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## Potential territorial risk in eastern Ukraine

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**Abstract.** The research presented here is focused on assessment of potential territorial risk in the East part of Ukraine, where the military conflict has been going on for five years. Such kind of risk can be classed as a complex risk level of hazardous facilities or territories. This study determines the boundaries of territorial risk distribution with defined levels of danger.

The practical implementation is reflected in the web-based geographic information system (web-GIS) for displaying environmental information in Donetsk and Luhansk regions in real time. The research defines an opportunity for further practical application of this development considering the military conflict in the Donbas. The Donbas Environmental Information System (DEIS) is an interactive map of Donetsk and Luhansk Regions. It was developed within the framework of the Project “Environmental Assessment and Recovery Priorities for Eastern Ukraine” by the OSCE Project Co-ordinator in Ukraine upon the request of the Ministry of Ecology and Natural Resources of Ukraine. The supporting of the system is carried out by the State Ecological Academy of Postgraduate Education and Management (DEA) of the Ministry of Ecology and Natural Resources of Ukraine, in particular the Center for Environmental and Resource Restoration of the Donbas within the framework of the Project of the OSCE Project Co-ordinator in Ukraine “Assisting the Ministry of Ecology and Natural Resources of Ukraine in improving environmental monitoring mechanisms”. The main task of this study is to implement the software for collecting, processing and visualization of the information about the environment and factors that may affect it. This will make it possible to increase the effectiveness of environmental management in order to meet the environmental safety requirements in Donetsk and Luhansk regions.

**Keywords:** *environmental safety, geoinformation system, Donbas Environmental Information System, environment, military conflict, OSCE, environmental monitoring*

## Потенційний територіальний ризик на сході України

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**Анотація.** Дослідження зосереджено на оцінці потенційного територіального ризику у східній частині України, де військовий конфлікт триває вже п'ять років. Такий вид ризику може служити комплексом рівня ризику небезпечних об'єктів або територій. Дослідження визначає межі поширення територіального ризику з певними рівнями безпеки. Розроблено веб-орієнтовану геоінформаційну систему (веб-ГІС) для відображення екологічної інформації стосовно Донецької та Луганської областей в реальному часі з урахуванням збройного конфлікту. Здійснено експериментальні дослідження її роботи у сфері тестування програмного забезпечення. Відзначено перспективи подальшого практичного застосування даної розробки з урахуванням військового конфлікту на Донбасі, великий внесок у забруднення техноекосистеми може вносити як підприємства, так і продукти згоряння після бойових дій. Інформаційна система довкілля Донбасу (DEIS) – це інтерактивна карта Донецької та Луганської областей. Вона розроблена в рамках проекту «Оцінка шкоди, завданої довкіллю на сході України» на замовлення Міністерства екології та природних ресурсів України Координатором проектів ОБСЄ в Україні. Подальше наповнення та розвиток системи здійснюється в рамках проекту Координатора проектів ОБСЄ в Україні «Допомога Міністерству екології та природних ресурсів України в удосконаленні механізмів моніторингу довкілля» Державною екологічною академією післядипломної освіти та управління (ДЕА) Мінприроди, зокрема Центром еколого-ресурсного відновлення Донбасу. Основним завданням є впровадження в практику природоохоронної діяльності органів державної влади програмного забезпечення щодо збору, накопичення, обробки та представлення інформації про стан довкілля та чинники, які можуть на нього вплинути для підвищення ефективності управління природоохоронною діяльністю та додержання вимог екологічної безпеки у Донецькій та Луганській областях.

**Ключові слова:** *екологічна безпека, геоінформаційна система, інформаційна система довкілля Донбасу, навколишнє середовище, військовий конфлікт, ОБСЄ, моніторинг довкілля, відновлення Донбасу, техноекосистема*

**Problem statement.** Currently the functioning of the state environment monitoring system in Ukraine is substantially ineffective. There are many scientific publications focusing on a certain approach aimed at modernizing the existing environmental monitoring system, which can be applied for the coal enterprises of Ukraine, and in particular for the Donbas. On the other hand, they are too conceptual or merely related to the engineering component of the problem, such as the development of software and hardware measuring equipment. The aforementioned conditions require a fundamentally new approach towards improving the information technology system and its structure for further obtaining, processing and visualization of the data about the quality of the environment.

**Identification of the remaining challenges.** Currently, is it especially relevant to implement the environmental information systems and software products using the geoinformation technologies and web-technologies to take prompt decisions on monitoring tasks. Web GIS is a geographic information system which is based on web technologies and enables one to combine the individual components of environmental features in on-line maps. Web-based GIS services provide access to spatial data, processing, analysis, search and visualization. In particular, the mapping services allow maps to be displayed; geo-processing services make it possible to simulate the spatial relationships between features and analyse them. Considering the functionality, it can be concluded that web GIS is almost equal to the desktop GIS systems: the ultimate users have the tools enabling them to add, edit, analyze and search information, use various maps, assign geographic coordinates of features, etc. To use web-based GIS, it is not necessary to have any specialized software or specific qualification - just a web browser (Firefox, Google Chrome, Safari, etc) and a stable Internet connection.

