The Use of Geographic Information Systems for Presentation of Emergency Planning Zones

J. Rak, L. Jurikova, D. Sevcik, and M. Adamek

***Abstract*—** This article describes the methods and use of information support in the field of the management of emergencies in the Czech Republic. Specifically, it deals with the use of specialized software and geographic information systems in the planning and preparation for assessing industrial disasters in relation to environmental risks. The introduction of this article is focused on the ways of determining emergency planning zones together with their graphic representation for the needs of prevention of damage to the environment, life and public health. Furthermore, it analyses issues from the perspective of the municipalities with extended powers as well as the regional authorities which are primarily responsible for population and environment protection in the Czech Republic.

Supporting documentation for the determination of emergency zones and their explanation are based on the legislation that is valid in the Czech Republic. Nevertheless, this presentation can also serve as an example for the solution of the given issues in other countries.

The results presented were obtained by means of the analysis and synthesis of current methods for the implementation of emergency planning. The method of analysis and synthesis was primarily used in the graphical part and the presentation. The data acquired was consequently evaluated. The desired output emerging from the comparison enables the determination of the key points for the whole process.

Thus, the main objective of the research is the creation of a map of risks affecting the environment of the municipalities with extended powers, which would increase the preparedness of the authorities responsible for the implementation of safety measures in case of industrial disasters and other events threatening the environmental security

***Keywords*—** Geographical information system, Spatial analysis, Civil protection, Environmental risk, Risk analysis, Risk mapping..

I. Introduction

ALONG with the development of human society and the increase in industrial production come the related hazards and risks. These hazards include, for instance, dangerous leakage of chemical substances, explosions of production facilities, etc. Generally, these hazards are referred to as industrial accidents. Not only do the industrial accidents threaten lives, health and the property of the population but they also threaten the environment. These hazards are, for example, contamination of water streams and groundwater, fire, contamination of soil and air, etc. Such accidents can then cause irreversible damage to the environment. The removal of these damages and all consequences requires considerable funding and extensive use of human resources and technologies. Renewal and revitalization of the environment to its original condition also requires a substantial amount of time. In some cases the renewal may take decades.

With respect to these facts, the prevention of industrial accidents represents the primary element of the protection. In the Czech Republic as well as in many other countries considerable attention is being paid to the prevention of industrial accidents. However, the full security in the field of prevention can never be guaranteed and it is therefore necessary to make preparations to cover possible industrial accidents. Mapping of the affected area, method of evacuation of persons and animals and other activities form part of this preparation. The use of geographic information system (GIS) and other specialized software within this process enables a significant reduction in costs and time required. Together with this it also contributes to the visualization and presentation of data, such as emergency zones, evacuation routes, affected areas, etc.

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II. Problem Formulation

In the Czech Republic industrial accidents are regulated by Act No. 59/2006 Coll. along with implementing regulations No. 256/2006, Coll. and No. 103/2006, Coll. These documents contain basic responsibilities for manufacturing companies and other entities handling excessive amounts of dangerous chemical substances; furthermore, these regulations stipulate the execution of security measures and compliance with the procedures for the safe handling and safe use of dangerous substances. Moreover, these documents specify the procedures and activities of the authorities that are responsible for controlling and ensuring compliance with these procedures as well as a description of security documentation (specifically external emergency plans) and identification of zones of emergency planning. Nevertheless, a more extensive description of these documents is beyond the capacity of this article. Documents are listed in the bibliography (14 and 15). For the purposes of the research, a method for the identification of emergency zones is particularly significant –

these are areas, which are supposed to be affected due to industrial accidents. The zone for emergency planning is an area around a building or a facility in which the regional authority, in whose territory the object or facility is located, applies the requirements on emergency planning by means of the external emergency plan.

A. Methods for the determination of emergency zones

Methods for defining zones of emergency planning are regulated by Decree No. 103/2006 Coll. Of the primary significance is the determination of an R parameter which represents the minimum radius for the determination of initial boundaries. Methods for calculating the parameter R are listed in the Decree. For a more detailed study Document 3 in the bibliography is recommended. For the purposes of this article the means for the presentation of these methods and searching of points of interest in the zones are important.

