Application of Open and Specialized Geoinformation Systems for Computer Modelling Studying by Students and PhD Students

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Abstract. The article contains research on use of open and specialized geoinformation systems to prepare students and postgraduates on specialties: 101 “Environmental Sciences”, 103 “Earth Sciences”, 122 “Computer Sciences”, 183 “Environmental Technologies”. Analysis of the most common world open geoinformation systems is done. Experience of geoinformation systems use for students and postgraduates teaching for different specialties is described. Predominant orientation towards the use of geoinformation systems in educational process is determined based on the analysis of scientific publications and curricula of the most popular Ukrainian universities. According to the authors the material that is given narrows knowledge and skills of students and postgraduates, particularly in computer modeling. It is concluded that ability of students and postgraduates to use geoinformation systems is interdisciplinary. In particular, it develops knowledge and skills in computer modeling of various processes that may arise in the further professional activity. Examples of professional issues and ways to solve them using geoinformation systems are given. Recommendations are given on the use of open and specialized geoinformation systems in the educational process. It is recommended to use both proprietary (ArcGis, MapInfo) and open GIS (uDIG, QGIS, Whitebox GAT) to teach students. Open GIS (uDIG, QGIS, Whitebox GAT) and specialized

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(Modular GIS Environment, GEO + CAD, GeoniCS, AISEEM) can be used to teach both students and postgraduates.

Keywords: geographic information system, computer simulation, open software, specialized geographic information system, training of students, graduate students

1 Introduction

Improvement of education quality is one of the most important issues in the development of Ukrainian society. The modern world is rapidly evolving and changing. Updating and improving of information technologies is performed almost each year. Therefore, the national higher education system does not have time to adapt curricula and plans to the requirements of the market and society. This problem is urgent in the field of specialists training: 101 “Environmental Sciences”, 103 “Earth Sciences”, 122 “Computer Sciences”, 183 “Environmental Technologies”.

For example, educational and professional training program of students of the specialty 122 “Computer sciences” is focused first of all on the preparation of competitive specialists with already formed professional competencies in the field of information technology. It should be sufficient for effective fulfillment of professional tasks in the design of information systems and their components. This program includes many aspects of training, ranging from mastering programming languages, software design methodologies, creation of ready-made software and technological solutions and their use in specific areas of activity (financial, consulting, logistics, etc.). One of the potential application areas of the knowledge of future specialists in the above-mentioned specialties is socio-ecological. It includes tasks related to ensure efficient use of natural resources, environmental protection, ensuring of authorities’ openness, land management and even more. It is important to use geoinformation systems and technologies to solve these problems efficiently.

Modern geoinformation systems (GIS) are not only systems for automated processing of geospatial data, vectorization and visualization of objects and events in real time mode. It is also a powerful complex of geospatial analysis, strategic support for managerial stuff decision-making.

For Ukraine, the issue of development and implementation of GIS is relevant. It is emphasized in the following regulations: the Concept of the digital economy and society of Ukraine for 2018-2020 [15], the Concept of eGovernment development in Ukraine dated 20.09.2017 No 649-p [16], the Concept of creation of the national automated system “Open environment” [17], Decree of the President of Ukraine on “Sustainable Development Goals of Ukraine for the period up to 2030” dated 30.09.2019 No 5 [31] and others.

Higher education institutions are now required to enhance the geo-information vector of their students and postgraduate’s education, in particular, to use modern GIS and the software in teaching process. It would satisfy educational goals and professional competence of professionals to the maximum extent. Validity of specific software using in the learning process is conditioned by the knowledge and experience of the teacher who teaches the GIS course. It is accepted that the Environmental Systems Research Institute with the ArcGis software product line is the world leader in the development and implementation of GIS. Therefore, the use of these products in the educational process will give students greater competitive advantage in the future [18]. It should be noted that according to the G2 Crowd analytical platform [5] in the GIS world market research the Google Earth Pro took first place, while ArcGis was second in the top rankings. In addition, according to experts and users ArcGis products are useful as corporate GIS and their licenses value is inaccessible to small and medium-sized businesses, budgets and other organizations in our country. We believe that student with skills of working in the ArcGis environment (convenient, thoughtful, with 24-hour service support) will simply not be able to work with another software environment, and during development will try to imitate principles of operation of the familiar system [46].