While exploring the pollution level of the Donbas the main interest was focused not on the pollution of a city or district but on the research on each single pollution source, which are not obtainable from the government agencies involved in the environmental monitoring system. Currently, taking into account the military conflict in the Donbass, a huge contribution to the pollution of the techno-ecosystem can be made both by industrial enterprises and combustion products resulting from combat operations.

The Donbas Environmental Information System (DEIS) is an interactive map of Donetsk and Luhansk Regions. It was developed within the framework of the Project “Environmental Assessment and Recovery Priorities for Eastern Ukraine” (2017) by the OSCE Project Co-ordinator in Ukraine upon the request of

the Ministry of Ecology and Natural Resources of Ukraine. The supporting of the system is carried out by the State Ecological Academy of Postgraduate Education and Management (DEA) of the Ministry of Ecology and Natural Resources of Ukraine, in particular the Center for Environmental and Resource Restoration of the Donbas within the framework of the Project of the OSCE Project Co-ordinator in Ukraine “Assisting the Ministry of Ecology and Natural Resources of Ukraine in improving environmental monitoring mechanisms” (2018-19).

**Scientific objective of the paper:** The paper is aimed at researching and discovering the potential territorial level of risk in the East part of Ukraine, in particular in Donetsk and Luhansk regions, where combat activities are taking place. The objective is achieved through the analysis, comparison, combination, and prioritization of various factors which might have an effect.

**Practical objective of the paper:** To develop and implement software allowing collecting, processing and visualization of the information about the environment and the factors that may affect it. This will help increase the effectiveness of environmental management and as a result help to meet the environmental safety requirements.

**Methodology section of the paper.** The complex risk measure characterizing a dangerous facility or territory (in our paper it is the East part of Ukraine) is a potential territorial risk – the spatial probability distribution (or frequency) of the negative impact of a certain level.

In the works (Lysychenko G.V., 2008, Kachinskiy A.B., 2001; Rudko G., 2016, Bilyavsky G. 2006, Shmandiy V.M., 2013) territorial risk is defined as “the probability of dying of a person who is located in a given place of space from potential sources of danger.” It is assumed that the conditional probability of the object of impact in a given place of space is equal to 1 (a person is at a certain point of space throughout the period of time under consideration).

The potential territorial risk determines the potential of the maximum possible risk for specific objects of impact, located at a certain point of space. The potential territorial risk can vary in a wide range. We consider potential territorial risk as an intermediate level of danger, which will be used to assess the individual and/or social risk of technogenic emergencies in the future.

In the simulation of hazardous man-made processes for assessing the risk associated with the release of hazardous substances, the potential territorial risk at a given point (x, y) is determined by the formula:

$$R_i(x, y) = \sum_j P_i(A)P_{ij}(x, y)P_j(L),$$

where  $R_i(x, y)$  – potential territorial risk;  $P_i(A)$  – probability of an accident in scenarios  $i$ ;  $P_{ij}(x, y)$  – probability of realization of  $j$ -th mechanism of impact at point  $(x, y)$  for the accident script  $i$ ;  $P_j(L)$  – the probability of case of dying (or disease) from realization of the mechanism of impact  $j$ .

In practice, as a rule we often know the distribution of potential territorial risk for individual sources of danger and for individual accident scripts. In this case, the probability of an event initiating an accident is often assumed to be equal to 1. Consequently, the potential territorial risk is defined by the probability (or frequency) of the negative result of implementing the mechanism of impact at the point of the territory where the emergency occurred (Fig. 1 - Donetsk and Luhansk regions, located in the East of Ukraine).

Within the framework of cooperation, the Ministry of Environment and Natural Resources of Ukraine, the OSCE Project Coordinator in Ukraine, and the State Ecological Academy of Postgraduate Education and Management are focused on providing the accuracy and completeness of information. However, they are not responsible for the reliability of data, which were obtained from open sources. Informational messages obtained from such unofficial sources can be used for analysis and for further research (Shapar A.H., 2015; Bondar O.I., 2018;

Bondar O., 2017; Ulytsky O., 2018; Ulitskiy O.A., 2018; Denisov N., 2017).

The information under control and observation is shown on the right in Fig. 1.

- Elements of the Nature Reserve Fund (Fig. 1). The system contains 147 items of the NRF of Donetsk region and 195 items of Luhansk region with a brief description of infringements recorded since the beginning of the fighting. The information regarding the majority of described items is obtained from official archives. On the other hand, the information concerning the infringement at any particular element of the NRF has been recorded based on unofficial sources.
- Elements of industry and critical infrastructure (Fig. 2). The locations of industrial elements and critical infrastructure are determined using the Earth remote sensing data. It is known, that such data are not very accurate, so their position on the map is approximate. All the objects are divided into 8 different categories. The list of objects is not full and merely displays those of them where any accidents caused by the fighting have taken place.
- Disruption of working processes at infrastructure objects (Fig. 3). Such information is collected from open sources (reports of the National Security and Defense Council of Ukraine, reports of the OSCE Special Monitoring Mission to Ukraine, media

