Development and use of Digital Technology when Studying of Environment

A.I. Gavrishin*

Platov South-Russian State Polytechnic University (NPI), Novocherkassk, Rostov Oblast, Russia

Abstract: The aim of the research is to show the possibilities of using digital classification technology in the study of patterns of formation of natural-anthropogenic systems. With the help of the original digital computer classification technology, AGAT-2 identified the types of chemical composition of mine waters in the Eastern Donbass and assessed their impact on the environment. All surveyed periods (20 years, 1966, 1992 and 2015) discovered four main types of composition of mine waters. The first type is the acidic sulphate water with high concentrations of metals Which causes the most heavy environmental pollution. The second type is formed by chloride-sulphate waters, the third by sulfate-chloride to a lesser extent enriched with metals. The fourth type is formed by soda water, which may indicate the presence of oil fields in the region. An assessment of pollution of groundwater and surface water is given.

Keywords: Digital classification technology, G-mode, mine water chemical composition.

INTRODUCTION

Digital computer technology AGAT-2 has been used to assess the negative impact of the coal mining and coal processing industry in the Eastern Donbass (ED) on the state of the region's air, water, and geological, biological and social environments, based on the original G-method of classifying multidimensional observations. According to the theory and methods of classification of multidimensional observations, there are thousands of works that propose the use of cluster analysis, the use of classification algorithms in the conditions of prior information about the classification structure observations (task with the teacher) and to a lesser extent the task of self-organization (without the teacher) [1-20]. Many works have also been completed in the area of geological and environmental data classification [4, 6-10, 12, 15, 16, 18]. In the ED under the influence of coal mining and coal processing industries negative phenomena such as the reduction of groundwater levels, the formation of man-made fracturing, subsidence of the earth's surface, the emission of «dead air », catastrophic pollution of surface and groundwater and many others. A significant number of publications are devoted to the characterization of these negative phenomena in the environment of the ED [2, 4, 6-10, 13-15, 17, 19, 20].

The selection and description of the main types of chemical composition of mine water in the ED has been made for the four most characteristic periods of coal industry development in the region. And earliest period (1921-1928) is associated with the availability of the first quantitative data on the chemical composition of mine waters. The second (1966) is the period of the most intensive development of the coal industry in the region (the "golden age" of the ED). The third period is timed to the beginning (on the eve) of mass liquidation of coalmines. The fourth period (2015) is the stage of total completion of the mass liquidation of coalmines in the region. The chemical composition of the mine water during these periods is brought in the Table **1**.

According to the anion composition, mine water is considered chlorine-sulphate with a decrease in chloride-ion content by 2015 due to decrease in the inflow of sodium groundwater into the mines. It's cationic composition mainly consists of magnesium-sodium water, neutral, with a significant increase in iron concentration and mineralization by Remove comma due to the strengthening of sulfide oxidation processes and the dissolution of sulphates in flooded Mines.

METHODS OF STUDIES

Classification methods play an important role in the process of cognition of the person and the world around him. Each researcher, when constructing a new classification of observations gets the opportunity to discover new previously unknown patterns. The analysis of hydrogeochemical information was carried out using standard mathematical and statistical methods and digital computer classification technology AGAT-2. This technology is based on the original G-method of constructing the classification of multidimensional observations in self-organization (a task without a teacher) and on the criteria of Z^2 [4, 6-9, 16, 18].

*Address correspondence to this author at the Platov South-Russian State Polytechnic University (NPI), Novocherkassk, Rostov Oblast, Russia; E-mail: agavrishin@rambler.ru

Table 1: Chemical Composition of Mine Waters ED in Different Periods (mg/l and %-mole)

Years	HCO_3	SO_4	Cl	Ca	Mg	Na	Fe	M	pH
1921-1928	199	1443	397	233	184	405	0.1	2845	6.9
	7	68	25	26	35	39			
1966	256	1741	448	98	217	710	1.1	3470	6.7
	8	68	24	10	35	55			
1992	580	1700	730	205	137	1035	3.6	4390	7.5
	15	54	31	15	17	68			
2015	591	2837	347	293	267	966	34	5301	6.9
	12	76	12	17	28	55			

Note. M – Mineralization.

$$Z^2 = \frac{M}{\sum_{sk} r_{sk}^2} \cdot \sum_{ij}^{MN} \frac{\left(X_{ij} - \bar{X}_j\right)^2}{S_j^2} = K \sum_{ij}^{MN} Z_{ij}^2$$

$$f = K \cdot M \cdot N, \qquad G = \sqrt{2Z^2} - \sqrt{2(f-1)},$$

where Xij is the value of the j sign in observation i; $\bar{X}_j$, S_j - average and standard deviation of the sign j; r_{sk} - correlation ratio between s and k; M - number of signs; N - number of observations; F - number of degrees of freedom; G - conversion of distribution to normal with parameters (0.1). If the calculated G≥Gq, then observation (or N observations) on M signs does not belong to this homogeneous class of observations with a level of importance q.

