Application of GIS elements in underground water monitoring in the region of municipal wastes dump

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Abstract

Department of Environmental Monitoring in Central Mining Institute since 1996 has been performing the monitoring of ground and underground waters in the region of operative wastes dump in Zakopane in the Tatra Mountains. This dump is the highest above the sea level situated waste dump in Poland. The underground waters are related to flyschy residual clay with slightly basic reaction. These waters have high concentrations of different contaminants (among others heavy metals and nitrogen in different forms). The elements of GIS techniques were used to create a propagation model of contaminants coming from the dump.

Introduction

The purpose of water monitoring is to gain, collect and process the data concerning waters quality in the region of environment contaminant sources that is a municipal wastes dump. The realization of this purpose relies on the periodic measurements of representative water quality parameters and indexes most often settled by law. Within the local monitoring of ground and underground waters in the region of municipal waste dumps it is possible to create, as in the case of wastes monitoring, Quality Water Monitoring System – QWMS. For the proper procedure during water monitoring in the region of wastes dump both the literature data (Alley 1993, Bzowski et al 2000, Bojarska et al 2002, Szymanski 1991) and ordinance of Ministry of Environment Protection on the classification for the presentation of ground and underground waters quality, the way of conducting monitoring and the way of result interpretations should be applied (2004).

The environment monitoring for the evaluation of its changing needs the supportive tool in the form of methodology coming from the statistic. Especially useful are methods of geostatic simulation (Wiatr 1996). Such simulation is the defined set of mathematical and logical relations that determine the quantitative relations between characteristics and the factors of a model. The application of such simulation in monitoring of the contaminant distribution in different environment elements: air, underground and ground waters, soils and plants decides about the correctness of consideration in the range of prognostic analysis and dynamic of changes.

Object and methods of testing

Department of Environmental Monitoring in Central Mining Institute since 1996 has been performing the monitoring of ground and underground waters in the region of operative wastes dump in Zakopane in the Tatra Mountains. This dump is situated on the north bank of stream Zoniowka, on the local altitude with the peak ordinate around 873 meters above the sea level and the base ordinance (at the stream) from 853 to 865 meters above the sea level. The foundation of this area is build of Quaternary grey clays here and there interbeded with brown-grey dust. These formations with the thickness from 0.5 to 3.0 meters lie on Tertiary, dark-grey sandy and clay slates of Carpathian flysch.

Nine piezometers were placed around the dump. They were marked as P-1, P-2, P-3, P-5, P-6, P-7, P-8, P-9, P-10. These pedometers take underground waters occurring in the floor of Quaternary sandy clay. The layout of piezometers is presented on the figure 1.

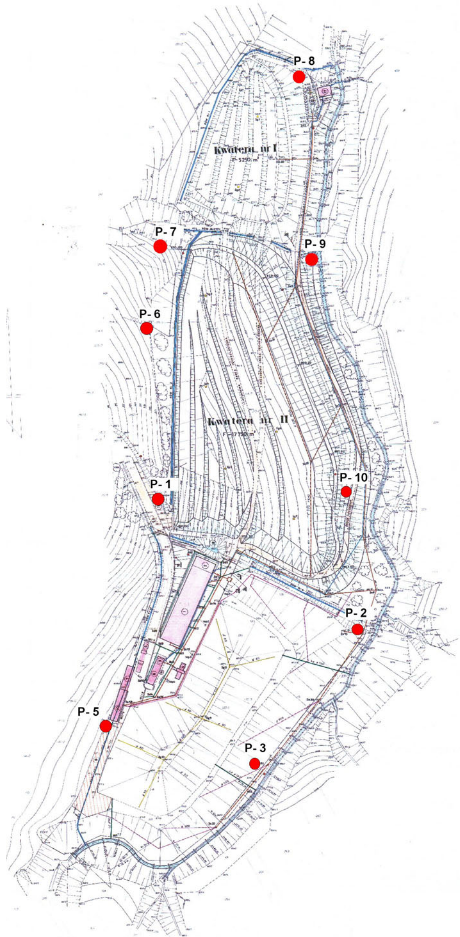

Figure 1 The layout of piezometers net

The following parameters were analysed in the tested waters: electrolytic conductivity, pH, nitrates, nitrites, phosphates, fluorides, chlorides, bicarbonates, sulphates, sodium, potassium, calcium, magnesium, iron, and heavy metals (chromium, zinc, cadmium, manganese, copper, nickel, lead). During the analysis both classical and instrumental methods were used. The determination of heavy metals was done by ICP-AE spectrometry.

