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The role of anthropogenic water reservoirs within the landscapes of mining areas – a case study from the western part of the Upper Silesian Coal Basin

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ABSTRACT

A few thousand anthropogenic water reservoirs can be found in the area of the Upper Silesian Coal Basis (USCB) located in southern Poland. In this paper the role of such anthropogenic lakes in the landscape of the western part of the USCB was presented and illustrated with the example of Knurów, a mining city, and its immediate surrounding area. The study of landscape changes in this area was carried out on the basis of archival and contemporary cartographic materials, historical sources, and interviews with inhabitants and direct field observations. It was found that the origin of the majority of the water reservoirs is related to hard coal, clay and sand mining. They were created primarily as a result of filling subsidence basins and post-mining excavations with water, as well as being the result of the construction of various hydro-technical facilities (settling ponds, fire protection water reservoirs, etc.) In the study area the anthropogenic water reservoirs are of different sizes, shapes and durability and play different roles in the environment. Between 1884 and 2001 their number increased 25-fold, while at the same time their total surface area increased more than 8-fold. The role of the newly created water reservoirs in the landscape primarily involves the transformation of the existing terrestrial ecosystems into wetland ecosystems. The agro-forestry landscape of the late 19th century was transformed into a typically anthropogenic landscape with a dominant share of water reservoirs, settlement ponds and mining waste heaps. The most common species of plants around the water reservoirs are *Phragmites australis*, *Typha latifolia*, *Ceratophyllum demersum*, *Elodea canadensis*, *Potamogeton natans*, *Lemna sp.*, *Acorus calamus*, *Myriophyllum verticillatum*, *Sagittaria sagittifolia*, *Alisma plantago-aquatica* and *Glyceria aquatica*. The most valuable elements of the flora include *Trapa natans* and *Ruppia maritima*, species recognized in Poland as threatened with extinction. Changes in the vegetation cover can be considered favourable since the analysed area is currently characterised by greater biodiversity. Reservoirs are in general positively perceived by residents and used for recreational purposes.

KEY WORDS: wetland ecosystems, biodiversity, mining, Silesian Upland

1. Introduction

In many mining areas in the world anthropogenic water reservoirs formed in the excavations after open-cast mining of raw mineral materials or in subsidence basins (troughs) in mining areas and are now a characteristic element of the landscape (Drecker et al., 1995; Kapfer, 1998; Eary, 1999; Werner et al., 2001; Denimal, 2005; Martinec et al., 2005; McCullough et al., 2006; Rzętała, 2008). The creation of water reservoirs may also be associated with various technological processes accompanying the mining activities (e.g. settling ponds, drilling fluid). Depending on the type and scale of the mining the anthropogenic water reservoirs are of different sizes, shapes and durability and play different roles in the environment. Although within the scale of geological time their functioning in the landscape is relatively short-term, in many areas they are the most characteristic determinant for decades or even longer (e.g. Clark, 1963; Machowski, 2010).

In Europe the Upper Silesian Coal Basin in Poland is one of the areas with a particularly high concentration of anthropogenic "lakes". The origin of a significant part of approximately 4,770 water reservoirs occurring there today is related to the mining of mineral raw materials – hard coal, stowing sands, clays, limestones and dolomites (RZĘTAŁA, 2008). For several decades they have been the subject of research in the field of natural sciences undertaken mostly by hydrographers, geomorphologists and botanists (ZIEMOŃSKA, 1979; JANKOWSKI & WACH, 1980; CZAJA & DEGÓRSKA, 1988; JANKOWSKI, 1991, 1999; JANKOWSKI & RZĘTAŁA, 1996; TOKARSKA-GUZIK & ROSTAŃSKI, 1996; RZĘTAŁA, 1998, 2000, 2008a,b; DULIAS & RUDNICKA, 2000; CZYLOK & BARYŁA, 2003; JANKOWSKI ET AL., 2003; KAMIŃSKI ET AL., 2003; RZĘTAŁA M.A., 2003; RUMAN, 2004; DULIAS, 2003a,b, 2005; BŁOŃSKA ET AL., 2008; JARUCHIEWICZ, 2008; MACHOWSKI, 2010; SOLARSKI & PRADELA, 2010). In this paper the role of anthropogenic water reservoirs in the landscape of the western part of the Upper Silesian Coal Basin over the past 130 years is presented and illustrated with the example of Knurów, a mining city, and its immediate surrounding area.