The method allows the use of dependent signs, to allocate homogeneous taxa of different levels (classes, subclasses, etc.), to assess the similarity-difference between taxa, to determine the in formativeness of traits and to classify new observations.

When generalizing hydrogeochemical information, ions are included in the name of the waters at more than 20-25% of the moles and are arranged in the order of increasing contents.

TYPES OF COMPOSITION OF MINE WATERS IN 1921-1928

The study of the types of chemical composition of mine waters in 1921-1928 was carried out on the results of 192 chemical analyses. According to digital classification technology, 10 homogeneous hydrogeochemical types of mine water have been identified, which are combined into four types to change the content of macro components.

The most obvious features of the chemical composition of the allocated types are visible from the data of Table **2**. The first type is typical sulfate (90%-mole), acidic and rather mineralized water, which caused the most intense water pollution in the ED. The second and third types are characterized by high levels of chloride-ion, which negatively affects the composition of the region's natural waters. The fourth type, as noted above, refers to the original chemical

Table 2: The Average Chemical Composition of the Types of Mine Waters in 1921-1928 (mg/l and %-mole)

Type	pH	HCO_3	SO_4	Cl	Ca	Mg	Na	M
1	4.43	132	3054	191	380	352	539	4648
		3	90	7	27	41	32	
2	7.25	286	1520	884	208	172	874	3944
		8	52	40	16	23	61	
3	7.00	270	1687	1868	463	457	702	5450
		4	38	58	25	41	34	
4	7.55	373	650	1080	44	30	1058	3235
		12	28	60	4	4	92	

Table 3: The Average Chemical Composition of the Types of Mine Waters in 1966 (mg/l and %-mole)

Type	pH	HCO_3	SO_4	Cl	Ca	Mg	Na	M
1	4.5	65	2900	195	149	286	830	4390
		2	90	8	11	35	54	
2	7.8	353	1893	483	76	212	876	3940
		10	67	23	6	30	64	
3	6.9	299	1700	1543	125	284	1246	5240
		6	42	52	8	28	64	
4	7.7	545	856	626	39	84	832	2920
		20	39	41	4	15	81	

composition of soda waters and may indicate the presence of oil accumulations in the region.

TYPES OF COMPOSITION OF MINE WATERS IN 1966

The results of the classification and selection of the types of chemical composition of mine waters that were selected in 1966 are broadly similar to those described above for the 1920s, indicating the resilience of the patterns detected.

The study of the types of chemical composition of mine waters in 1966 was based on the results of 84 chemical analyses. According to digital classification technology, 13 homogeneous hydrogeochemical types of mine water have been identified, which are combined into four types.

The most obvious features of the chemical composition of the allocated types are visible from the data of Table **3**. The first type is typical sulfate (90%-mole), acidic and rather mineralized water. The second (chloride-sulfate) and the third (sulfate-chloride) types of water are characterized by high levels of chloride-ion, which negatively affects the composition of the region's natural waters. The fourth type is the original chemical composition of soda water, which may indicate the presence of oil accumulations in the region.

TYPES OF COMPOSITION OF MINE WATERS IN 1992

The results of the classification of the chemical composition of the mine waters, selected in 1992 before the mass liquidation of coal mines, are broadly similar to those described above for the 20s and 1966, which once again demonstrates the resilience of found Patterns.

Based on the results of 41 chemical analyses, the types of chemical composition of mine water in the ED were studied in 1992. According to the digital classification technology, 13 homogeneous hydrogeochemical types of mine water have been identified, which are combined into four types to change the content of macro components.

