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NASYP: Online expert tool on the control of major-accident hazards involving dangerous substances

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Abstract

NASYP is an online Geoportal tool being developed in cooperation with state and regional authorities to improve insufficient practices based on implementation of Directive nr. 2003/105/ES on the control of major-accident hazards involving dangerous substances. The tool is applicable for managing the permits, reporting and regular monitoring issues. Furthermore, it's applicable for a risk assessment and a rapid management of disasters in the initial phase. There're simple modeling tools included to simulate early stages of the contamination caused by disasters occurred to be used for decision making and effective use of emergency services. In this manner, there're low atmospheric and surface water pollutions taken into account. For the study area, Liberec region was chosen covering the area of 3,163km2 and containing 533 potentially dangerous objects categorized accordingly to the Directive nr. 2003/105/ES. The model simulations are responding to daily hydrological and meteorological situation, a capability of automated updates from databases operated by the Czech Hydro Meteorological Institute, and communicate with databases of substances operated by the regional authorities. NASYP is suitable especially for the "N" class of the operators defined in the Directive, where because of smaller amounts of stored dangerous substances the safety measures and regular inspections are limited.

Key words

Spatial data, geoportal, risk management, modelling.

Anotace

NASYP je soubor online nástrojů pro Geoportál, který je vyvíjený ve spolupráci se státními a regionálními orgány s cílem zlepšit postupy související s implementací směrnice č. 2003/105/ES o kontrole nebezpečí závažných havárií s přítomností nebezpečných látek. Tento nástroj je použitelný pro řízení procesu udělování povolení, podávání zpráv a pravidelného sledování problémů. Dále je použitelný pro vyhodnocování rizik a rychlé řízení záchranných prací v počáteční fázi nehod. Jedná se o jednoduché nástroje pro modelování, které umožňují simulovat počáteční fáze kontaminace způsobené katastrofami, a proto je vhodná jejich aplikace pro rozhodování a efektivní využití záchranných prostředků. Pro modelování šíření se využívají vlastnosti atmosféry a povrchových toků. Jako referenční oblast byl zvolen Liberecký kraj o rozloze 3163 km^2, který obsahuje 533 potenciálně nebezpečné objekty zařazené do kategorií podle směrnice č. 2003/105/ES. Modely reagují na každodenní změny hydrologické a meteorologické situace, přičemž systém dokáže automaticky aktualizovat data z databází provozovaných v Českém hydrometeorologickém institutu a komunikovat s databází látek publikovanou krajskými úřady. NASYP je vhodný především pro tzv. „N“ třídy operátorů definovaných ve směrnici, kde jsou z důvodu menšího množství uložených nebezpečných látek omezená bezpečnostní opatření a pravidelné kontroly.

Klíčová slova

Prostorová data, geoportal, krizový management, modelování.