Therefore, it is important to develop the skills of working with undergraduate and graduate students with proprietary as well as open and specialized GIS. This will greatly enhance their practical experience and enable them to understand the mechanism of transformation of geospatial data, regardless of the type or type of GIS.

2 Literature analysis and problem statement

Geoinformatics, as a science, is relatively young in Ukraine. Therefore, educational and methodological materials are not developed sufficiently. Various aspects of the GIS use for solving environmental safety problems are discussed in [22, 28, 29, 30, 39, 41, 43]. Development of specialized GIS was described in publications [1, 40, 43]. Comparative characteristics of open source and proprietary software and their use in educational process are subject of research [9, 21]. Problems of GIS using in educational process for the preparation of different specialties students are revealed in the works: 101 "Environmental Sciences" [33], 122 "Computer sciences" [46], 183 "Environmental protection technologies" [10, 33] and others. Features of software for computer simulation of various processes are disclosed in [4, 19, 22, 24, 28, 42]. However, potential of open and specialized GIS using to teach computer modeling by is insufficiently disclosed and needs further investigation.

3 The aim and objectives of the study

Aim of the article is to select open and specialized GIS which should be used to teach computer modeling disciplines to students and PhD students.

Tasks of the research:

1. to analyze peculiarities of using open GIS in educational practice;
2. to compare characteristics of open GIS functionality;
3. to describe specific application of specialized GIS (for example, AISEEM);
4. to give examples of computer simulation by using specialized GIS in environmental monitoring tasks.

4 Research results

4.1 Application of GIS in education

GIS is one of the information systems types implemented on the basis of modern computer technologies to perform various tasks related to geospatial analysis. It is designed to create geographical thematic maps and analysis of objects of the real world, to monitor their state, to study the dynamics of events in real time, etc. [46].

The work [6] states that GIS is an automated information system based on geospatial data. Purpose to teach the discipline “GIS and database” is to study basic provisions and knowledge of modern development, patterns of construction and operation of information systems in general, and information systems related to the geospatial location of objects in particular and to make management decisions based on these systems in real time. Laboratory work on the discipline “GIS and Database” is performed in the software product ArcGIS 10.3. After discipline studying students should know: theoretical foundations of GIS construction; GIS functionality; GIS data collection tools; models of presentation of graphic information; GIS analysis and modeling capabilities; methods for creating of common and thematic maps using GIS. They should be able to: collect primary information for GIS; enter data into GIS; represent data of processing results; perform data analysis and modeling; use GIS to create generic and thematic maps and plans.

Syllabus of educational discipline “Ecological systems and GIS technologies” is done in accordance with educational and professional program of specialist of higher education “Master” of specialty 101 “Ecology” and 183 “Environmental protection technologies”. The subject is organization and functioning of ecosystems and use of GIS technologies in ecology. Discipline “Ecological systems and GIS technologies” gives students master program the opportunity to gain in-depth knowledge in the field of modern computer systems. It includes systems of spatial data processing and database management and skills in using these systems to solve various tasks of managing a balanced nature management [10, 33].

Teaching GIS basics to students of computer specialties is mainly concentrated in “Geoinformation systems” discipline. It can be stated based on the curricula of educational and vocational training programs for specialists in the specialty 122 “Computer Science”. The discipline is taught at the first (bachelor) and second (master) levels. It is given to bachelors in the 3rd semester of full-time study (for example, at National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”, Vadym Hetman Kyiv National Economic University, in the 4th semester (e.g. Vinnytsia Institute of Economics), in the 5th semester (Zaporizhzhia National University); for masters it is given in the 3rd semester (discipline “Geoinformation systems and technologies in nature management”, The National University of Life and Environmental Sciences of Ukraine). The discipline is selective in all cases. It implies that the discipline is not necessary for students. The main tasks of the discipline “Geoinformation systems” for the specialty 122 “Computer sciences” are following: acquiring of the knowledge and skills necessary to work with modern GIS by students; development of spatial analysis capabilities and work with large data sets; formation of theoretical and practical skills of independent development of elementary model of GIS (its prototype). On the basis of acquired knowledge students should be able to: choose methods and means of entering geological and geophysical data in digital and graphic formats; create prototypes (fragments) of GIS that perform certain application tasks; apply geoinformation methods to construct structural, parametric and thematic maps; perform various GIS (ArcGis, Saga GIS, MapInfo, Google Earth, QGIS, etc.) [46].