The average features of the chemical composition of the selected types are clearly visible according to the

Table 4: The Average Chemical Composition of the Types of Mine Waters in 1992 (mg/l and %-mole)

Type	pH	HCO_3	SO_4	Cl	Ca	Mg	Na	M
1	6.0	360	2515	266	349	205	730	4450
		9	80	11	26	26	48	
2	7.6	516	1577	730	290	138	873	4235
		14	53	33	23	18	59	
3	7.8	487	1489	1396	179	124	1370	5055
		10	40	50	11	13	76	
4	7.6	1217	1105	885	107	84	1350	4566
		29	34	37	8	10	82	

data of Table **4**. The first type is typical sulfate (80%-mole), mildly acidic, rather mineralized water. The second (chloride-sulfate) and the third (sulfate-chloride) types of water are characterized by high levels of chloride-ion, which negatively affects the composition of the region's natural waters. The fourth type, as noted above, is the original chemical composition of soda water, which may indicate the presence of oil accumulations in the region.

TYPES OF COMPOSITION OF MINE WATERS IN 2015

The results of the classification of the chemical composition of mine waters, selected in 2015 after the completion of the mass liquidation of coalmines, differ significantly from those described above for the 20s remove ‘for’ 1966 and 1992.

The study of the types of chemical composition of mine water in 2015 was based on the results of 40 chemical analyses. According to digital classification technology, seven homogeneous hydrogeochemical types of mine water have been identified, which are combined into three types to change the content of macro components.

Features of the chemical composition of the allocated types are clearly visible according to the data of Table **5**. The first type is typical sulfate (90%-mole), mostly acidic and rather mineralized water, which formed the most intense streams of water pollution in the ED. The second type is characterized by relatively high levels of chlorine-ion and high mineralization, and the third type of sulphate chloride water was not detected in 2015. The fourth type is still the original chemical composition of soda water, which may indicate the presence of oil accumulations in the region.

GENESIS OF TYPES OF FORMATION OF CHEMICAL COMPOSITION OF MINE WATER

The results of the classification of hydrogeochemical information described above allow us to characterize the genetic features of the types of chemical composition of mine waters in the ED. Similar to the results of the classification analysis on the test data from 1921 to 1992 (before the mass liquidation of coal mines) theyindicate high stability of the detected patterns.

The first type is acidic sulphate with high content of Fe, Mn, Al, Be and other water metals, which is caused by the intensive development of sulphide and sulfur oxidation processes and sulfate dissolution. It is the first type of mine water that generates the most intense pollution flows in the region's environment.

In the second type, neutral chloride-sulphate water is formed enriched with metals to a lesser extent than the first type. The process of increasing chloride-ion concentrations due to the influx of chloride groundwater is beginning to play a significant role. The third type is sulphate-chloride water, in which the concentration of chloride-ion increases dramatically due to the influx of chloride groundwater during the development of deep mine horizons.

The fourth type is of soda water with relatively high HCO_3 content and very low Ca and Mg is formed. The leading role is played by the inflow of soda groundwater, which is formed as a result of evaporation and condensation processes in the water-carbon gas phase. The most popular hypotheses for the appearance at significant depths of low-mineralized soda waters are infiltration, juvenile, dehydration and evaporative condensation [9].

The infiltration factor affects the composition of the waters under consideration to a depth of 250-300 m

Table 5: The Average Chemical Composition of the Types of Mine Waters in 2015 (mg/l and %-mole)

Type	pH	HCO_3	SO_4	Cl	Ca	Mg	Na	Fe	M
1	5.73	256	4766	230	359	400	1435	43.8	7480
		4	90	6	16	30	54		
2	6.73	536	4123	660	322	306	1719	3.2	7667
		8	76	17	14	22	64		
3 отсутствует									
4	7.30	426	1216	211	38	32	806	1.1	2730
		18	66	16	5	7	88		

Table 6: Mine Water Volume (Million m^3/year) and their Stream on Surface of Solutes

Date	Volume	Components of mine waters (thousand t/year)						pH
		Solutes	SO_4	Cl	Ca	Mg	Fe	
1966	75	270	131	34	7.3	16	0.1	6.7
1992	90	395	155	63	18	13	0.3	7.5
2015	79	413	222	27	23	21	2.7	6.9

and infiltration processes cannot explain the transition to soda at significant depths. The formation of soda waters cannot be associated with endogenous origin in such ancient geological structure as Donbas.

Dehydration processes seem to be taking place, but coal deposits have passed the lithium mostly much earlier. The formation of low-mineralized soda water in the ED is most likely associated with the condensation of water vapor from the water-carbon gas phase. Soda water is found at different depths and is attributed to areas of vertical tectonic fracture, which explains their spread vertically. Taking the hypothesis of evaporative-condensation genesis of soda water, it should be recognized within the open ED within certain traps of oil and gas clusters. In the areas of coalmines where the fourth type of soda water is found, the prospects for the detection of oil and gas manifestations are highest, for example, in the structures of the Gukovo-Sverevsky coal-bearing region [6-9].

