APARATURA

BADAWCZA I DYDAKTYCZNA

Computer application for predicting pollution of the Tisza River in emergency situations

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ABSTRACT:

The software and mathematical model for forecasting the pollution of rivers in emergency situations is described. This software contains a database of maximum allowable concentrations to assess the health hazards of people. The use of this software is grounded in the conditions of the Tisza River.

Zastosowanie komputera do przewidywania zanieczyszczeń rzeki Cisa w sytuacjach zagrożenia

Słowa kluczowe: rzeka Cisa, program komputerowy, sytuacja zagrożenia, modele przewidywania zanieczyszczenia

STRESZCZENIE:

Opisano program komputerowy i model matematyczny do przewidywania zanieczyszczenia rzek. Program zawiera zbiór dopuszczalnych stężeń w celu oszacowania niebezpieczeństwa dla zdrowia ludzi. Zastosowanie tego programu jest przystosowane do warunków rzeki Cisa.

1. INTRODUCTION

Surface waters pollution and mainly rivers pollution, represent a significant issue, they need a special attention, as they represent the main sources of drinking water and water supply.

The studied problem appears especially in case of accidents, when a large number of toxic substances move in the riverbed. And this represent a significant threat to the people who use the water. In case of transboundary rivers, in case of accidents the water pollution becomes an international subject, as toxic substances, which were released into a river in one country, migrate to the territory of others. Therefore, it is very important to forecast the spread of toxic substances to certain point along the riverbed, the concentration of pollutants in this point, and to determine the risk degree of water use to the population.

Tisza is one of this type of transboundary rivers, and history showed that it is important in view of transboundary transport of toxic substances in case of various accidents. This river is the longest tributary of the Danube. Its length reaches 966 km, of that 201 km are in Ukraine. It flows over the territory of Romania, Hungary, Slovakia and Serbia.

For this, we developed a software, that would give a quick, efficient and accurate forecast regarding the spread of dangerous substances in Ukraine on the Tisza River in cases of an accident. Its actual task is to determine the danger and using appropriate measures help to eliminate the accident's hazard.

2. SELECTION A PREDICTION MODEL

The proposed model would allow to asses and predict the spreading of pollution in case of an accident through a river. This is done with the help of a software, that is based on this model, and so it must user friendly, enough accurate and quick to estimate the time of release at specified points and the concentration of pollutants in these points, also to assess the danger to the population health.

Thus, the software must contain the necessary databases for the river data that are necessary in the calculations. Some parameters have to be entered in the context of a particular situations, that provides an accurate forecast. Based on the mathematical model of the application, called «RESit», the basic empirical regression equations is used [1].

Characteristics, which must be entered into database of the software, are:

- catchment area:
- catchment area at spill site, m^2 (A_{pol});
- catchment area at measurement point, m^2 (A_{prof});
- a distance from the point of contamination to the forecast point, m (D);
- annual river runoff, m^3/s (R).

Variable characteristics, which has entered for forecasting are:

- the mass of the pollutant that was spilled into the water, mg (M);
- measured runoff of water at the point of pollutant spill, m^3/s (Q).

To facilitate the analysis of uneven flow, a characteristic of the dimensionless area and dimensionless relative water runoff can be simplified.

Average catchment area (A) include a mean of catchment area at spill site (A_{pol}) and catchment area at measurement point (A_{prof}), and determined, as:

$$A = \frac{A_{pol} + A_{prof}}{2}.$$

A formula of dimensionless area (A_{rel}) is

$$A_{rel} = \frac{A \cdot \sqrt{g}}{R},$$

where R – annual river runoff (m^3/s, R), g – acceleration of gravity.

Dimensional relative runoff (R_x) is defined as

$$R_x = \frac{Q}{R}.$$

After accepting these simplifications, it is possible to estimate the initial characteristics of the distribution of water flow in the river.

Equation for the velocity of peak concentration (V_p) (m/sec):

$$V_p = 0.152 + 8.1 \cdot A_{rel}^{0.595} \cdot \frac{Q}{A}.$$

An equation of a possible maximum speed (V_m) (m/sec):

$$V_m = 0.2 + 40.0 \cdot A_{rel}^{0.595} \cdot \frac{Q}{A}.$$

The most possible peak travel time (T_p, h) to the forecast point is defined as

$$T_p = \frac{D}{V_p \cdot 3600},$$

where D – distance, m.

For unit peak concentrations (C_{up}), the regression equation is used

$$C_{up} = 857 \cdot T_p^{-0.760 \left(\frac{Q}{R}\right)^{-0.079}},$$

where Q – measured water runoff at pollutant spill section, m^3/s.