2. Material and research methods

The study of the landscape changes in the area surrounding Knurów was carried out on the basis of archival and contemporary cartographic materials, historical sources, and interviews with inhabitants and direct field observations. The following maps were used: MESSTISCHBLÄTTER 1:25 000 from 1881–1884, maps of the Military Geographical Institute – TOPOGRAPHISCHE KARTE 1:25 000 from 1933–36, topographic maps 1:25 000 from 1960 and 1986 (MAPA TOPOGRAFICZNA, 1960, 1986), topographic map 1:10 000 from 1993 (MAPA TOPOGRAFICZNA, 1993), hydrographic map 1:50 000 from 2001 (ABSALON ET AL., 2001) and unpublished maps from "Szczygłowice" and "Knurów" coal mines. The cartographic materials listed above are used for the determination of changes in the number, sizes, shapes and distribution of anthropogenic water reservoirs in the period from the late 19th century to contemporary times. During the fieldwork lists of vascular plant species occurring in the shore zone were prepared for selected water reservoirs, and the naming of plants was taken from MIREK ET AL. (2002). In the case of certain reservoirs their origin, period of functioning and manner of removal were established on the basis of interviews with inhabitants.

3. Study area

The study area is sited on the border between the highly industrialised and urbanised Katowice Upland and the agro-industrial Rybnik Plateau. The study area is mainly located within the borders of the city of Knurów, but in part it also includes the cities of Gliwice and Czerwionka-Leszczyny as well as the communities of Gierałtowice, Ornontowice and Pilchowice. The economic development of the area has been related to the exploitation of rich hard coal deposits. These can be found at depths of 100–200 m below the cover of Miocene clays (STUPNICKA, 1997). Pleistocene boulder clays and their rock mantle can be found on the surface in the north-eastern part of the study area, and glacial and fluvio-glacial sandy and gravel sediments – in the south-western part. The relief of the described area resembles a rolling plain (230-260 m a.s.l.), dissected by the Bierawka valley and its tributaries: Knurówka Stream, the Szczygłowicki Stream, Krywałdzki Stream, Żernicki Stream, Książenice Stream, and the Wilcza Stream (KLIMASZEWSKI, 1972). The riverbeds of the afore mentioned streams have been anthropogenically transformed (regulated, embanked, deepened, etc.), and the said river waters are polluted above the accepted standards. The study area is dominated by pseudopodsolic soils and, moreover, leached brown soils and alluvial soils.

4. Results

4.1. The landscape of the area surrounding Knurów at the end of the 20th century

In the second half of the 19th century forests and farmlands dominated the landscape of the area surrounding Knurów. The settlement was concentrated in three villages – Knurów, Krywałd and Szczygłowice (Fig. 1). Water reservoirs occurred in river valleys in the areas neighbouring the afore mentioned villages . It follows from historical materials that in the 19thcentury several mills were operating in the analysed area, next to which small fish ponds were located – in the headwaters of the Knurówka Stream in the vicinity of the so-called "castle" and in the Krywałdzki Stream („Jagielnia"). The largest water reservoir from this period was sited within the area of the present village of Kuźnia Nieborowska. The first records mentioning it date back to the 16th century. There are suppositions about its natural origin (KOZIEŁEK, 1990). All of the mentioned water reservoirs were used as breeding ponds, and their surface area was less than 29.4 ha. With the exception of the largest one, the remaining reservoirs did not play a major role in the agricultural and forest landscape of the area.