After the completion of the mass liquidation of coalmines in the ED by 2015, there were significant changes in the types of chemical composition of mine waters. On the first type, there was an increase in the processes of oxidation, leaching and dissolution. This has led to an increase in water mineralization (average 7.5 g/l) and micronutrient content due to the intense inflow into old mining excavations of aggressive atmospheric and surface waters. The flow of water is now directed through mining into the containing rocks that forms intense halos of groundwater contamination. In the second type, the concentration of chloride-ion has been drastically reduced, as the mining excavation has ceased to receive chloride groundwater. For this reason, the third type of sulphate-chloride water is completely absent. The fourth type was also manifested after the liquidation of coalmines and its characteristics are similar to the one above.

MINE WATERS AND POLLUTION PROBLEM

In the Eastern Donbass, mine waters on the surface waters on the surface are carried by huge quantities of substances, the characteristic of which in the studied periods is given in the Table **6**. The largest amount of pollutants is caused by mine waters in the post-mine period and is therefore currently the most heavily polluted environmental component in the region. The lack of data for the 1920s is because for this period there is no information on the volume of mine water.

Given in Table **7** is a comparison between the composition of mine water, groundwater and surface water of the ED with the maximum allowable concentrations (MAC) for water economy, drinking and cultural- household use on 20 components.

In the waters of the region, the average concentrations of some components do not exceed MAC (K, Co, Cu, Pb, Sr, Cr, zn), but in mine waters excess equities in some cases reach dozens of times (Al, Be, Fe, Li, Mn). Excess of MAC by average concentrations in mine waters is recorded for 55% of components, in groundwater for 45% and in urface waters for 40%. It should be noted that for some components the maximum concentrations exceed MAC by ten sand hundreds of times. Consequently, large and intensive flows of natural water pollution are formed in the ED, which requires measures to improve and expand effective treatment technologies.

CONCLUSION

To study the types of chemical composition of mine waters, the ED was used as a digital computer technology to classify multi-dimensional observations of AGAT-2, which allows to build classification in conditions of uncertainty, to use dependents signs and to allocate homogeneous taxa of different levels.

According to the classification technology, homogeneous hydrogeochemical observations are isolated, which are combined into four main types. It has been established that intensive processes of sulphide oxidation and dissolution of sulfates cause the first type; it has the greatest impact on pollution in the region. In the second and third types, chloride-sulphate

Table 7: Comparison of the Content of Components in the Waters with MAC

Component	Type of water					
	Mine water		Groundwater		Surface water	
	Mean	By MAC	Mean	By MAC	Mean	By MAC
Al	3.01	+	0.2	+	0.34	+
Be	0.0017	+	0.0007	+	0.0008	+
Fe	33.7	+	3.13	+	0.45	-
Cd	0.0017	+	0.001	-	0.0005	-
K	25.5	-	14.8	-	13.0	-
Co	0.028	-	0.002	-	0.002	-
Li	0.31	+	0.06	+	0.16	+
Cu	0.005	-	0.004	-	0.003	-
Mn	5.1	+	0.61	+	0.61	+
Ni	0.073	+	0.002	-	0.009	-
Pb	0.0011	-	0.001	-	0.0010	-
Se	0.017	+	0.016	+	0.019	+
Sr	6.1	-	3.1	-	3.92	-
Cr	0.007	-	0.002	-	0.0018	-
Zn	0.134	-	0.08	-	0.014	-
SO_4	2837	+	1511	+	1773	+
Cl	347	-	333	-	212	-
Mg	267	-	152	-	146	-
Na	966	+	437	+	575	+
M	5300	+	3230	+	3400	+

Note. The "+" sign indicates exceeding the MAC; the "-" sign indicates the content below the MAC.

and sulphate-chloride water are formed and this is associated with the inflow into the deep mining excavations of mineralized chloride groundwater. The fourth type includes the original soda water, the origin of which is associated with the development of evaporative condensation processes in the gas phase; this may indicate the presence of oil and gas clusters in the ED.

Comparison of component concentrations in the mine, groundwater and surface waters of the ED with the MAC of the waters of economic, drinking and cultural use showed their significant excess over the standards. In mine waters, excess of MAC was found for 55% of components, in ground – for 45% and in surface - for 40%. This demonstrates the need to further develop and improve treatment technologies in the region.

REFERANCES

[1] Akopov AS. Simulation. M.: Nauka 2018; p. 389.