Quality of underground waters

The results of physical and chemical tests of collected waters were compared with the limit values stated in the Appendix 3 of the Ordinance of Ministry of Environment dating from 11th of February 2004. On this base the classification of underground waters was done.

Waters from this area (table 1 and 2) may be fall into 4 groups:

- first group – waters highly contaminated by the outlets from the dump, concentrations of some parameters exceed the limit values what caused that these waters are classified as waters of bad quality. This concerns waters from the piezometer P-1.

- second group – waters slightly less contaminated than the ones mentioned above, with the chemical composition that meets the requirements for the IV class of underground water quality – waters of unsatisfactory quality. Waters from piezometers P-3 and P-10 belong to this group.
- third group – waters with the chemical composition that meets the requirements for the III class of underground water quality – waters of satisfactory quality. Waters from piezometer P-9 belong to this group.
- fourth group – waters from piezometers P-1, P-5, P-6, P-7 and P-8. No significant contaminants were found in these waters. Their quality meets the requirements for the II class of underground water quality – waters of good quality. Waters from these piezometers are the natural one, not influenced by the dump.

Chemical composition of waters from piezometers classified to the first and the second group reflects the influence of municipal wastes dump on the underground waters of this area. In waters from piezometers P-2, P-3, and P-10 high concentrations of sodium, potassium, chlorides, nitrates, nitrites and high electrolytic conductivity were found. These piezometers are situated very close to the dump. Waters from piezometers P-1, P-5, P-6, P-7 and P-8 have the lowest concentrations of contaminants. The mineralization of waters from these piezometers is low. These waters are calcium-magnesium-bicarbonate type and are typical for waters of Carpathian region.

Research method

The test results were used for creating the project realised with the use of INTERGRAPH Microstation MGE software package that includes the following modules in the Windows 95 system:

- Microstation 95;
- MGE Basic Nucleus;
- MGE Basic Administrator;
- MGE Base Mapper;
- MGE Terrain Analyst;
- MGE Grid Generator;
- MGE Co-ordinate System;

in conjunction with a Centura SQL database functioning on the Novell 4.11 platform.

The raster was recorded in the system by assigning the co-ordinate values of 8 control points. Then a local co-ordinate system was defined, connected with the orthogonal-square grid of measuring points. At the same time, the structure of the database was prepared in accordance with the information data (co-ordinates x, y; contaminant).

In the course of creating the project from the Microstation MGE level, the authors have designed scripts in the SQL - Century language.

By using the Terrain Analyst module, on the basis of the data collected in the project base, both three-dimensional triangle (TIN) and rectangular (GRID) models were created. To generate the diagrams presented below the most accurate available interpolation MGE “bicubic” was used.

The creation of interpolation models, to the highest extent possible representing the values of water contamination needed to apply the coefficients (constant for each of the contaminant), that eliminate the effect of the dynamics of the data values on the visualisation of the phenomenon.

No	Factor	Unit	PIEZOMETER				
			P-1	P-2	P-3	P-5	P-6
1	Electrolytic conductivity	µS/cm	934	3340	1420	444	353
2	PH	pH	7,10	7,10	7,00	7,25	7,25
3	Nitrates	mg NO_3/l	1,60	40,64	< 0,05	1,07	1,66
4	Nitrites	mg NO_2/l	<0,01	0,73	<0,01	0,01	<0,01
5	Phosphates	mg PO_4/l	0,06	0,03	0,04	<0,03	<0,03
6	Fluorides	mg F/l	0,14	0,27	0,25	<0,1	0,28
7	Chlorides	mg Cl/l	189,7	632,8	171,9	28,36	8,86
8	Bicarbonates	mg HCO_3/l	268,4	768,6	777,8	198,3	180,0
9	Sulphates	mg SO_4/l	33,50	196,0	<5	43,50	29,0
10	Sodium	mg Na/l	134,5	390,8	61,84	9,79	3,68
11	Potassium	mg K/l	2,42	96,19	11,77	1,17	2,15
12	Calcium	mg Ca/l	81,16	190,4	200,0	81,36	62,73
13	magnesium	mg Mg/l	8,20	88,70	45,81	7,97	8,08
14	iron	mg Fe/l	0,03	0,029	0,035	0,032	0,14
15	chromium	mg Cr/l	< 0,01	<0,01	<0,01	<0,01	<0,01
16	zinc	mg Zn/l	0,03	0,033	0,028	0,027	0,22
17	cadmium	mg Cd/l	<0,002	<0,002	<0,002	<0,002	<0,002
18	manganese	mg Mn/l	no	no	no	no	0,066
19	copper	mg Cu/l	<0,01	0,026	<0,01	<0,01	0,014
20	nickel	mg Ni/l	<0,01	0,044	0,03	<0,01	<0,01
21	lead	mg Pb/l	<0,01	0,012	<0,01	<0,01	0,021