The article [8] discusses a need to amend curricula of higher education institutions in accordance with current requirements. Possession of software and ability to create variety of thematic maps with it and basic theoretical training in cartography is an integral competence of modern experts in the field of Earth sciences. Geoinformation education should be one of the system-forming factors in formation of students imaginative analytical system-spatial thinking. GIS education has specific features that distinguish it from other areas of training. Among them are: wide range of software applications; interdisciplinary nature; high information saturation, etc.

GIS specialists should have systematic knowledge and skills in the field of GIS design, operation and development. GIS education is aimed at: comprehensive solution of natural-economic and social problems; assimilation of new methods and data processing tools that provide high clarity of displaying heterogeneous information, processing and analysis of spatial information; use of modern means of operative solution of management problems, evaluation and control of surrounding processes [8].

Researchers point out [34] that the modern learning process cannot be imagined without innovation. These innovations typically develop dialectical approach in observing objects, phenomena, and real-world processes. The introduction of GIS into the teaching process assists students in observation, analysis and interpretation of spatial information. It is easier for students to study different subjects using GIS tools to model different processes. Students' academic performance becomes more effective due to GIS. They are motivated to learn new skills using modern technologies.

The publication [1] states that GIS is a window into the past, present and future. It facilitates access to information regarding natural, social and cultural aspects. In this way, GIS become indispensable when it comes to cognition, study and environmental quality. The authors describe the use of Google Earth in environmental education through creation of didactic routes taken by students at the University of Córdoba (Spain).

Analysis of the textbooks, manuals, laboratory workshops [24, 27, 32, 36] showed that question of open GIS use in the educational process is limited by analysis of classification approaches. Attention is paid to use of proprietary software GIS-complexes like ArcGis and MapInfo. Practical aspects of open GIS use in the educational process are disclosed only in [35] and [37]. Most of the available scientific and methodological developments are concentrated in the field of design and implementation of geoinformation GIS in practice, solving real scientific and applied problems [43, 7, 19, 22, 28, 39, 44].

Modern GIS have a wide range of capabilities. There is always a need to improve and complicate geoinformation systems, thus complicating calculations, increasing the number of operations per unit of time, thereby obtaining greater accuracy and reliability with the constant development of technology and increasing demands for information systems. The most modern GIS perform complex information processing using the following functions: data input and editing, support of spatial data models, information storage, transformation of coordinate systems and transformation of cartographic projections, raster-vector operations, measurement operations, polygonal operations, spatial analysis operations, various types of spatial modeling, digital terrain modeling and surface analysis, presentation of results in various forms, and many different specific, depending on the recognition spare system modeling functions. Determining of maximum list of GIS requirements is one of the most important steps in modeling of such systems today. GIS offer rich selection of tools for processing of spatial information. Geo-processing is a key environment for modeling and analyzing location data. With this environment it is possible to synthesize data that cannot be obtained from one source or another [45].

Geoinformation modeling is a high-tech process of terrain model creating of certain territory in the environment of geoinformation systems. The created model visualizes quantitative and qualitative parameters of simulated terrain. It reflects intensity of the processes (e.g. hydrological, technological), gives an objective assessment of the state of the object (urban environment, individual components of the natural environment, human economic activity, etc.). Usually geoinformation modeling is a tool for decision making when developing recommendations for optimization of nature management, urban development, reduction of destructive anthropogenic impacts on the environment, prevention of man-made incidents and development of dangerous phenomena and processes [11].

One of the main strategic goals of geoinformation modeling is to see the whole. User can detect in-depth systemic relationships and trends that are unavailable for cognition using traditional methods of cognition using geoinformation modeling, with the introduction of a large amount of reliable and accurate data into the system. For example, the digital terrain model developed on the basis of GIS-modeling serves as a solid foundation for making decisions about the future state of territory. Geoinformation modeling can also provide: construction of phenomena density models; object location analysis; change modeling; distribution of objects by categories; search and definition of patterns of distribution of spatial and attribute data; analysis of the nearest neighborhood; defining spatial attributes of objects; three-dimensional visualization of the final results [11].