[2] Borisova VE, Serbinovskaya AM. Alternative methods of mine waters purification in Eastern Donbass. In the collection "Science. Education. Culture. Novocherkassk: SRSTU 2016; pp. 153-156.

[3] Buhtojarov VV. Three-stage evolutionary method of forming ensembles of neural networks for solving classification tasks. Software Products and Systems 2012; 4: 101-106.

[4] Coradini A, and 32 colleagues. Identification of spectral units on Phoebe. ICARUS 2008; 193(1): 233-251. https://doi.org/10.1016/j.icarus.2007.07.023

[5] Fomin JA. Pattern recognition: theory and application. M.: PHASIS 2012; p. 429.

[6] Gavrishin AI. The Methodological Aspect of Development and Application Multivariate Classification G-Mode for Analyses Geochemical Trend. Journal of Advances in Applied & Computational Mathematics 2014; 1(1): 21-27. https://doi.org/10.15377/2409-5761.2014.01.01.4

[7] Gavrishin AI. Multidimensional Classification Method in the Study of Natural and Anthropogenic Systems. Journal of Advances in Applied & Computational Mathematics 2018; 5: 16-21. https://doi.org/10.15377/2409-5761.2018.05.3

[8] Gavrishin AI. Development and application of digital classification technology. G-method. Modern High Technologies 2019; 7: 25-29. https://doi.org/10.17513/snt.37584

[9] Gavrishin AI. Mine Waters of the Eastern Donbass and Their Effect on the Chemistry of Groundwater and Surface Water

in the Region. Water Resources 2018; 45(5): 785-794. https://doi.org/10.1134/S0097807818050081

[10] Hatvani IG, and five colleagues. Analysis of long term water quality changes in the Kis-Balaton Water Protection System with time series- cluster analysis and Wilks' lambda distribution. Ecol Eng 2011; 37(4): 629-635. https://doi.org/10.1016/j.ecoleng.2010.12.028

[11] Juravlev YI. On the algebraic approach to solving the problems of recognition or classification. Problems of cybernetics. M.: Science 2005; 33: 5-68.

[12] Katasev AS, Emaletdinova LY. Fuzzy-production cascading model of diagnosing the condition of a complex object. Software Systems and Computational Methods 2013; 1: 69-81.

[13] Korponai J, and six colleagues. Transition from shallow lake to a wetland: a multi-proxy case study in Zalavari Pond, Lake Balaton, Hungary. Hydrobiologia 2010; 641(1): 225-244. https://doi.org/10.1007/s10750-009-0087-0

[14] Kovacs J, and five colleagues. Key question of sampling frequency estimation during system calibration, on the example of the Kis-Balaton Water Protection System's data series. Georgikon for Agriculture 2011; 14(1): 53-68.

[15] Mokhov AV. The Hydrogeochemical Structure of Water Bodies in Flooded Openings of Coal Mines. Doklady Earth Sciences 2012; 445(1): 903-905. https://doi.org/10.1134/S1028334X12070252

[16] Orosei R, and six colleagues. Self-affine behavior of Martian topography at kilometer scale from Mars Orbiter Laser Altimeter data. Journal of Geophysical Research 2003; 108(E4) (8023): GDS 4-1 - 4-10. https://doi.org/10.1029/2002JE001883

[17] Ritter A, Munoz-Carpena R, Bosch DD. Agricultural land use and hydrology affect variability of shallow groundwater nitrate concentration in South Florida. Hydrological Processes 2007; 21(18): 2464-2473. https://doi.org/10.1002/hyp.6483

[18] Tossi F, and seven colleagues. G-mode classification of spectroscopic data. Earth, Moon and Planets 2005; 96: 165-197. https://doi.org/10.1007/s11038-005-9061-7

[19] Tutu H, McCarthy TS, Cukrowska EM. The chemical characteristics of acid mine drainage with particular reference to sources, distribution and remediation: the Witwatersrand Basin, South Africa, as a case study. Applied Geochemistry 2008; 23: 3666-3684. https://doi.org/10.1016/j.apgeochem.2008.09.002

[20] Zakrutkin VE, Sklyarenko GY. The influence of coal mining on groundwater pollution (Eastern Donbass). International multidisciplinary Scientific Geo Conference Surveying Geology and Mining Ecology Management, SGEM 15th. 2015; pp. 927-932.

Received on 19-11-2019 Accepted on 24-12-2019 Published on 30-12-2019

DOI: http://dx.doi.org/10.15377/2409-5761.2019.06.3