Table 1 Physical and chemical parameters of underground water samples

Presentation of the results

The obtained results of underground waters monitoring are the base for the analysis of water environment condition (state) in the region of a municipal wastes dump. They allow assessing the environmental impact of a dump.

The values of electrolytic conductivity and concentrations of nitrate, sodium and chloride were chosen for the presentation. These parameters reflect the best, the changes taking place in water environment as a result of wastes dump existence on this area.

Isolines of the concentrations of the chosen parameters in underground waters are presented on figure 2-5.

From the analysis of both data and graphic presentation results that, apart from water from P-2 piezometer, the distribution of nitrate concentrations in remaining analysed waters show the influence of natural nitrification processes in the thin layer covering water-bearing formations (figure 3). Nitrates in water from P-2 piezometer indicate the negative influence of the waste dump. In case of sodium and chlorides the significant changes of their concentrations increase and the propagation of underground waters with the concentrations of these parameters exceeding the standard values can be observed. The significant influence of the municipal waste dump on the concentration of sodium and chlorides is evident.

No	Factor	Unit	PIEZOMETER			
			P-7	P-8	P-9	P-10
1	electrolytic conductivity	µS/cm	340	355	1020	1920
2	pH	pH	7,20	6,95	7,00	7,00
3	nitrates	mg NO_3/l	1,64	5,76	2,62	0,08
4	nitrites	mg NO_2/l	<0,01	<0,01	<0,01	<0,01
5	phosphates	mg PO_4/l	<0,03	<0,03	<0,03	<0,03
6	fluorides	mg F/l	0,35	0,29	0,28	0,43
7	chlorides	mg Cl/l	7,09	10,64	175,5	400,6
8	bicarbonates	mg HCO_3/l	176,9	140,3	228,8	341,6
9	sulphates	mg SO_4/l	26,5	28,5	57,0	94,0
10	sodium	mg Na/l	3,40	2,60	96,56	214,7
11	potassium	mg K/l	2,19	1,72	4,38	5,71
12	calcium	mg Ca/l	62,12	60,12	105,20	160,3
13	magnesium	mg Mg/l	7,65	7,98	12,76	17,13
14	iron	mg Fe/l	0,71	0,97	2,77	2,40
15	chromium	mg Cr/l	<0,01	<0,01	0,01	0,01
16	zinc	mg Zn/l	0,31	2,75	4,40	7,25
17	cadmium	mg Cd/l	<0,002	<0,002	0,0031	0,002
18	manganese	mg Mn/l	0,065	0,33	1,56	3,17
19	copper	mg Cu/l	<0,01	0,010	0,019	0,018
20	nickel	mg Ni/l	<0,01	<0,01	0,011	0,014
21	lead	mg Pb/l	<0,01	0,012	0,043	0,030

