AN INTEGRATED QUALITY MANAGEMENT TOOL BASED ON GIS TECHNOLOGY

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Abstract. According to the Water Framework Directive 2000/60/EC, water bodies have to achieve the good status by 2015. In order to fulfill this objective the quality management must be improved. An integrated GIS application, called GESRO, was created. It is an extension to ArcGIS that uses its functionality to automatically classify the water quality into classes based on measured values. This classification is done for chemical and biological indicators, dangerous substances, drinking water, vulnerability to nitrates and fish fauna.

Key words: GESRO, GIS, database, quality management

INTRODUCTION

The quality management of surface water is key to water management resources. Romania has to achieve important objectives regarding the status of water bodies since Water Framework Directive 2000/60/EC requires all water bodies to achieve the good status by 2015 (Normative 161/2006).

Starting from these premises an integrated quality management application has been developed using GIS technology in the frame of INWAQ (Integrated Water Quality Management System) project. After the project was completed there was a continuous development of what is called today GESRO application. This application is now under implementation to the Romanian Waters National Administration and all its eleven Water Directorates.

GESRO is completely integrated in ArcGIS, thus extending its functionality (Gianella *et al.,* 2004). Even if it is integrated in GIS environment and uses its advantages like the spatial reference of data and the geodatabase storage format for the data (Maidment, 2002), the users don't need to know how to use ArcGIS. GESRO application has an operational toolbar in ArcMap and all its functionalities are available in one core. The menus are in Romanian and are easy to use in friendly interfaces.

The methodology that is behind GESRO is in keeping with the operational normatives (Normative 161/2006) at the Romanian Waters National Administration.

Hence, GESRO is an application that allows storage of measured quality data, assesses the quality class based on quality computations and on the basis of these results generates quality maps and reports.

INSTALATION OF THE APPLICATION KIT

GESRO is operated in a similar manner to any extension for ArcGIS. After installing the kit of the application, the extension has to be checked in order to be used in ArcGIS environment and the operational toolbar has to be loaded in ArcMap (Fig. 1).

The toolbar becomes available once the application has been activated (Fig. 2).

DATA INPUT

WFD 2000/60/EC defines rivers as water bodies which fall into categories mainly divided according to quality class. The quality class is determined based on measured values for quality indicators from different sections along the river course. There is a fixed number of sections and each one cor-