Peak concentration (C_p, m^3/s) can be calculated by the formula

$$C_p = \frac{C_{up} \cdot M}{Q},$$

where M – pollutant mass, mg.

With these formulas, the numerical model forecast the pollution and its main characteristics: the peak travel time and concentration at a certain distance from the point of pollutant spill.

3. MAXIMUM ALLOWABLE CONCENTRATION

An estimation of the danger to the health of the population at the forecast points is determined by comparing the predicted concentration at the point, for given forecast, with the maximum allowable concentrations of the content of toxic substances in water of surface water bodies. Hare a database of maximum allowable concentrations of substances that could migrate to Tisza in emergency situations adopted in Ukraine was introduced [2].

4. «RESIT» DESCRIPTION

A «RESit» software (Fig. 1) uses the mathematical model described above, a database of constant data regarding Tisza, and database of maximum allowable concentration, that gives possibility to predict and evaluate the consequences of pollutant discharge into the water of the Tisza River. Also, there is a possibility to enter data for autonomous prediction without use of defined points on a map, with use of data, that can be entered directly in measurement by operator. A databases of Tisza and maximum allowable concentration are saved to MySQL server, where an application download data one time, and update it as needed.

In the simulation as the input characteristics, the first step is choosing of database server and specification the point for prediction of pollution (Fig. 2, 3), or manually enter the quantity, constant and situational mathematical characteristics of the points (Fig. 4, 5).

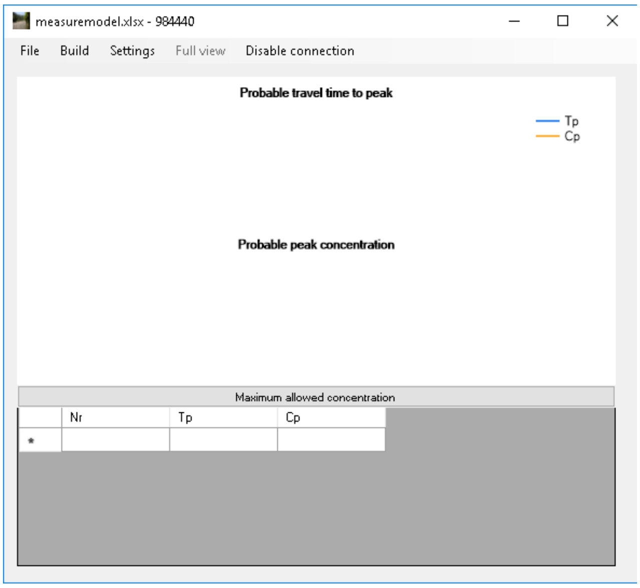

Figure 1 Initial window «RESit»