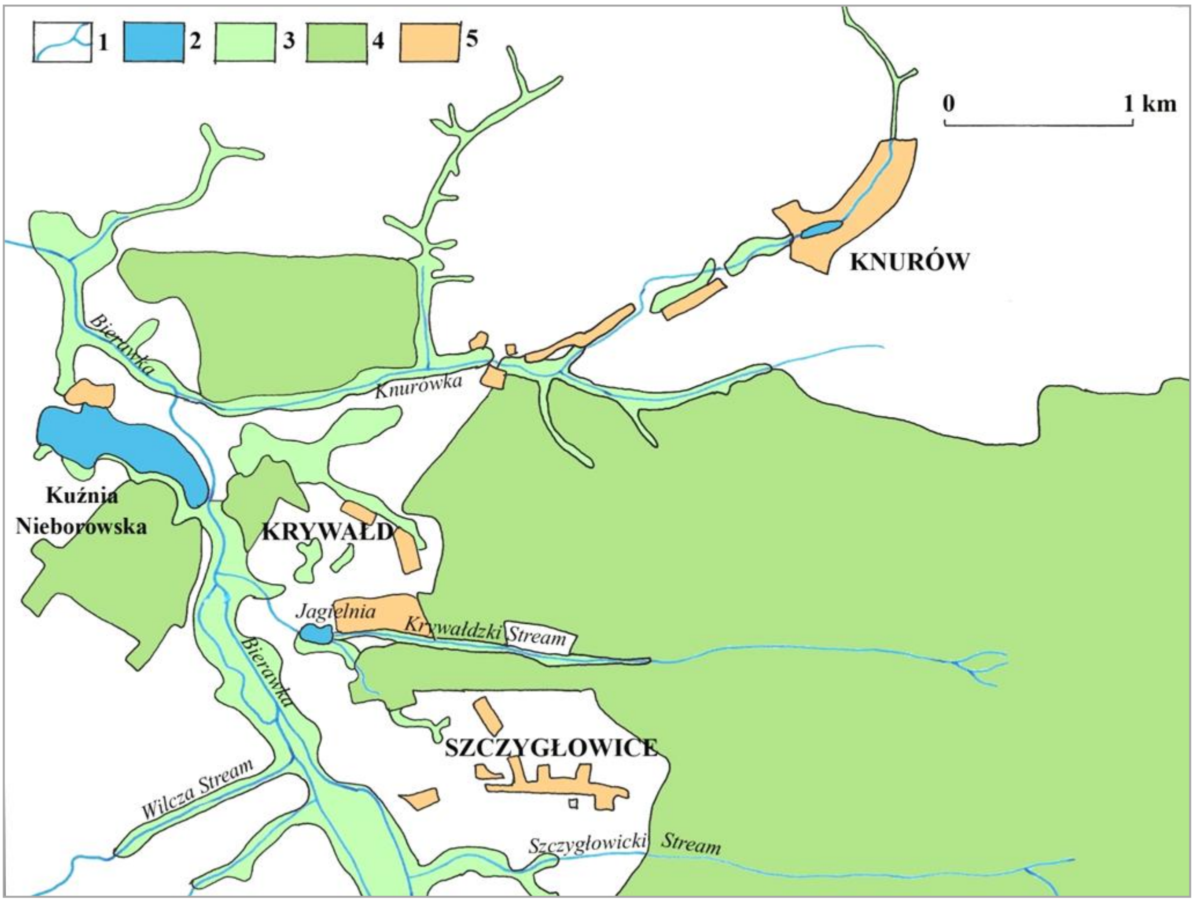

Fig. 1. Water reservoirs in the Knurów neighbourhood in 1884
1 – rivers, 2 – water reservoirs, 3 – wetlands, 4 – forests, 5 – built-up areas

