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ALGAE COMMUNITIES IN SPRINGS OF ŁÓDŹ HILLS SCARP WITH DIVERSIFIED HYDROCHEMICAL CONDITIONS

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Summary. The work presents the first results of the three years' project carried out in ten springs of the Łódź Hills scarp. In 2003 algae communities were studied against the background of hydrochemical water conditions. Multifactor analysis of twenty two physico-chemical properties of water revealed hydrochemical differentiations of the examined springs. Qualitative analysis of algae communities, mainly diatoms, indicates a connection between hydrochemical conditions and species composition of these organisms, particularly in the objects under the anthropogenic influence.

Key words: springs, hydrochemical conditions, algae, diatoms

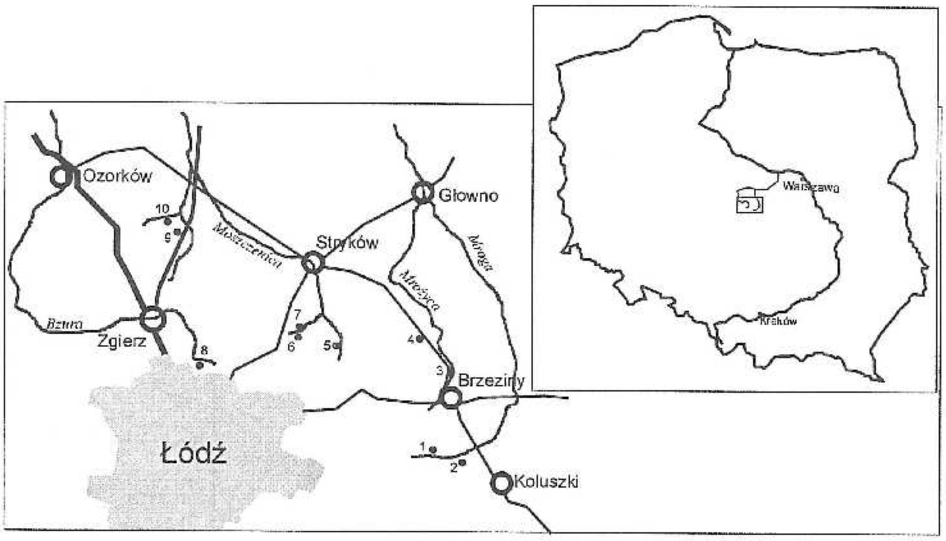
STUDY AREA

Land management changes affecting the environment have been taking place in the suburbs of big cities. Springs that are some of the most valuable natural forms readily react to such environmental changes. In the zone of the impact of Łódź agglomeration, in the upper part of Bzura catchment and in the northern part of Łódź Hills scarp a lot of springs are situated (Fig. 1).

The main purpose of this research is to examine the abiotic conditions in springs and their influence on algae community. Among the catchment conditions hydrochemical agents are of special importance.

Studied of ten springs in the northern part of Łódź Hills Range scarp, in the head-streams of Bzura, Moszczenica, Mrożyca and Mroga rivers began in 2003. The springs belong to class IV (no. 4, 10), V (no. 3, 8, 9), VI (no. 1, 2, 5, 6) and VII (no. 7) in the Meinzer's yield classification. The examined springs represent the limnocrenic type (six springs) and the reocrenic type (four springs).

In the northern part of Łódź Hills Range springs are alimentated from Quaternary sediments built of grotnicko-lućmierski sander, intermoraine sediments lying under clay of Middle Poland glaciation and alluvial deposits of Mazovian interglaciation although from glacitectonic displacement of moraine stratas [Maksymiuk and Mela 1995].



5• – marking of explored spring – oznaczenie badanego źródła

Fig. 1. Layout of the explored springs
Rys. 1. Położenie badanych źródeł

Sampling started in January 2003 and will continue until June 2005, as described in the schedule submitted to the State Committee for Scientific Research, grant no. 3P04G 057 23.

