event and is intended for operational assessment and forecast of the development of the observed field: phenomena, events using GIS technologies of spatial and temporal analysis data. The client-server structure of the database of air pollution indicators and the architecture of the database have been developed, which ensures the independence of the descriptions of the database - the database schema, obtained at various levels, therefore, the independence of applications from the data, which is one of the main advantages of the database.

In the fourth chapter, the rationale for the choice of software tools for Web GIS technologies for the development of GIS monitoring of the air basin of a megalopolis is considered. Software for GIS "MESM" has been developed and a set of basic components of the system has been implemented, which includes: a subsystem of user rights; data model subsystem; processing and presentation subsystem. These components are extensible, which makes it possible to use them to solve problems in various subject areas. All these components are implemented and tested as plugins of the modular system platform. The analysis of the results of the state of the air basin of the megalopolis as placed layers in ArcGISOnline is carried out.

The conclusion reflects the main results and conclusions of the dissertation work.

Approbation of work. The main scientific results and conclusions obtained in the dissertation work were presented and discussed at the following international scientific conferences:

1. The VIIth International scientific and practical conference. 21 century: fundamental science and technology, 25-26 January 2016, North Charleston, USA.

2. International scientific-practical conference "The role of technical sciences in the development of society", Kemerovo, Russia, November 26-27, 2015

3. XXIII International scientific-practical conference "Actual problems of science of the XXI century", Moscow, Russia, June 30, 2017

4. III-I International scientific-practical conference "Prospects for the development of modern science" Kiev, Ukraine, July 15 - 16, 2017

5. The 4th International scientific and practical conference "Innovations and prospects of world science", 1-3 December 2021, Vancouver, Canada.

6. International Satpayev Readings. "The role and place of young scientists in the implementation of the new economic policy of Kazakhstan", 2015 Almaty, Kazakhstan.

7. II International scientific and practical conference on the topic "Information and telecommunication technologies: education, science, practice", 3-4 December 2015 Almaty, KazNRTU named after K.I. Satpayev.

8. International Satpayev Readings. "The role and place of young scientists in the implementation of the new economic policy of Kazakhstan", 2016 Almaty, Kazakhstan.

9. International Satpayev Readings "Innovative solutions to traditional problems: engineering and technology", 2018, Almaty, Kazakhstan.

10. International scientific and practical conference on the topic: "Development of new technologies in traditional and alternative energy and prospects for economic development", November 26, 2021 - Kostanay, Kazakhstan, PI "Kostanay Engineering and Economics ESU named after M. Dulatov "and the International Telecommunication Union" MO.

Publications. The main scientific results of the dissertation were published in 16 publications on the topic under consideration, of which: 1 article with a non-zero impact factor, indexed in the **ISI Web of Knowledge** database and **Scopus** SJR = 0.199, **percentile: 45%, quartile: Q3**, in journals recommended By the Committee for Control in the Sphere of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan - 5 articles; 10 articles have been published in the proceedings of international scientific conferences.

The results of research on the topic of the dissertation were published in 16 publications:

Articles in international peer-reviewed scientific journals included in the Scopus / Web of Science database:

1. A. Bissarinova, A. Mamyrova, B. Tussupova, L. Balgabayeva, and O. Mamyrbayev. Simulation modeling of the spread of harmful emissions into the atmosphere on the basis of geographic information system (GIS) of monitoring environmental condition of a megalopolis. // Open Engineering, Vol. 6, Iss. 1, 2016, pp. 298-304, ISSN: 2391-5439, ISI Web of Knowledge, Scopus (SJR = 0.199), quartile: Q3, percentile: 45%.

Articles in publications recommended by the Committee for Quality Assurance in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan:

2. Bisarinova A.T., Mamyrova A.K., Tusupova B. B. Алматы қаласының экологиялық жағдайының мониторингінің геоақпараттық жүйесінің (ГАЗ) құрылымын талдау // Bulletin of KazNTU named after K.I.Satpayev, No. 6 (112), 2015 g., pp. 3-7, ISSN 1991-3494.

3. A.T.Bisarinova, T.Omarbekuly, A.K. Mamyrova. Атмосфераға зиян қалдықтардың таралуының имитациялық модельдеуінің кезеңдері. // Bulletin of KazNRTU named after K.I.Satpayev, No. 5 (123), Almaty, 2017, pp. 157-162, ISSN: 1680 - 9211.

4. A.T.Bisarinova. Мегаполистің ауа бассейнінің мониторингін жасау үшін ГАЗ жобалаудың программалық қамтамасын құрудың ерекшеліктері. // Bulletin of KazNRTU named after K.I.Satpayev, No. 5 (123), Almaty, 2017, pp. 235-239, ISSN: 1680 - 9211.