4.2. The landscape of the area surrounding Knurów in the first half of the 20th century

The "Knurów" hard coal mine and coke plant started operatation in the study area in 1902 and 1913, respectively. The development of these plants increased the demand for water which was imported mainly from the "Kwitek" source of the River Knurówka, especially for the purpose of preparation of backfilling (Koziełek, 1990). The flow rate of this stream and consequently also the level of water in the reservoir existing on it were decreased in this way. The use of backfilling in underground workings reduced the sinking of the ground in this area; and therefore, during this period water reservoirs were not formed in subsidence basins. However, the development of the "Knurów" coal mine forced the construction of the first settling pond in the western part of the area ("Bagier") and in the vicinity of the "Foch" shaft. During the extension of the railway network embankments in the valleys of the streams were constructed, and hence, dammed reservoirs were created. An example would be a quite large reservoir in the northern part of the area, used for the preparation of backfilling for the "Foch" shaft mentioned above.

The operation of two brickyards – one in the vicinity of the "Knurów" coal mine and the second one, so-called "Machoczki" brickworks, in the area of the former Szywałd commune (Bojków) – had an impact on the shape of the landscape around Knurów. Surface exploitation of clays accompanying the operation of these plants led to the formation of a number of excavations, and later, under the simplest form of rehabilitation, to the formation of new water reservoirs. Over the years they took on different shapes and sizes as well as changing in number which resulted from the ongoing mining operations. One brickyard was decommissioned and then deepened and transformed into a settling pond; the second one is in operation to this day.

In the first half of the 20th century sand was also extracted on a small scale for backfilling purposes. This resulted in a relatively insignificant transformation of the relief; and the later gradual sinking of the area as a result of exploitation of hard coal was conducive to the emergence of water reservoirs in this place.

4.3. The landscape of the area surrounding Knurów in the second half of the 20th century

In the mid-twentieth century the landscape of the area surrounding Knurów bore the clear hallmark of anthropogenic transformation (Fig. 2). The most significant change in the landscape occurred between 1960 and 1985 in connection with the sinking of the area over the underground excavations after the exploitation of hard coal. Mainly due to the exploitation with the use of the roof caving method the subsidence of the original surface was significantly large – it ranged from 4 m to the north of the analysed area to 18 m in the Central Mining Waste Disposal Site. At that time vast wetlands, water reservoirs and numerous new watercourses were formed in the large forest complex in the south-eastern part of the study area. The newly-formed water reservoirs included mainly unstable marshes on the Krywałdzki Stream and subsidence basins in the area neighbouring the spoil tip.

In the analysed period about 50 new water reservoirs in the subsidence basins and valleys of streams and more than 20 settling ponds were formed in the area around Knurów. Such a significant increase in the number of water reservoirs resulted, among other things, from the opening of the second coal mine – "Szczygłowice" in the area of Knurów, an increase in the production in the "Knurów" coal mine (in the 1950s and 1960s to the highest level throughout the whole Rybnik Coal District) and discontinuation of the use of backfilling (LIGĘZA, 1970). The settling ponds retain the post-industrial waters; these usually include: mine water, backfilling water, post-floatation water.

It is difficult to determine the exact number of settling ponds because some of them due to their small size were not included on maps. However, it follows from the stock-taking undertaken that the described area is characterised by one of the greatest concentrations of settling ponds in the Silesian Upland (JANKOWSKI & WACH, 1980). The borderland between Knurów – Szczygłowice and Krywałd, where in the Bierawka valley a vast water area was created over a very short period of time, which was completely transformed in comparison to the area of the previous period, grew to be a particularly characteristic place. Next to the purposefully constructed settling ponds and regulated Bierawka river bed, water reservoirs in subsidence basins and on smaller watercourses, separated by piles of gangues, were formed.