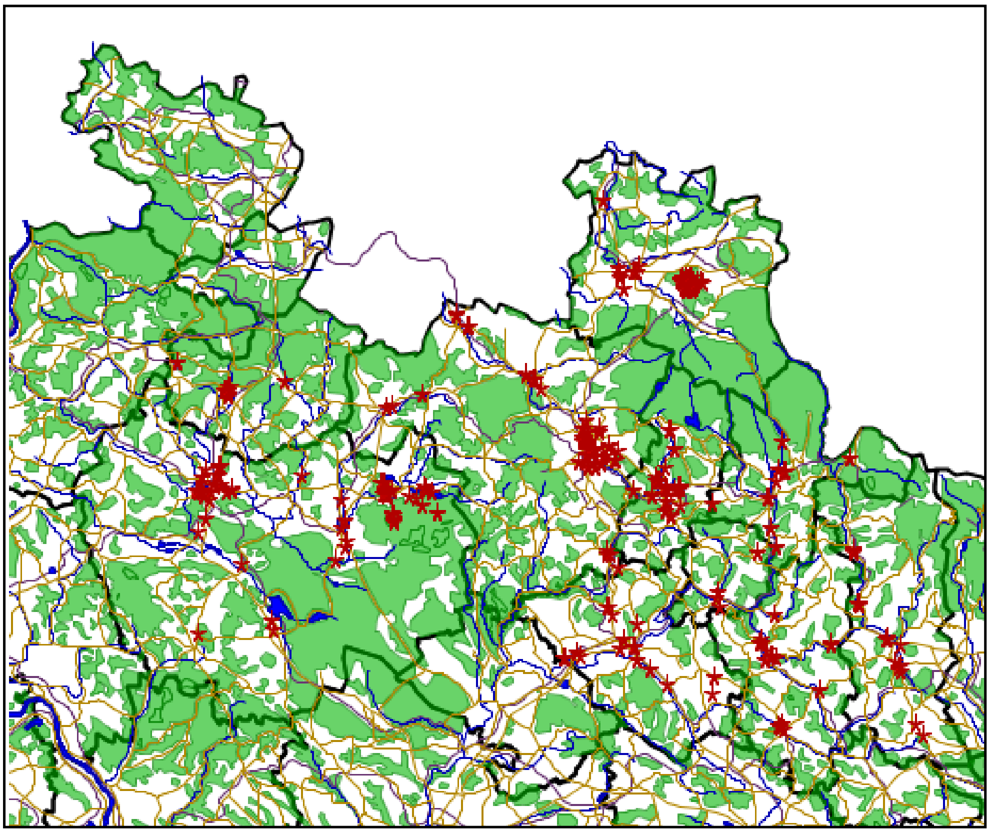

Figure 1: Places with dangerous substances in Liberec region.

Introduction

NASYP is a prototype of a prevention system of major accidents with respect to potential sources of the risks in harmony with the implementation of the directive of the European Parliament and the Council No.2003/105 in new states of EU. The final output of the project will be represented by the uniform geoportal component of evaluation of the risks, supplemented with an innovation module system for the formation of applications. This could be effectively used in the sphere of integrated control of risks which will enable a simple looking at the existing state, and thanks to this system it will even simplify a following actualization of information, classification, etc. The results should contribute to the Law No. 59/2006 of the Collection of Laws on prevention of major accidents in the Czech Republic (implementation of the directive of the European Parliament and Council No. 2003/105/ES from December 16th, 2003 in the Czech Republic) and the relating operating regulations. Within the frame of the project, the information has been collected and elaborated clearly in a simple form, familiar to the users (tables, data bases, maps). So, the results could be suitably used for a purpose of Regional authorities for the fulfillment of their duties according to the law and for the elaboration of regional accident plans. The acquired data could also contribute for better evaluation of cases of synergy effects of individual objects registered according to the law which have not been uniformly evaluated yet. Data are subsequently used for a selection of suitable scenarios. A simple point system - till now missing in general practice - evaluating the receiver of the risk - will make part of the project, in the year 2010. The system of preventing major accidents will be, in the form of regional scenario, prepared for selected regions in Czech Republic and Poland. Within the frame of international cooperation, even a testing system across the borders (Czech Republic/Poland) is planned. The project NASYP is consisting of modeling and database applications. The issue of risk management in GIS is followed up also in the article of Alhawari.

Technical Solution

The technical solution of NASYP project is based on a web application (geoportal), which is connected to the four main components:

1. Database (created and managed in PostgeSQL) containing the spatial data. These data sets describe objects in Liberec region keeping the risk material (e.g. gas stations,

chemical plants or store of explosives) – Figure 1. The current version of the database contains except above mentioned items these tables – an overview of risk materials and their characteristic (codes, labels etc.) and codetables. In the database, buffers representing risk zones around spatial objects were created.

2. Database (web) client to database updating and exploiting, including interconnection to partners' tools (e.g. transfer of results of controls or date of a next control). The client is developing in cooperation with final users. They declared following requirements – possibilities of filtering according selected data attributes (a type of danger material), access rules for all types of users, including public, pre-prepared compositions for all types of users.

3. Geovisualization framework (Figure 2) – a part of geoportal which ensures the cartographic visualization of data. This component is very important in the terms of efficiency and conveniences. The database could be interconnected to many another visualization tools (e.g. Quantum GIS, Google Earth etc.). Users (the parts of crisis management in the Czech Republic) are not forced to work with a potentially unsafe web solution, but they can use the close desktop solution (database & desktop geographic information system /GIS/) as well. Geovisualization tools are based on a technology developed called Geoportal4everybody. It is solution supporting visualization and sharing of spatial information, but also providing Web based analysis and on line vectorization. The components of the Geoportal4everybody could be also easy integrated with other systems. Risk mananagement and geoportal solutions are also dealed by authors Giuliani and Peduzzi.