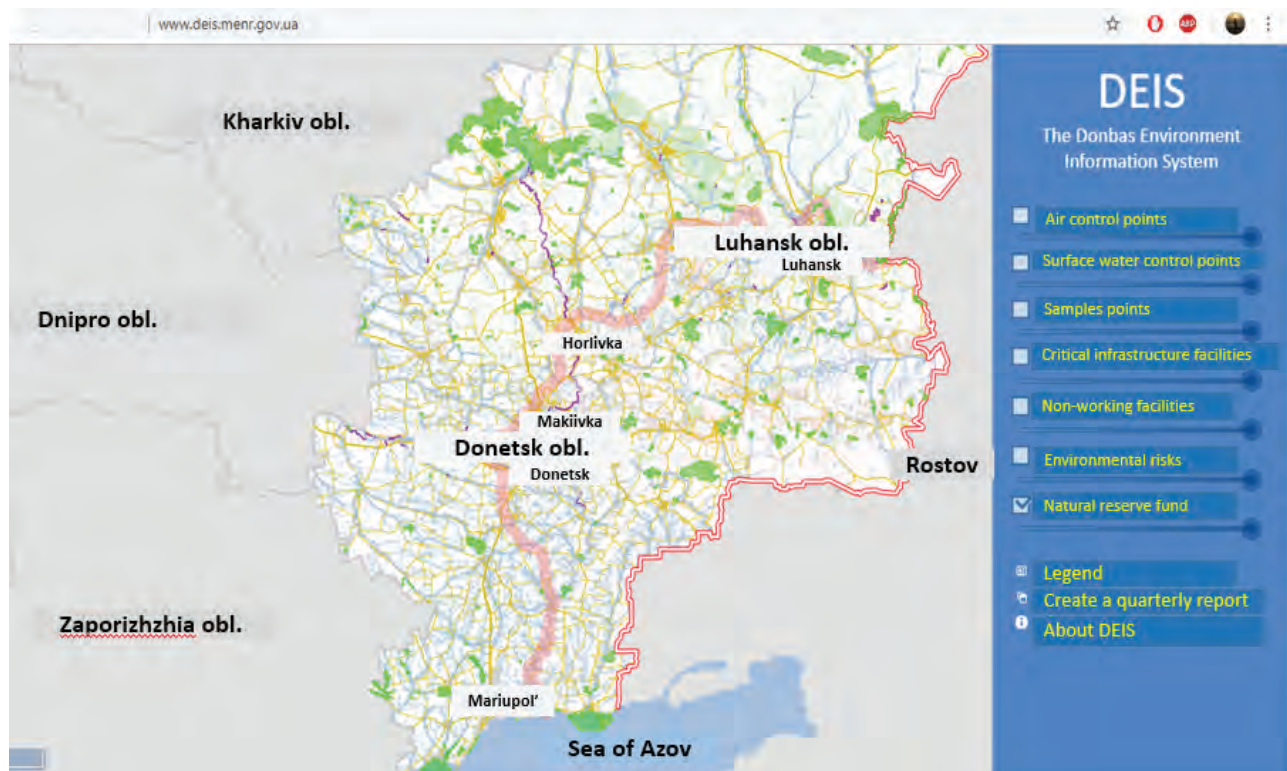


Fig. 1. Map of Donetsk and Luhansk Regions presented in DEIS involving the elements of the Nature Reserve Fund (NRF)