MATERIAL AND METHODS

Physicochemical properties of spring waters (temperature, pH-reaction, conductivity, redox potential and dissolved oxygen) were recorded, together with algal sampling, once a month. General physicochemical properties of spring waters, major ions and selected secondary ions were determined once every three months [Witczak and Adamczyk 1995]. Heavy metal content examinations have been done twice; future analyses of this type were not scheduled as no evidence of these elements in water was recorded.

Factor analysis on the basis of all twenty two hydrochemical properties was used to establish hydrochemical diversification in PCA procedure, carried out in Statistica [StatSoft Inc. 1995]. The hydrochemical data set was divided into two groups and was calculated for the replacement values – factors. The first group comprises TDS, oxidizability, TH, water colour, temperature, conductivity, pH-reaction, redox potential, dissolved silica and oxygen. The following ions were examined in the second group: Na^+, K^+, Ca^{2+}, Mg^{2+} and NH_4^+ as well as Cl^-, HCO_3^-, SO_4^{2-}, NO_3^-, NO_2^- and PO_4^{3-}.

Samples for algological studies were collected from springs once a month during the year 2003. Benthos was collected from the surface layer of the substrate

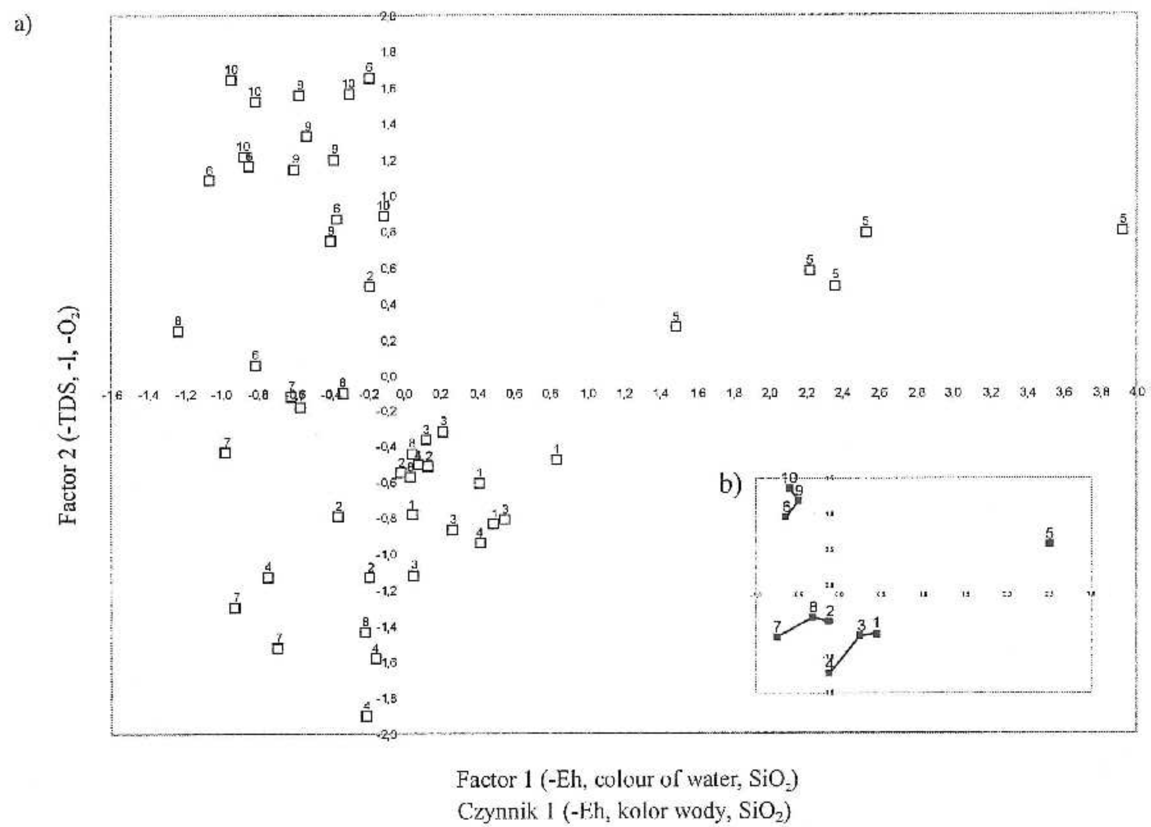


Fig. 2. Hydrochemical diversity of spring waters with respect to the physicochemical properties; a – factor scores, b – grouping by cluster analysis