B. Supplementary tools for the determination of zones at risk

Specialized software tools can be especially useful for calculations related to the affected area, calculations of the extent of contamination or similar values. In the Czech Republic the most frequently used tool is “TEREX” software. Terex offers several basic modules used for the determination of areas at risk or affected areas.

C. “TEREX” software

Terex is a simple tool that allows the quick determination of areas at risk. It contains several modules by means of which it is possible to determine the effects of dangerous substance leakages, explosive systems and toxic agents. The acquired results can also be displayed as circular zones in base maps of the particular areas, which enables the visual evaluation of objects in the area at risk. The basic modules are, as follow:

a) Dangerous chemical substances – evaluation:

- models of type TOXI – reach and shape of a cloud according to concentration of toxic substance.
- models of type UVCE – effects of an air shock wave causing detonations of a mixture of the substance and the air
- model PLUME – prolonged release of the gas into a cloud, boiling liquid leakage with rapid evaporation into a cloud, slow evaporation of the liquid from a pool into a cloud
- model PUFF – one-shot release of the gas into a cloud, boiling liquid leakage with rapid evaporation into a cloud
- models of type FLASH FIRE – size of the space in which persons are at risk by a flame zone (Flash Fire, Jet Fire and Pool Fire effects)

b) Explosive systems – evaluation:

- model of type TEROR – possible effects of detonations of explosive systems based on the condensed phase, used with the aim of exposure of the surroundings of the detonation to danger

c) Toxic agents – evaluation:

- model POISON – spread of a cloud formed by dispersion of the toxic agent to a particular territory (according to the size of the territory, kind of the agent, means of dispersion and secondary evaporation)
- model ATP-45C – dependence of results on the way the substance is applied and on the strength of the wind. The model ATP-45C proves to be very rough for the evaluation of terrorist use of toxic agents and is more suitable for military use.

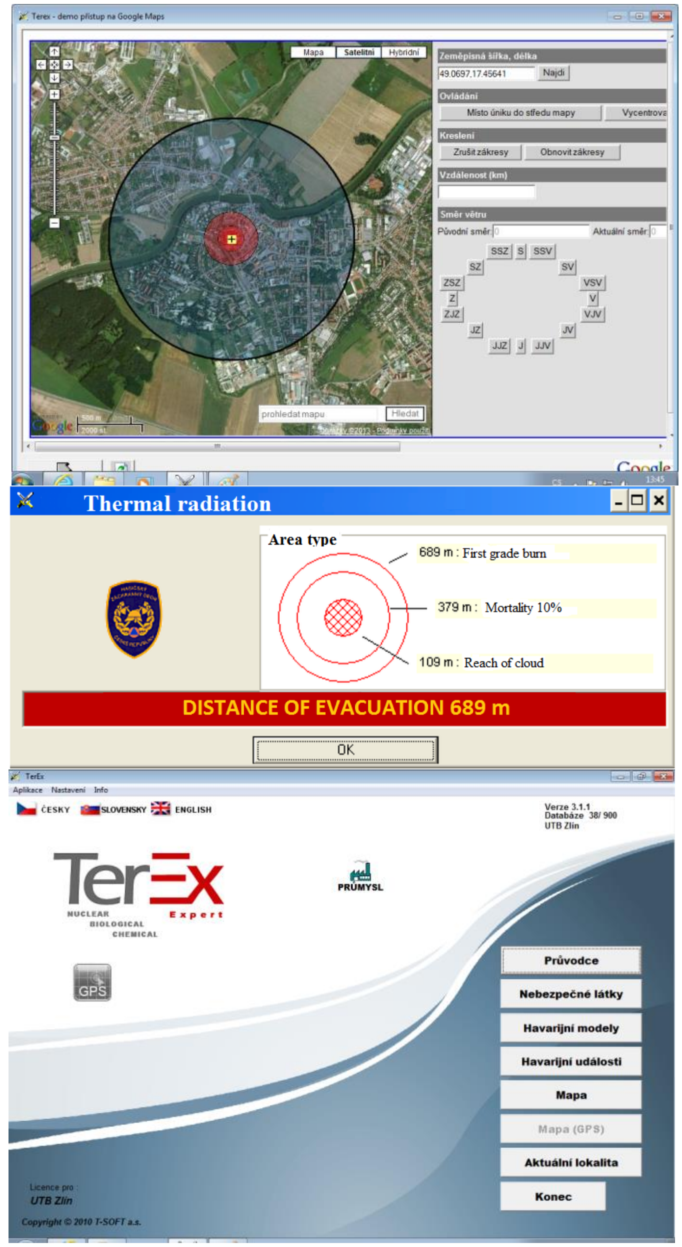


Fig. 1. Examples of "TEREX" software [28]

