DOI: 10.21005/AAPZ2016.40.4.04

FOLIA POMERANAE UNIVERSITATIS TECHNOLOGIAE STETINENSIS
Folia Pomer. Univ. Technol. Stetin., Agric., Aliment., Pisc., Zootech. 2016, 330(40)4, 33–46

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HYDROELECTRIC POWER PLANTS IN THE BASIN OF SŁUPIA RIVER – TOURISTIC ATTRACTION OR ECOLOGICAL THREAT?

HYDROELEKTROWNIE DORZECZA SŁUPI – ATRAKCJA TURYSTYCZNA CZY ZAGROŻENIE EKOLOGICZNE?

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Streszczenie. W badaniach wyznaczano zawartość jonów i wybranych metali ciężkich oraz toksyczność w próbkach wody powierzchniowej i przydennej oraz osadów dennych pobranych powyżej i poniżej sześciu hydroelektrowni w dorzeczu Słupi. Z wyjątkiem niektórych substancji biogennych profil jonowy wody wskazuje na jej wysoką czystość. Nie wykryto toksyczności próbek wodnych za pomocą przesiewowego testu Microtox, jak również za pomocą testów Spirotox i Daphtoxkit F. Mimo że średnie stężenia metali w wodzie i osadach dennych były bardzo niskie, wykryto nieznaczną toksyczność próbek osadów. Tylko w przypadku dwóch elektrowni (Krzynia, Skarszów Dolny) toksyczność osadów powyżej nich była wyższa niż poniżej. Obserwowane zależności są prawdopodobnie związane z naturalnym lub sztucznym charakterem kanałów doprowadzających wodę do elektrowni. W ujęciu ogólnym funkcjonowanie hydroelektrowni nie przyczynia się do wzrostu stężenia metali ciężkich i toksyczności próbek wodnych i osadów dennych. Obecnie hydroelektrownie są wyjątkową atrakcją turystyczną.

Key words: Słupia river, hydroelectric power plants, heavy metals, bottom sediments, toxicity, canoe trail.
Słowa kluczowe: Słupia, hydroelektrownie, metale ciężkie, osady denne, toksyczność, szlak kajakowy.

INTRODUCTION

Water is the most common substance on Earth. Plentiful water resources are present in Europe, however their geographic distribution is diverse. Among European countries only Austria and Bulgaria have excess water. In the contrary, Belgium and Poland suffer from of its absence (Małecki and Gołębiak 2012).

Water is essential for human life, and among variety of applications its energetic function on the planet is of great importance. Together with the wind, sun, tides and geothermal energy is an unconventional source energy. This is why it is very often called as "white coal". It is estimated that around 17–20% of world-wide electricity comes from hydroelectric power plants,

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however only 1.5% of Polish electricity is obtained in that way (Warać et al. 2010; Wiatkowski and Rosik-Dulewska 2012). The reason of this situation is that Poland is a lowland country, with relatively low precipitation. Therefore, the energetic utilization of water reservoirs is also minimal (Kalda 2014).

Increasing environmental awareness joined with inevitable perspective of the use non--renewable fossil fuels have increased interest in renewable energy sources. Despite of this electricity production by the use of small hydroelectric power plants (SHPP) encounters several difficulties. This is mainly due to natural circumstances. On the one hand, after joining to European Union Poland has to increase energy generation from renewable energy sources, including SHPP, while on the other to implement Water Framework Directive and ensure adequate ecological status of national water resources. Increase of use of renewable energy sources and expanding network of hydroelectric power plants become a topic of discussion of many ecologists. Both supporters and opponents give plenty arguments for and against SHPPs. The most important advantage of use of SHPPs is decrease of global greenhouse gases emission and fossil fuels consumption (Warać et al. 2010). Although in Western Europe they are considered and unprofitable, in Poland they can contribute the increase ofwater retention and improve water regime in the country, especially in basins of small rivers. Opponents are concerned about the devastation of natural water channels as well as surrounding environment. The most often argument put forward is that hydroelectric power limit fish migration, which may ultimately lead to extinction of the species. The last aware concerns leakage of turbine oil, emission or accumulation of metals below and above dams as well as general increase of toxicity in the vicinity of the power plant infrastructure (Jarosiewicz and Obolewski 2013). Various types of toxicity classification systems have been elaborated by scientists in different countries, with the aim of attributing a hazard score to polluted environments or toxic wastewaters or of ranking them in accordance with increasing levels of toxicity. All these systems are based on batteries of standard acute toxicity tests (several of them including chronic assays as well) and are therefore dependent on the culturing and maintenance of live stocks of test organisms. Toxicology testing is conducted to determine the degree to which a substance can damage a living or non-living organisms (Persoone et al. 2003).

Having in mind an information presented above the primary aim of the paper was to assess toxicity of surface and near-bottom water as well as bottom sediments collected in the vicinity of several small hydroelectric power plants located in the Słupia river basin. Simultaneously ionic profile of river water was determined as well as some selected heavy metals (Zn, Mn, Cr, Ni and Cu) were measured in water and bottom sediments. The secondary aim of the study was to interpret mutual relations between measured parameters using the self organizing map algorithm (SOM) in order to identify reasons of possible toxicity.

MATERIALS AND METHODS

Study sites

Six hydroelectric power plants located in the Słupia river basin were chosen in this research: Krzynia (K), Soszyca (So), Gałąźnia Mała (G), Konradowo (Ko), Skarszów Dolny (SD) and Słupsk (S). Their location in the basin is shown in Fig. 1.