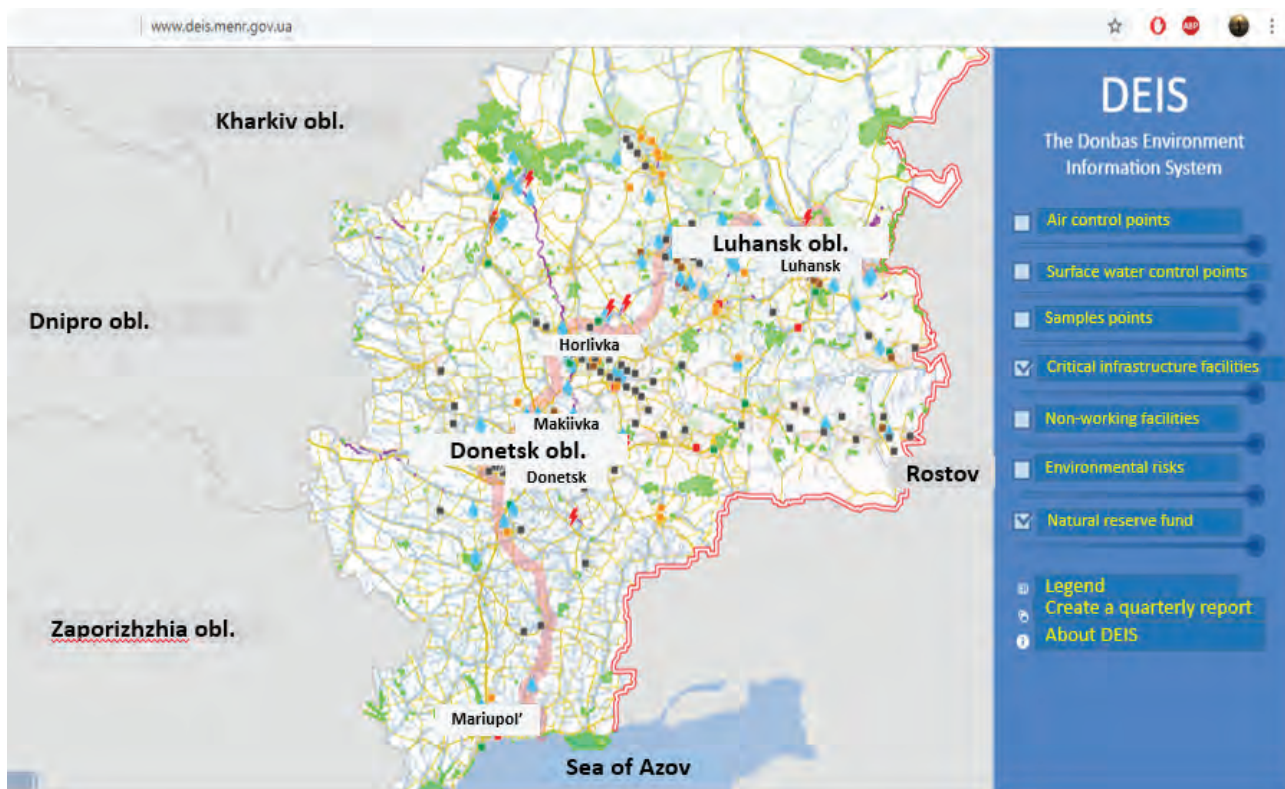


Fig. 2. Map of Donetsk and Luhansk Regions in the DEIS involving the elements of the critical infrastructure

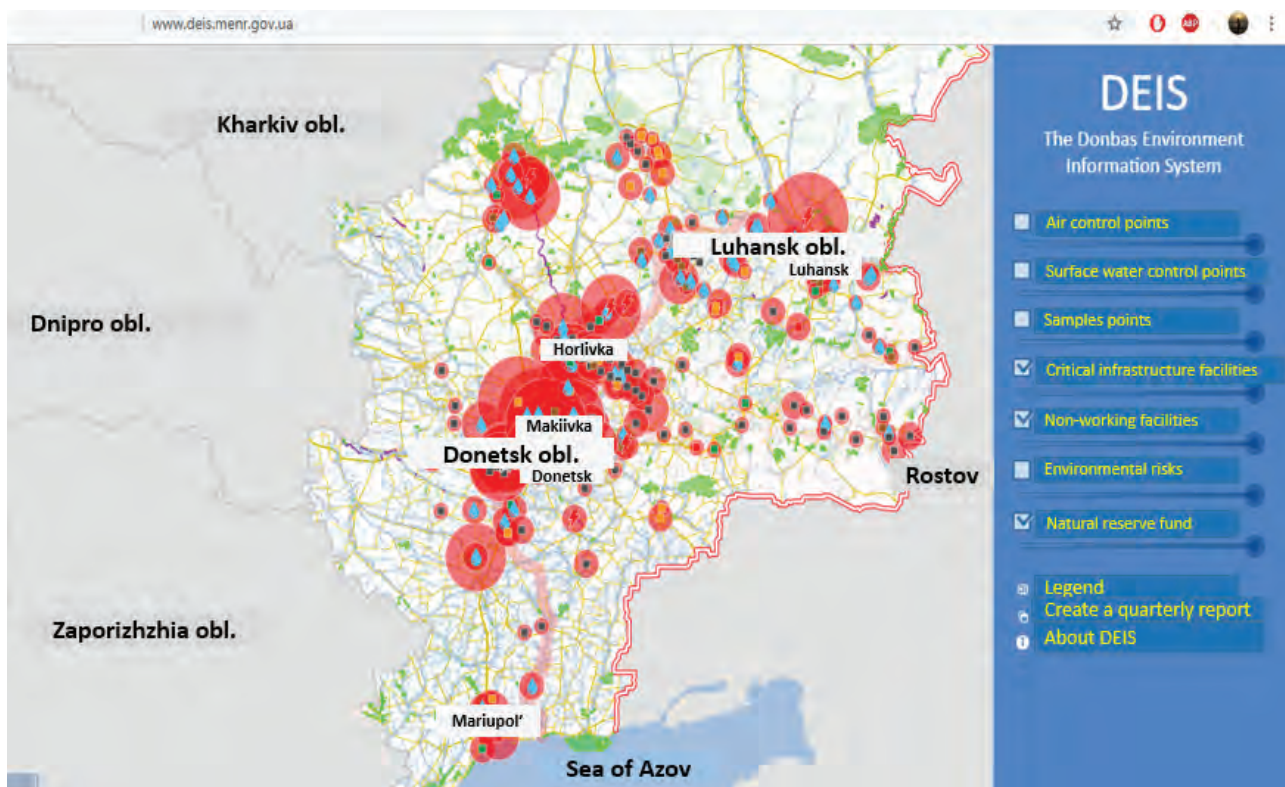


Fig. 3. Map of Donetsk and Luhansk Regions in DEIS involving the elements of critical infrastructure and disruption of working processes

reports). In the process of information base formation, the primary analysis and sampling were undertaken. At the same time, the open source data need to be verified. The information can be used for analytical and research purposes, with

the further involvement of additional sources and data verification methods. The information in the section is divided into two categories - the official reports of the national departments and the data from the open unofficial sources.

