

ГОДИШНИК НА УНИВЕРСИТЕТА ПО АРХИТЕКТУРА, СТРОИТЕЛСТВО И ГЕОДЕЗИЯ – СОФИЯ

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## ASSESSMENT OF WATER QUALITY OF ARTIFICIAL WATER BODIES IN VOJVODINA (SERBIA) USING FACTOR AND CLUSTER ANALYSIS

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*Research area:* hydraulics and hydrology

### ABSTRACT

Multivariate statistical techniques, such as factor analysis (FA)/principal component analysis (PCA) and cluster analysis (CA), were applied to the evaluation of variations and the interpretation of water quality data of artificial water bodies in Vojvodina (Serbia). Factor analysis is applied to physicochemical parameters of artificial water bodies with the aim classification and data summation as well as segmentation of heterogeneous data sets into smaller homogeneous subsets. CA showed similarities and dissimilarities among the sampling sites and explained the observed clustering in terms of affected conditions.

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## 1. Introduction

River water pollution is mainly the result of anthropogenic activities that occur within the river basin. In order for a river to be properly managed, these activities need to be identified and functionally related to the water pollution parameters [1]. It is well known that environmental data are usually characterized by high variability, because of a variety of natural and anthropogenic influences. The best approach to avoid misinterpretation of environmental monitoring data is the application of multivariate statistical methods for environmental data classification and modeling [2]. This paper illustrates the utility of Factor analysis/Principal component analyses (FA/PCA) and Cluster analysis (CA) techniques for analysis and interpretation of water quality data sets and identification of pollution sources/factors with a view to get better information about the water quality and design of monitoring network for effective management of water resources. The analysis of water quality is based on the data of the Republic Hydrometeorological Service of the Republic of Serbia published in the Hydrology Almanac – Water quality for the period 2008–2011.

## 2. Study area

The Autonomous Province of Vojvodina covers an area of 21 506 km<sup>2</sup>, it is located in the Pannonian Plain, where the natural landscape consists mainly of low-lying flat land, except for Srem which is dominated by the Fruška Gora Mountain (the highest peak 539 m) and the southern-east part of the province dominated by the Vrsacka Mountains (the highest peak 641 m). Vojvodina is intersected by three navigable rivers: Danube, Sava and Tisa, dividing its territory into three geographic-historic areas: Backa, Banat and Srem. With a population of about 2 million, Vojvodina accounts for 27% of the total population in Serbia. The capital of the province is Novi Sad located on the left bank of the Danube river (rkm 1255) with over 300 000 inhabitants. Canals of the Danube-Tisa-Danube Hydrosystem run through almost all settlements in the Province, or in close proximity. The navigable canal network in Vojvodina forms an integral part of unique hydro-engineering system Danube-Tisa-Danube covering Backa and Banat District and connecting the Danube and Tisa rivers. The entire length of main canals of the Hydrosystem DTD (DTD Hs), together with the parts of nature water course, that while having regulative works have lost the character of natural rivers, is 930 km., where 421 km are in Backa, and 509 km are in Banat. Regarding its height, the DTD Hs is divided into pools. A pool is made of one or greater number of canals limited by gates, ship-locks and pumping stations, and there is, concerning water flow and water level (in compliance with technical capacities and adequate rule books), controlled water regime. The Bajski Canal is meander of the Danube river that extends from Baja in Hungary to Bezdán in Serbia, with total length of 44,8 km. It rises at the Sugavica Canal near Hungarian town Baja, and flows into Vrbas-Bezdán Canal at the kilometer 77+460 [3]. The Jegrička had been a natural stream in the central part of the Vojvodina Province which was made part of the canal network of the multi-purpose Danube-Tisza-Danube Hydro System. The Jegrička runs for a greater part through agricultural land, flowing through or near several urban areas. Due to such geography, the stream is exposed to a number of point and non-point pollution sources which directly affect the quality of water and sediments on river bottom [4]. The Navigable Begej or Begej Canal springs in the Craiova Mountains (Pojana Ruske) under the peak of Mt Padeşin the neighbouring Romania, at the absolute altitude of 1,135 mANV. The length of the stream, including the unified section of the stream from Klek to the mouth, is 233 km [5].