Rys. 2. Zróżnicowanie wód źródlanych pod względem parametrów fizykochemicznych; a – wartości czynnikowe, b – grupowanie metodą klastrową

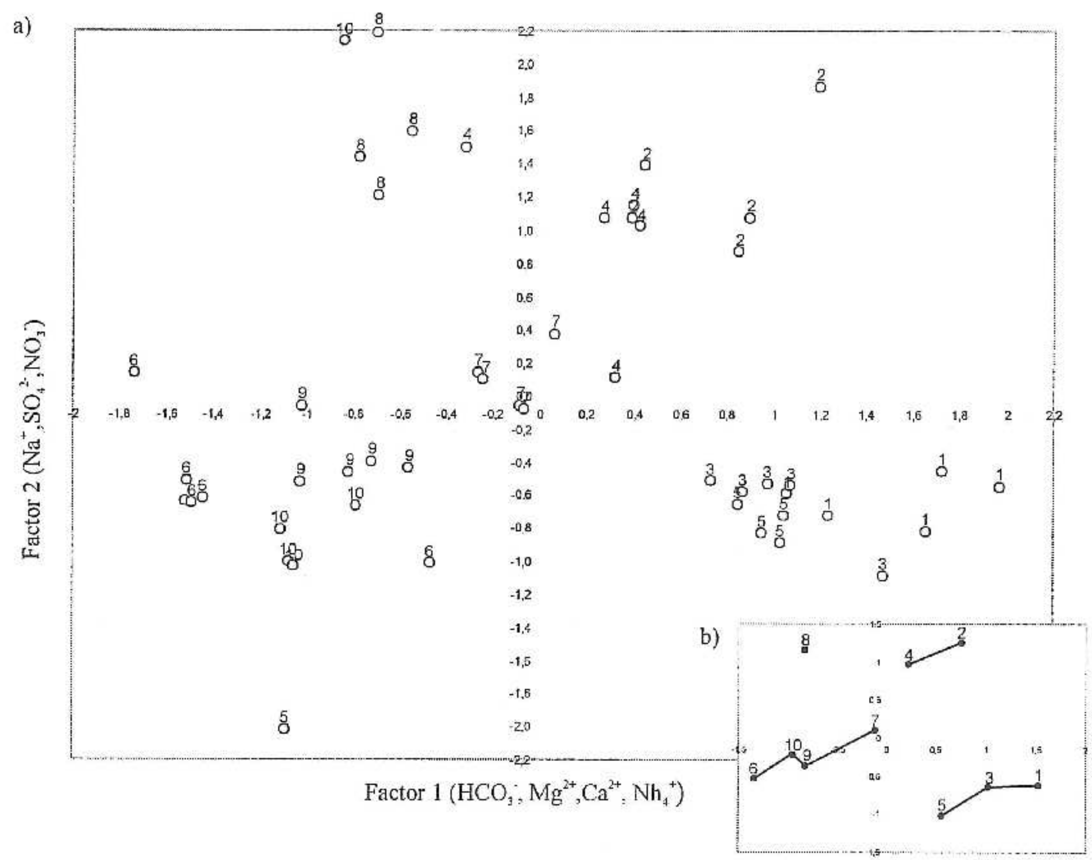


Fig. 3. Hydrochemical diversity of spring waters with respect to the ion composition; a – factor scores, b – grouping by cluster analysis

Rys. 3. Zróżnicowanie wód źródlanych pod względem parametrów fizykochemicznych; a – wartości czynnikowe, b – grupowanie metodą klastrową not further than one meter downstream from the outflow. Samples were refrigerated for no longer than three days for the purposes of observation and classification of the live material. The samples were next fixed in a 4% formaldehyde solution.