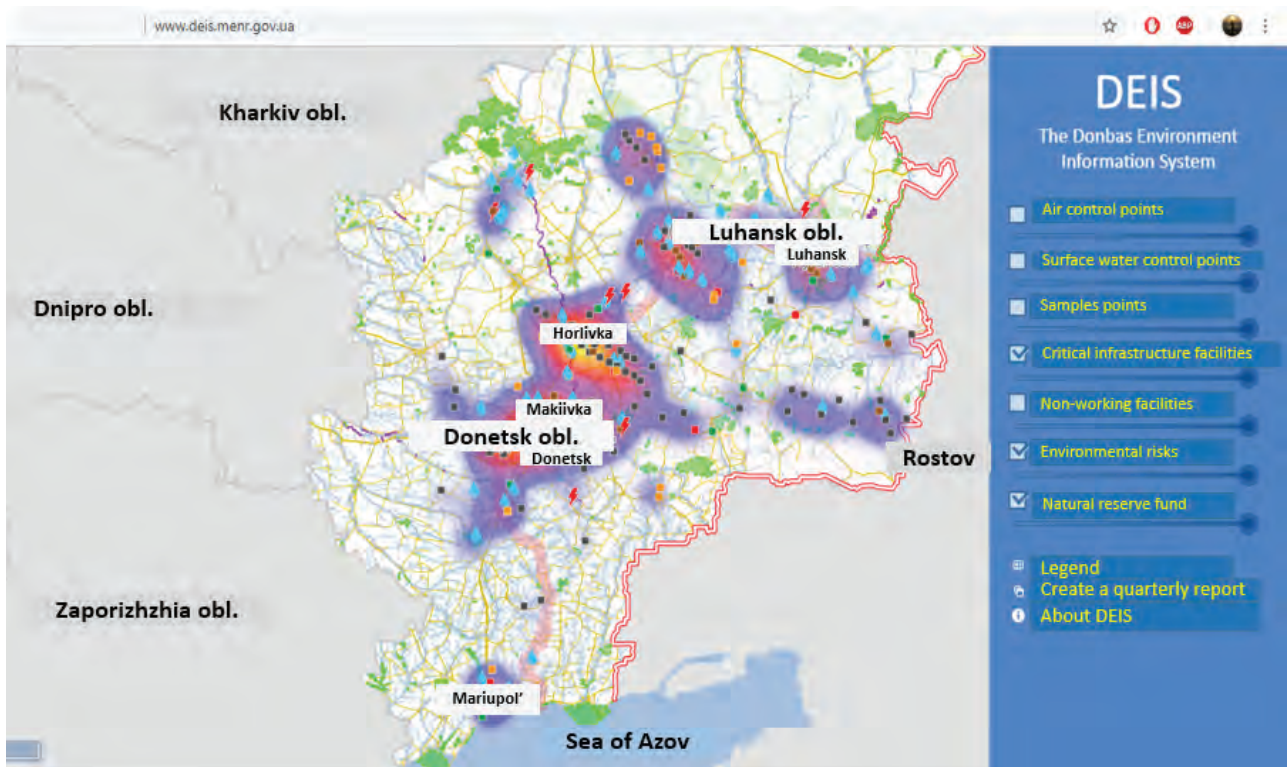


Fig. 4. Map of Donetsk and Luhansk Regions in DEIS involving the elements of critical infrastructure and environmental risks

- Environmental risks (Fig. 4). Environmental risks of critical infrastructure elements were determined on the basis of peer review, taking into account information about the type of activity and location. Monitoring of atmospheric air (Fig. 5). Data on

the quality of atmospheric air comes from automated measurement stations and are provided by the Department of Ecology and Natural Resources of Donetsk Region State Administration. The system contains 7 monitoring stations for atmospheric air (20 indicators). The data from automated stations are