5. Bisarinova A.T., Abudujialeli Niyazibieke (Jiang, Zhongying), Omarbekuly T., Mamyrova A.K. Ауа бассейнінің мониторингінің геоақпараттық жүйесін (ГАЗ) құру және ArcGIS Online-де қабаттардың орналасуы ретінде сараптау нәтижелерін жариялау. // Bulletin of KazATK, No. 3, (102) Almaty, 2017, pp. 59-65, 2017, ISSN 1609-1817.

6. Bisarinova A.T. Ауа бассейніне мониторинг жүргізетін ГАЗ-де қолданылатын модельдер мен әдістердің салыстырмалы сараптамасы. // Bulletin of KazATC, No. 1 (108), 2019, Almaty, P.204-211, ISSN 1609-1817.

International scientific and practical conferences:

7. Bissarinova A.T., Mamyrova A.K., Tusupova B.B. Mathematical modeling of expenditure in emission planning on the example of one of the territorial districts of the city. // Materials of the VIII International Scientific-Practical Conference, North Charleston, USA, January 25-26, 2016., Vol. 3, pp. 116-122, ISBN: 978-1523778348.

8. Bisarinova AT, Mamyrova AK, Tusupova BB .. A model for analysis of GIS monitoring of the ecological situation in a megalopolis. // Proceedings of the International Scientific and Practical Conference "The Role of Technical Sciences in the Development of Society", Kemerovo, Russia, November 26-27, 2015, pp. 10-14, ISBN 978-5-906805-29-4

9. Bisarinova A.T. The use of GIS technologies for monitoring the air basin of a megalopolis. // Collection of articles of the XXIII International scientific-practical conference "Actual problems of science of the XXI century", Moscow, Russia, June 30, 2017, pp.16-21; ISSN: 5647-2412.

10. Bisarinova A.T., Mamyrova A.K. Publish the results of the analysis of the state of the air basin of a metropolis as hosted layers in ArcGIS Online. // Proceedings of the III-th International scientific-practical conference "Prospects for the development of modern science" Kiev, Ukraine, July 15-16, 2017, part 2, pp.5-8.

11. Bisarinova A.T. Optimization of operating parameters of the functioning of fuel-using objects of the megalopolis based on the exergy method // Proceedings of the 4th International scientific and practical conference "Innovations and

prospects of world science", 1-3 December 2021, Vancouver, Canada. Pp. 275-281. ISBN 978-1-4879-3794-2

12. Bisarinova A.T., Mamyrova A.K., Balgabaeva L.Sh and others. Geographic information systems (GIS) for monitoring the ecological situation in Almaty. // Proceedings "The role and place of young scientists in the implementation of the new economic policy of Kazakhstan" of the international Satpayev readings Almaty: KazNTU 2015, Volume IV, pp.101-105, ISBN 978-601-228-806-3.

13. Bisarinova AT, Mamyrova AK, Tusupova BB .. Rationale for the use of Web-GIS technologies for the development of GIS MESM. // Proceedings of the II International Scientific and Practical Conference "Information and Telecommunication Technologies: Education, Science, Practice", Almaty, Kazakhstan, 3-4 December, KazNRTU, 2015, Volume I, P.137-139, ISBN 978-601-228 -817-4.

14. Bafubaeva U. Yu., Balgabaeva L.Sh., Bisarinova A.T. Development of the structure and algorithm for the functioning of the website "Eco-monitoring". // Proceedings of the international Satpayev readings "The role and place of young scientists in the implementation of the new economic policy of Kazakhstan", - Almaty: KazNTU 2016, volume II, pp. 250-254, ISBN 978-601-228-807-0.

15. Talipova A.A., Bisarinova A.T. Aua basininin monitoringin zhasaudyk mobildi kosymshasyn uru. // Proceedings of the International Satpayev Readings "Innovative solutions to traditional problems: engineering and technology", April 12, 2018 - Almaty: 2018, pp. 1264-1269, ISBN 978-601-323-111-2.

16. Bisarinova A.T. Megapolisti aua poolinin monitoringinin geoakparattyk zhuyesinin (GAZH) yrylymyn zhane derekter kamtamasyn uru // Proceedings of the XIII International Scientific and Practical Conference "Development of New Technologies in Traditional and Alternative Energy and Prospects of Economic Development", November 26, 2021, Ch. University of Engineering and Economics. M. Dulatov "and the International Telecommunication Union" MO.