4. Modeling tools (details in the chapter Modeling)

Modeling

Surface water

The project is capable of solving simple linear pollution transport scenarios for surface streams in the pilot region. For these model calculations the data are prepared using GIS software (Khan, Akhter, Ahmad, 2011). In the vicinity of the watercourses, there're selected areas with potential leaks polluting substances. Concerning leakages to surface water clusters with a radius of 1 km are used to identify possible pathways of the contaminants. The model calculates two basic variables. The first variable is the time for a contaminant to reach from point A to point B concerning the current flow. The second variable is the concentration of

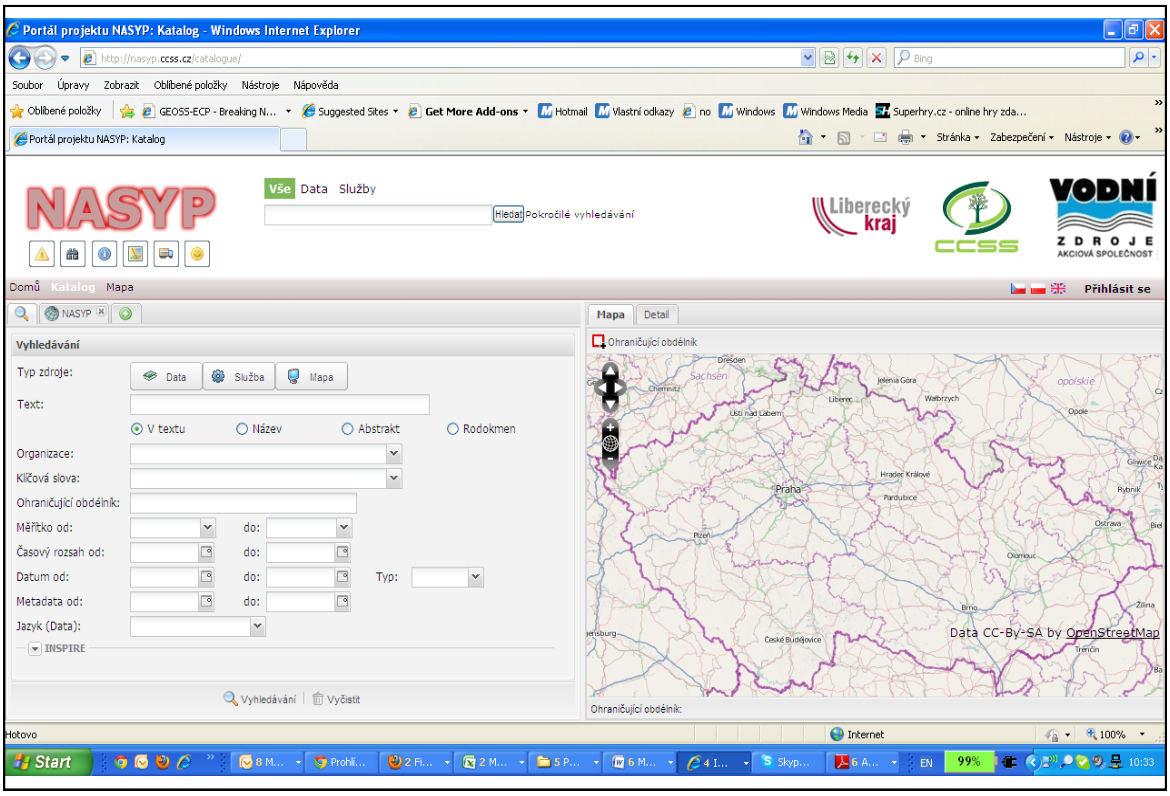

Figure 2: Nasyp Geoportal.