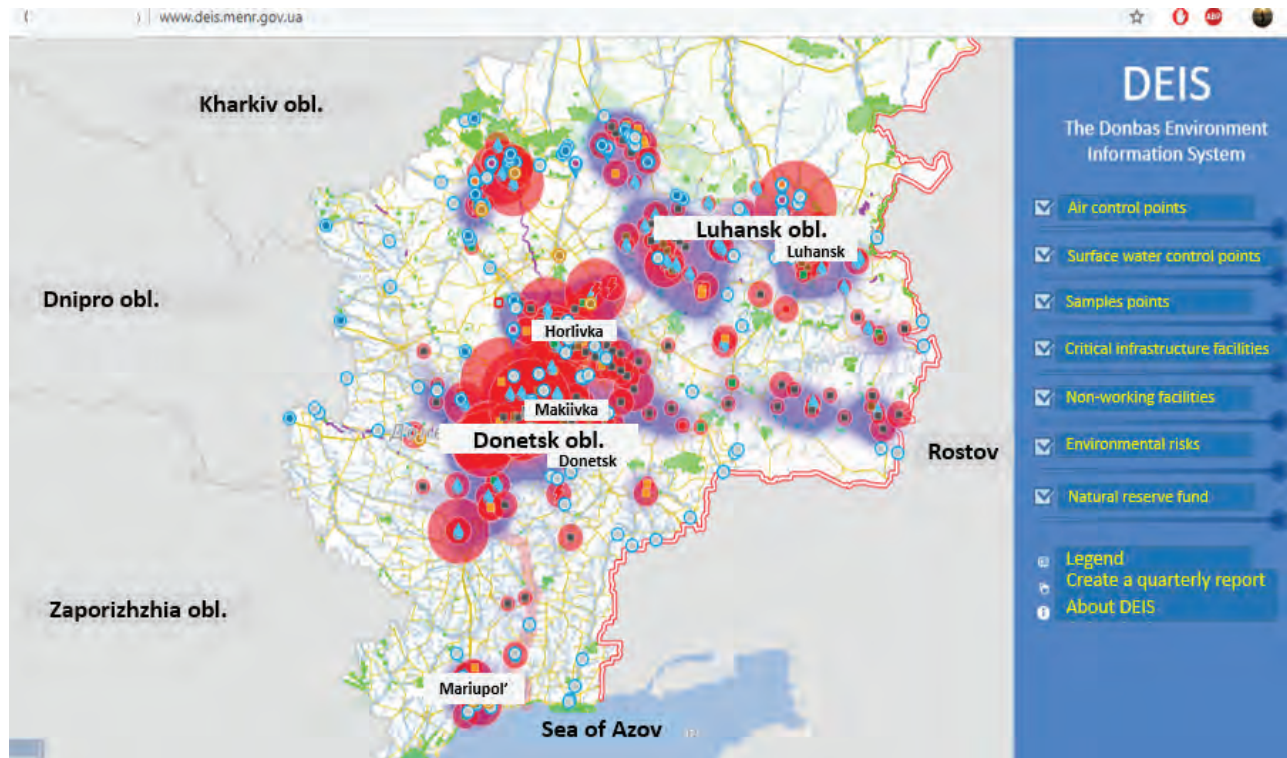


Fig. 5. Map of Donetsk and Luhansk Region in DEIS involving the areas of territorial risk

updated on daily basis.

Surface water monitoring (Fig.5). Data on the condition of water surface is provided by the Siversky-Donets Basin Water Resources Administration of Ukraine. The system contains the monitoring data on the condition of water surface of the Siversky Donets river basin since 2000. The number of data sets depends on the period selected and the operating conditions. This section also includes data from 2

the indicators of danger.

Environmental monitoring involves monitoring the environmental status, assessing the capacity of the environmental impact and predicting the consequences of its results for human health and the environment (Mossner,2001; Ulanowicz, 2004).

Critical infrastructure elements can be considered as permanent sources of environmental pollution. Their emissions must be monitored by an automated system