In order to obtain clean diatom frustules, the collected benthic material was digested. To make permanent slides, the diatom material was mounted in Naphrax.

The qualitative and quantitative analysis of diatom communities was performed on the basis of permanent slides. In each sample 500 valves were counted. The following groups of diatom species were considered: dominant species with the participation above 5%, subdominants 2-5%, influents 1-2%, accessory and alien species below 1%.

RESULTS

As the conducted factor analysis of physicochemical properties show, those parameters whose factor load is higher than +/- 0.6 play an important role in hydrochemical diversification of spring water. The first factor includes redox potential, water colour and dissolved silica (28%), the second factor includes TDS, conductivity and dissolved oxygen (21%), while the third factor – pH-reaction and temperature (13%). Therefore, these three factors explain 62% variance in the hydrochemical data set. The most important role is played by the two first factors, thus the hydrochemical classification of spring waters was established on this basis. Relationships between individual replacement values of springs are given in Fig. 2a. Cluster analysis was used to determine hydrochemical differentiation in a more specific way. Individual mean values of spring (Fig. 2b) were used as the basis of this method. The occurrence of four groups of springs (1, 3 and 4; 6, 9 and 10; 2, 7 and 8; 5) was confirmed in the analysis. Properties of the hydrochemical environments represented by these groups are shown in Table 1.

Spring 5 seems particularly interesting. The redox potential of the water is negative; its colour is deeper and the concentration of dissolved silica is higher. Water colour, redox potential and concentration of dissolved oxygen indicate that organic matter is present in the drained aquifer. The differences between remaining springs are attributed to silica concentration, TDS and dissolved oxygen. A group of springs in the forefield of sanders (6, 9 and 10) clearly illustrates this case.

Factor analysis of the second group, i.e. ion elements, provided information on chemical variability of spring waters, caused by: HCO_3^-, Mg^{2+}, Ca^{2+} and NH_4^+ (first factor – 24% participation); Na^+, SO_4^{2-} and NO_3^- (second factor – 20%) and Cl^- with PO_4^{3-} (third factor – 15%). These three factors explain 59% variance in the data set of ion elements. Similarly to the first group of water properties, the two first factors were used for the hydrochemical classification. Relationships between individual replacement values of springs are given in Fig. 3a. Cluster analysis was conducted next. The following sets were identified within the group of all springs: 1, 3 and 5; 2 and 4; 6, 7, 9 and 10, as well as 8 (Fig. 3b). The main ion composition of the identified springs set is presented in Table 2.

Table 1. Mean values of physicochemical properties of the groups of springs
Tabela 1. Średnie wartości cech fizykochemicznych wytypowanych grup źródeł

Physicochemical properties Parametr fizykochemiczny	Groups of springs Grupy źródeł			
	I 1, 3, 4	II 5	III 2, 7, 8	IV 6, 9, 10
Eh (mv)	211	-55	217	215
Colour ($mgPt \cdot dm^{-3}$) – Kolor	4.0	8.5	3.0	3.5
SiO_2 ($mg \cdot dm^{-3}$)	19.6	25.6	16.0	16.2
TDS ($mg \cdot dm^{-3}$)	386.6	367.6	356.9	262.8
Conductivity ($mS \cdot cm^{-1}$) – Przewodnictwo	0.430	0.400	0.440	0.310
Dissolved oxygen ($mgO_2 \cdot dm^{-3}$) – Rozpuszczony tlen	52.5	4.2	50.3	30.5

The composition of the first factor allows us to identify the group of ions with geochemical processes, which form hydrochemical conditions in the aquifers drained by springs. The longer the time of the water presence in the lithosphere, the higher the factor values. The composition of the second factor shows that it is an indicator of anthropogenic groundwater transformation caused by the inflow of pollutants. The three hydrochemical elements are indicators of agricultural pollution [Macioszczyk 1995]. The higher the factor score, the more polluted the water in the sampled spring.