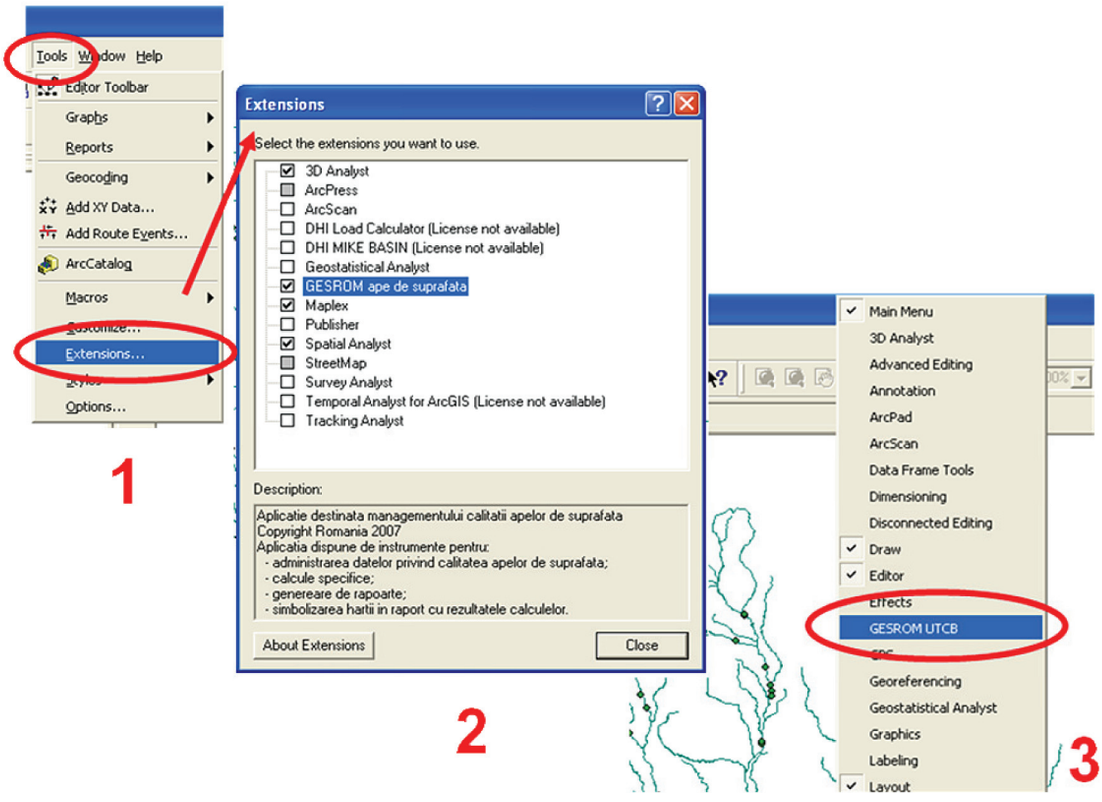


Fig. 1 Loading GESRO extension in ArcGIS

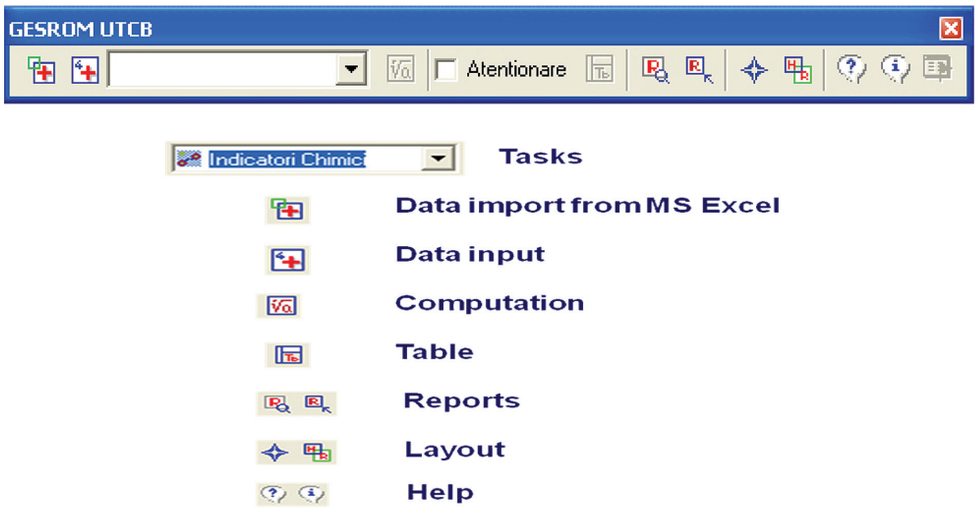


Fig. 2 GESRO toolbar

responds to a measurement program. Mainly, water samples are taken from each section and different classifications are made for the surface water. GESRO can classify the water quality for chemical indicators, biological indicators, dangerous substances, drinking water, vulnerability to nitrates and fish fauna. In order to facilitate the use of the application an import functionality has been developed for existing data, which can be stored as well in the database. The only condition for import is that the data have to be in an *.dbf format (Excel files). It is possible that only a part of the data from one or several sheets to be imported. If specific data have already been imported, they are marked with different colour in the table and the user decides whether to overwrite them or not. This makes it easier to choose the data that weren't already introduced and thus the user has a bigger control over data.

If the data come from new measurements there is an update functionality in which the user introduces the data manually in different windows according to each task (*e.g.* chemical indicators, biological indicators). The introduction windows have common elements like the date and hour of the measure, the ID of the river reach and its kilometer start and end (Fig. 3). The indicators are different from one task to another.

If there are indicators for which values weren't measured for whatever reason (*e.g.* bad weather condition, measurement error), GESRO gives the possibility to leave the corresponding box blank. Instead, in the database, -1 will be added automatically for those indicators and they won't be taken into consideration for computations. There is also the possibility to modify those values or any other input values and overwrite them in the database later.

At the time of introducing the data each cell turns into a colour according to the quality class in which it is classified. This is a preclassification for each indicator in one measurement campaign to give the user an idea of what quality he could expect from that campaign. This is a consequence of the comparison of the measured value with its corresponding limit in the normative. The cells that don't color or have the measurement unit shaded don't have a limit in the normative and are not taken into consideration in the computation.

Chemical indicators fall into five broad categories: physical indicators, oxygen regime, nitrates, salinity, metals. All these indicators represent a support for determining the ecological status of the rivers. But the biological indicators have the main influence in this classification, especially macrozoobenthos. The trend is given by the Water Framework Directive which stresses the fact that even if the chemical indicators might designate a good quality, the living organism in the water may be affected by some noxious substances meaning the water is not clean enough for human use or other purposes. In GESRO biological data are entered or imported in a different window (Fig. 4).