GIS integrate various data required in the decision-making process on spatial basis: characteristics of pollutant emissions in the region; regional geographical, socio-economic, ecological and medical-epidemiological characteristics. Use of GIS for displaying and analyzing pollution fields on electronic maps is common. Geoinformation systems are interesting in of information visualization. They provide visual representation of multidimensional environmental information. This is very useful during assessing of environmental risks and informing decision-makers. Thus, it is possible to distinguish the main GIS capabilities that are used in environmental quality management tasks: 1) preparation of data for analysis and modeling. GIS is used both to obtain and systematize information (regarding sources of pollutant emissions, surface characteristics) and to analyze and transform using powerful data display tools; 2) spatial analysis and modeling of the distribution or changes of the researched objects and processes; 3) publication of results, which is a process of forming procedure where results of calculations and analytical research are transformed into user-friendly thematic maps. The maps are revealed in the pattern of analysis in the best possible way for decision-maker. Modern information systems often use GIS server technologies where processing of analysis results is process of forming client server procedure [25].

The publication [20] describes the use of GIS for measurement, modeling and mapping. Experience of teaching students to use GIS is presented, namely use of geographical positioning tools to determine location and integrate these measurements into GIS. The isee systems' STELLA Modeling software for forecasting tasks is also used.

The research [40] describes a CyberGIS system that combines cyber infrastructure, geoinformatics, spatial analysis, and modeling to provide research opportunities. It became the next-generation GIS, enabling better information retrieval, visualization and visual analytics, data management, and collaborative problem solving and management decision-making.

The main directions of GIS technologies application in modern conditions are described in [3]. The article presents various classifications of GIS, history of GIS technology development since the late 50's of the last century. Experience of GIS application in the state security service, emergency service, medicine, ecology and nature management, education, business is shown.

4.2 Characteristics of the open GIS

The main motive for development of the open GIS segment in the world is inability to meet all market needs by proprietary GIS including: small or non-profit organizations (scientific laboratories, educational institutions, government institutions) that are unable to acquire required number of licenses. This is also typical for Ukraine in background of understanding of importance and necessity of GIS in most fields of activity. There are no enough available resources for their implementation. Therefore, it is not expected that studying of ArcGis or MapInfo functionality at high user level will prepare future specialists for work. That is why we emphasize the need to use open and specialized GIS in the learning process.

Open source software is software with open code which can be read or modified by the user [26]. Features of open source software are: free distribution, available source code, permission to modify source code. Conditionally all open GIS can be divided into three classes: web (working through a web browser), desktop (installed on a computer), spatial databases (which contain geospatial data). Let's analyze desktop open GIS.

According to Monde Geospatial, 2017 [2] the list of open desktop GISs available in the world today exceeds more than 350 solutions. The most common are: GRASS GIS, QGIS, Whitebox geospatial analysis tools (Whitebox GAT), gvSiG, Saga GIS, ILWIS, MapWindow GIS, uDIG, etc. General characteristic of 5 open GIS is described in the following sentences. Functionality of presented open GIS is same to their commercial counterparts. All open GIS are updated and refined. It evidenced by analysis of the installation versions available in the network and how often they are updated. Architectural solutions of open GIS are characterized by a multilevel modular structure.

Features of open desktop GIS functionality:

1. QGIS. Purpose and Functionality: cartography (creation, design, modeling), support for raster, vector, geospatial analysis, plugins for procedure automation. Year of development: 2002. Number of tools available: >500. Supported operating system: Windows, Linux, Mac OS X, Android. Update: v. 3.10.2, release dated 10.2019. Programming language: C++. Presence of Ukrainian (Russian) translation of supporting documentation: Ukrainian – nominally, Russian – partially.
2. GRASS. Purpose and Functionality: creation, analysis of image design and graphics; geospatial analysis, data management support for work with raster, vector, satellite data. Year of development: 1982. Number of tools available: >300. Supported operating system: Windows, Linux, Mac OS X. Update: v. 7.8.2 release from 12.2019. Programming language: C. There is no Ukrainian (Russian) translation of supporting documentation.
3. Whitebox GAT. Purpose and Functionality: Educational and research goals, geospatial analysis, vectorization and image processing tools, spatial filters, multicriteria project evaluation. Year of development: 2009. Number of tools available: >400. Supported operating system: Windows, Linux, Mac OS X. Update: v. 3.4.0, release from 01.2017. Programming language: Python, JavaScript. There is no Ukrainian (Russian) translation of supporting documentation.
4. The Saga. Purpose and Functionality: educational and research goals, geospatial analysis, cartography, support for raster, vector, satellite data. Year of development: 1990. Number of tools available: >600. Supported operating system: Windows, Linux, Mac OS X. Update: v. 7.6.1, release dated 02.2020. Programming language: C++, Python. There is no Ukrainian (Russian) translation of supporting documentation.
5. GvSiG. Purpose and Functionality: 3D visualization, real-time geospatial analysis, cartography, support for raster, vector, satellite data. Year of development: 2004. Number of tools available: >200. Supported operating system: Windows, Linux, Mac OS X. Update: v. 2.5, release from 11.2019. Programming language: Java. There is no Ukrainian (Russian) translation of supporting documentation.