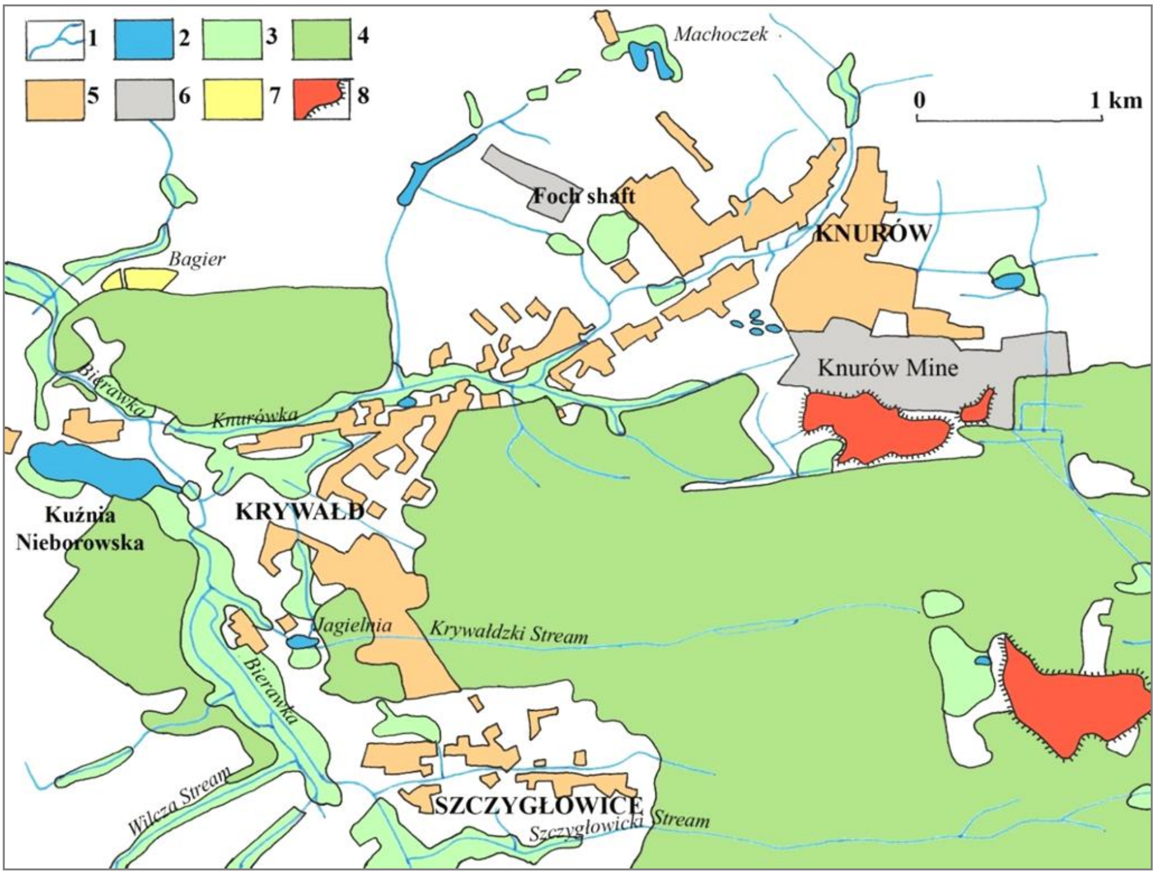

Fig. 2. Water reservoirs in the neighbourhood of Knurów in 1960
1 – rivers, 2 – water reservoirs, 3 – wetlands, 4 – forests, 5 – built-up areas, 6 – mining areas, 7 – settlement ponds, 8 – mining spoil heaps

For various reasons some older water reservoirs disappeared from the landscape. As part of the reclamation works some waterlogged sand excavations were partially filled with gangues and afforested. The vegetation succession led to the overgrowing of several small water reservoirs – the supply of fertilizers from agricultural fields accelerating the eutrophication of water reservoirs was a factor accelerating this process. This is particularly true of water reservoirs in the northern part of the area in the vicinity of the "Machoczka" brickyard and in the western part, in the area of Kuźnia Nieborowska, where the surface area of the largest reservoir clearly decreased. The disappearance of the reservoirs was also associated with the filling of the reservoirs with mining waste. At the end of the 20th century the landscape of the area surrounding Knurów could be described as anthropogenic with a large proportion of water reservoirs, settling ponds and spoil tips.