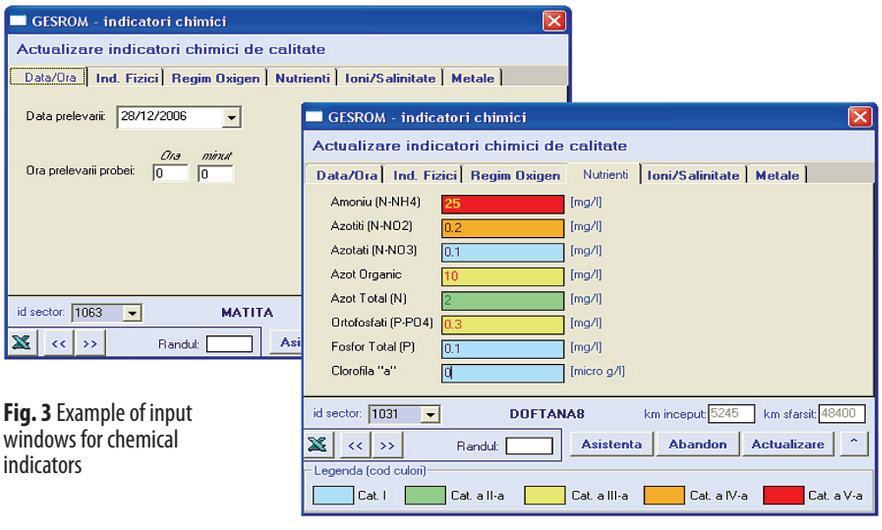


Fig. 3 Example of input windows for chemical indicators

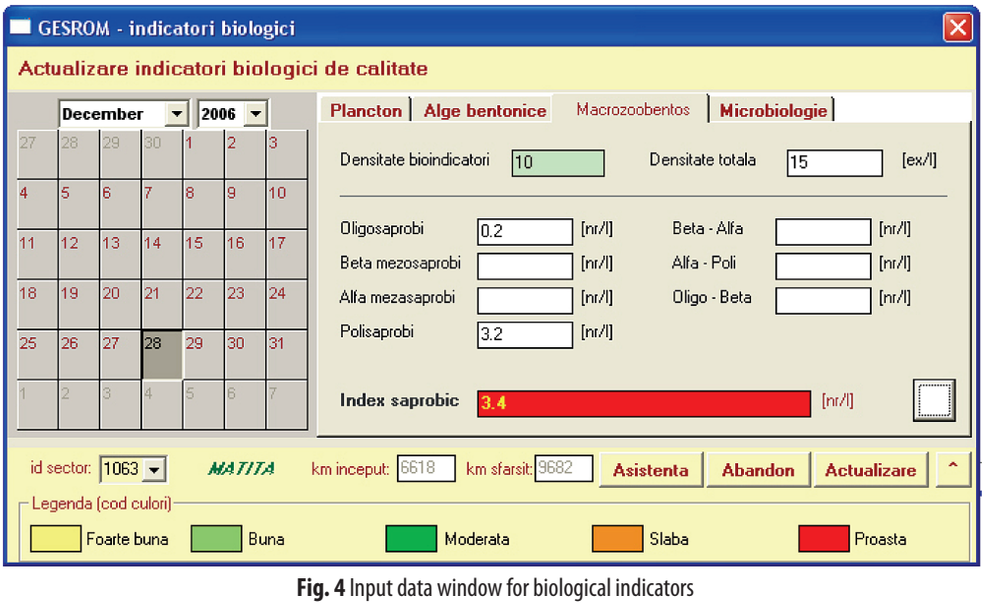


Fig. 4 Input data window for biological indicators

The mechanism is also different when entering data for biological indicators. There is a list of over 2500 living organism that were identified in the water by biologists. A saprobic index has to be computed by several steps among which the most important are the selection of the organisms from the list mentioned before, that were found in the water sample and the identification of the organisms' density for each species (Fig. 5).

In a similar way, the measured values for dangerous substances are entered through a new window where the user has the possibility to chose from a list of substances which were identified in the water sample taken in the measurement campaign.