The analysis of water quality is based on the data of the Republic Hydrometeorological Service of the Republic of Serbia. Data sets consists of annually average values of water quality variables measured during period 2008-2011. [6] in a quality monitoring network (Figure 1): **Canal DTD**: Sombor (1), Mali Stapar (2), Vrbas 1 (3), Vrbas 2 (4), Srpski Miletić (5), Savino Selo (6), Bačko Gradište (7), Novi Sad (8), Bač (9), Bački Petrovac (10), Melenci (11), Vlakovac (12), Kajtasovo (13); **Jegrička**: Žabalj (14); **Kikindski Kanal**: Novo Miloševo (15); **Canal Nadel**: Uzdin (16), Starčevo (17); **Bajski Canal**: Bački Breg (18); **Navigable Begej**: Srpski Itebej (19), Klek (20), Stajićevo (21).



Figure 1. Study area

### 3. Factor and cluster analysis

**Factor analysis**, a multivariate statistical method, yields the general relationship between measured variables by showing multivariate patterns that may help to classify the original data [7]. Factor analysis integrates a large number of variables into several significant factors that explain the correlations among the observed variables [8]. FA can be expressed as is given in Eqn. 1 [9]:

$$F_i = a_1x_1j + a_2x_2j + \dots + a_mx_m \quad (1)$$

Where:  $F_i$  = factor

$a$  = loading

$x$  = measured value of variable

$i$  = factor number

$j$  = sample number

$m$  = total number of variables

There are three stages in factor analysis [10] – [11].

- For all the variables a correlation matrix is generated
- Factors are extracted from the correlation matrix based on the correlation coefficients of the variables
- To maximize the relationship between some of the factors and variables, the factors are rotated.

**Cluster analysis** is an exploratory data analysis tool for solving classification problems [12]. A good outcome of cluster analysis will result in a number of clusters where the observations within a cluster are as similar as possible while the differences between the clusters are as large as possible [13]. The Euclidean distance usually gives the similarity between two samples and a ‘distance’ can be represented by the ‘difference’ between analytical values from both the samples. Hierarchical agglomerative CA was performed on the normalized data set by means of the Ward’s method, using Euclidean distances as a measure of similarity [14]. The similarities–dissimilarities were quantified through Euclidean distance measurements; the distance between two objects (monitoring point locations),  $i$  and  $j$ , is given in Eqn. 2:

$$d_{i,j}^2 = \sum_{k=1}^m (z_{i,k} - z_{j,k})^2 \quad (2)$$

Where  $d_{i,j}$  denotes the Euclidean distance,  $z_{i,k}$  and  $z_{j,k}$  are the values of variable  $k$  for object  $i$  and  $j$ , respectively, and  $m$  is the number of variables. Hierarchical agglomerative cluster analysis (HACA) was used to investigate the grouping of sampling points. HACA is a common method to classify variables or cases (observations/samples) into classes (clusters) with high homogeneity level within the class and high heterogeneity level between classes with respect to a predetermined selection criterion. HACA starts with each point in separate clusters and iteratively agglomerates the closest pair of clusters in each iteration until all points belong to a single cluster. The final hierarchical cluster structure is called a dendrogram, a tree like structure that shows which clusters are agglomerated at each level. The dendrogram provides a visual summary of the clustering processes, presenting a picture of the groups and their proximity, with a dramatic reduction in dimensionality of the original data [1]-[12]-[15]-[16]-[17].

#### 4. Results and discussion

The selected parameters for the estimation of surface water quality characteristics were: Temperature (T), suspended solids (SS), dissolved oxygen (DO), total hardness (TH), pH, electrical conductivity (EC), ammonium nitrogen (NH<sub>4</sub>-N), nitrate nitrogen (NO<sub>3</sub>-N), total phosphorous (TP), (Ca<sup>2+</sup>), magnesium (Mg<sup>2+</sup>), biochemical oxygen demand (BOD<sub>5</sub>), surface-active substances (SAS). Water quality data (mean value) are presented at Table 1.

Calculated eigenvalues, percent total variance, factor loadings and cumulative variance are given in Table 2. The factor analysis generated four significant factors which explained 82.61 % of the variance in the data set.

First factor F1 explained 33.21 % of the total variance and had strong positive loadings on NH<sub>4</sub>-N, BOD<sub>5</sub> and SAS, moderate positive loading on TP, strong negative loading on dissolved oxygen and moderate negative loading on pH. First factor represents influence of point sources pollution on water quality.

Second factor F2 explained 33 % of the total variance and had strong positive loadings on TH, EC, Ca<sup>2+</sup> i Mg<sup>2+</sup>, moderate positive loadings on pH and TP. Second factor represents hydro chemical component of water quality.