III. Problem Solution

A. The use of a geographic information system – the creation of a map of risks

The GIS is a computer based information system for acquisition, storage, analysis and visualization of data which has a spatial relationship to the Earth’s surface. Geographical data with which the GIS operates is defined by the geometry, topology, attributes and dynamics.

The geographical information system enables the creation of models of the Earth's surface using available software and hardware resources. This model can then be used for Land Registry records, weather forecasting, identifying flood zones of rivers, selection of a suitable location for a waste treatment plant, planning of roads, etc. [19]. Rudiments for creating maps of interest are spatial analyses and queries.

The use of the GIS extends the possibilities for the presentation and display of zones of emergency planning. It also makes it possible for the data created during the determination of emergency planning zones to be used in emergency planning and management, or other activities, such as planning of transportation of dangerous substances, etc. Within the framework of territorial units (municipalities, regions) this data serves for the creation of maps of risks, vulnerability and hazard. As a result of this, it is possible to create comprehensive maps of risks in any given territory which can be used for various purposes. In addition, it can be used for the creation of a map of environmental risks. Provided such a map is supplemented by additional information (risks of different nature – mining of mineral resources, road transport, transport of dangerous substances, etc.) it is possible for the given territory to create a map of primary environmental risks.

The fact that the GIS is capable of providing geographic information is one of its major advantages, which enables the use of spatial and other analyses. By means of these analyses it is, for instance, possible to locate rivers at risk within the zones of emergency planning, or to plan the transport of dangerous substances, including the identification of areas at risk and many others.

B. *Spatial analyses in the GIS*

Spatial analyses are sets of techniques for analysis and modelling of localized objects where results depend on the arrangement of these objects and their properties. Spatial analyses represent sets of analytical methods that require the attribute data of the studied objects, as well as their locations to be obtained.

Spatial data analyses are associated with the study of the spatial data arrangement. Specifically, they deal with a search for new relations between arrangement and objects' attributes or features within the studied area and with the modelling of these relationships in order to achieve a better understanding and predicting of progression in the area [8].

The analyses of the spatial data can be divided into several categories. Primarily, these are [8]:

- ***Used procedures of applied techniques***
- Spatial statistics;
- Map analysis – in the sense of map algebra;
- Overlay operations;
- Methods of mathematical modelling;
- Interpolation methods;
- Location and allocation methods;
- Network analyses;
- Other analyses of the area and their connections.

- ***Method of data processing***
- Visualization methods: they focus on visualization of spatial data without modification of graphical elements of data;
- Research methods: do not show the original data but use spatially modified data;
- Methods of modelling: their objective is to create an appropriate model and to verify its appropriateness for the intended purpose.

C. *The spatial character of population sheltering – the use of the GIS*

The common factor of the individual parts of the aplication process is their spatial character. Individual elements (evacuation routes, etc.) are also defined by their positions (a spatial relation to the ground). Apart from the spatial data the individual elements are also defined (described) by the attribute data. These factors predetermine the GIS for solving problems associated with planning, preparation and implementation of potential determination of emergency zones. Fig. 2 (the basic scheme of the GIS) clearly depicts a way of processing the spatial and attribute data in general terms.