A new concept for entering data appears at drinking water functionality as parameters are measured at the water intakes (Fig. 6). First, the user has to chose the intake and then to select the category of the treatment plant (A1, A2 or A3) and, in the end, to introduce the measured values for indicators. These values will be compared with the appropriate limits for the categories mentioned before. Vulnerability to nitrates input data functionality has a very simple window for only one indicator (nitrate).

The sustainability for fish life is the last functionality in GESRO and the only element that differs from the other input windows is that the fish category should be chosen before entering measured values because the limits are different depending on the fish category.

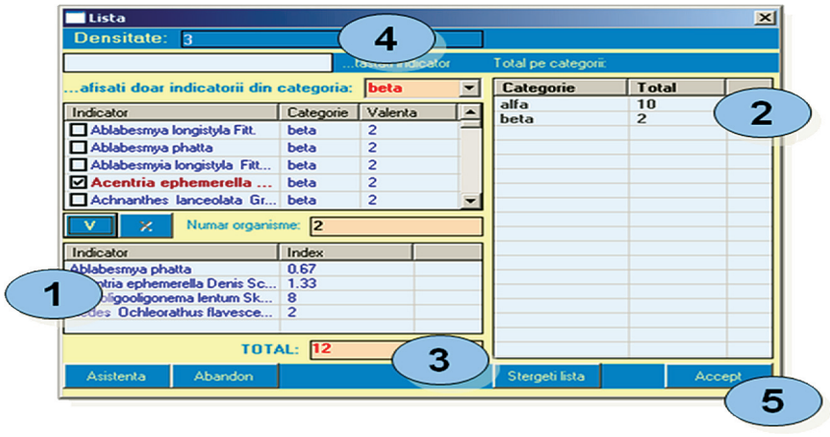


Fig. 5 Steps for entering biological indicators'measured data

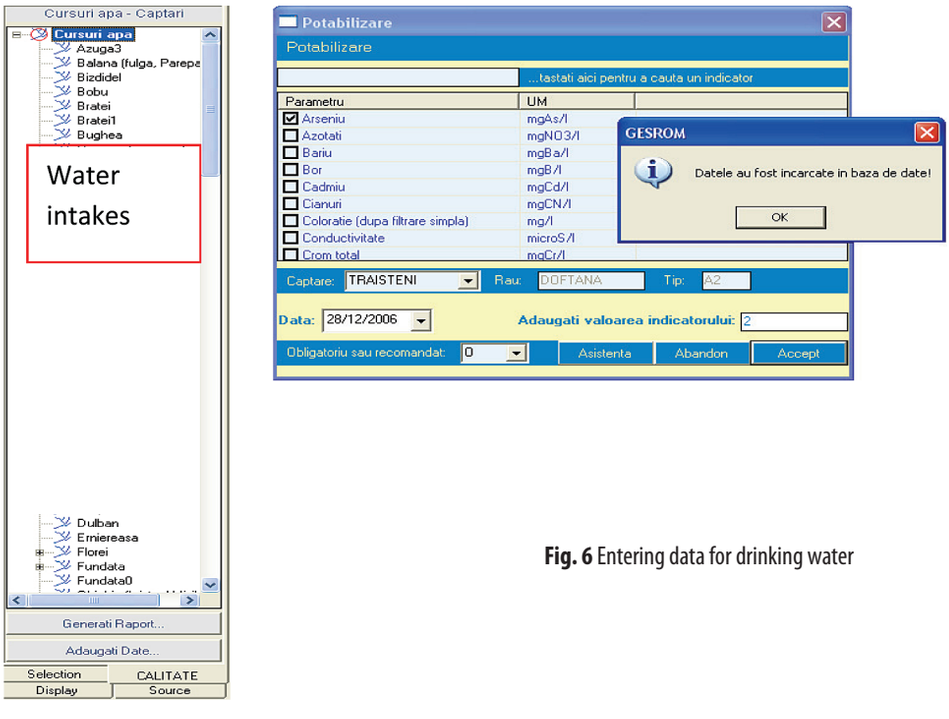


Fig. 6 Entering data for drinking water

COMPUTATION OF QUALITY CLASSES

Once the user entered all data, the quality class has to be computed. Special formulas are used for chemical and biological indicators and for the other classification a comparison between measured values and their limits is done. The computation can be carried out for a semester or for one year, for a certain indicator category or globally for all indicators (*e.g.* oxygen regime or chemical indicators). The method for computation can also be chosen: mean, minimum, maximum or percentile. The formula on which the computation is based is the following:

$$\frac{\sum \frac{C_i}{L_i}}{N} < 1$$

where C_i is the measured value for an indicator, L_i is its limit in the normative and N is the number of measured values.

