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METHODOLOGY OF STREAM HYDROCHEMICAL ANALYSIS IN SPATIOTEMPORAL TERMS

METODOLOGIA ANALIZY HYDROCHEMICZNEJ CIEKU W UJĘCIU CZASOPRZESTRZENNYM

A b s t r a c t

Hydrochemical profiles were used to create a spatiotemporal hydrochemical analysis of a watercourse. This method is based on the correlation between the concentration of pollutants and the intensity of water flow in the watercourse. It is a method that allows for an analysis of qualitative and quantitative changes of pollutants occurring in the watercourse. The paper describes the steps to be followed to obtain hydrochemical profiles of the watercourse. The function of time has been introduced in order to illustrate the analysis in a three-dimensional way. All of the profiles are shown in one graph, where qualitative and quantitative changes are visible within water levels at a specified time interval. The results are presented as graphs allowing for the classification of the course due to water quality, showing the hydrochemical shell in the watercourse during the year.

Keywords: *spatiotemporal hydrochemical analysis*, *surface water quality*

S t r e s z c z e n i e

Do stworzenia czasoprzestrzennej analizy hydrochemicznej cieku wykorzystano metodę profili hydrochemicznych. Metoda ta opiera się na zależności korelacyjnej pomiędzy stężeniem zanieczyszczeń a natężeniem przepływy wód w cieku. Umożliwia ona analizę zmian jakościowych i ilościowych zanieczyszczeń zachodzących na długości cieku. Opisane zostały kolejne kroki, jakie należy wykonać w celu uzyskania profili hydrochemicznych cieku. Aby przedstawić analizę w ujęciu trójwymiarowym, wprowadzono funkcję czasu. Wszystkie profile przedstawione zostały na jednym wykresie, gdzie widoczne są zmiany jakościowe i ilościowe wód w cieku na przestrzeni zadanego przedziału czasowego. Wynikiem były wykresy pozwalające dokonać klasyfikacji cieku ze względu na jakość wody przedstawiające powłokę hydrochemiczną na cieku w ciągu roku.

Słowa kluczowe: *czasoprzestrzenna analiza hydrochemiczna*, *jakość wód powierzchniowych*

Translated by Małgorzata Gąsińska.

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1. Introduction

Consumers of water take in water from a source, use it and then return it to circulation. As a result of use, water quality changes due to changes in the physical, chemical and biological properties. Some of this water flows into rivers in the form of sewage, contributing to the deterioration of the quality of the existing water resources. The consumers include the population, industry, public utilities, agriculture and forestry. The water may be used by them for drinking, as a basic production raw material or an essential element of production processes. The discharges of post-consumer water and sewage generated in the production process greatly affect the quality of water flowing in courses. Solving the problem of wastewater treatment to allow for its reuse is a necessary condition of a well-functioning economic water cycle [2].

Surface waters have a certain self-purification potential associated with the biological life developing in the aquatic environment. An adequate dissolved oxygen content in the water is a factor determining aquatic life development, and thus the continuity of the process of self-purification. Dissolved oxygen is consumed in the mineralization of organic compounds entering the water with sewage. It is therefore necessary to have a balance between the self-purification potential of water and the amount of oxygen required for the mineralization of pollutants which naturally enter the watercourse and originate from municipal and industrial wastewater [3].

The level of water pollution in rivers depends not only on the amounts introduced with sewage, but also on the flow in the river, which affects the dilution of pollutants [2]. Water volume in streams is not constant over time. It is connected with variable rainfall during the year. The geographical location and the geological catchment area also affect the water supply. Controlling the flow rate of watercourses is also related to the specific needs of consumers. Even short-term water shortages could cause major damage in many areas of economic activity. Further intakes are determined so as not to impede the existing ones.

The necessity for the continuous monitoring of the quality and quantity of water pollution in watercourses is due to the specific requirements of water for use. This is an important part of water management, the task of which is to supply or make water available in the necessary quantity and quality sufficient both for the population, and for individual sectors of the economy [2].

2. Methods

The method of hydrochemical profiles is one of the methods used to perform analyses of watercourses. It was created as a result of attempts to harmonize ways of testing watercourses, it was proposed by H. Mańczak in 1963 [2]. Hydrochemical profiling is a statistical method of assessing the degree of water pollution in rivers based on the results of periodic testing of water in measuring and control sections. The research allowed for establishing the correlation between the concentration of the pollutant and the water volume flow rate (***Q***) in individual cross-sections. The existence of this correlation allowed for the reference of average pollutant concentrations to the low flow (*SNQ*) which was formally recognized as a concentration relevant for the assessment of the level of pollution in river water. Concentrations related to *SNQ* are applied onto the longitudinal profile of the course. In this way, changes in the level of water pollution in the river along its length are illustrated. The resulting hydrochemical profile includes abrupt changes due to point-discharges of pollutants or resulting from the increase in water flow in the river due to its tributaries. Hydrochemical profiling has been used in the assessment of water quality in rivers in Poland.