Third factor F3 explained 16.42 % of the total variance and had strong positive loadings on SS and NO<sub>3</sub>-N, moderate negative loading on pH. Third factor represents explained influence of coastal erosion and surface runoff.

The correlation matrix of variables was generated and factors extracted by the Centroid method, rotated by Varimax rotation. Only factors with eigenvalue greater than one were selected for this analysis. Factor loadings can be classified as “strong,” “moderate,” and “weak,” corresponding to absolute loading values of >0.75, 0.75–0.50, and 0.50–0.30, respectively [18]-[19].

From the results of factor analysis, it appears that such type of analysis has identified the sources of water quality variations in the study area. This shows the importance of such technique for water quality management agencies [20].

**Table 1. Water quality data of artificial water bodies in Vojvodina (mean value)**

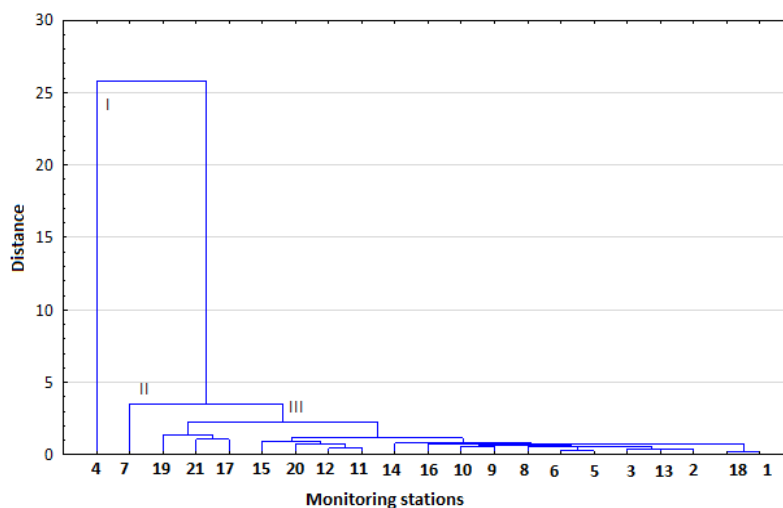
	T (°C)	SM (mg/l)	Ras. O <sub>2</sub> (mgO <sub>2</sub> /l)	UT (mg/l)	pH	EP (µS/cm)	NH <sub>4</sub> -N (mg/l)	NO <sub>3</sub> -N (mg/l)	TP (mg/l)	Ca <sup>2+</sup> (mg/l)	Mg <sup>2+</sup> (mg/l)	BPK <sub>5</sub> (mg/l)	PAM (mg/l)
Sombor	15.90	12.19	8.80	281.62	8.07	605.42	0.04	0.66	0.07	66.50	28.18	3.13	0.02
Mali Stapar	15.94	12.12	10.22	278.93	8.16	653.37	0.04	0.68	0.06	62.26	30.15	3.09	0.01
Vrbas 1	17.02	12.23	10.58	269.60	8.32	708.06	0.03	0.44	0.06	53.75	33.04	3.05	0.04
Vrbas 2	16.44	34.01	2.73	316.36	7.76	911.88	7.58	0.37	1.18	63.89	38.42	31.07	0.15
Srpski Miletić	15.53	20.16	10.31	217.79	8.11	527.29	0.06	1.18	0.15	56.36	18.95	3.62	0.02
Savino Selo	16.13	17.86	10.10	224.97	8.06	556.89	0.08	1.00	0.14	56.27	20.67	3.78	0.02
Bačko Gradište	14.86	31.46	10.96	247.25	8.34	657.35	0.40	0.75	0.26	53.25	27.78	7.78	0.04
Novi Sad	15.64	15.18	9.51	235.22	8.08	577.29	0.12	0.53	0.12	52.53	25.38	3.82	0.03
Bač	16.32	16.74	8.40	225.80	7.84	547.74	0.17	0.52	0.14	53.67	22.44	4.24	0.03
Bački Petrovac	16.21	15.13	8.90	248.38	7.97	596.41	0.09	0.40	0.13	55.68	26.63	3.98	0.03
Melenci	15.44	22.93	7.78	210.62	7.89	663.74	0.17	0.99	0.19	53.63	18.70	2.20	0.02
Vlajkovac	15.41	36.09	8.25	166.39	7.88	480.77	0.21	1.08	0.21	39.10	15.88	2.15	0.04
Kajtasovo	15.64	32.34	9.93	171.32	8.03	467.58	0.14	0.99	0.17	45.22	13.40	3.12	0.02
Žabalj	15.03	28.27	9.50	248.89	8.26	875.40	0.36	0.25	0.19	49.41	30.66	4.59	0.03
Novo Miloševo	15.65	27.22	7.06	231.48	7.82	782.67	0.47	0.95	0.34	56.85	21.74	3.43	0.04
Uzdin	15.96	15.94	11.18	187.06	8.25	667.94	0.04	0.44	0.07	41.71	20.19	2.54	0.02
Starčevo	15.18	42.06	5.88	434.51	8.06	1271.03	0.94	1.13	1.32	66.30	65.49	5.06	0.03
Bački Breg	14.81	11.59	9.00	267.34	8.07	570.14	0.06	0.41	0.07	64.62	25.67	3.23	0.02
Srpski Itebej	14.06	24.69	5.74	113.63	7.39	308.18	1.96	0.45	0.45	30.33	9.22	5.87	0.20
Klek	14.22	28.30	7.73	174.57	7.76	517.32	0.52	0.93	0.27	45.15	15.08	2.79	0.04
Stajićevo	15.14	27.14	5.73	168.80	7.60	515.12	0.79	0.84	0.41	44.74	13.93	5.27	0.05