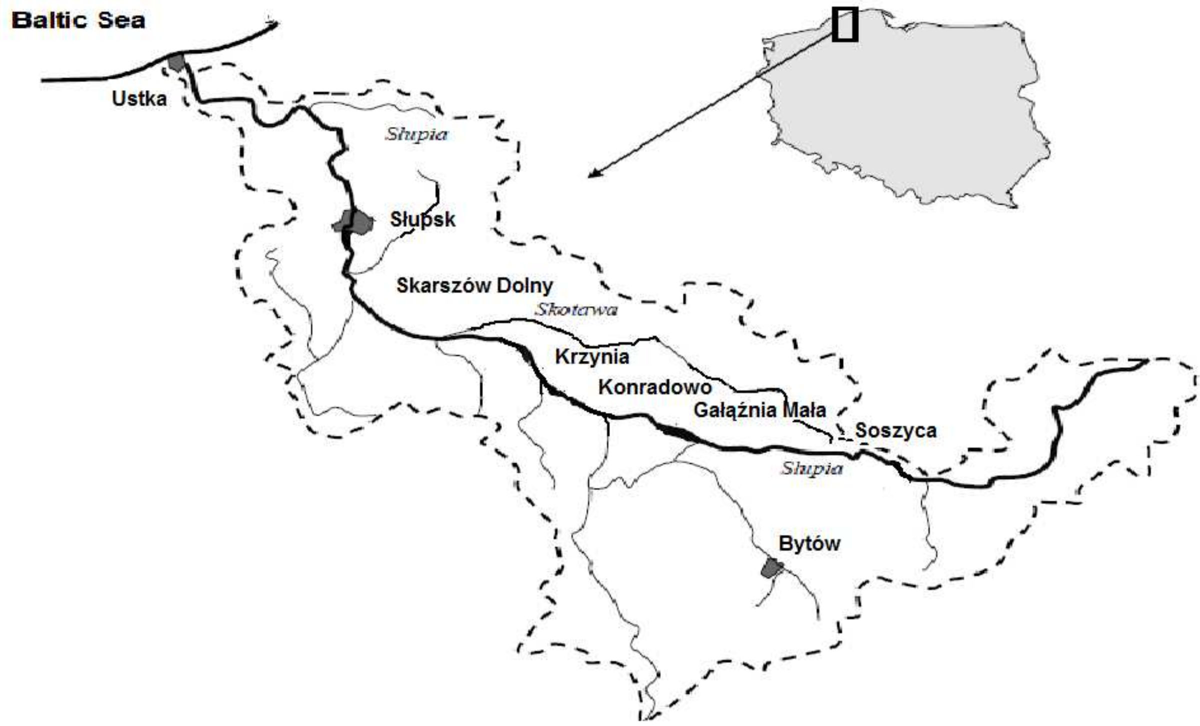

Fig. 1. Geographical location of the study area and six SMPPs in the Słupia river basin
Ryc. Położenie geograficzne obszaru badań i sześciu elektrowni wodnych w dorzeczu Słupi

The Słupia River is located in the central part of Pomeranian region in northern Poland. Although it flows trough lowland area in several sections it is considered as mountain river because of its rapid current. The watercourse is 139 km long and the catchment located in Pomorskie Voivodship occupies the area about 1620 km^2 (Obolewski et al. 2016). The spring of the Słupia river is located in the Kashubian Lake District, near Sierakowska Huta, at an altitude of 178 m above sea level (Jarosiewicz and Obolewski 2013). The Słupia river is classified to the group of small rivers of length and catchment area smaller than 200 km and 10000 km^2, respectively. The width of the riverbed ranges from 7 m in the upper part of the river to 40 m at the estuary, where the average flow is 15.5 $m^3 \cdot s^{-1}$, while the average decline around 1.3‰ (Obolewski 2011). The Słupia River basin is diverse. It consists of pristine glacial landscapes, numerous hills and clear lakes. In its upper and middle section there are numerous tributaries that form unique hydrographic network. Because of its natural and ecological uniqueness the river valley is protected from 1981 in the framework of Słupia Valley Landscape Park. In 2004 the basin has also been protected under Natura 2000 as a special protection area for birds.

The Słupia river basin is characterized by moderate anthropopression, especially in the upper and middle section. In the contrary lower section is seriously impacted by the city of Słupsk, waste water treatment plant in Słupsk as well as wastes from numerous food factories (Moczulska et al. 2006). The most serious pollution source in the upper and middle section is agricultural runoff from farmlands. Significant anthropogenic impact could be also related with numerous hydroelectric infrastructure spread in the basin (Jarosiewicz and Obolewski 2013). Due to mountain characteristic of the Słupia river in the middle of XVIII century various regulatory actions was carried out. Subsequent works included riverbeds' dredging, removing boulders and tree trunks, as well as the elimination of bends (Florek 1991; Bajkowski and Górnikowska 2013). Today, the unique characteristic of the Słupia river is additionally increased because of presence of the oldest in Europe, working hydraulic engineering system. The entire network of small hydroelectric power plants is a major attraction for both tourists and historians. The canoe trail "Electric Słupia" – a trace of hydro-technical system begins in Bylina village, and sailing up to the river bed one can visit most of the plants in the basin.