Taking into account the function of time in carrying out the hydrochemical analysis, we obtain a three-dimensional hydrochemical shell showing the changes in the watercourse quality, as they occur between the profiles within a year.

The following information is needed to perform such a hydrochemical analysis:

- location of balance cross-sections along the length of the watercourse,
- water gauges ***W***,
- water quality at monitoring points ***M***,
- cross-sections of the estuaries of side tributaries ***d***,
- water intake points **p** and the discharges of sewage ***z***,
- partial catchment areas closed with balanced cross-sections [km^2],
- the volume of the average intensity of low flow $\boldsymbol{SNQ_R}$ in water gauge cross-sections,
- the volume of the relevant $\boldsymbol{BZT_5}$ concentrations at monitoring points [mg/dm^3],
- the volume of water intakes $\boldsymbol{Q_p}$ [m^3/s] and the volume of wastewater discharges $\boldsymbol{Q_z}$ [m^3/s] and the BZT_5 content in the discharges $\boldsymbol{S_z}$ [mg/dm^3] [1].

If it is impossible to measure gauges on tributaries, it is necessary to add the catchment area of each tributary to the catchment area of the main course. This results in increases in the catchment area of the main watercourse in the cross-sections of estuary tributaries. Knowing the actual *SNQ* values [m^3/s] measured in gauge-points and the volume of water intakes Q_p [m^3/s] and discharges Q_z [m^3/s], natural SNQ_N values can be determined in gauge cross-sections. Then, using the principle that the SNQ_N increase growth is directly proportional to the increase in the catchment area, SNQ_N values across all balance cross-sections can be determined by means of interpolation and extrapolation. Knowing the value of SNQ_N across all balance cross-sections, and the volumes of intakes and discharges, SNQ_R [m^3/s] can be determined across all balance cross-sections. The next step is to determine the size of pollution loads in all cross-sections. This can be done based on the values measured at monitoring points. In connection with the occurrence of water intakes along the course, it is necessary to set the actual loads at water intakes. The pollution load from the watercourse along with water is the product of the concentration of pollutants at the intake S_p and the volume of the intake Q_p. Both of these values (S_z and Q_z) are known for sewage discharges. To calculate the concentrations of pollutants in intakes, it is necessary to calculate the size of a unit load $ł_j$, i.e. the load increase associated with the SNQ_N increase at the watercourse section between the monitoring points. Following the calculations of the SNQ_N concentrations in cross-sections where water is taken, pollutant loads collected from the course along with the water can be calculated. Knowing the values of the collected loads and the values of the loads discharged into the course measured at monitoring points, the natural values of loads at individual monitoring points can be calculated, followed by interpolation and extrapolation to calculate natural load values for all balanced cross-sections. Using the known volumes