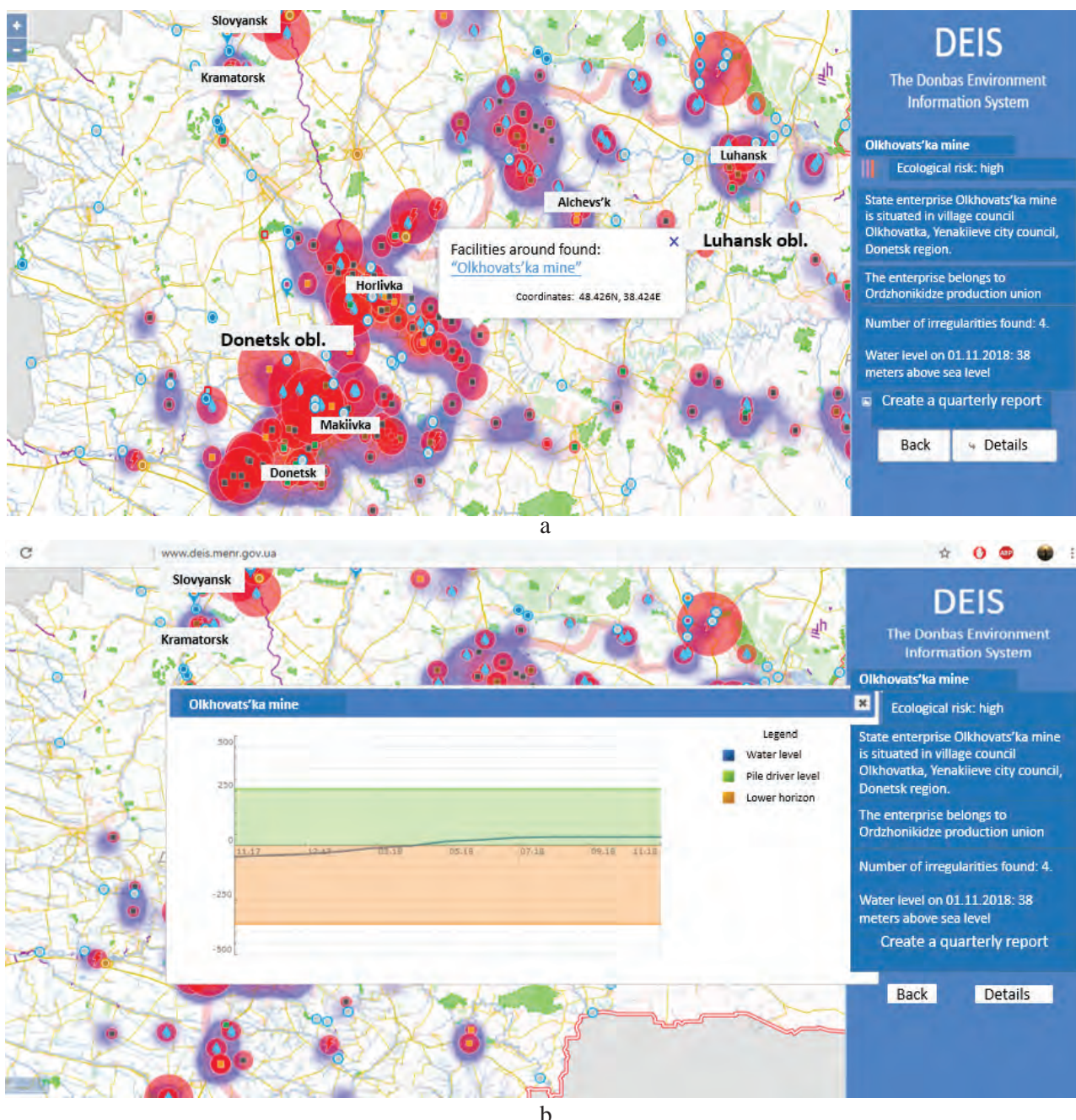

















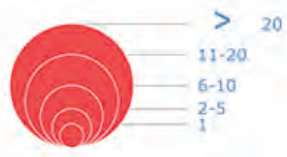












Fig. 6. Graphic report (level of flooding) at the Olkhovatska mine

automated stations of the Department of Ecology and Natural Resources of the Donetsk Regional State Administration.

Table 1 shows the legend of the interactive map of Donetsk and Luhansk regions in DEIS involving

providing the real-time environmental data. Currently , considering the ongoing military operations , this is difficult to achieve. Automated control systems must necessarily become basic in cities and industrial centers (Malymon , 2009; Loreau, 2002; Balvanera,

**Table 1.** Symbols on the map of Donetsk and Lugansk regions in DEIS involving the hazard indicators

<b>Sampling points</b>	
	Sampling points of the OSCE Project Co-ordinator in Ukraine
	Sampling points of other organizations
<b>Stations to monitor atmospheric air and surface water</b>	
	Stations of air quality monitoring of Donetsk Regional State Administration
	Stations of surface waters' quality control of the Seversky-Donets Basin Water Resources Administration
	Closed stations of surface waters' quality control of the Seversky-Donets Basin Water Resources Administration
<b>Elements of nature reserve fund and elements of critical infrastructure</b>	
	Territories of elements of nature reserve fund
	Elements of the metallurgical industry
	Elements of the chemical and coke industry
	Elements of the mining industry
	Elements of the machine-building industry
	Elements of the energy industry
	Elements of water supply and drainage
	Other elements
<b>Environmental risks</b>	
	Maximum risks
	Minimal risks
<b>Infringement at the elements</b>	
	
<b>Surface waters</b>	
	Rivers
	Channels
	Water elements
<b>Transport infrastructure</b>	
	Highways
	Railways
<b>Territories</b>	
	Settlements
	Industrial elements
	Forest
<b>Borders</b>	
	State border
	Borders of the regions
	Boundaries of districts
	Line of delimitation

2006; Dzhygyrey, 2007; Lavryk, 2002; Talanchuk, 1991; Maslov, 2005).

For example, using this system, you can obtain a

graphic report for a coal mining enterprise (Fig. 6a) and see the level of its flooding (Fig. 6b)