The first hydroelectric power plant is located in Struga. It works continuously since 1896 and is considered as the oldest in Europe and one of the oldest in the world. To the plant water is provided through the canal from the Żukowskie lake. It uses water fall of 14 m and produces 250 kW of energy. Next plant is located in Gałąźnia Mała. It is the most beautiful and the largest one. Water is supplied from the Głębokie lake by two pipes (ø 190 cm) enabling the water fall of 38.5 m.The third plant is located in Konradowo. It was partially destroyed during II World War, however in 1948 it was again set in motion. It is the second largest plant in the Słupia river basin. Another hydroelectric complex is located in Krzynia. It consists of an earth dam as well as retention reservoir of surface of 78 hectares. Since this power plant is the last before the city of Słupsk, its task is to maintain a constant level and water flow in the Słupia river. The next plant on the canoe trail is located in Skarszów Dolny on Skotawa river (the largest tributary of the right bank of Słupia river). It is small one and produces only 180 kW of energy. The last one is located in Słupsk. Hydroelectric infrastructure is a part of historical Pomeranian Dukes Castle. Today it is not operated as a plant, however it is an important historical attraction of the city.

Sampling and analytical techniques

The study was conducted in April, 2015. Water samples were collected using van Dorns' dredge from subsurface (~1 m) and near-bottom layer of water flux flowing through the power plant. In majority of locations samples were collected as close the dam as possible above and below the hydroelectric power plant infrastructure. Only in Gałąźnia Mała water samples above the dam were collected from "water castle" which is located 670 m far from the main building of the plant. In the same locations bottom sediments were collected using Eckman-Birge'a dredge.Ionic profile, physical parameters, selected heavy metals concentration (Zn, Mn, Cr, Ni and Cu) and toxicity (using Microtox, Spirotox and Daphtoxkit F magna) were determined in water samples, while for bottom sediments only toxicity and heavy metals' concentration were measured. The analyses of heavy metals were performed in the oxyacetylene flame by atomic absorption spectrometer Aanalyst 300 (Perkin Elmer, Waltham, MA, USA) while all solutions and standards were made with high-quality deionized water obtained using Hydrolab 10 (Hydrolab, Poland) device. 1 g $\cdot$ L^{-1} single-element standard solutions of Zn, Mn, Cr, Ni and Cu (Merck KGaA, Darmstadt, Germany) were used for calibration. The accuracy of determinations of the total content of heavy metals was verified against certified reference materials (CRM 601 (lake sediment) and SLRS-6 (river water)) which were analyzed at the beginning and the end of the sampling series. The observed error was less than 5% of the certified value.

Physical and chemical data (pH, electrolytic conductivity (EC) [mS $\cdot$ cm^{-1}]) were collected in the field using pH-meter equipped with glass electrode (CPI551 Elmetron, Poland) and conductometer equipped with calomel electrode (CC315 Elmetron, Poland), respectively. Prior to determination of major cations (Na^+, K^+, Ca^{2+}, Mg^{2+}, NH_4^+) and anions (F^-, Cl^-, NO_2^-, NO_3^- and SO_4^{2-}) using ion chromatograph 881 Compact IC Pro (Metrohm, Switzerland) subsurface and near-bottomwater samples were filtered throw 0.20 μm sterile syringe filter. The aforesaid determinations were done using Metrosep C4 250/4.0 and Metrosep A Supp 5 250/4.0 analytical columns equipped with Metrosep C4 Guard/4.0 and Metrosep A Supp 4/5 Guard 4.0 precolumns, respectively.Chromatographic analysis quality was controlled by means of analysis of the Certified Multielement Ion Chromatography Anion Standard Solution (Fluka Analytical Switzerland) of lot BCBB8958.

Microtox is an acute toxicity test using the marine luminescent bacterium *Vibrio fischeri*. This bacterium emits light as a result of normal metabolic processes. A reduction in luminescent ability during exposure to contaminants or pollutants is taken as a measure of toxicity (Nałęcz--Jawecki 2003).

The Spirotox test utilizes a large ciliate protozoan, *Spirostomumambiguum*, as a bioindicator. The Spirotox test was based on the Spirotox-volatile procedure (Nałęcz-Jawecki and Sawicki 1999). Briefly, conventional, disposable 24-well microplates were used as test containers while diluted Tyrod solution was used as a diluent. A samples series was prepared in triplicate directly in the microplate. First, the protozoa were introduced into the wells and a microplate was then covered with a sheet of polyethylene film and tightly closed with the lid. After incubation in the dark at 25°C, two kinds of test responses were observed after 24 and 48 h of incubation: 1) different deformations, which mean morphological changes such as shortening, bending of the cell, etc.; 2) lethal response-spherical deformation and autolysis. On this we base two values: EC50 and LC50 were calculated.

Test with Daphna magna – small freshwater Daphnia – was to put ten individuals in a culture vessel, pouring their water sample. Then (after 24 hours) observing the behaviour and appearance of animals under special device simulating UV rays. "Individuals contained in contaminated water will be immobilized and cease to float freely. This is because the toxins interfere with the functioning of the nervous system" (Nałęcz-Jawecki 2003).

Intelligent data analysis procedure

Various statistical multivariate techniques are commonly used for environmental data clustering, modelling and assessment. This research involved the use of the self-organizing map (SOM) algorithm – one of the most efficient neural network architectures for solving problems in the fields of exploratory data analysis, clustering, and data visualization. The theoretical background of the SOM approach can be found elsewhere (Kohonen et al. 1996; Vesanto 2000; Giraudel and Lek 2001) and this is why it is skipped here. To avoid repetition of description of the procedure applied in this study readers are kindly referred to the chapter (Astel and Simeonov 2009) and series of papers dealing with environmental data exploration in which consecutive steps of analysis using the SOM algorithm are described in detail (Astel and Małek 2008; Astel et al. 2008).

All calculations in this study were performed using MatlabR2014a (MathWorks, Inc.) and Statistica 12.0 (Statsoft, Inc.) running on a Windows 8.0 platform.