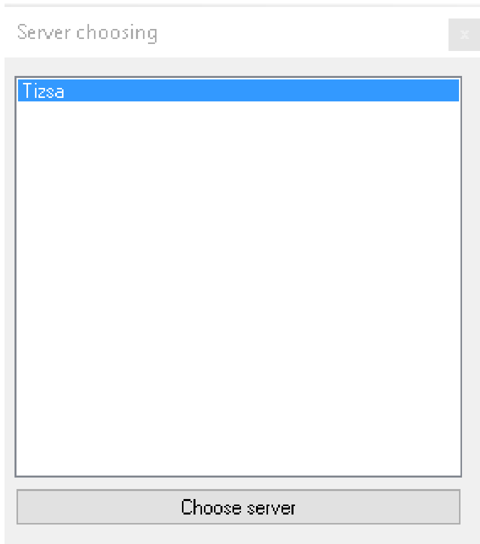

Figure 2 Select a database server and points to measure in database mode

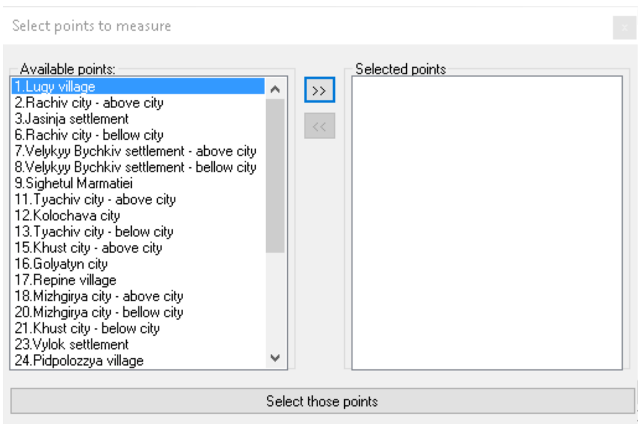

Figure 3 Select a database server and points to measure in database mode

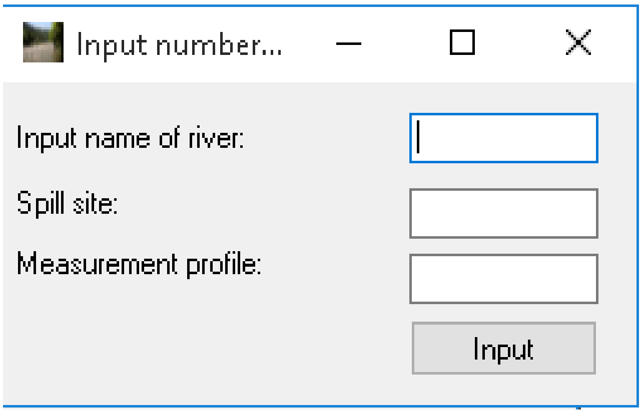

Figure 4 Entering a characteristic of points and situation input data

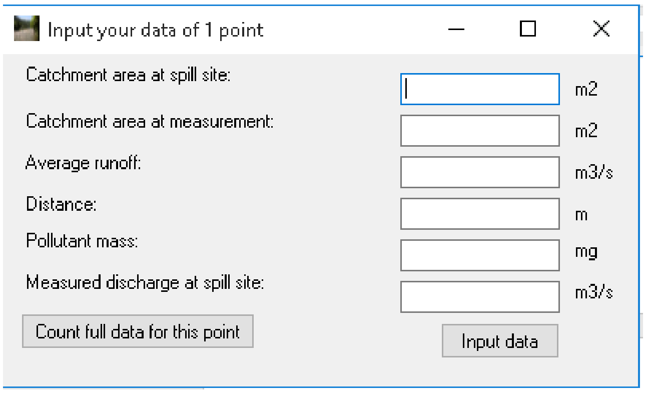

Figure 5 Entering a characteristic of points and situation input data

The second step for database mode is entering the situational data, in particular, the discharges and water consumption (Fig. 6).

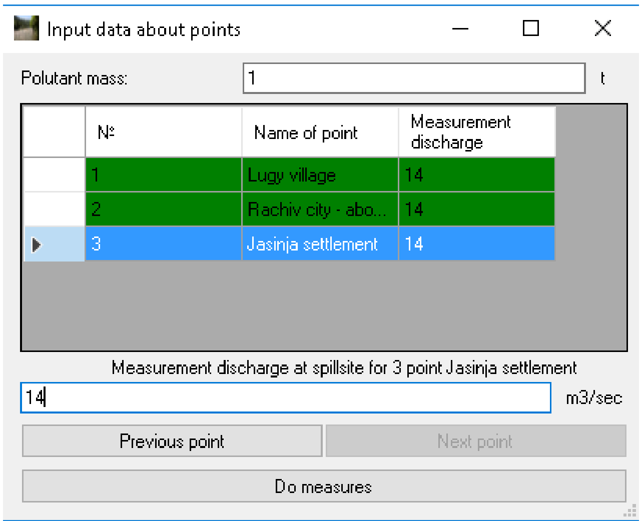

Figure 6 Entering of situational data for points

After entering these data, a result that includes charts and table data is shown. If server data is used, then there is a possibility to see a map with monitoring points placed on it, as an addition.

The prediction results are displayed as a table, linking to the map.

An example of displayed result in the form of a graph and a table is shown at Fig. 7, 8.