The dominating group of algae in the examined springs consists of diatoms. In six out of ten springs representatives of the following phyla were identified: *Chlorophyta*, *Euglenophyta*, *Rhodophyta*, *Cyanoprokaryota* and the class *Xanthophyceae*. Species of *Cyanoprpkaryota* occurred mainly in spring 5. These were the species: *Anabaena affinis* Lemmermann, *Nostoc paludosum* Kützing, *Oscillatoria limosa* Agardh, *O. splendida* Greville, and *Phormidium tinctorium* Kützing. Also, spring 5 was the only one where representatives of *Euglenophyta*: *Trachelomonas hispida* (Perty) Stein, *T. oblonga* Lemmermann and *Euglena* sp. were present. In spring 3 macroscopic filamentous algae occurred. The spring is situated inside a boarding with the bottom overgrown with *Vaucheria* sp. Among its thalli numerous filaments of *Tribonema viride* Pascher, *T. aequale* Pascher from *Chrysophyta* and of *Cladophora* sp., *Oedogonium* sp., *Spirogyra* sp., *Ulothrix* sp. from *Chlorophyta* were entangled. Also, unicellular *Closterium ehrenbergii* Meneghini ex Ralfs (*Chlorophyta*) was found in this spring.

Qualitative and quantitative analysis of diatom communities in ten examined springs revealed the group of dominant species characteristic of each of them. The most distinct diatom species composition was found in spring 5 with dominant species of *Achnanthes conspicua* Mayer, *Navicula minima* Grunow, *N. veneta* Kützing, *Stauroneis smithii* Grunow. In respect of dominant species, springs 2, 7, and 10 were also conspicuous. The following diatom prevailed in spring 2: *Sellaphora pupula* (Kützing) Mereschkowsky, *Nitzschia constricta* (Kützing) Ralfs, *N. linearis* (Agardh ex W. Smith) W. Smith; in spring 7: *Rhoicosphaenia abbreviata* (Agardh) Lange-Bertalot, *Amphora pediculus* (Kützing) Grunow, *A. ovalis* (Kützing) Kützing, *Campylodiscus hibernicus* Ehrenberg; in spring 10: *Achnanthes clevei* Grunow, *Cocconeis pseudothumensis* Reichardt, *Navicula striolata* (Grunow) Lange-Bertalot.

The studied springs were also diversified in terms of diatom species diversity. Two groups of spring can be distinguished. The first one, with less than 60 diatom species, was represented by springs 2, 3, 4, 7, 8, and 10. The second one, with the diatom community consisting of more than 80 species, was represented by springs 1, 5, 6, and 9.

Table 2. Mean values of ion composition in the identified set of springs
Tabela 2. Średnie wartości stężeń jonów w wodach wytypowanych grup źródeł

Ion Jon ($mg \cdot dm^{-3}$)	Groups of springs Grupy źródeł			
	I 1, 3, 5	II 2, 4	III 6, 7, 9, 10	IV 8
HCO_3^-	217.8	183.0	121.4	142.7
Mg^{2+}	7.1	5.0	4.8	3.2
Ca^{2+}	77.6	84.0	56.1	77.5
NH_4^+	0.17	0.15	0.14	0.14
Na^+	5.5	7.0	5.9	12.4
SO_4^{2-}	42.8	65.2	47.4	62.7
NO_3^-	9.9	28.7	24.9	25.4