RESULTS AND DISCUSSION

The collected water samples were characterized by slightly alkaline pH (7.18–8.66) and very low electrolytic conductivity (270–433 mS · cm^{-1}] indicating a low content of ionic substances. The range of variation of ions determined in subsurface and near-bottom water samples is shown in Table 1.

In general, determined concentrations of ions were characterized by negligible vertical and little spatial variation. The lowest concentration of anions was found in samples collected in Soszyca and Skarszów Dolny, while the highest in Krzynia. The highest range of changes was observed for sodium and chlorides. In case of sodium cations the dam in Krzynia impacts on their concentration since above the dam the determined concentration of Na^+ was the lowest, while below the highest. An average concentration of chlorides was equal to 10.3 mg · L^{-1}, while an average concentration of Na^+ was 8.00 mg · L^{-1}. Their abundance is typical for freshwater reservoirs and comparable with values determined in Łeba, Głaźnia and Słupia rivers observed by others (Moczulska et al. 2006).

An average concentration of Ca^{2+} was equal to 57.3 mg · L^{-1}. Minimal value was found in Krzynia above the dam, while maximal in Słupsk below the infrastructure of hydroelectric power plant. An opposite trend was observed for Mg^{2+}. In Krzynia above the dam its concentration was the highest, while the lowest in Konradowo (2.46 mg · L^{-1}).

Despite the fact that Słupia river basin might be significantly polluted by agriculture runoff it was not found an increased concentration of nutrients in examined water samples (Jarosiewicz and Obolewski 2013). Among of them the highest concentration was determined for NO_3^-. The lowest concentration of nitrates was determined in Soszyca (0.42 mg · L^{-1}), while the highest in near-bottom water in Krzynia above the dam (4.13 mg · L^{-1}). Additionally, in water samples collected in Soszyca the lowest concentration of nitrites was also found (0.42 mg · L^{-1}). Generally, in Słupia river an oxidized forms of nitrogen prevail since it flows very rapidly and turbulently. This characteristic facilitates oxygen dissolution in river water (Jarosiewicz and Dalszewska 2008).

In the entire set of analyzed samples (subsurface and near-bottom water and bottom sediment samples) an abundance of heavy metals were diversified. In water there were only Zn, Mn and Ni found, while in bottom sediments there were also Cr and Cu. An average concentration of metals determined in water and sediment samples according to sampling place location (above and below the dam) is presented in Fig. 2 and Fig. 3, respectively.

As ensues from Fig. 2 in the analyzed water samples there were symbolic, and comparable to values determined by others, concentration of heavy metals present (Jonczak et al. 2014; Parzych and Cymer 2014). General concentration of heavy metals in water is quite low and characteristic to water of 1st class of purity (DzU 1.03.2014, no. 32, pos. 284). This is because Słupia river flows through an area of Słupia Valley Landscape Park and lack of serious anthropogenic impacts is observed (Skorbiłowicz and Wiater 2003). As was reported previously by Obolewski (2010) the chemical analysis of waters of the Słupia river points to its moderate to low contamination. It fits with general improving of ecological state of Polish rivers due to reduction of the content of biogenic substances (Mysiak 1994; Załupka 2004).

Table 1. Ionic profile of subsurface and near-bottom water samples collected above and below dams of six SMPPs in the Słupia river basin
Tabela 1. Profil jonowy próbek wody powierzchniowej i przydennej pobranej powyżej i poniżej zapory sześciu elektrowni wodnych w dorzeczu Słupi

SMPP – Elektrownie wodne	Sample Próbka	Lons – Jony [mg L^{-1}]									
		F^-	Cl^-	NO_2^-	NO_3^-	SO_4^{2-}	Na^+	NH_4^+	K^+	Ca^{2+}	Mg^{2+}
		DL 0.03	DL 0.01	DL 0.05	DL 0.03	DL 0.35	DL 0.10	DL 0.20	DL 0.15	DL 0.2	DL 0.20
Krzynia above – powyżej zapory	s.w.	1.43	10.93	0.42	2.98	25.4	10.9	1.14	6.41	49.7	4.97
	n.b.	2.74	13.18	0.43	4.13	25.9	6.08	0.28	2.14	52.7	4.21
Krzynia below – poniżej zapory	s.w.	0.44	8.63	0.43	1.68	24.0	11.3	0.70	6.20	59.7	4.57
	n.b.	0.53	8.61	0.42	1.37	24.0	6.61	0.39	2.58	55.7	4.47
Gałąźnia Mała above – powyżej zapory	s.w.	0.32	10.40	0.43	2.68	24.5	7.87	0.19	2.54	58.2	4.48
	n.b.	1.00	11.86	0.44	3.54	26.5	8.32	0.32	2.88	58.4	4.29
Gałąźni Mała below – poniżej zapory	s.w.	0.67	11.44	0.43	3.17	25.8	7.61	0.21	2.46	59.1	4.19
	n.b.	0.05	9.17	0.42	1.90	23.8	7.99	0.24	2.62	58.8	4.21
Soszyca above – powyżej zapory	s.w.	n.o.	8.18	0.42	1.52	22.8	7.70	0.25	2.44	60.3	4.06
	n.b.	n.o.	8.82	0.42	0.42	23.3	7.76	0.17	2.40	60.3	3.78
Soszyca below – poniżej zapory	s.w.	0.26	9.67	0.43	2.17	24.4	7.23	0.14	2.15	57.2	3.70
	n.b.	0.13	9.34	0.43	1.98	23.5	7.24	0.10	2.03	60.4	4.15
Skarszów Dolny above – powyżej zapory	s.w.	0.65	11.06	0.44	2.68	25.0	8.28	0.24	2.95	60.0	3.99
	n.b.	n.o.	8.72	0.43	1.83	24.2	8.45	0.33	2.82	60.6	4.14
Skarszów Dolny below – poniżej zapory	s.w.	0.23	9.36	0.43	2.15	24.4	6.99	0.21	1.98	58.4	3.87
	n.b.	n.o.	8.41	0.42	1.61	23.0	6.48	0.11	1.87	55.8	3.60
Konradowo above – powyżej zapory	s.w.	0.06	10.14	0.66	3.58	25.7	8.33	0.38	2.54	54.4	2.67
	n.b.	0.11	10.87	0.46	3.67	25.9	7.77	0.50	2.02	54.7	2.69
Konradowo below – poniżej zapory	s.w.	n.o.	10.51	0.66	3.83	26.0	6.62	0.19	1.64	52.7	2.46
	n.b.	0.04	9.70	0.67	3.43	25.5	6.87	0.42	1.53	54.3	2.59
Słupsk above – powyżej zapory	s.w.	n.o.	12.67	0.43	2.40	25.7	9.12	0.11	1.93	57.1	3.47
	n.b.	n.o.	12.45	0.42	2.47	25.5	9.11	0.13	1.95	57.3	3.50
Słupsk below – poniżej zapory	n.b.	n.o.	12.73	0.43	2.50	25.7	9.41	0.05	2.04	62.7	3.77