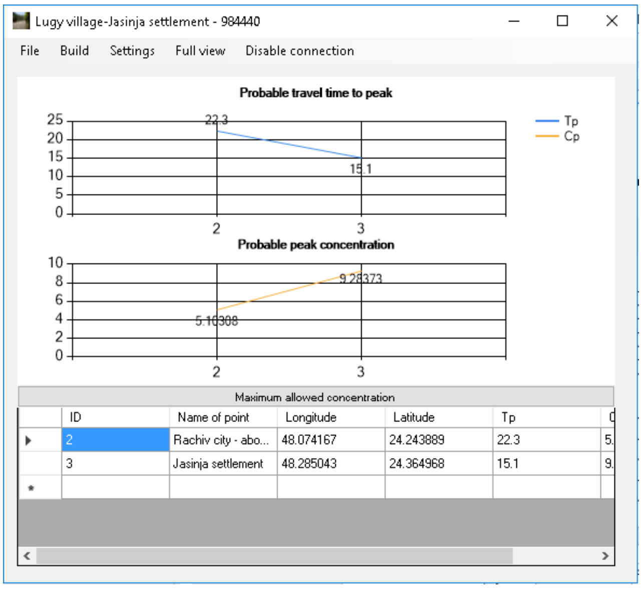

Figure 7 An example of result

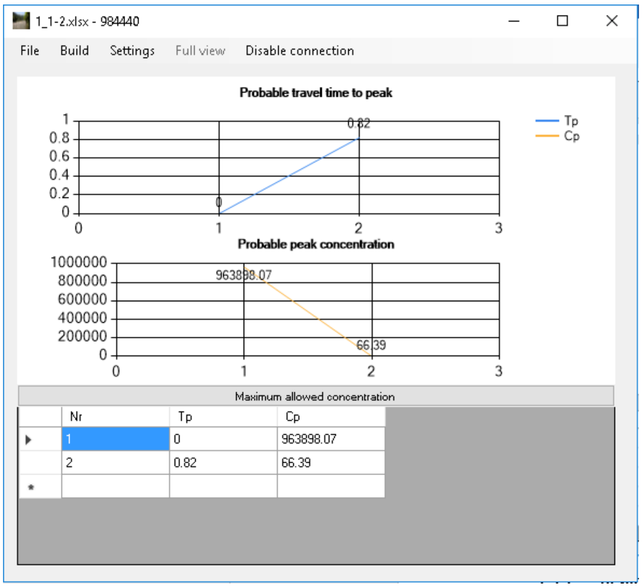

Figure 8 An example of result

The graphical result is constructed in the view of two charts that reflect characteristics such as peak travel time and peak concentration at a specific point.

A table result shows sequence number, or characteristics of point, in depends from used data and high described result characteristics, where T_p – travel time of peak, C_p – peak concentration.

Also, there is a possibility to view a result by clicking on button «Full view». After that, a window with a result in table and cartographic form will be shown (Fig. 9).

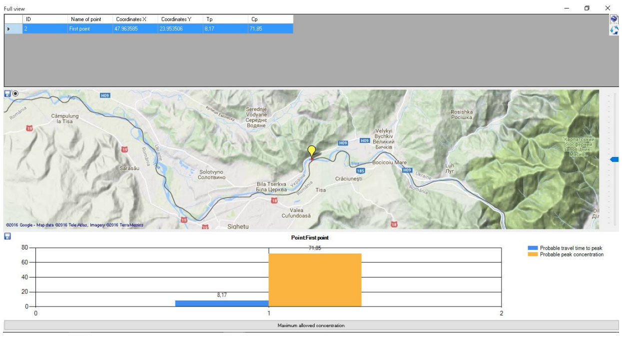

Figure 9 Window with full view

To estimate the level of danger of concentration on the graph, an axis showing the allowable value can be added. It compares a peak with the concentrations at the monitoring points.
Thus, the monitoring point, where the level of concentration of the pollutant becomes allowable, will appears (Fig. 10).

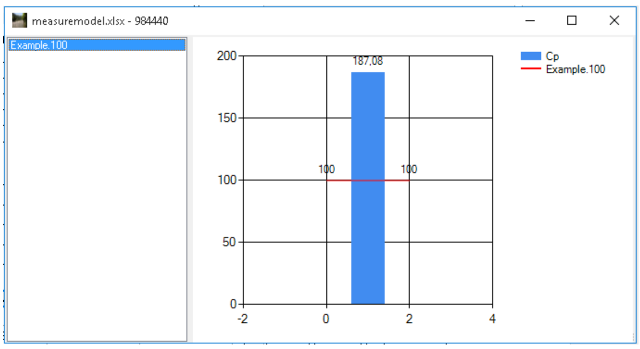

Figure 10 Comparison between a result (concentration peak) with allowable concentrations

Output data can be saved in * .xls or * .kml format for comparing RESit and such GIS software, as Google Maps, ArcGIS, QGIS, etc.
Regarding system requirements, because RESit was written with C# using .NET Framework 4.5 technology, it supports OSes like Windows Vista SP2, Windows 7 SP1, 8, 8.1, 10, Windows Server 2008 R2 SP1 (x64) or R2 SP2.

5. IMPLEMENTATION

A «RESit» software was implemented in Ecological inspection and Hydrometeorological center of Transcarpathian region.
"RESit" can be used for assessment and prediction of water pollutants consequences in accidents for other rivers, if necessary data can be added to the database.

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