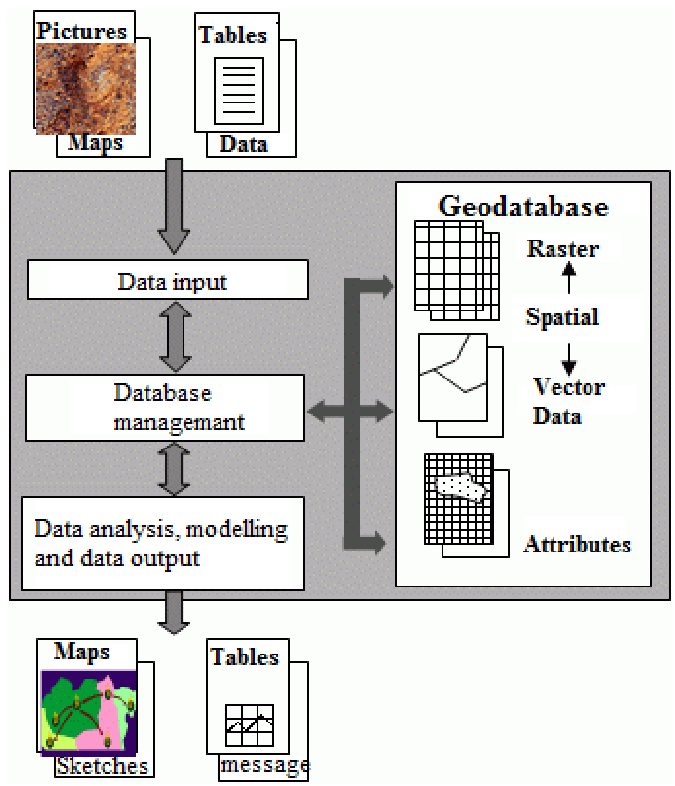


Fig.2. The basic scheme of the GIS [8]

D. *Data acquisition and processing – the fundamental problem in the process of the use of the GIS in the process of sheltering the population*

Owing to its properties the GIS is perfectly suited for solving tasks associated with planning and the possible implementation of determination of emergency zones. Nevertheless, the data and its sources (see Figure 3 Key components of the GIS) are fundamental issues for the effective use of the GIS.

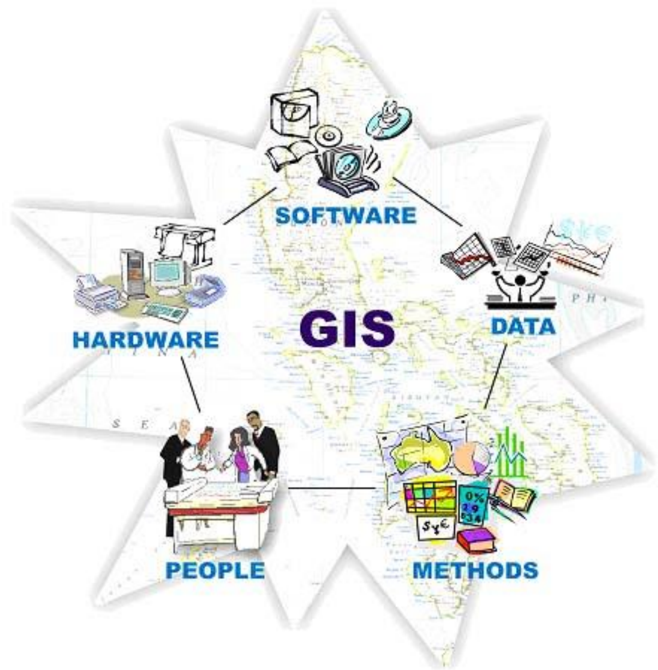


Fig.3. Key components of the GIS [29]

The quantity and quality of data correspond proportionally to the acquired outputs (results). For this reason data acquisition (sharing or creating) represents an essential building block of the entire process and it is therefore necessary to pay particular attention to this stage. In the Czech Republic and in most countries of Central Europe there exists only a limited amount of suitable data and in most cases it is necessary to generate data (to convert available data on the population sheltering and shelter infrastructure to an electronic form suitable for use in the GIS) [22].

E. Data for the GIS – types and sources

With respect to the issues being dealt with, the data is divided as follows:
- Reference;
- Thematic;

Reference data:

Reference data is the initial data, which is not thematically focused on issues being dealt with (e.g. base map of the Czech Republic, map of road and railway systems, etc.).