**Table 2. Rotated factor loadings, communalities, eigenvalues and percentage of variance for water quality parameters**

Variable	F1	F2	F3
T	-0.066296	0.401567	<b>-0.609853</b>
SS	0.391267	0.158375	<b>0.796834</b>
DO	<b>-0.862549</b>	-0.078248	-0.327730
TH	0.065859	<b>0.976044</b>	-0.023214
pH	<b>-0.620678</b>	<b>0.518190</b>	-0.330159
EC	0.160222	<b>0.907066</b>	0.185464
NH <sub>4</sub> -N	<b>0.939458</b>	0.195539	-0.067892
NO <sub>3</sub> -N	-0.316381	0.032106	<b>0.760485</b>
TP	<b>0.702878</b>	<b>0.512011</b>	0.460249
Ca <sup>2+</sup>	-0.065029	<b>0.820731</b>	-0.224438
Mg <sup>2+</sup>	0.126879	<b>0.944945</b>	0.068610
BOD <sub>5</sub>	<b>0.861765</b>	0.293105	-0.165042
SAS	<b>0.872871</b>	-0.310080	0.018783
Eigenvalue	4.318312	4.286415	2.135658
Total variance (%)	<b>33.217786</b>	<b>32.972420</b>	<b>16.428138</b>
Cumulative (%)	33.217786	66.190206	<b>82.618344</b>

Cluster analysis was performed to detect similarity group between the monitoring stations. On basis of cluster analysis in relation to the first factor, as shown in Figure 2., monitoring stations are divided as follows:

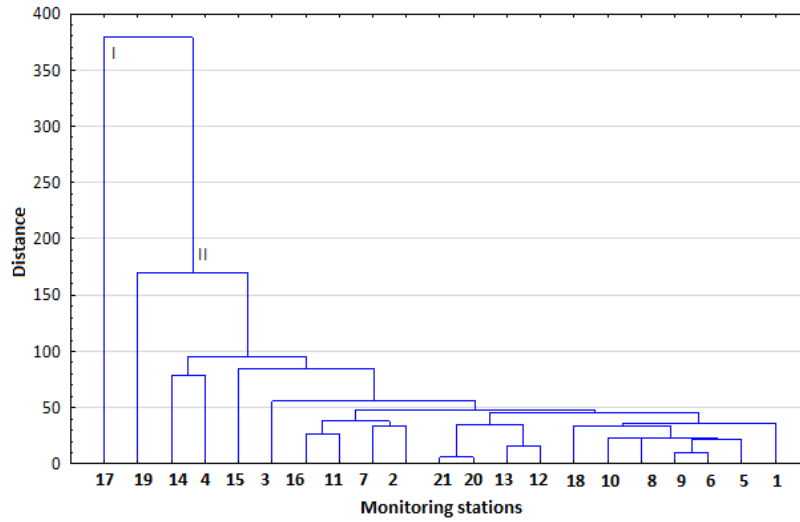
- Cluster I: monitoring station (4)
- Cluster II: monitoring stations (7,19,21,17)
- Cluster III: all others monitoring stations