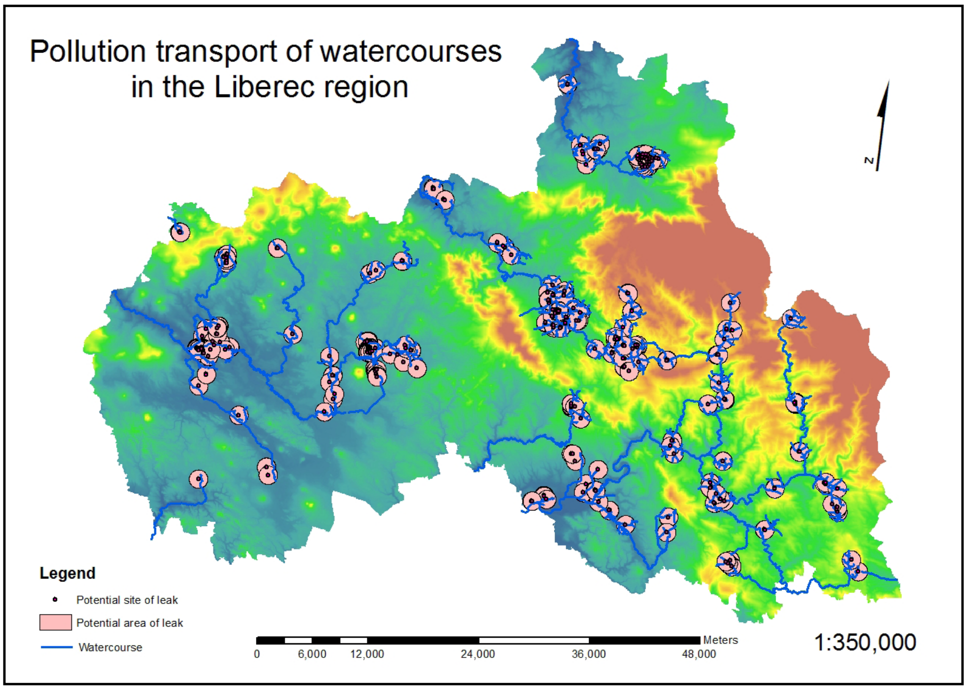

Figure 3: Streams and potential threats for surface water contamination – Liberec region, Czech Republic.

pollutant at a particular time. Among the required data for calculations (the hydrological model) we can identify the flow rates at specific sites, data on individual sections of the streams and data on the quantity of discharged pollutant. General possibility of solving are also given in article by Fewtrell.

For time measurements for contamination transport from point A to B, the method of sections is applied. With use of interpolation and data modification, we know the average flow rate of individual sections of the watercourse and their lengths. Time for a pollution arrival from the upper end of the section to the bottom end = length / speed. This calculation is performed for all sections related to the possibly contaminated site and monitored at the end point. The resulting times are summed to create the final time.

Concentration measurements of the pollutants are determined through flow rate interpolation in individual sections. Furthermore, we know the amount of spill and the time at which the contaminant escaped. First step is to find out the mass of water flowed during the contaminant discharge time (V = Q * S). Secondly the volume is increased by volume of the contaminant itself. The sum of share volume and contaminant concentration occurs to us at that time. For the next sections we will consider, as if the contaminant flowed at the top of this section which consequently changes the water flow on underlying sections. The measured concentration value is used for each section separately.

The simplicity of this model allows a rapid use in emergency situations. Due to the large scale of the model area just the principle of adjective diffusion is applied. Available data do not allow more detailed modeling. Interesting case study is presented by Gurzau.

Air pollution

Flow field modeling

A calculation of the three-dimensional flow fields in the boundary layer of the atmosphere in the study area is performed by the computational fluid dynamics (CFD) code as a numerical solution of the system of Reynolds averaged Navier-Stokes (RANS) and continuity equations. The Reynolds stresses tensors are calculated following the Boussinesq hypothesis. The isotropic coefficient of turbulent viscosity μt is obtained from the turbulent kinetic energy and its dissipation rate using the standard k - ε model of turbulence closure (Jones and Laudner, 1972). Numerical steady state solution of the system of equations was performed by the standard method of control volumes in a three dimensional non-orthogonal boundary fitted grid using a collocated variable arrangement in hexahedral cells. The lower boundary of the computational domain is delimited by the detailed model of the surface in the study area in the altitude map. The domain of 11000 m by 11000 m in the horizontal and 1000 m in the vertical was gridded with a 220 × 220 regular grid in the horizontal plane and a 27 node grid in the vertical direction. A vertical step in the hexahedral grid was designed as a boundary layer i.e. was increasing