s.w. – subsurface water – woda podpowierzchniowa; n.b. – near-bottom water – woda przydenna; n.o. – not determined – nie określono; above – above the dam – powyżej zapory; below – below the dam – poniżej zapory; DL – detection limit – granica wykrywalności.

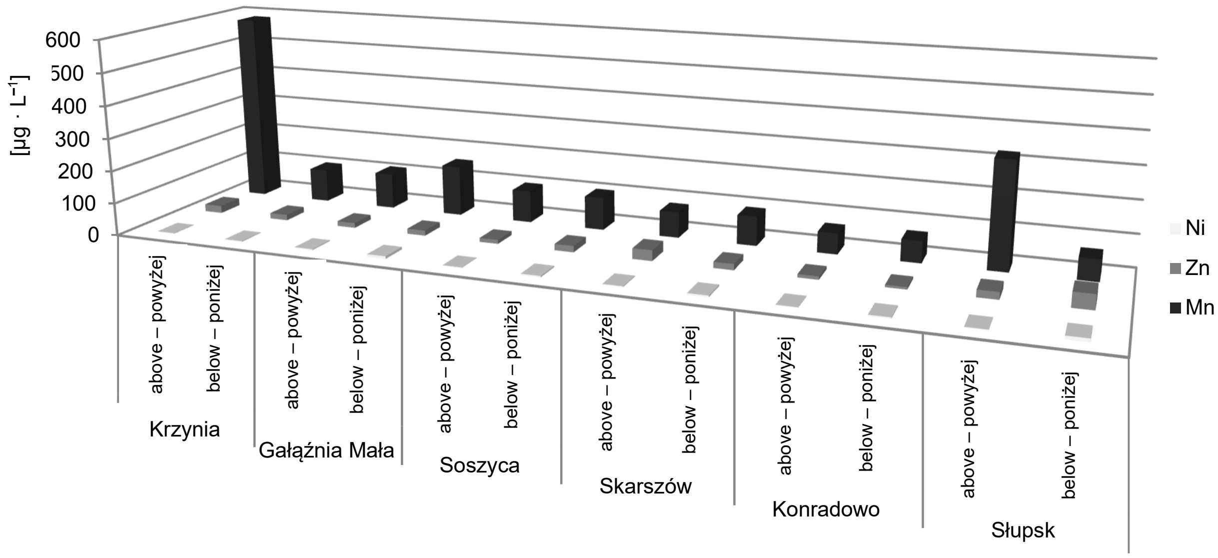

Fig. 2. Average concentration of Ni, Zn and Mn in water samples collected above and below dams of six SMPPs in the Słupia river basin
Ryc. 2. Średnie stężenie Ni, Zn i Mn w próbkach wody pobranej powyżej i poniżej zapory sześciu elektrowni wodnych w dorzeczu Słupi

