Geo-Information Technology for Assessment of Accidental Chemical Pollution

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Abstract

A system for assessment of accidental chemical pollution is being developed and the first version of a prototype has been completed. The geo-information approach developed by one of the authors for assessment was used. This approach uses the mathematical models and methodological developments in geo-information systems for assessment of chemical hazard zone dimensions. The zones are represented on computer maps of the region. The system structure is described in the paper.

1. Introduction

It is known that the number of chemical accidents has grown all over the world during the last few decades. Chemical accidents are some of the largest sources of environmental chemical pollution. Consequently, there is a need for spatial information about air pollution for emergency management and mitigation purposes. It is necessary to use computer systems and geo-information technologies for more effective problem-solving. Currently, GIS has no tools for the assessment of the danger to the atmosphere resulting from chemical pollution. Therefore, it is necessary to develop GIS tools for modelling chemical pollutant dispersal in the air and the spatial analysis of the information about atmospheric chemical pollution resulting from chemical accidents.

An approach to defining danger zones in a region is suggested in Polichtchouk (1997, 1998). In order to define the danger zones, ordinary environmental quality indices are not suitable. Therefore, new indices of chemical pollution are suggested for identifying the zones.

2. Danger zone determination and object vulnerability assessment

A danger zone is a part of the territory inside which a value of the pollution index, Q, exceeds some *maximum permissible level,* Q_0, causing no hazard to human health and one's ability to work. The danger zone boundary is determined from the condition

$$Q=Q_0. \qquad (1)$$

Usually the value of Q_0 is determined on the basis of the results of complex medical-biological studies of the influence of environmental pollution on human health, taking into account the joint pollution of all the components of the environment (air, water, soil, biota, etc.). As far as we know, such medical-biological studies aimed at the determination of the Q_0 value, have not been accomplished yet. Therefore, the value of Q_0 must be estimated, at least for the purpose of emergency management, by evaluations on the basis of the environmental protection experience, taking into consideration the simultaneous joint action of the combinations of pollutants in the air. Thus, according to Polichtchouk et al. (1999) it is possible to take the value Q_0=5 for the environmental components considered further in the paper for defining a danger zone.

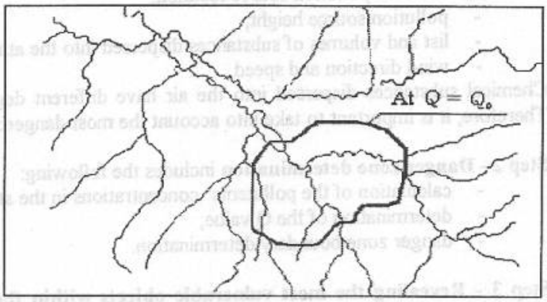

Fig. 1. Danger zone boundary

Fig.1. shows the boundary of the danger zone. There are two different cases in danger zone determination. The first case is an account of a single pollutant in the air. The second one is an account of n pollutants. The first case value of Q_0 may be chosen equal to the pollutant maximum permissible level (MPL). Index Q is determined by the expression:

$$Q = \frac{\frac{C}{C_0}}{1-\frac{C_0}{M}}, \qquad (2)$$

where C = concentration of danger substance,

C_0 = MPL,

M = danger concentration of pollutant that can bring harm to human health and cause a loss of the ability to work.

In the case of n pollutant, the Q value may be calculated by following expression:

$$Q = \sum_{i=1}^{n} Q_i\,,\ i = \overline{1,n}, \qquad (3)$$

where Q_i = value of Q index calculated by (2) for each i-th substances.

A generalized assessment procedure includes the following steps:

- **Accident identification;**
- **Danger zone determination;**
- **Identification of the most vulnerable objects within the danger zone;**
- **Assessment of accidentally released pollutants' impact on vulnerable objects and decision-making support of emergency management.**

Step 1 - **Accident Identification** is a determination of the following accident parameters:

- accident pollution source location;
- pollution source height;
- list and volumes of substances dispersed into the atmosphere;
- wind direction and speed.

Chemical substances dispersed into the air have different degrees of danger. Therefore, it is important to take into account the most dangerous substance.

Step 2 - **Danger zone determination** includes the following:

- calculation of the pollutants' concentrations in the atmosphere;
- determination of the Q value;
- danger zone boundary determination.

Step 3 - **Revealing the most vulnerable objects within the danger zone.** Examples of vulnerable objects are kindergartens, schools, etc.

Step 4 - **Assessment of accidentally released pollutants' impact on vulnerable objects.** Concentration of the pollutant at the object location is calculated. This information may be used for the decision support of emergency management.

3. Structure of the Accident Consequence Assessment System

The structure of the accident consequence assessment system (ACACS) is shown in fig.2.