The group of indicatory diatom species was also distinguished in the studied springs. *Navicula antonii* Lange-Bertalot, a species indicating an anthropogenic influence [Lange-Bertalot 2001], was present in springs 2, 8 and 10. *Sellaphora pupula*, a species typical of α-mezosaprobic waters [Krammer and Lange-Bertalot 1986], dominated in spring 2. Also, *Nitzschia constricta* and *Nitzschia hungarica* Grunow, the species typical of α-mezosaprobic waters [Krammer and Lange-Bertalot 1988], occurred exclusively in this spring. *Navicula striolata* is an indicatory species of oligosaprobic waters [Lange-Bertalot 2001]; this species dominated in springs 4 and 10, and occurred as subdominants in springs 6 and 8. *Meridion circulare* (Greville) Agardh is a species occurring in waters with high calcium content, springs and rapidly flowing mountain streams [Krammer and Lange-Bertalot 1991]; it was noted only in springs 1, 3, 6, and 9. *Navicula joubaudii* Germain is an indicator of oligosaprobic waters [Krammer and Lange-Bertalot 1986]; it occurred in springs 4, 6, 7, and 9. In these springs participation of *Navicula joubaudii* in diatom communities did not exceed 2%.

CONCLUSIONS

Research of springs attempted to decide whether stable conditions in springs select organisms specialized for the habitat. Some studies on diatom communities in springs show that these communities do not have specific species [Round 1960]. In the case of diatoms, however, such species are recorded in springs [Cantonati 1998].

The presence of dominant species, influents and accessory species having a narrow range of tolerance for physicochemical water conditions, allow distinction and definition of diatom community of each spring.

The analysis of diatom communities of different hydrochemical types of springs reveals that the objects heavily influenced by man (springs 2, 4 and 8) are characterized by low species diversity. This can indicate stable hydrochemical conditions and constant presence of pollutants.

The hydrochemical water conditions in the studied springs reflect the catchments management. Positive values of factors II and I show the influence of agricultural practices (spring 2 and 4), while positive values of factor II and negative value of factor I, indicating the presence of other ions: Cl^- and PO_4^{3-}, representing factor III, show the effect of urban catchment (spring 8).

Qualitative analysis of diatoms seems to confirm the influence of different kinds of pollutions on the studied springs. It can be seen clearly in spring 2, where the species characteristics of α-mezosaprobic waters were present. Also, the occurrence of *Navicula antonii*, a species indicating an anthropogenic influence [Lange-Bertalot 2001], was recorded in springs 2, 8, and 10.

The present research confirms the previous observation [Żelazna-Wieczorek, in press] that the diatom community of spring 10 is distinctly different from the other springs in respect of diatom species, low species diversity and occurrence of *Navicula antonii*. The occurrence of *Navicula striolata* and *Navicula joubaudii*, the indicatory species of oligosaprobic waters [Krammer and Lange-Bertalot 1986], is a distinct feature of springs 4.

Hydrochemical typology of spring 5, based on physicochemical parameters as well as the composition of algae community was completely different from the other springs.

A comparison of hydrochemical and algological analysis of springs does not confirm at the present stage of the research that the character and composition of alga is determined mainly by the features and composition of waters in the spring niches. The occurrence of *Amphora ovalis*, a diatom of shady places, in springs 4, 7, 8, 9, and 10, indicates the role of light as a possible factor modifying the composition of diatom communities in springs.

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ZBIOROWISKA GLONÓW W ZRÓŻNICOWANYCH HYDROCHEMICZNIE TYPACH ŹRÓDEŁ W STREFIE KRAWĘDZIOWEJ WZNIESIEŃ ŁÓDZKICH

Streszczenie. W pracy przedstawiono pierwsze wyniki badań prowadzonych w ramach trzyletniego projektu badawczego, obejmujące sezon 2003 roku. Badania dotyczą zbiorowisk glonów występujących w 10 źródłach strefy krawędziowej Wzniesień Łódzkich, w powiązaniu z warunkami hydrochemicznymi. Zróżnicowanie hydrochemiczne źródeł przedstawiono na podstawie dwudziestu dwóch parametrów fizykochemicznych, których rolę określono przy wykorzystaniu analizy wieloczynnikowej. Analiza jakościowa zbiorowisk glonów źródeł, głównie okrzemek, wskazuje na powiązanie warunków hydrochemicznych z ich składem gatunkowym, zwłaszcza w obiektach znajdujących się pod wpływem antropopresji.

Słowa kluczowe: źródła, warunki hydrochemiczne, glony, okrzemki