The given open GISs do not have high hardware requirements and support ability to work on different operating systems except ILWIS, which runs exclusively on Windows. Considered open desktop GIS are created in different programming languages, and in their current versions support writing scripts in most available languages (Python, C, C++, etc.).

We will emphasize such important aspect of mastering geoinformation systems as working with geospatial databases. Most open GIS support reading and writing (editing) features of geographical and spatial data as well as temporal characteristics and attributes. For example, GRASS GIS and QGIS support PostGIS, and uDIG and gvSiG also work with Oracle. The current version of Saga GIS implements model of exporting/importing data to/from PostgreSQL, MySQL [46].

We believe that lack of available documentation in Ukrainian or at least Russian languages is holding factor to active use of described open GIS in the educational process. All available documentation, libraries, tools are described in detail on the developers' websites in English. Analysis of interface part of open GIS showed that they are inferior to convenience and intuitiveness of ArcGis and MapInfo, but not all. Practice shows that open GIS such as uDIG, QGIS, and Whitebox GAT are accessible and understandable to students. It is more difficult to master the GRASS and Saga GIS tools and functionality, since the constant execution of procedures and the challenge of operating teams requires students to have initial skills and understanding of the principles of these GIS. Therefore, these GIS can be used in teaching of students and postgraduates.

4.3 Computer modeling in monitoring of environment

In order to demonstrate examples of GIS work it is necessary to prepare a number of monitoring data. It is possible to monitor the environment, simulate and display pollution levels, predict the occurrence of environmental emergencies, identify areas with the highest concentrations and areas of risk to public health, inform the population about the current environmental status of the environment, the dynamics of its environment , sources of pollution, disposal of waste, the nature of the impact of environmental factors on human health, providing free access to environmental information [12] using GIS in environmental monitoring tasks.

Monitoring data should be presented appropriately. Only a narrow group of experts in environmental quality monitoring or modeling assessments are able to use raw data, not decision makers or the general public. Interpretation of spatiotemporal variability of pollution is greatly facilitated if conventional digital data are presented in the form of graphs, drawings and maps [12]. Use of geographical maps makes presentation of more complex comparative characteristics of pollution easier. Pollution concentrations for different observation points can be demonstrated in a simple way.

Today following domestic and foreign information software-modeling systems are used to solve problems of environmental monitoring of the atmospheric surface layer, namely: EOL-2000 [h], "Povitrya", ARM EKO, "Ekotrans", EcoStat, "ЭРА-Vozdukh", "EPK ROSA", UPRZA "Ekoloh", "Mahystral-horod 2.3", "HYS – atmosphere", "RADExpert", RODOS, RECASS, NOSTRADAMUS, ARGOS, JSPEEDI, NARAC, MEPAS and others.

Important practical aspect is use of information software developed by the authors for the tasks of monitoring and control of the environmental status of urban areas - the AISEEM system by future specialists.

The AISEEM system includes unit of statistical analysis and preliminary assessment of technogenic atmospheric loads; mathematical modeling and forecasting unit of atmospheric pollution and risks for the population; block of visualization and construction of ecological maps. This system has an electronic map unit, number of tools for working with them and certain characteristics of GIS. So, it can be considered as specialized GIS.

The developed information software is aimed to solve many scientific and practical problems of environment monitoring of ground atmosphere layer described in the publication [12].

Currently, AISEEM is implemented in various organizations, enterprises and several higher education institutions.