4.4. The landscape of the area surrounding Knurów at the turn of the 20th and 21th centuries

Over the last few years of the 20th century the surface area of water reservoirs in the vicinity of Knurów increased to 247.3 ha (2001). The area was increased primarily by large water reservoirs in the eastern and south-western parts of the area – currently, as many as 6 water reservoirs with an area of more than 10 ha are located in the study area. The number of small reservoirs decreased, so in total there are 77 water reservoirs, that is 12 fewer than in 1986 (Tab. 1). For example, as a result of water engineering works small water reservoirs in the Bierawka and Knurówka valleys disappeared from the landscape. Small and shallow water reservoirs who's functioning was dependent on the groundwater level also ceased to exist; some of them were filled with waste rock. In addition, some marshes in the river valleys were drained, e.g. "Nowy Dwór" in the valley of the Krywałdzki Stream (Fig. 3). According to the projections, the target subsidence in the Knurów area will range from 16 to 26 m, therefore the surface area of water reservoirs will continue to increase in the coming years (STRATEGIA, 2005). In addition to the dominant reservoirs in subsidence basins, the analysed area also includes the reservoirs constructed for the purposes of mining, industry, municipal management and recreation. This group of anthropogenic lakes includes small reservoirs of regular shapes.

Table 1. Water reservoirs in the neighbourhood of Knurów between the years 1884-2001

Year	Number of water reservoirs			Surface area of water reservoir [ha]	
	Total	Subsidence basins	Settling ponds	Total	Settling ponds
1884	3	-	-	29.38	-
1960	16	3	3	31.38	4.82
1986	89	43	26	174.31	38.25
2001	77	31	28	247.25	70.25

Fig. 3. Small water reservoir in the valley of the Krywałdzki Stream (*E. Jaruchiewicz*)

Fig. 4. "Zacisze" water reservoir (*E. Jaruchiewicz*)

Changes in the landscape surrounding Knurów which occurred in connection with the formation of new water reservoirs were related to the transformation of the existing terrestrial ecosystems into wetland ecosystems. The marshes formed in river valleys and some water reservoirs in the basins flooded meadow and forest areas located in the immediate vicinity, contributing to the displacement of the natural flora and invasion of aquatic species. Further development and functioning of reservoirs are largely dependent on the quality of their water. The biological and chemical studies undertaken of three water reservoirs located in the forest, a field and in the vicinity of the mine, may lead to the conclusions concerning the degree of pollution of reservoirs situated in similar environmental conditions (SALWA, 1995).

The water reservoirs located in the forest area are represented by the "Zacisze" water reservoir (Fig. 4, 5). Due to a high content of iron and manganese, the water quality does not meet the standards of purity (although the low content of nitrates and low degree of acidity classify the waters in the 1st class of purity) (Tab. 2). The condition of the water quality of the said reservoir is affected by the lack of connection with small and heavily contaminated streams occurring in this region. Thus, it is considered to be one of the cleanest in the area and, among others, for this reason a didactic path was created around it. Common reed (*Phragmites australis* (Cav.) Trin. ex Steud.), common reedmace (*Typha latifolia* L.), reed sweet-grass (*Glyceria maxima* (Hartm.) Holmb.), sedges (*Carex* spp.), bulrush (*Schoenoplectus lacustris* (L.) Palla), swamp horsetail (*Equisetum fluviatile* L.), yellow iris (*Iris pseudacorus* L.), marsh marigold (*Caltha palustris* L.) and branched bur-reed (*Sparganium erectum* L. emend. Rchb. s. str.) can be found in the surroundings of the reservoir. Furthermore, aquatic floating plants such as floating-leaf pondweed (*Potamogeton natans* L.), common water-crowfoot (*Batrachium aquatile* (L.) Dumort.), yellow water-lily (*Nuphar lutea* (L.) Sibth. & Sm.) and common frogbit (*Hydrocharis morsus-ranae* L.) can be seen there. The wealth of the fauna is linked to the occurrence of many species of amphibians and reptiles, and – to a lesser extent – birds. The area is inhabited, among others, by green frogs (*Rana esculenta complex*): common frogs (*Rana temporaria*) and moor frogs (*Rana arvalis*), common toads (*Bufo calamita*), green toads (*Bufo viridis*), newts (*Lissotriton vulgaris* and *Triturus cristatus*), and by reptiles such as grass snake (*Natrix natrix*) and common viper (*Vipera berus*). Quite common birds that inhabit the area include: mallards (*Anas platyrhynchos*), grebes (*Podiceps cristatus*) and grey herons (*Ardea cinerea*).