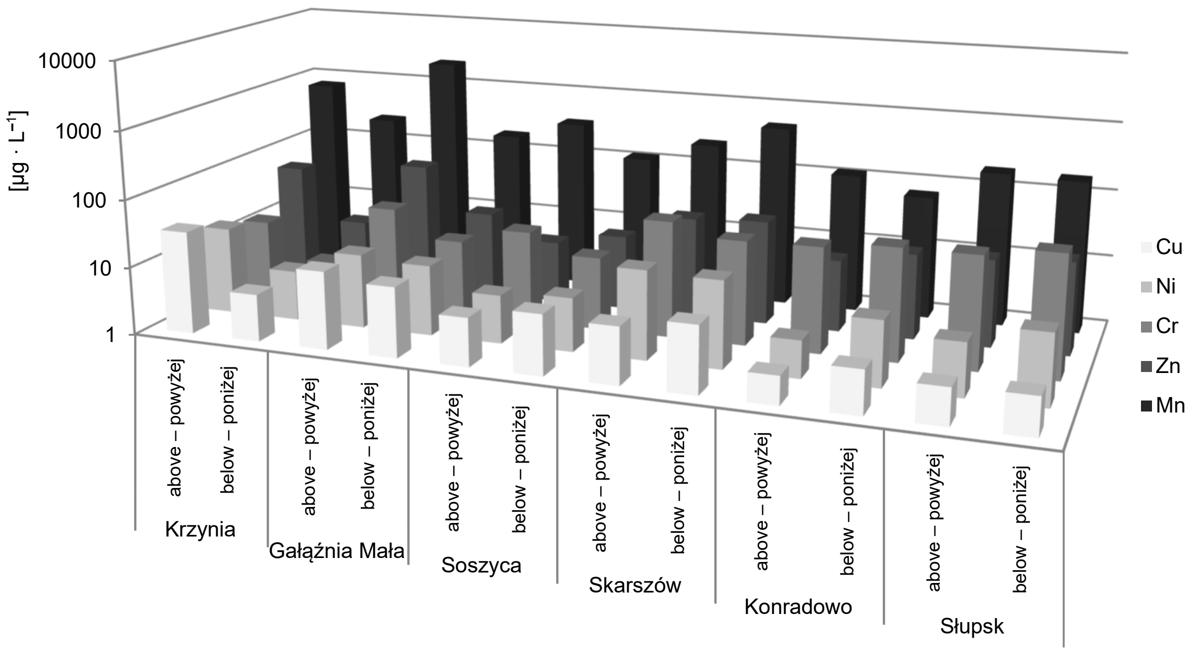

Fig. 3. Concentration of Cu, Ni, Cr, Zn and Mn in bottom sediment samples collected above and below dams of six SMPPs in the Słupia river basin
Ryc. 3. Stężenie Cu, Ni, Cr, Zn i Mn w osadach dennych pobranych powyżej i poniżej zapory sześciu elektrowni wodnych w dorzeczu Słupi

However, the heavy metal content is an important element in the assessment of the ecological state of the environment in the immediate vicinity of hydroelectric power plant.Working turbines, lubricants and intensive continues flow can release metals into environment. Among analyzed metals the highest variation was observed for manganese. Its concentration ranged from 56.5 μg · L^{-1} in the near-bottom water taken from Konradowo above the dam to 1080 μg · L^{-1} in subsurface water collected in Krzynia also above the dam. An average concentration of Zn in water was 18.7 μg · L^{-1} with negligible variability. The lowest concentration was found in Konradowo, while the highest in Słupsk. Generally, higher concentration of analyzed metals was found in subsurface water above dams, while lower below them. The opposite relation was observed for near-bottom water samples. Lower concentration of metals was determined above dams, while higher below them. This phenomenon can be explained by turbulent and very intensive water flow after the dam which raises sediments and makes release of immobilized heavy metals possible (Banach and Chlost 2005, 2007).

In the sediment samples much higher concentration of heavy metals than in water was observed. Moreover, in this kind of samples some other metals (Cr, Cu), absent in water, were found (Fig. 3). As was in water, the highest concentration of metals in sediments was determined for manganese. Its concentration varied between 67.8 μg · g^{-1} in Konradowo below the dam to 2224 μg · g^{-1} in Gałąźnia Mała above it. In case of remaining metals significantly lower concentration values were determined. An average concentration of Cu, Ni, Cr and Zn was 8.75 μg · g^{-1}, 10.5 μg · g^{-1}, 30.5 μg · g^{-1} and 26.9 μg · g^{-1}, respectively. In sediment samples collected in Krzynia and GałąźniaMała (water fall of 38.5 m) the higher concentration of metals was found below the dam. Presumably it is caused by faster water flow after departure from the hydroelectric power plant. The water flowing out with a large force increases bottom erosion and facilitates metals' release into the water (Trojanowska-Olichwer 2013). Surprisingly, higher concentration of metals was found below the dam in Słupsk, which is out of operation and plays only a historic role. Higher abundance of metals in this location can in this case be associated with the presence on busy street with heavy traffic. Although general concentration of heavy metals is sediment samples in the vicinity of hydroelectric power plants is also low it was assumed that metalsare able to increase toxicity, especially when released from sediments by turbulent water flow.

As mentioned above in collected water and sediment samplestoxicity was assessed using three different tests since toxicity should be analyzed on all levels of trophic chain. None of toxicity was found for water samples using Microtox screening, Spirotox and Daphtoxkit F magna tests. However, there were toxicity changes observed for sediments. Only in case of two hydroelectric power plants (Krzynia and Skarszów Dolny) sediments collected above were much toxic than these collected below. In case of remaining location an increase of toxicity of sediment samples was observed below the dam. In Fig. 4 toxic effect of sediments collected above and below dams of all hydroelectric power plants was shown (Banach and Chlost 2005, 2007).

Although EC_{50} values were quite high some interesting spatial variation was observed. Toxicity increase above the dam in Krzynia and Skarszów Dolny is due to artificial concrete canals made to supply water directly to turbines. In case of other locations supplying canals have natural origin. The highest changes in toxic effect above and below the dam were found in Słupsk and Soszyca. In Soszyca EC_{50} value above the plant was equal to 22 490 mg · L^{-1}, while below it was 3403 mg · L^{-1}. In Słupsk respective values were 291 500 mg · L^{-1} and 18 900 mg · L^{-1}.