In the Czech Republic, the reference data has a relatively broad base. The most significant databases of the reference data are as follows [30]:
- cadastral map in digital form ("DKM/KM-D"), large-scale maps;
- base map in the scale of 1:10,000 –"ZABAGED" (the basic database of geographic data) or "RZM 10" (raster base map);
- military topographic map in the scale of 1:25,000 – "DMU 25" (digital model of the territory);
- special map of surface situation ("UMPS"), large-scale maps;
- other maps for "wider territorial coverage" – in the scale of 1:500,000;
- spatial data of basic registers of Information systems of public administration ("ISVS") – address points, the basic residential unit;
- orthophotomaps.

Thematic data:

Thematic data is primarily related to the issues being dealt with (e.g. area at risk, type of chemical substances etc.). This data is acquired in two possible ways:
- Internally, by the staff of regional and local authorities;
- Externally, by purchasing or directly using data generated by external subjects (e.g. mutual data exchange / sharing).

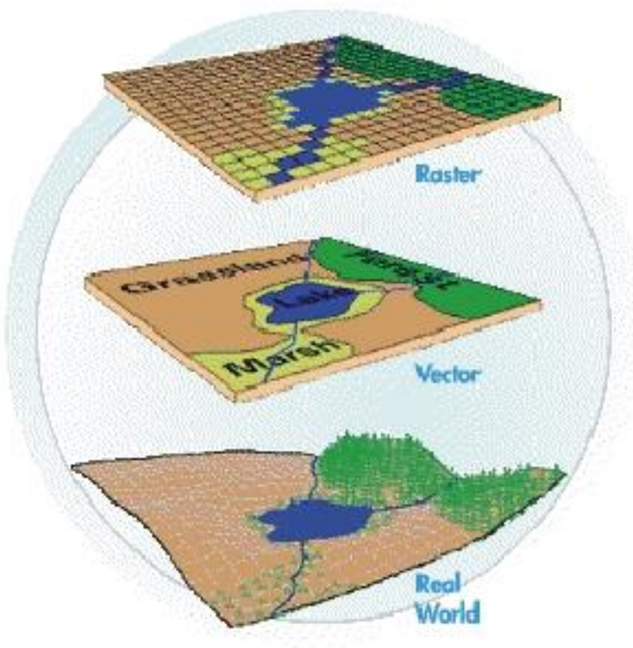
From a technical point of view the data can be divided, based on the characteristics, as follows:
- Spatial data ("Geodata"), which is directly related to surface – it describes geometric properties of an element;
- Attribute data, which describes non-geometric properties of the element (e.g. capacity of a shelter, etc.);
- Metadata, which describes content together with qualitative and other characteristics of spatial data [16, 30].

The spatial data is further divided into vector and raster data. The GIS operates with a variety of these types of data. In the world and in the Czech Republic in particular, the widely used format of the vector data is "shapefile", the native format of the ESRI software. The file name extension is SHP. In addition to their location and shape, each of the individual elements in the data layer (e.g. a river, a school, a region of the Czech Republic) bears additional information called attributes. The attribute data is stored in a table; in case of vector data of the shapefile format, the format of the database table is dBASE IV (DBF).

Geo-objects describing the same theme are joined and saved into map layers, sometimes called thematic map layers of the GIS. These themes can be, for instance, waters, roads, soil types, altitude, etc. The division of geographic data into map layers simplifies the data analysis. The actual analysis is the most common reason for the use of the GIS for reality modeling.

Each map layer is stored in a single data file that can be separately transferred and used in several mapping projects. The map layer is sometimes called the monothematic map, or just the map for short (e.g. river map, road map, etc.). According to the modeled data and its purpose, the GIS map layers can be divided into two groups – vector and raster.

The GIS operates with a variety of formats of vector and raster data. In the world and in the Czech Republic in particular, the widely used format of the vector data is "shapefile", the native format of the ESRI software. In addition to their location and shape, each of the individual elements in the data layer (e.g. a river, a school, a region of the Czech Republic) bears additional information called attributes. The attribute data is stored in a table; in case of vector data of the shapefile format, the format of the database table is dBASE IV (DBF). A more detailed description of data formats suitable for the GIS is beyond the scope of this article. More information can be found, for example, in [3], [8].