The determination of the quality class is an iterative process as the ratio has to be under 1.

The saprobic index for the biological indicators is computed with another formula that takes into consideration the density of the living organism from one species and the area where they live. Based on the saprobic index for macrozoobenthos, the ecological state of the rivers is designated as very good, good, moderate, poor and bad. For other classifications (*e.g.* vulnerability to nitrates) a comparison between measured values and the limits is made. Another important classification is that of the dangerous substances; it assesses the chemical status of the river.

RESULTS

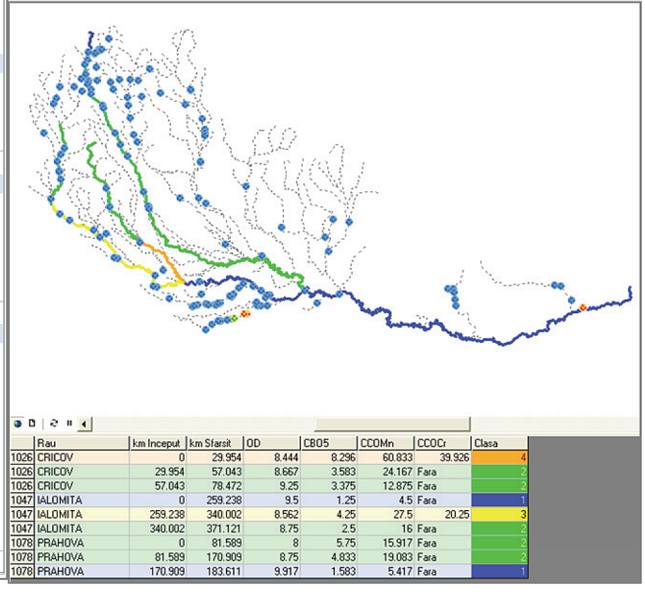
GESRO has the functionality for generating reports (Fig. 7) based on the computations for each classification.

The results are also shown on a georeferenced map in ArcMap which is generated automatically after the computations are done. A table with results is generated and can be exported to Excel or any *.dbf format. If the user wants to create maps for printing, a layout functionality is available and another one for exporting the map in different formats.

CARACTERIZAREA CALITATII APEI IN RAPORT CU INDICATORII GENERALI

Data generarii raportului: 05/07/2007

	UM	MEDIA	MINIM	MAXIM	DEV ST	Clasa	Percentile 50%	Percentile 90%	MPD
Curs de apa: CRICOV					Km Inceput: 0			Km Sfarsit: 29954	
A.1. Indicatori fizici:									
Debit:	[mc/s]								
Temperatura:	[grd C]	16.75	4	24	7.7				
pH:	-	8.25	8	9	0.4				
Suspensii:	[mg/l]	33.25	25	43	7.2				
A.2. Regim oxigen:									
Oxigen dizolvat:	[mg/l]	8.444	4	10	2.6	I	10	10	
Oxigen la saturatie:									
CBO5:	[mg/l]	8.296	5	13	3.0	III	7.5	13	
CCO Mn:	[mg/l]	60.833	3	88	20.8	V	61	88	
CCO Cr:	[mg/l]	39.926	5	68	17.9	III	36	68	
Clasa calitate regim oxigen:		IV	II	IV					
A.3. Nutrienti:									
Amoniu (N-NH4):	[mgN/l]	0.25	0	1	0.4	I	0	1	
Azotiti (N-NO2):	[mgN/l]	0	0	0	0.0	I	0	0	
Azotati (N-NO3)	[mgN/l]	7	5	10	1.9	IV	6.5	10	
Azot total (N):	[mgN/l]	2.75	2	4	0.8	II	2.5	4	
Ortofosfati (P-PO4):	[mgP/l]	2.25	1	3	0.8	V	2.5	3	
Fosfor total (P):	[mgP/l]	1.75	1	3	0.8	V	1.5	3	
Clorofila "a":	[mcrg/l]								
Clasa calitate nutrienti:									
A.4. Ioni generali, salinitate:									
Reziduu fix:	[mg/l]	469	451	502	21.1	I	461.5	502	
Cloruri (Cl):	[mg/l]	40.25	31	58	10.6	II	36	58	
Sulfati SO4:	[mg/l]	35.5	31	44	5.1	I	33.5	44	
Calciu (Ca):	[mg/l]	99.5	83	110	10.2	II	102.5	110	
Magneziu (Mg):	[mg/l]	30.75	27	33	2.3	II	31.5	33	
Sodiu (Na):	[mg/l]	41.5	35	55	8.3	II	38	55	
Alcalinitate:	[mval/l]	8	7	9	1.0		8	9	
Bicarbonatati (HCO3):	[mg/l]								
Duritate permanenta:	[grdG]								
Duritate totala:	[grdG]	21.5	19	24	1.8		21.5	24	
Fier total (Fe):	[mg/l]	0	0	0	0.0	I	0	0	
Mangan total (Mn):	[mg/l]	0	0	0	0.0	I	0	0	
Bariu:	[mg/l]								
Clasa calitate salinitate:									