You can also obtain a quarterly report on the of

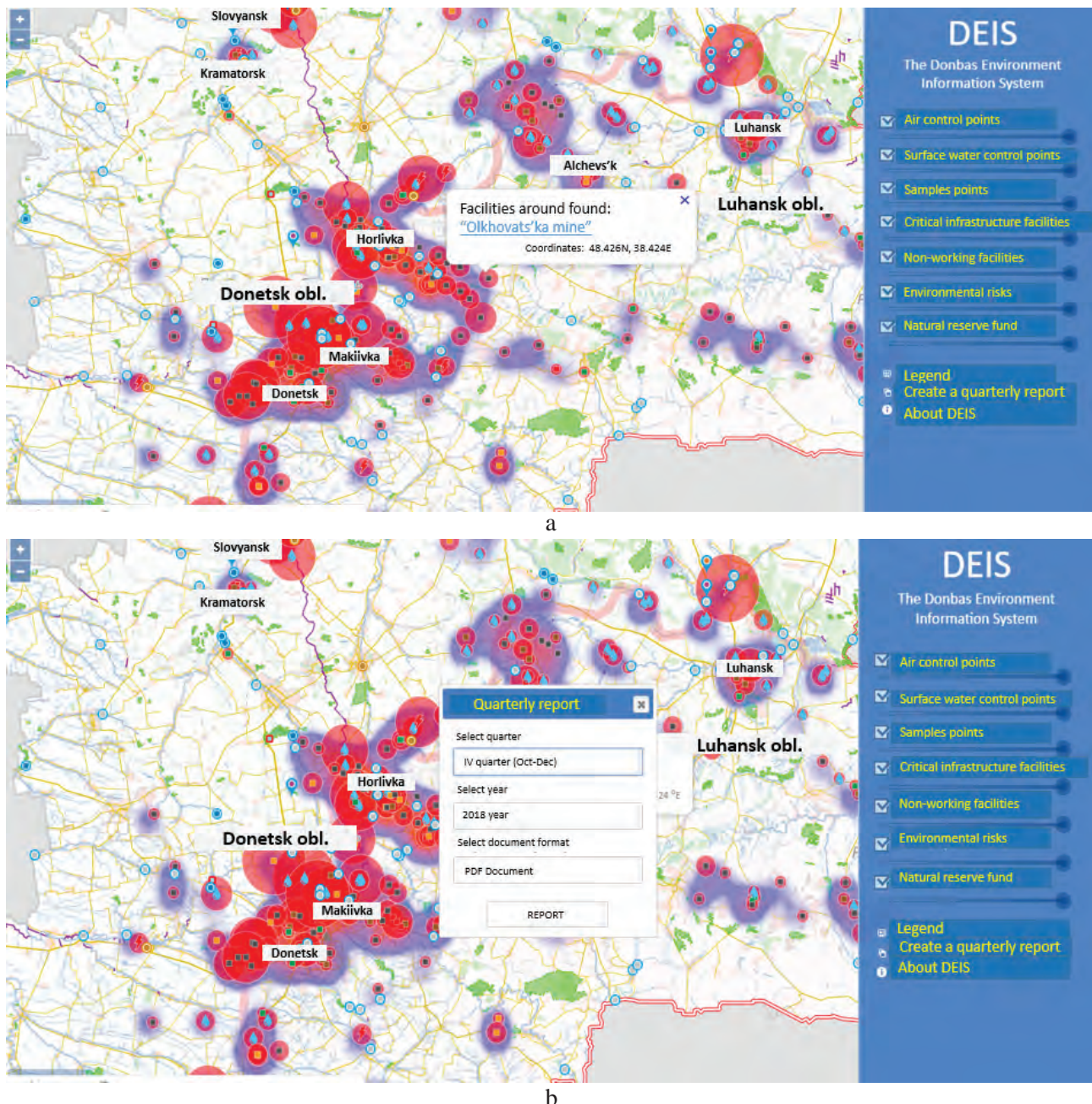


Fig. 7. Quarterly report on the state of the environment in the East of Ukraine

the air condition, water surface, about infringements of the critical infrastructure elements, flooding of mines in the eastern part of Ukraine (Fig. 7).

During the analysis of the risks affecting the emergency situations, we identified: a) equipment/plants where an accident is likely to occur and which have the highest emission of hazardous substances; b) the enterprises where accidents have the highest probability of occurring and from which hazardous emissions can affect the nearby territory as well; c) the zones of the highest pollution, their type, and level of possible negative impact; d) facilities which appear in such zones and should be under permanent monitoring (high priority monitoring).

The safety assessment of each facility which is in-

cluded to the list of high priority monitoring involves analysis of the technological environment, presence of dangerous substances, their chemical, physical, thermophysical and other properties, which reflect the danger level. During the analysis we estimated a) the probability that dangerous substances can be released and enter the atmosphere; b) the probability that dangerous process can occur within equipment, pipelines, including uncontrolled reactions.

From a safety point of view, the main emphasis is focussed on humans. As elements of the ecosystem, where the impact of accidents is possible the following components, should be considered: flora and fauna; air; water (rivers, reservoirs, groundwater, sea water); land; other features of influence.



Conclusions. The authors have studied and determined the boundaries of the territorial risk zones distribution, which are divided into several levels depending on the potential danger.

The information regarding the potential risk distribution and population density in the researched area gives a quantitative estimation of social risk. In order to obtain this, it is required to calculate the number of people affected in accordance to each possible scenario of accident and hazardous source, and then define the frequency of such events  $F$ , which would affect  $N$  and more people. As a result, the criterion of the possible risk will be defined not by the number of the singular event, but the curve built based on the various accident scenarios taking into account their probabilities.

The main idea of DEIS system development and support is to create a complex hierarchical structure enabling users to collect, process, store and sort the information. Such interaction will allow a permanent estimation to be made of any emergency cases, and, based on information support, a quick decision to be made focusing on providing a environmentally safe environment.

To ensure that the results of mathematical modelling can help in making decisions in a given situation, they should be transmitted into GIS and website online, and likewise, the data from GIS should be recognized and used in the mathematical modelling calculations. Such interaction will allow the best possible outcome to be obtained from monitored and modelled data, and, further, allow the area of GIS application to be extended.

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