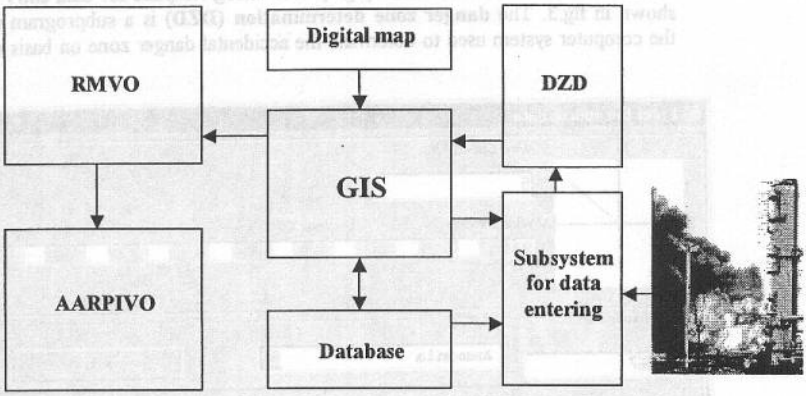

Fig.2. Accident consequence assessment system architecture

A computer systems for accident consequent assessment, ACACS, is being developed in GIS media. **GIS** (see fig.2) provides the following:

- Representation of initial information and simulation results on the computer maps;
- Determination of the coordinates of accidental sources of air pollution;
- Revealing the objects within the danger zone.

The external **database** (see fig.2) of the given system is intended for the collection of information about potential pollution sources (accident pollution source location, pollution source height, list, and volumes of substances thrown into the atmosphere, etc.) and data on the pollutant. The **database** includes over 2000 records of dangerous pollutants that can be dispersed into the atmosphere as the result of an accident. This database includes the following chemical substance characteristics:

- Maximum permissible level for a residential district;
- Maximum permissible level for a industrial district;
- Danger class;
- Impact on health (carcinogenic, mutageneous, embryonic toxic, neuro-toxic, eco-toxic);
- Biologic accumulating;
- Chemical and biochemical stability, etc.

The **subsystem for data entering** (fig.2) receives initial information about an accident and transmits it to **DZD** (fig.2). The dialog template for data entry is shown in fig.3. The **danger zone determination (DZD)** is a subprogram of the computer system used to determine the accidental danger zone on basis of

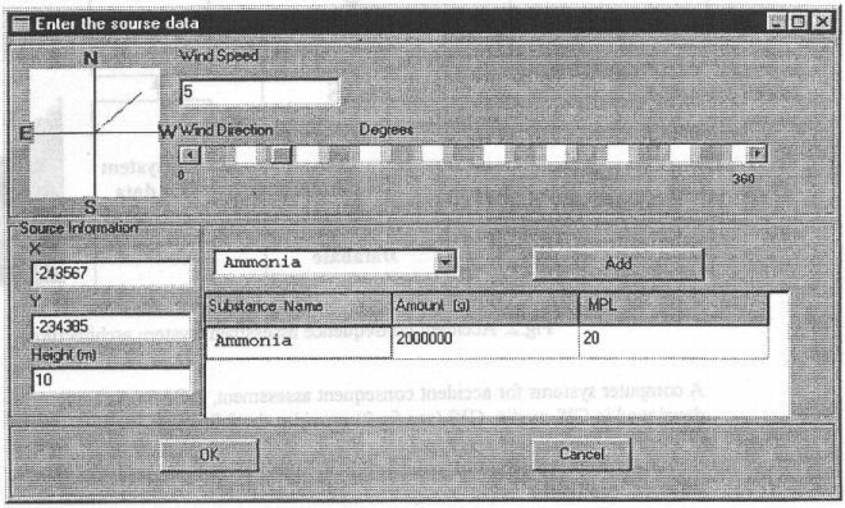

Fig. 3. Dialog form for data entering.

modeling chemical dispersion in the air. The special grid-lay on the digital map, the concentration, and the Q value for every substance is calculated at every cell. The cells with a Q value greater than Q_0 form the "blot"--the boundary of the danger zone. Dispersal modelling and calculation of the pollutant concentrations use the Gaussian model.

Information from the **database** and results of modelling and calculations are represented by means of **GIS** on the **Digital Map** (fig.2).

Subsystem **RMVO** (revealing the most vulnerable objects) is intended to point out the degree of vulnerability of each object impacted by the accident (fig.2). This information is transmitted to the subsystem of assessment of accidentally released pollutants' impact on vulnerable objects **(AARPIVO)** for calculating the concentration of the pollutants at the object's location. The information is used for emergency management purposes.

The ACACS uses ArcView 3.0 GIS software. It has been developed using the Avenue programing language that is included in ArcView 3.0. When the program runs the DLL (dynamic link library), the unit is called. This unit has been developed using Delphi 4 and it includes software for data entry and a subprogram for determining danger zones. The database uses dBASE tables.

The database interface system is the Borland Database Engine (BDE), which provides access to the local and remote database servers. The subprogram of the RMVO was developed using the Avenue program language.

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