**Figure 2. Cluster analysis dendrogram of monitoring stations in relation to the first factor F1**

On basis of cluster analysis in relation to the second factor, as shown in Figure 3., monitoring stations are divided as follows:

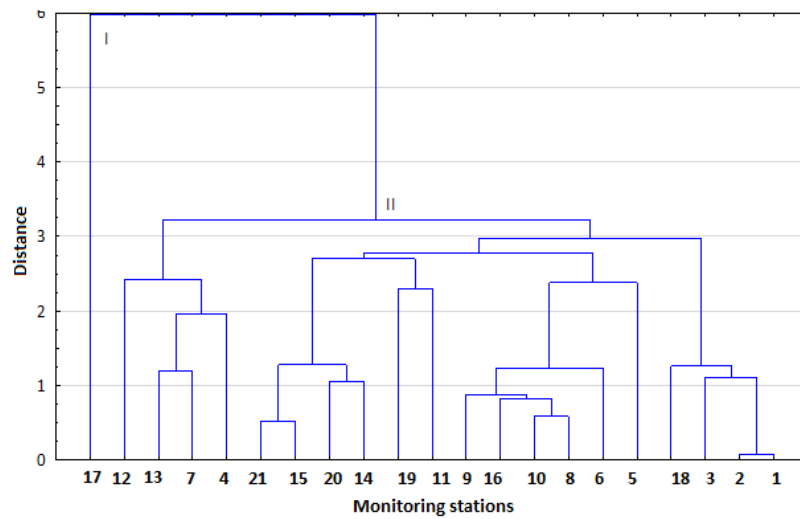
- Cluster I: monitoring station 17
- Cluster II: all others monitoring stations



**Figure 3. Cluster analysis dendrogram of monitoring stations in relation to the second factor F2**

On basis of cluster analysis in relation to the third factor, as shown in Figure 4., monitoring stations are divided as follows:

- Cluster I: monitoring station 17
- Cluster II: all others monitoring stations



**Figure 4. Cluster analysis dendrogram of monitoring stations in relation to the third factor F3**

CA could be useful tool in designing optimal sampling strategy, which could reduce the number of monitoring stations. The number of the monitoring sites could be optimized in such a way that for rapid quality assessment studies only representative sites from each cluster (not all monitoring sites) can be used. This reduces the number of analysis and the cost of the risk assessment procedure [21].

## 5. Conclusion

The application of FA and CA on the available data indicated that the water quality variations are mainly due anthropogenic (point and non point sources of pollution) and natural processes (erosion and runoff). From the results of factor analysis, it appears that such type of analysis has identified the sources of water quality variations in the study area. CA could be useful tool in designing optimal sampling strategy that could reduces the number of analysis and the cost of the risk assessment procedure.

## LITERATURE

1. *H. Juahir, S. M. Zain, A. Z. Aris, M. K. Yusoff, M. B. Mokhtar.* “Spatial assessment of Langat river water quality using chemometrics”, *J. Environ. Monit.*, 2010, 12, 287–295.
2. *V. Simeonov, J. W. Einax, I. Stanimirova and J. Kraft.* “Environmetric modeling and interpretation of river water monitoring data”, *Anal Bioanal Chem* (2002) 374, pp. 898–905, DOI 10.1007/s00216-002-1559-5.
3. *B. Miljanović, S. Pogrmic, Š. Šipoš, N. Pankov, I. Mijić, Bajčetić R.* Ecological-touristic potential of Bajski Canal, Conference Book, 22nd World Canals Confefence, Novi Sad, Art print, Novi Sad, p. 80, 2009.
4. *R. Savić, L. Maksimović, S. Cimpeanu, D. Bucur, G. Ondrašek, J. Vasin, M. Harja and S.o Milić.* “Hazardous and harmful substances in sediments of the Jegricka stream”, *Journal of Food, Agriculture & Environment*, Vol.11 (1), January 2013, 1152- 1156.
5. TICAD Tisa Catchment Area Development, NATIONAL STUDY Serbia 1<sup>st</sup> Draft, October 2010, Novi Sad
6. Hydrology Almanac – Water quality for the period 2008- 2011.Republic Hidrometeorological Service of Serbia, Belgrade. 6
7. *C. W. Liu, Kao-Hung Lin, Y. M. Kuo.* „Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan”, *The Science of the Total Environment* 313(2003)77–89.
8. *H. B. Chu, W. X. Lu1, and L. Zhang.* “Application of Artificial Neural Network in Environmental Water Quality Assessment”, *J. Agr. Sci. Tech. (2013) Vol. 15: 343-356.*
9. *A. Mahmood, W. Muqbool, M. W. Mumtaz and F. Ahmad,* “Application of Multivariate Statistical Techniques for the Characterization of GroundWater Quality of Lahore”, *Gujranwala and Sialkot (Pakistan), Pak. J. Anal. Environ. Chem. Vol. 12, No. 1 & 2 (2011) 102-112.*