	Rau	km Inceput	km Sfarsit	OD	CBO5	CCOMn	CCOCr	Clasa
1026	CRICOV	0	29.954	8.444	8.296	60.833	39.926	4
1026	CRICOV	29.954	57.043	8.667	3.583	24.167	Fara	2
1026	CRICOV	57.043	78.472	9.25	3.375	12.875	Fara	2
1047	IALOMITA	0	259.238	9.5	1.25	4.5	Fara	1
1047	IALOMITA	259.238	340.002	8.562	4.25	27.5	20.25	3
1047	IALOMITA	340.002	371.121	8.75	2.5	16	Fara	2
1078	PRAHOVA	0	81.589	8	5.75	15.917	Fara	2
1078	PRAHOVA	81.589	170.909	8.75	4.833	19.083	Fara	2
1078	PRAHOVA	170.909	183.611	9.917	1.583	5.417	Fara	1

Fig. 7 Report for the chemical indicators

IDENTIFICATION OF POTENTIAL POLLUTION SOURCES

The last powerful functionality of GESRO is that of the identification of potential pollution sources (Fig. 8). This can be achieved by a spatial search around one river reach where an exception occurred as some measured values for the quality indicators overpass the limits or usual values. Economic agents or industries are identified on a certain area around the affected reach and in this way the user narrows its search lists.

CONCLUSIONS

GESRO is an integrated GIS application that uses the WFD principles. It offers an integrated and global view upon water quality management issues at a river basin scale. This is due mainly because the data is stored in a geospatial database and queries can be made for several time periods on certain indicators.

GESRO means to be a real support for the daily activity at the monitoring department at the Romanian Waters National

Administration and its Water Directorates and a support for decision makers. This application is a diagnose tool that evaluates the water quality for surface water at present, identifies the potential pressure upon the environment and facilitates the activity of specialists through the automated generation of reports and maps functionality.

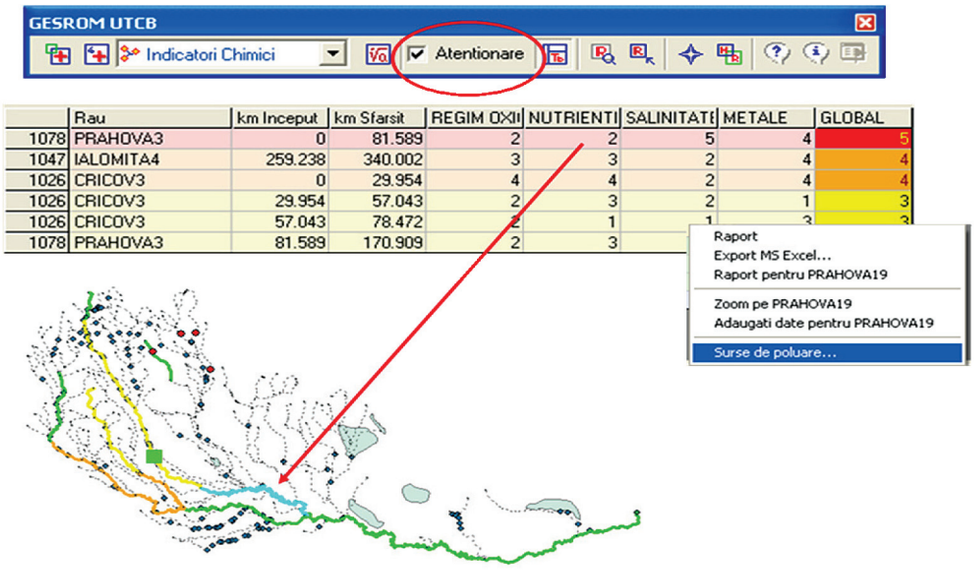


Fig. 8 Identification of potential pollution sources

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