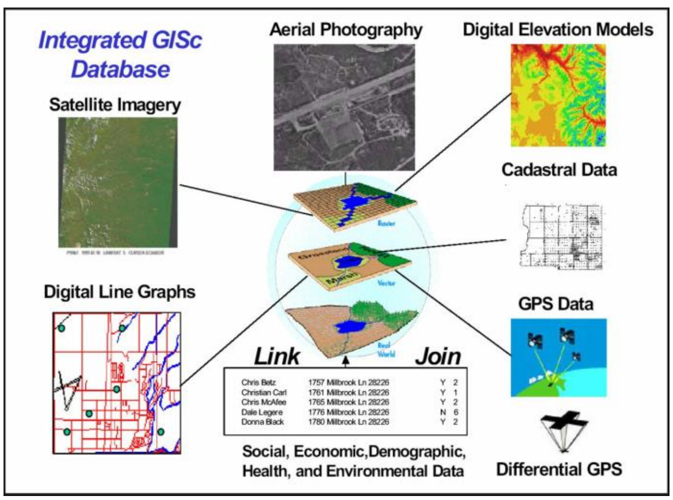


Fig.4. Reality model in GIS. [11], [31].

A. An example of the use of GIS for determination of the area at risk during the transport of dangerous substance

For the purposes of this article, locating of the area at risk during the transport of dangerous chemical substance serves as an illustrative example of the use of spatial analyses in determination of environmental risks. In the said area the transport of dangerous chemical substance from point A to point B is to be accomplished. The task is to determine possible environmental risks related to this transport.

The selection of a route and determination of the area at risk (based on the range of possible accidents gained by a calculation in "Terex" software) + the location of the rivers in the zones that can be affected, together with consequent contamination of lower sections of these rivers.

Fig. 5. depicts points A and B together with the transport route of the dangerous chemical substance. The figure further shows the location of the zones near the transport route which could be affected by DCS; the zones are located by means of the spatial analysis in Terex software, using the knowledge of a damage radius of the leakage or explosion of dangerous chemical substance.

Another part of the figure represents the location of rivers that are likely to be affected. The sections of the rivers that would be directly affected by dangerous chemical substance leakage are highlighted, together with their lower sections.

The creation of the map of environmental risks.

Fig. 6 depicts the final map of environmental risks connected to the transportation of DCS. The presentations of risks in the form of a map can considerably increase the efficiency and transparency of risk visualization.

Based on the creation of the map of environmental risks it is possible to adjust the security measures in order to ensure a higher degree of security during the transport of the dangerous chemical substance. For rivers at risk it is possible, for example to reduce the speed of a vehicle in the area at risk etc. Therefore, such information helps to streamline the work of the security forces and eventually reduce the costs if the system is employed. Maps of environmental risks makes it possible to present in quite a simple way a large amount of information, which is a great advantage compared to conventional methods (tables, calculations and text).

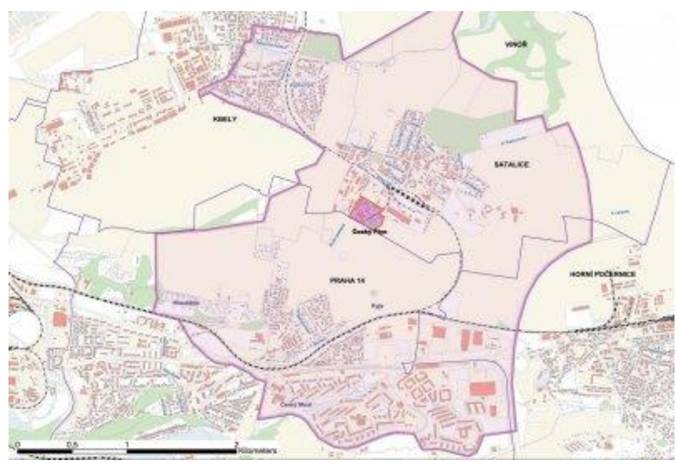


Fig.5. An example of determination of emergency zones.