Table 2 Physical and chemical parameters of underground water samples

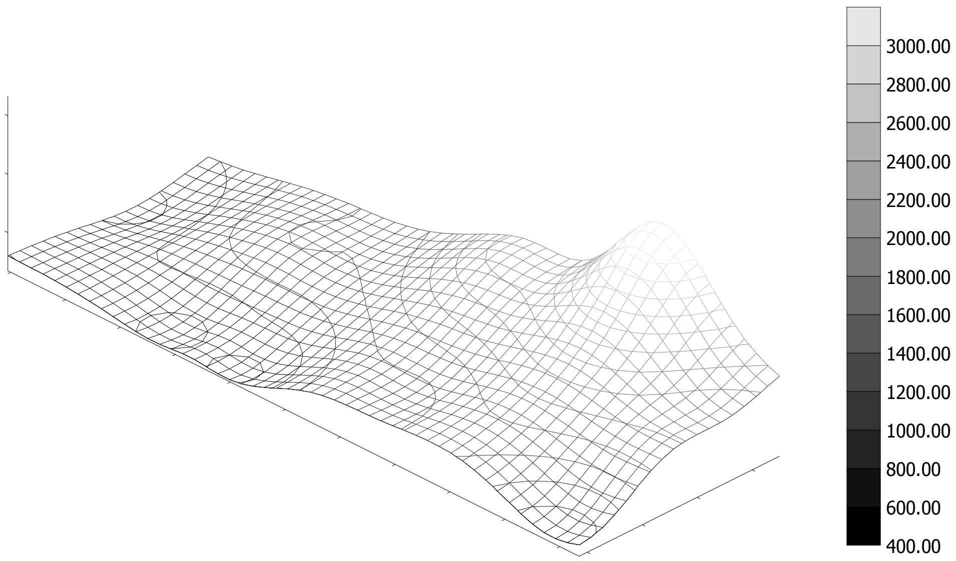

Figure 2 Isolines of electrolytic conductivity in underground waters

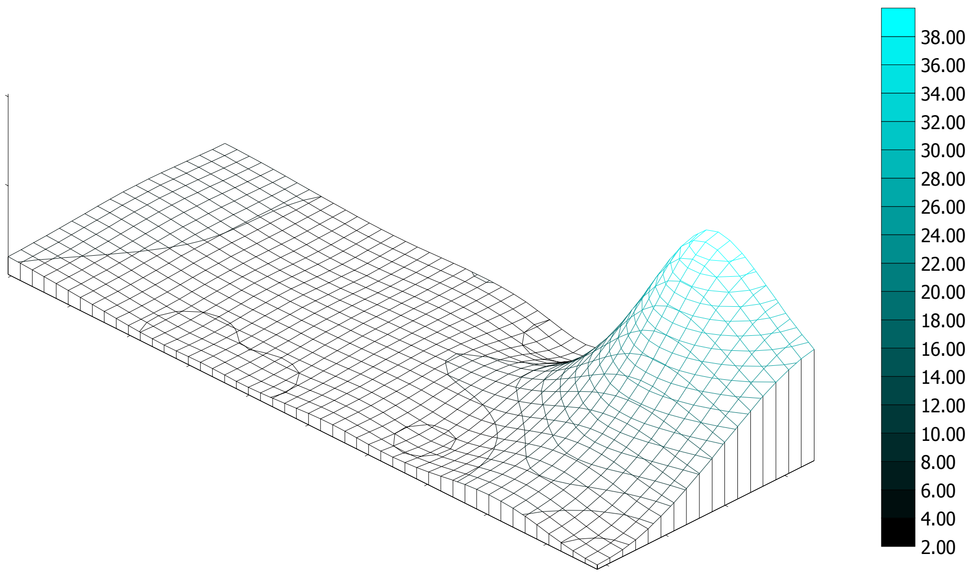

Figure 3 Isolines of nitrates concentrations in underground waters

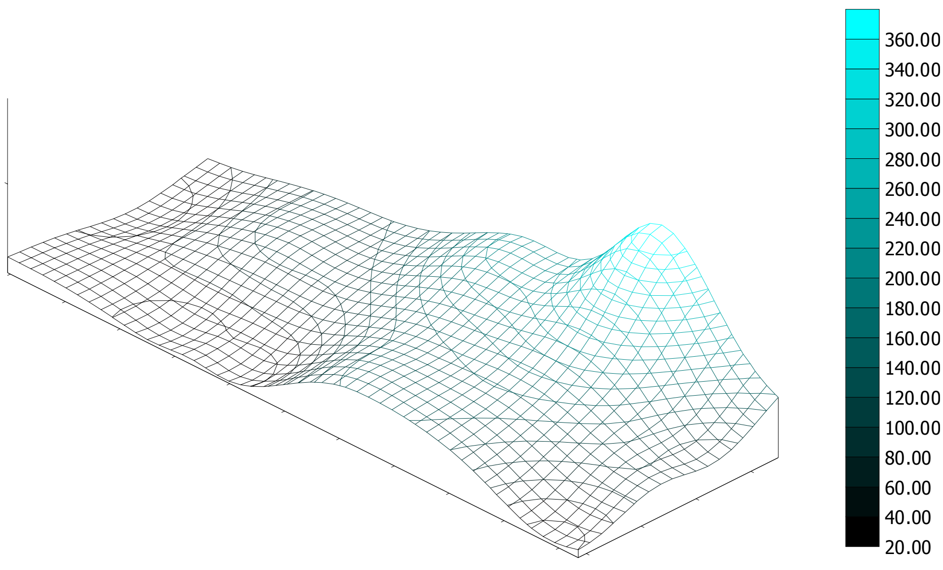

Figure 4 Isolines of sodium concentrations in underground waters

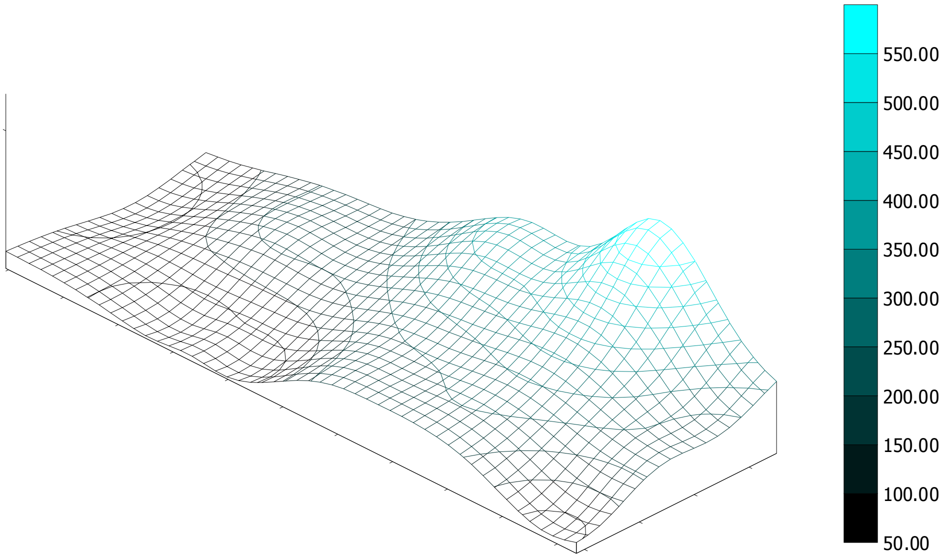

Figure 5 Isolines of chlorides concentrations in underground waters

Summary

Monitoring of underground waters in the region of municipal wastes dump in Zakopane (the Tatra Mountains) is the element of the influence evaluation of the way of wastes storing on the environment. The obtained test results of waters were used to create the model of local distribution of contaminants coming from the dumps. The software package INTERGRAPH Microstation MGE was applied for this purpose. It enables the visualization of the underground water monitoring results in order to undertake the proper actions for the environment protection.

References

Alley W.M. (1993) Regional Ground-Water Quality. VNR Press, New York, US

Bzowski Z., Dawidowski A., Konopa W. (2000) Monitoring of Quaternary waters contaminants in model formulation. *Proceedings of the Ecological Engineering Forum, Naleczow, Poland (in Polish)*, pp. 134-141

Bojarska K., Bzowski Z., Łabuz B. (2002) Monitoring of underground waters in the Region of reclamated municipal waste yard in Jaworzno. *Ekologia i Technika*, vol. X, Nr 4, pp. 113-122

Szymański K. (1991) The influence of the dump outflows for the underground waters. *Publications of University of Mining and Metallurgy, Krakow, Poland (in Polish)* no 31, pp. 171-184

Nielsen D.M. (1991) Practical handbook of ground-water monitoring. Lewis Publ. Chelsa, UK

Ordinance of Ministry of Environment Protection from 11 January 2004 on the classification for the presentation of ground and underground waters quality, the way of conducting monitoring and the way of result interpretations. (Dz.U. No 32, item 284).

Wiatr I. (1996) Geostatic methods in the monitoring of natural environment degradation state. *Ekoinżynieria (in Polish),* no 1, pp. 24-36