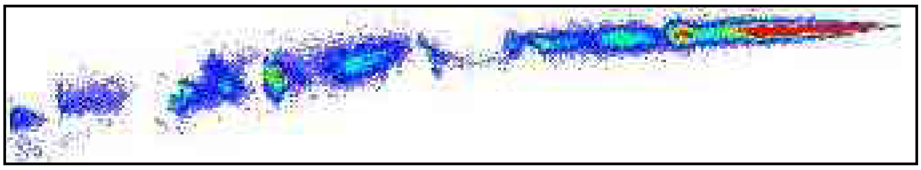

Figure 4: visualization of operated particle dispersion model.

in a direction towards the upper boundary of the computational domain by using a factor 1.2 for the distance increment. The first vertical grid node was adjusted 1 m above ground surface.

The calculation of the flow field in a neutrally stratified PBL was performed for eight basic wind directions set through the upstream boundary conditions as lateral inlet boundaries of the computational domain. The inlet wind profile was set through the logarithmic law.

At the inlet profiles for k – ε turbulence modeling is set estimation approached by Richards and Hoxey (1993). At the lower ground surface boundary of the computational domain, both components of the turbulent energy were standard determined by the wall functions.

The second order upwind approach was used as the spatial discretization scheme. A temporal discretization was achieved by an implicit scheme. The continuity was resolved through a pressure correction of the SIMPLEC type (Van Doormal and Raithy 1984). To get a steady state solution, the iterative process was converged after about 230 iterations.

Particles dispersion modeling

The modeled three-dimensional vector flow field generated input data for the related Lagrangian simulation of transport and diffusion dispersion of passive, gravitationally non-falling (or neutrally buoyant) model particles assumedly emitted from a point source. Local transport motion of each particle is determined by the velocity flow vector active in the partway of this motion. This vector is obtained through linear interpolation of the input flow field. The motion of the particles simulating the dispersion through turbulent diffusion is based on solution of the Langevin equations. The components of the fluctuation vector are given by Equation:

$$u_i(t+\Delta t) = a u_i(t) + b\sigma_{u_i}\xi + \delta_{i3}(1-a)T_{Lx_i}\frac{\partial}{\partial x_i}\left(\sigma_{u_i^2}\right)$$

The new position of the passive, gravitationally non-falling particles is caused by the joint action of the two vectors.

The amplitude of the modeled turbulent fluctuations including random parameter ξ varies in the range delimited by b = (1 – a2)1/2; a = exp(-Δt/TL); TL is the Lagrangian integral time, which, in agreement with the approach of Zannetti (1990), was set at 200 s in the horizontal plane and 20 s in the vertical plane. Variances of wind speed components σu were estimated from the modeled turbulent kinetic energy: σu = 0.91k1/2, σw = 0.52k1/2. The relevant constants are taken from the work of Panofsky et al. (1977) and correspond to neutral stratification. The time step for the motion of passive particles Δt was selected as 5 seconds. The emission flow of the source was set at 2000 fictive particles per Δt.

Conclusions

The development of web-based open solution for risk management represents a modern and very important part of geomatics and geoinformatics research. It is necessary to emphasize benefits of such a solution:

- Relations to international web standards enable the next development and/or modification of application as well as the interconnection to the similar solutions (e.g. external databases, other clients etc.).
- Web applications are accessible anywhere through the Internet connection. It is possible to use them not only in offices but in real emergent situation the mobile units can work with such application. This is important in conjunction with growing number of mobile hardware in crisis management.

Discussion

- The current version of NASYP application does not represent a final situation. Based on users‘ tests and consequent requirements, we plan these changes:
- Adaption of application to mobile hardware tools,
- New codelist of emergent materials,
- Interconnection to other similar applications (e.g. Flooding portal of Liberec region).

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