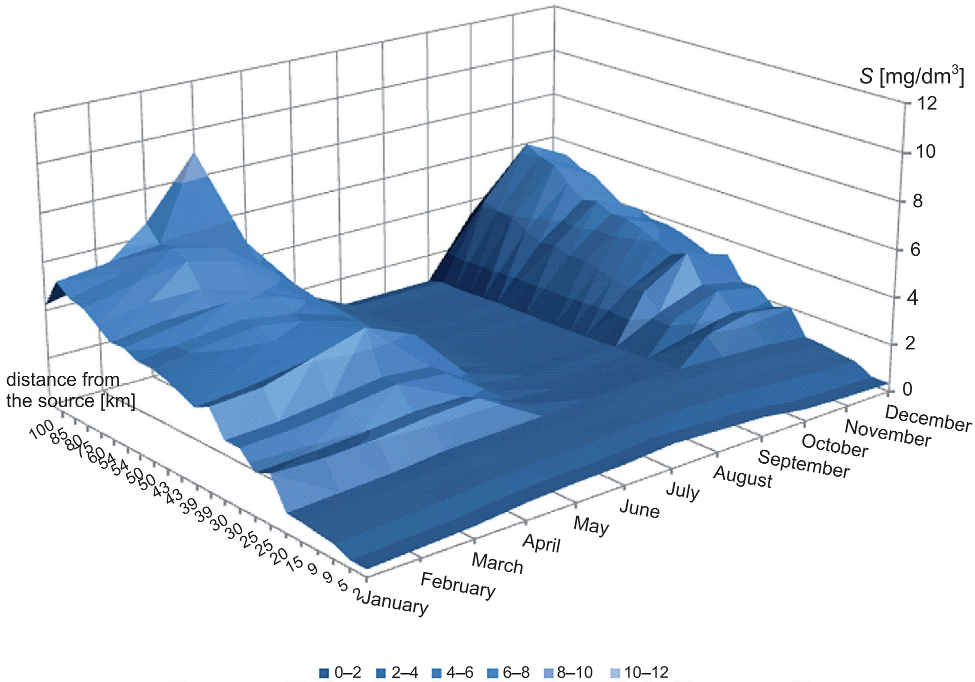

Fig. 1. Spatiotemporal graph of pollutant concentrations

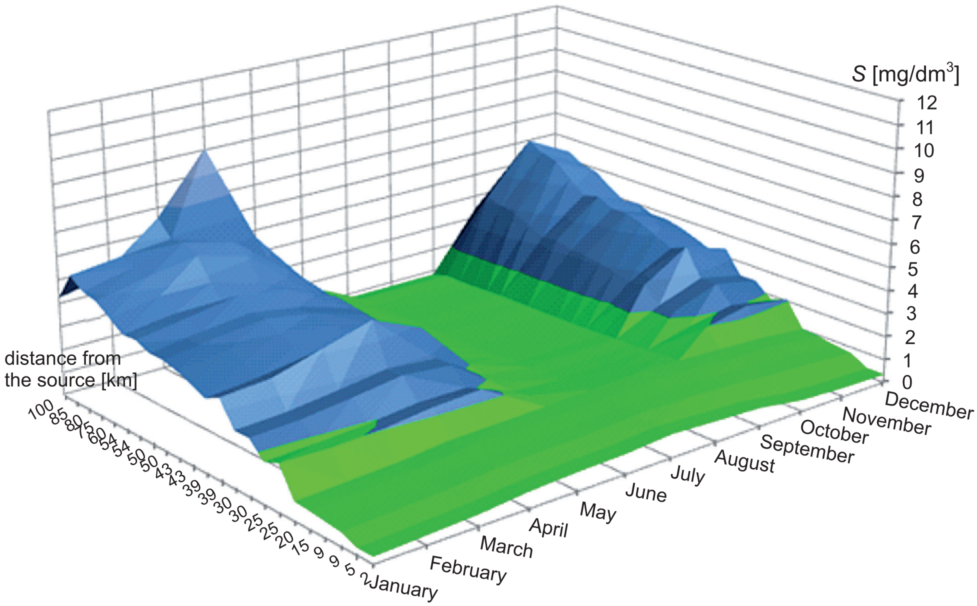

Fig. 2. Spatiotemporal graph of pollutant concentrations with the selected threshold concentration

and the volumes obtained by calculations, we can determine the volumes of the actual loads $Ł_R$ in all of the balanced sections.

In order to determine BZT_5 profiles, it is necessary to calculate concentrations in cross-sections along the entire course. The concentrations are calculated as the ratio of the actual load in the section and the actual value of the average low flow. Performing analogous calculations for a number of time intervals and plotting the results on a graph, we obtain the spatiotemporal image of the concentrations of pollutants in the course during a year.

Knowing the concentrations of all of the analyzed sections in the course, absorbency can be calculated. In the case of the assumed value of the threshold concentration, the load for each balance cross-section is calculated. Using the information on the volume of the threshold load, one can determine the ability of the course to adopt a sewage load in the given balanced cross-section so as not to exceed the threshold load. This value is absorbency, calculated as the difference between the threshold load at the cross-section and the actual load present at the same cross-section. Continuing the spatiotemporal assumptions of the analysis, absorbency can also be represented in its spatial form.