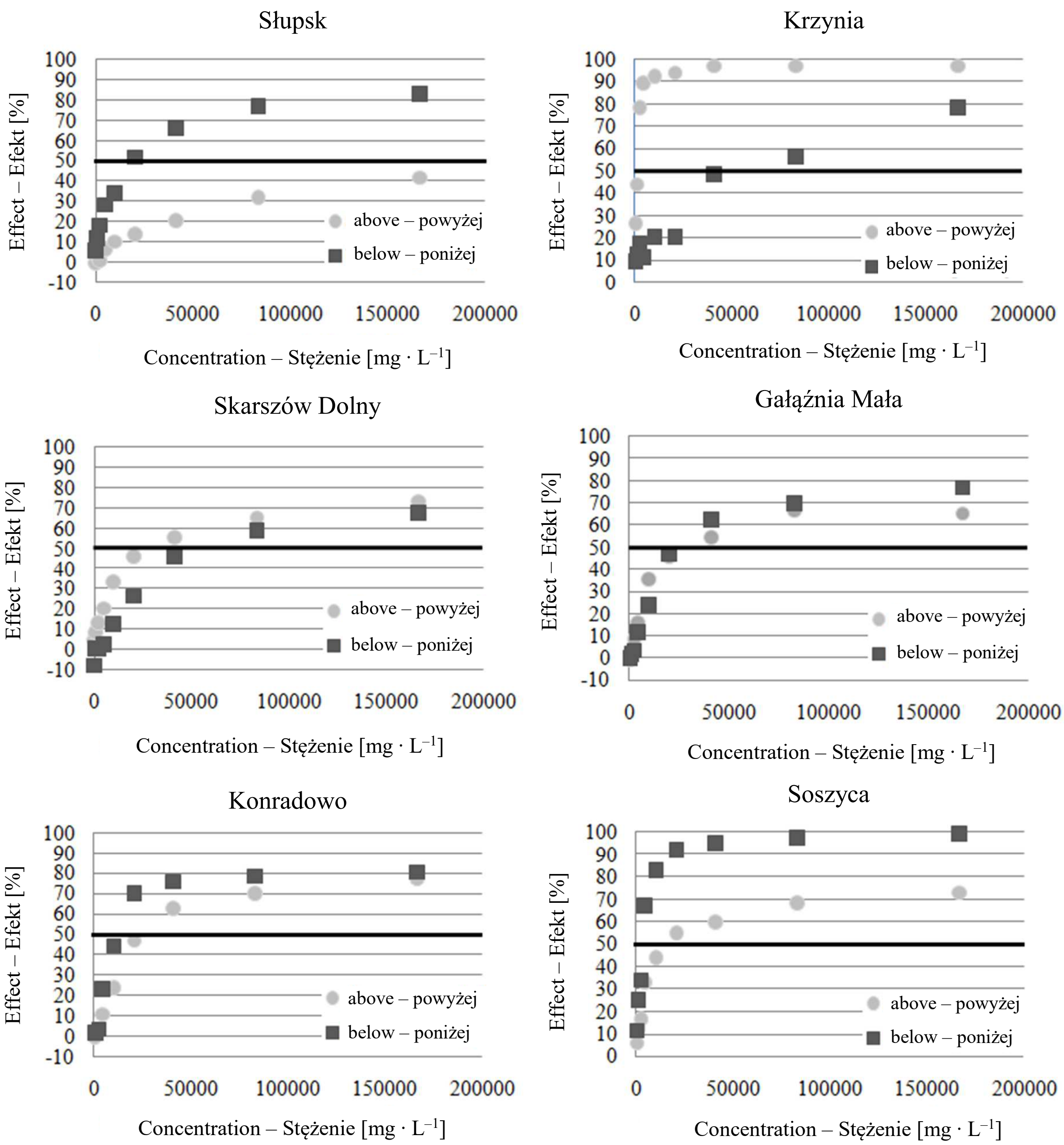

Fig. 4. Toxicity of bottom sediment samples collected above and below dams of six SMPPs in the Słupia River basin
Ryc. 4. Toksyczność osadów dennych pobranych powyżej i poniżej zapory sześciu elektrowni wodnych w dorzeczu Słupi

The toxicity of the bottom sediments can be affected by many factors, such as oxygenation, grain size and the content of organic matter (Szalińska et al. 2011; Wilk and Szalińska 2011). Therefore, an increase of EC_{50} value in the samples might not be associated with the presence of a hydroelectric power plant. An important element in toxicity evaluation is the intensity of water flow and water fall. On the one hand the highest flow the better oxygenation and possibly lower toxicity, however on the other the highest flow the more facilitated release of metals immobilized in the past. In order to identify reasons of EC_{50} increase in the vicinity of hydroelectric power plants the visualization based on the self-organizing algorithm was applied. The non-linear projection of heavy metals abundance and EC_{50} value for all samples collected in the vicinity of six SHPPs (above and below) together with the U-matrix plane are presented in Fig. 5. In Fig. 5 an additional diagram presenting samples assignedto particular hexagons on the SOM map was added.