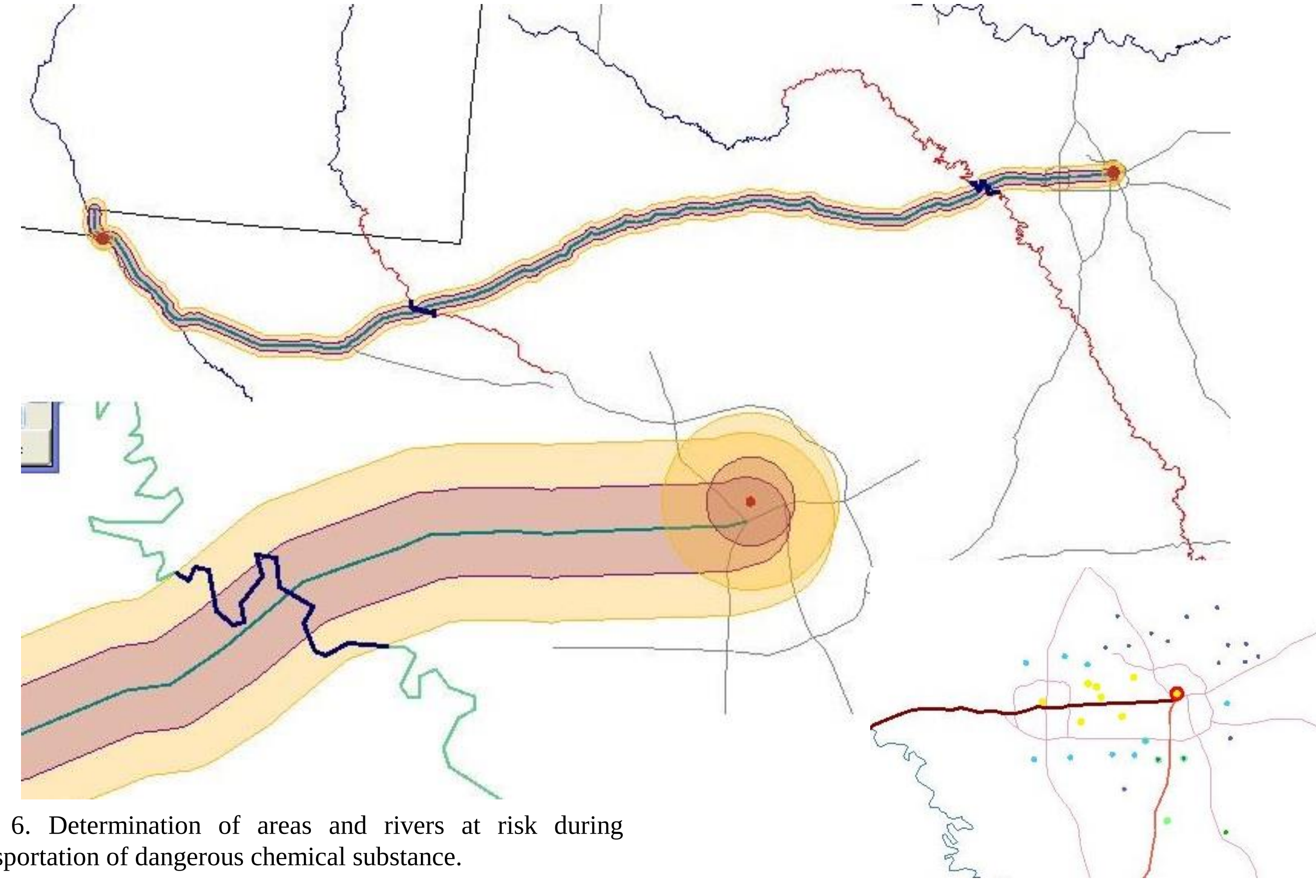


Fig. 6. Determination of areas and rivers at risk during transportation of dangerous chemical substance.