3. Results

Calculations were carried out in a tabular form, as presented. All of the calculations and graphs were prepared in MS Office Excel, 2010. This tool works well in the case of the hydrochemical method by Mańczak, however, a disadvantage appears in the case

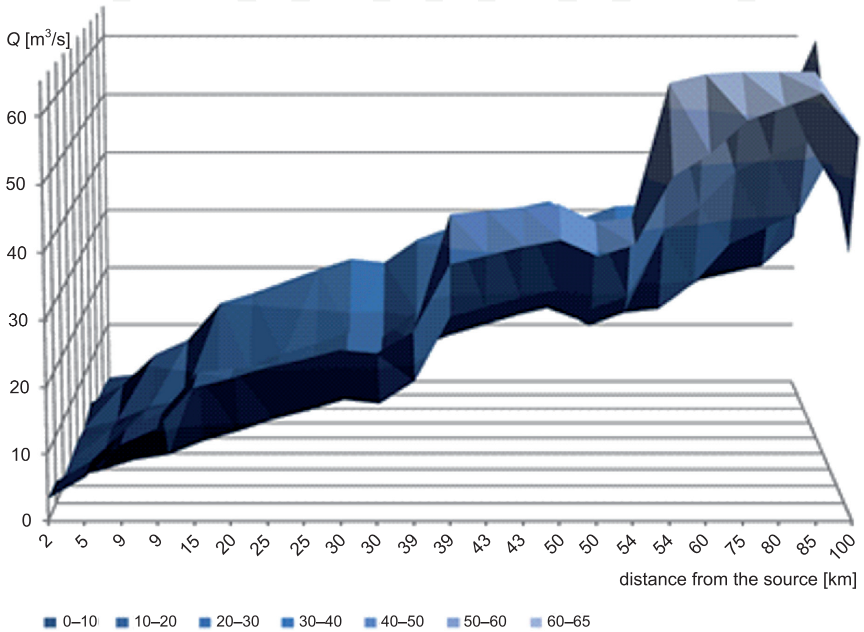

Fig. 3. Average low flow in the course in a particular month, presented as a panel graph cross-section

of the creation of three-dimensional diagrams. The panel graph, on an axis representing the course longitudinal profile, at the points of the increase of flows (tributaries, discharges, intakes), values are taken separately. Below, the two forms of graphs illustrate the course flows. Figure 3 shows *SNQ* as a cross-sectional panel graph in a selected month, while Fig. 4 shows *SNQ* of the same month as a flow value profile along the course.

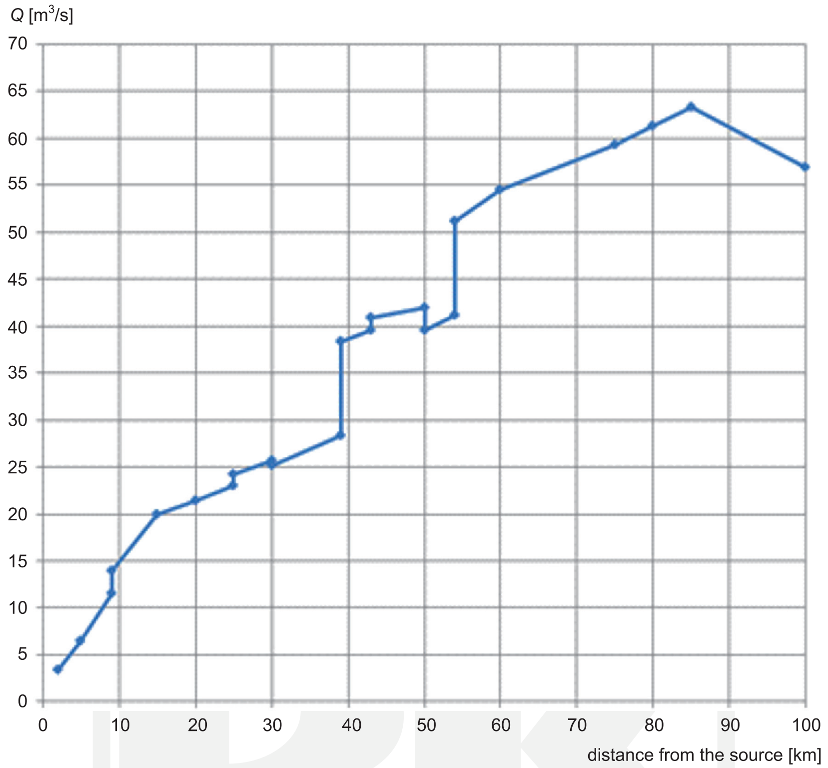

Fig. 4. Average low flow in the course in a particular month, presented as a watercourse profile

A three-dimensional image of the status of water in the watercourse was obtained as a result of the simulation. Three-dimensional graphs can easily provide profiles of pollutant loads in various research cross-sections along a watercourse during a year. An illustration of the qualitative and quantitative status of watercourses in a particular selected point over time can be easily obtained. Following the calculation of the concentrations of pollutants, it is also feasible to prepare a spatiotemporal diagram classifying waters into grades according to the criteria listed below.