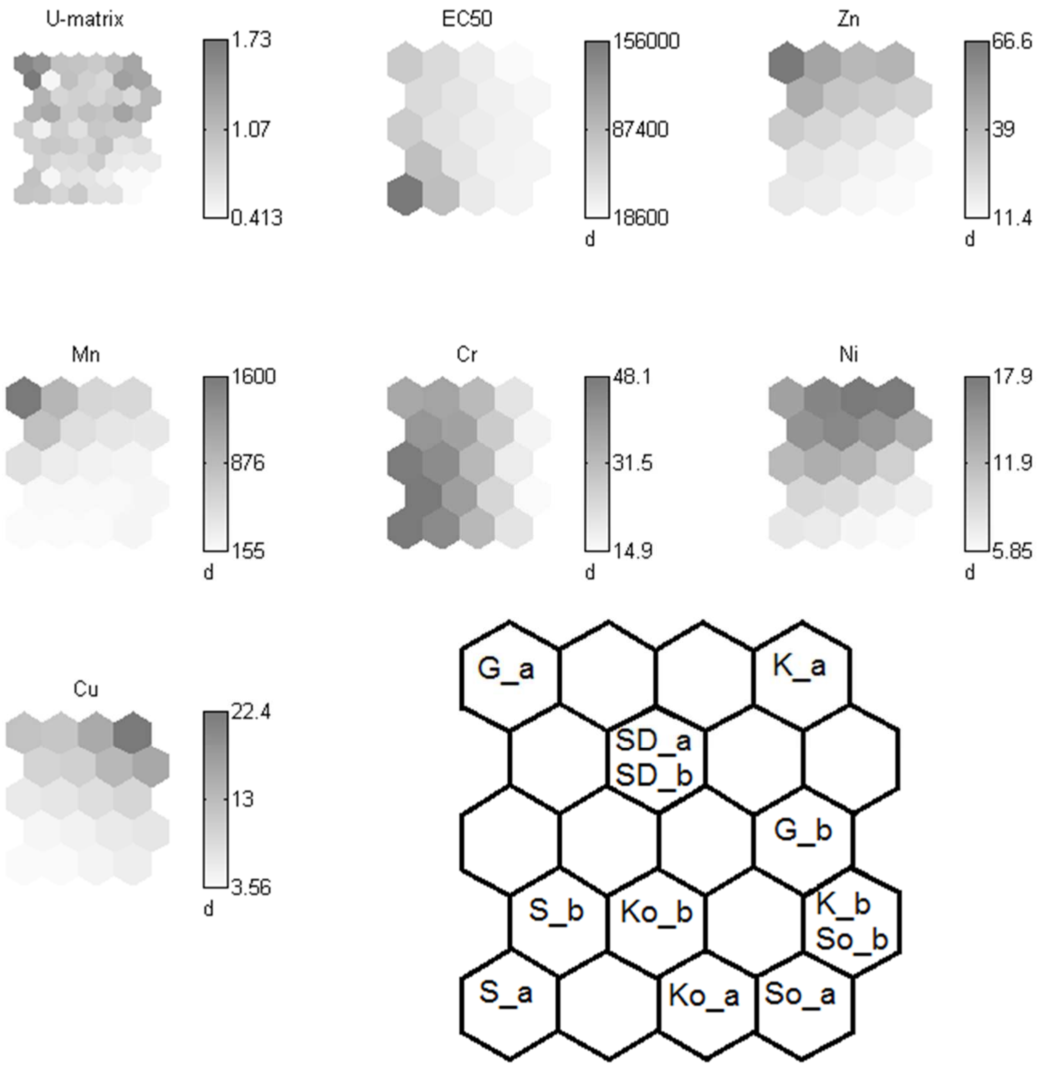

Fig. 5. U-matrix and SOM planes for heavy metals and EC50 values determined in bottom sediment samples, as well as visualization of samples assigned to hexagons on the SOM map: Krzynia (K), Soszyca (So), Gałąźnia Mała (G), Konradowo (Ko), Skarszów Dolny (SD) and Słupsk (S); _a – above, _b – below
Ryc. 5. Macierz i mapy podobieństwa dla metali ciężkich i wartości EC50 oznaczonych w pobranych próbkach osadów dennych w hydroelektrowniach: Krzynia (K), Soszyca (So), Gałąźnia Mała (G), Konradowo (Ko), Skarszów Dolny (SD) i Słupsk (S); _a – powyżej zapory, _b – poniżej zapory

An ensues from Fig. 5 the highest EC_{50} value in Słupskis related with the lowest concentration of majority of metals (Zn, Mn, Ni and Cu). Higher than in other locations Cr concentration in sediments collected in Słupsk is due to the impact of transport, however increase of Cr concentration does not reflect in general toxicity. The lowest EC_{50} and hence relatively the highest toxicity was found for sediments collected before the dam in Krzynia. Surprisingly, in this location only two heavy metals (Ni and Cu) were found in slightly increased concentrations in comparison with other locations. As mentioned above in Krzynia an artificial concrete canal supplies water directly to turbines. This is why the possible source of Ni and Cu can be concrete, however concrete foundation can also facilitates sedimentation of matter of specific grain size and thickness. In spite of higher than in other locations concentration of Zn and Mn, in Gałąźnia Mała EC_{50} value was relatively higher (toxicity lower). This phenomenon could be connected with natural origin of the supplying canal. In general, multidimensional visualization gave deeper insight in reasons of variation of EC_{50} value according to characteristic of particular SMPP.

CONCLUSIONS

An assessment of the impact of hydroelectric power plants on surrounding environment is not an easy task. In spite of the fact that they produce "clean energy" they impact on surrounding environment, especially when they require serious changes in water course. Reconstruction of the river has a negative impact on its ecosystem, changing water relations and destroying biocoenosis's homeostasis. However, it seems that in case of the Słupia River basin several SMPP are fully integrated with river ecosystem. Hydroelectric power plants do not contribute to significant increase of heavy metals concentration as well as toxicity of both water and sediment samples. Nowadays, they play mainly as extraordinary touristic attraction enabling admiring beautiful architecture and principle of operation.

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Abstract. An abundance of ions and selected heavy metals in subsurface and near-bottom water samples as well as bottom sediments collected above and below of six hydroelectric power plants in the Słupia River basin was assessed together with their toxicity. Except some nutrients, ionic profile of river water indicates its high purity. None of toxicity was found for water samples using Microtox screening, Spirotox and Daphtoxkit F magna tests. Despite the fact that an average concentration of metals in water and bottom sediments was quite low there were some slight toxicity changes observed for sediments. Only in case of two hydroelectric power plants (Krzynia and Skarszów Dolny) sediments collected above were much toxic than these collected below. Observed changes are probably connected with natural or artificial origin of the supplying canals. However, generally hydroelectric power plants do not contribute to significant increase of heavy metals concentration as well as toxicity of both water and sediment samples. Nowadays, they play mainly as extraordinary touristic attraction enabling admiring beautiful architecture and principle of operation.