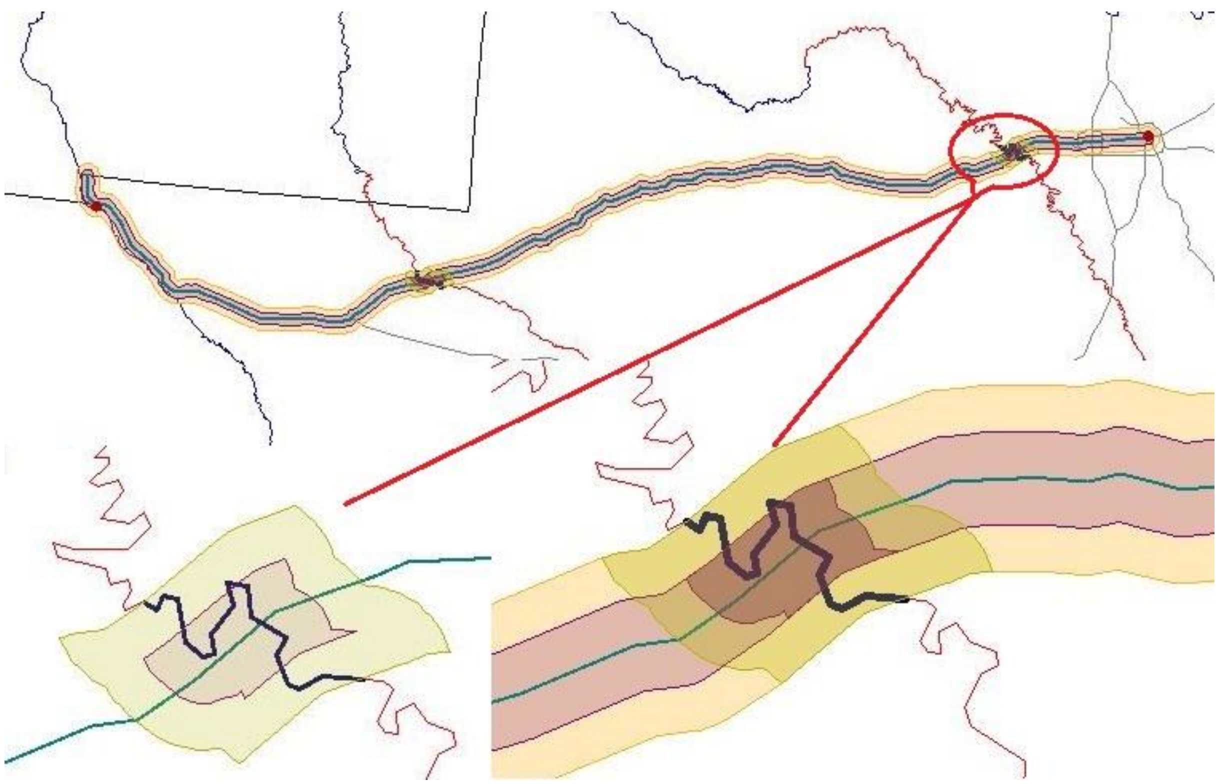


Fig. 7. The map of environmental risks connected to the transportation of dangerous chemical substance.

IV. Conclusion

The use of the GIS in determining and presenting environmental risks is an effective solution. The creation of maps of risks allows the reduction in the time spent in the evaluation of risks and it also simplifies the whole process. Owing to these qualities it seems to be the optimal solution. One undeniable advantage of the GIS is the possibility of the use of spatial analyses and the visual presentation of the acquired results. However, there are also certain disadvantages related to the GIS. It is, for instance, the requirement for large amounts of data in a particular format to be provided. Such data is not always available and it must often be modified or even created. Another crucial condition is knowledge of information technologies by the staff responsible for the emergency management and security. In the Czech Republic the wider use of information technologies is often rejected. However, in the course of time the trend for increasing computer literacy of the staff together with the growth in digital data required for the needs of the GIS are anticipated. From the perspective of the GIS, in particular, there is a space for development of spatial analyses and its interconnection with modelling methods. Thanks to this interconnection it will be possible to map risks with greater accuracy and in a superior quality. As an example of modelling in the GIS, flood prediction using modelling of the flow of rainwater based on the knowledge of slope of the terrain can be mentioned as well as direction and size of a cloud of dangerous chemical substance based on the knowledge of concentration of the substance together with direction and strength of wind and other variables. Not only do these activities predispose the GIS for the extensive use of environmental security but it is also generally of use in the field of emergency management and other related areas.

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