Due to assuming proper formatting criteria, the graph shows when, and at what points of the watercourse, given purity grades occur. The above watercourse graph shows that the waters of the course did not reach the levels of pollutants that would classify them in the fifth grade.

Table 1

Classification of water quality due to BZT_5 concentration

Water grade	Quality requirements	
First	$0 < S \leq 2$	[mg/dm^3]
Second	$2 < S \leq 3$	[mg/dm^3]
Third	$3 < S \leq 6$	[mg/dm^3]
Fourth	$6 < S \leq 12$	[mg/dm^3]
Fifth	$S > 12$	[mg/dm^3]

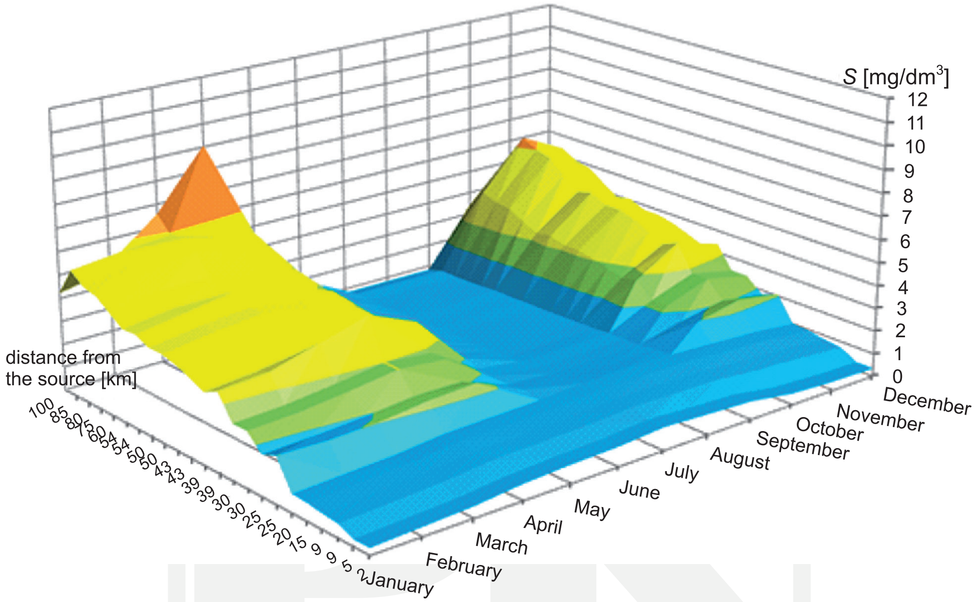

Fig. 5. Concentrations of pollutants with grades determined

4. Conclusions

The aim of the study was to present a three-dimensional hydrochemical analysis. It is based on the method of hydrochemical profiles that has been functioning for half a century. The methodology of the analysis has not been changed, however, an additional function of time has been introduced and the way of presenting the results has been changed. This was possible due to the available computer tools. The hydrochemical analysis allows for classifying rivers according to their purity. The three-dimensional representation of the hydrochemical analysis of water quality allows for referencing to the entire length of the course at a selected point in time. Hydrochemical profiling allows for the consideration of qualitative and quantitative needs in terms of water use for all water consumers. The three-dimensional graphs greatly facilitate the interpretation of results. They also provide additional aspects of the exploration of information on the status of the watercourse. They allow for modeling how will the changes in the method of watercourse exploitation affect the quantity and quality along the course in a broader perspective. They also provide the possibility of predicting how the changes in the environment of the watercourse during a year affect the selected points along the watercourse.

The spatiotemporal graphs allow for locating the areas where actions need to be taken to improve the quality of the water flowing along the watercourse during a year. In order to effectively improve the quality of the flowing water, it is necessary to fully identify and locate the factors which adversely affect the status of the watercourse. Perspective actions should be taken, not only causing a one-time effect on the improvement of water quality, but also bringing long-term effects, reducing the risk of pollution of watercourses.

References

[1] Chmielowski W., Jarząbek A., *Ćwiczenia i projekty z przedmiotu gospodarka wodna*, Pomoc dydaktyczna, Politechnika Krakowska, Kraków 2008.

[2] Piotrowski J., Szpindor A., *Gospodarka Wodna*, Państwowe Wydawnictwo Naukowe, Warszawa 1986.

[3] Tuszko A., *Gospodarka wodna*, Państwowe Wydawnictwa Szkolnictwa Zawodowego, Bielsko--Biała 1971.