Let's consider, for example, the application of AISEEM to simulate various tasks that may arise in the work of future specialists in the specialties: 101 "Ecology", 103 "Earth Sciences", 122 "Computer Science", 183 "Environmental Technology".

Task 1. Modeling of technogenic loads on the atmosphere during long period of time. Construction of adequate mathematical model for scattering of pollutants in the atmosphere is based on the solution of complete equation of turbulent diffusion. Today only solutions of simplified variants of this equation are known. It also does not allow to obtain sufficient accuracy of modeling of technogenic load from emissions of stationary sources of pollution taking into account various peculiarities of meteorological characteristics, emission parameters and mode of operation of a potentially dangerous object.

The authors of this paper constructed an adequate mathematical model of atmospheric pollution from stationary source emissions based on solution of turbulent diffusion equation in general form [43]. The model adequacy was verified by comparing modeling results of atmospheric air pollution by emissions from the respective stationary sources of pollution with data of full-scale measurements of the concentration of certain pollutants at the relevant points of influence area of technogenic object. Data from the emissions of the largest stationary technogenic emission sources in Kyiv and the data of concentrations of all substances monitored at the stationary observation posts in Kyiv for 2017 were used for the model validation. Values of pollutants concentrations were obtained by official request from Central Geophysical Observatory named after Boris Sreznevsky. The test results showed that the simulation error does not exceed 15%, which is absolutely acceptable for this class of problems.

Figure 1 illustrates examples of modeling of concentration distributions of atmospheric air concentrations near the Earth's surface as a result of emissions of relevant man-made stationary sources using the AISEEM system.

Task 2. Assessment of human health risks by technogenic atmospheric factors. The developed software helps to move from the spatial distribution of technogenic load levels to the distribution of individual risks for the population of urban areas (risk maps). Risk assessments complete the modeling process of technogenic loads impact on the city population and determine the criteria for managerial decision-making. According to the methodological recommendations for the risks assessment to public health, risks analysis of atmospheric air pollution includes four stages: danger identification of individual influence factors; assessment of effect degree of these factors; establishment of dose-concentration-effect relationship; characterization of risks to public health. These steps are reflected in detail in the authors' proposed expert-analytical approach to risk assessment based on environmental monitoring data [30].

The interpolation was performed on the multiplicity principle of exceeding maximum permissible concentrations. The resulting risk values are depicted on the maps as contours of different shades, colored according to the values of the scale shown at the bottom left of each figure.

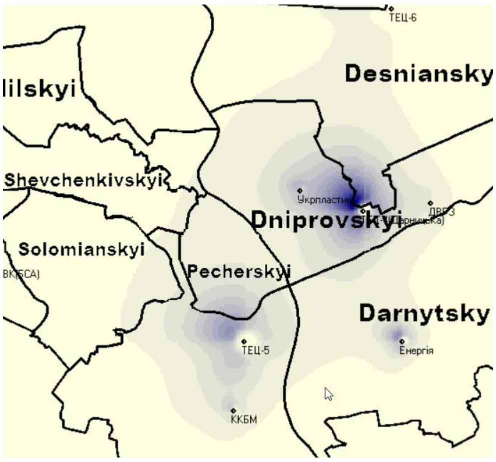
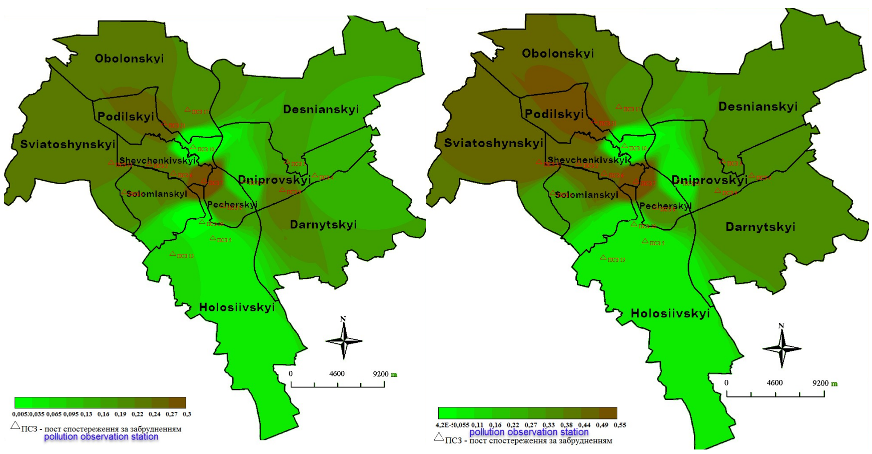


Fig. 1. Map of sulfur dioxide emissions distribution from the largest Kyiv`s enterprises (2019)

Algorithms and software were developed to implement possible scenarios for monitoring data analysis from different sources, taking into account expert assessments of the tolerability of different levels of health risks for different categories of population based on the proposed approach.