10. *H. Boyacioglu and H. Boyacioglu.* “Surface Water Quality Assessment by Environmetric Methods”, *Environ Monit Assess* (2007) 131, pp 71–376 DOI 10.1007/s10661-006-9482-4 M. J.
11. *B. Alam, A. A. M. Ahmed and E. AliI.* “Evaluation of Surface Water Quality of Surma River Using Factor Analysis”, *Proc. Of International Conference on Environmental Aspects of Bangladesh (ICEAB10)*, Japan, pp. 186-188, Sept. 2010.
12. *E. A. M. Salah, A. M. Turki, E. M. Al-Othman.* “Assessment of Water Quality of Euphrates River Using Cluster Analysis”, *Journal of Environmental Protection*, 2012, 3, 1629-1633.
13. *M. Templ, P. Filzmoser and C. Reimann.* “Cluster analysis applied to regional geochemical data, problems and possibilities”, *Applied Geochemistry*, 23 (8) (2008), pp. 2198–2213.
14. *K. P. Singh, A. Malik, D. Mohan and S. Sinh.* “Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India)—a case study”, *Water Research* 38 (2004) 3980–3992.
15. *T. Kowalkowski, R. Zbytniewski, J. Szpejna and B. Buszewski.* “Application of chemometrics in river water classification”, *Water Research* 40 (2006) 744-752.
16. *A. Mustapha and A. Z. Aris.* “Spatial Aspect of Surface Water Quality Using Chemometric Analysis, *Journal of Applied Sciences in Environmental Sanitation*”, 2011, 6 (4):411-426.
17. *S. Adakalavan, C. Chandrasekar.* “Towards new estimating incremental dimensional algorithm (EIDA)”, *Journal of Theoretical and Applied Information Technology*, ISSN: 1992-8645, 2013. Vol. 51 No.2, pp. 222-227.
18. *C. W Liu, K. H. Lin and Y. M Kuo.* “Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan”, *The Science of the Total Environment*, 313, 2003, pp. 77–89., doi: 10.1016/S0048-9697(02)00683-6.
19. *S. M. Ahmed, M. Hussain and W. Abderrahman.* “Using multivariate factor analysis to assess surface/logged water quality and source of contamination at a large irrigation project at Al-Fadhli, Easter Province. Saudi Arabia”, *Bull Eng Geol Env*, 64, pp. 315-232, 2005.
20. *S. M. Al-Rawi and A. S. Shihab.* “Application of Factor Analysis as a Tool for Water Quality Management of Tigris River within Mosul City”, *Raf. Jour. Sci.*, Vol. 16, No. 1 Geology, Special Issue, pp.56-64, 2005.
21. *V. Simeonova, J. A. Stratish, C. Samarac, G. Zachariadisb, D. Voutsac, A. Anthemidis, M. Sofonioub, and T. Kouimtisc.* “Assessment of the surface water quality in Northern Greece”, *Water Research* 37, pp. 4119–4124, 2003.

# ОЦЕНКА КАЧЕСТВОТО НА ВОДИТЕ НА ИЗКУСТВЕНИ ВОДНИ ТЕЛА ВЪВ ВОЙВОДИНА (СЪРБИЯ) ЧРЕЗ ФАКТОРЕН И КЛЪСТЕРЕН АНАЛИЗ

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*Ключови думи:* изкуствени водоеми, клъстерен анализ, анализ на факторите, качество на водата

*Научна област:* хидравлика и хидрология

## РЕЗЮМЕ

Оценка на вариациите и интерпретация на качеството на водите на изкуствени водни тела във Войводина (Сърбия) са извършени посредством прилагане на многомерни статистически методи като факторния и клъстерния анализ. Факторният анализ е приложен за физикохимичните параметри на изкуствените водни тела с цел класификация, обобщаване и на редиците от данни, както и разделянето на хетерогенни серии от данни в по-малки хомогенни под-серии. Клъстерният анализ дава приликите и разликите между зоните на отделните проби и обяснява установеното клъстериране посредством засегнатите параметри.

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