AISEEM calculates: the risk of chronic intoxication (RCI), the risk of immediate toxic effects (RITE), the characterization of the risk of developing non-carcinogenic effects, the characterization of the risk of developing non-carcinogenic effects due to the combined exposure of chemicals and carcinogenic risk.

Figure 2 shows examples of RCI and RITE integrated maps due to Kyiv air pollution in 2019, constructed using the weighted distance interpolation method.



a) b)

Fig. 2. RCI (a) and RITE (b) as a result of air pollution in Kyiv in January-December 2019

5 Conclusions

Nowadays GIS-based information materials as part of geoinformation knowledge and skills become very popular. However, the future specialists training in new technological era remains at a level that does not fully meet the needs of manufacture, science and management [14]. It should be noted that not all educational programs of higher education institutions and scientific institutions providing training in the specialties: 101 "Ecology", 103 "Earth Sciences", 122 "Computer Sciences", 183 "Environmental protection technologies" include GIS as a discipline. This is a major drawback due to the article`s authors opinion as far as the ability to use GIS is interdisciplinary. It develops knowledge and skills in computer modeling of various processes that may arise in the future professional activity.

Advantages of open GIS using in higher education and scientific institutions include following: cost savings (no need to acquire licenses); functionality of open GIS is not inferior to its commercial counterparts; most open GISs do not have high hardware requirements and support the ability to work across different operating systems; expanding the competences of undergraduate and graduate students to use different GISs and combining them to solve practical problems.

GIS for educational process is defined after the analysis of scientific publications and curricula of various Ukrainian higher education institutions. It significantly narrows the knowledge and skills of students and postgraduates particularly in computer modeling due to the authors' opinion. It was determined that the process of future specialists training in the fields of "Ecology", "Earth Sciences", "Computer Sciences" and "Environmental Technology" should be based on the use of powerful scientific and methodological training base using modern achievements in the information technology field. Used software choice in the educational process should be made not based on the subjective preferences of the teacher, but with the need for students and postgraduates to understand the process of GIS functioning in general, to develop a system of their thinking, ability to choose the best tool for solving a specific application problem. In this context use of open and specialized GIS helps students and postgraduates to understand the "logic" and "mechanism" of problem solving and to move away from the routine implementation of the learned sequence of actions. Open and specialized GIS give an additional opportunity for enrichment of educational courses with didactic material in higher education institutions and scientific institutions. Students and postgraduates obtain opportunity to work with different software solutions, compare them, choose to solve specific problem by the most optimal tools based on experience.

There are following main criteria for selection of open and specialized GIS that are appropriate to use to prepare students and postgraduates: their openness, functionality and suitability for use in higher education and scientific institutions of Ukraine.

Comparative analysis of the most common open GIS in the world was performed. It is recommended for students to use proprietary (ArcGis, MapInfo) and open GIS (uDIG, QGIS, Whitebox GAT). It is possible to use open GIS (uDIG, QGIS, Whitebox GAT) and specialized (Modular GIS Environment, GEO + CAD, GeoniCS, AISEEM) to teach students and postgraduates.

Therefore, advantages of open GIS using for students and postgraduates are following:

1. To create their own GIS prototypes (open license, wide library of ready-made tools, unrestricted integration into other systems, etc.);
2. To use Open Desktop GIS in different programming languages and to support scripting in most languages available to students;
3. To create facilitating of systematic understanding of work process with GIS by students and postgraduates, processing of geospatial data regardless of selected software type;
4. To modernize the educational process.

Based on our own experience we recommend to develop open and specialized GIS skills to address current environmental and socio-environmental challenges to educate students and postgraduates in computer modeling.

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