Reservoirs of water located in cultivated fields and the areas adjacent to roads are represented by the "Machoczek" reservoir situated next to the brickyard to the north of the study area. Adverse proximity to a busy road has a negative impact on the relatively high concentration of heavy metals, particularly iron and zinc. However, the farmlands in close proximity to the water reservoir have caused it to become eutrophic conducive to its eutrophication, it is characterised by a high organic matter content.

The third of the analysed water reservoirs – "Aniołki" – is located in the immediate vicinity of the "Knurów" coal mine and has the highest content of nitrates, sulphates and chlorides (Fig. 5, 6, Tab. 2). The reservoir became the site of sedimentation of pollutants emitted by the coke plant sited to the west of it. The decommissioning of this plant in the late 20th and early 21th century reduced the negative impact on the environment of the surroundings of the reservoir, facilitating the succession of plants and fauna. It can be concluded on the basis of the mentioned research results that the water reservoirs in the vicinity of the mines (Fig. 7) and spoil tips are most polluted, collecting the unclassified waters (only during the summer months – water of the 3rd purity class).

A high content of dissolved oxygen in water is an important criterion for biological life in a water reservoir. Some reservoirs in the environs of Knurów are well oxygenated, thus aquatic plants and animals can live and develop in them (WEILER & WOLNY, 1995). An example of a water reservoir with a thriving littoral and aquatic vegetation would be the largest water reservoir in the south-western part of the study area. In its littoral zone, the following vegetation zones were distinguished, starting from the basket willow (*Salix viminalis* L.), which is located furthest from the shore of the reservoir, through the reed bed of reedmace (*Typha latifolia*) and common reed (*Phragmites australis*), and further on to the zone of spiked loosestrife (*Lythrum salicaria* L.) and branched bur-reed (*Sparganium erectum*). This water reservoir is also characterised by a richer fauna than that of the other reservoirs. In addition to a larger number of different species of birds and amphibians common pond molluscs such as great pond snail (*Lymnaea stagnalis*) and great ramshorn snail (*Planorobis korneus*) were observed; probably the reservoir is also inhabited by mussel species.

Table 2. Chemistry and heavy metals in the waters of selected water reservoirs in the neighbourhood of Knurów (after Salwa, 1995)

Type of designation	„Zacisze" - water reservoir in the forest	„Machoczek" – water reservoir in the cultivated field	„Aniołki" – water reservoir in the industrial area
Dissolved oxygen [mg/dm³]	6.62	9.24	12.90
Acidity [pH]	6.77	7.90	8.57
Conductivity [mg/dm³]	179	529	3060
Nitrates [mg/dm³]	1.25	38.10	85.40
Sulphates [g/dm³]	0.693	1.876	7.772
Chlorides [mg/dm³]	25	64	718
Hardness [mval/dm³]	9.62	12.4	6.7
Lead [mg/dm³]	0.01	0.02	0.07
Iron [mg/dm³]	1.21	1.62	0.16
Copper [mg/dm³]	0.007	0.012	0.01
Zinc [mg/dm³]	0.06	0.45	0.12
Manganese [mg/dm³]	0.52	0.16	0.10

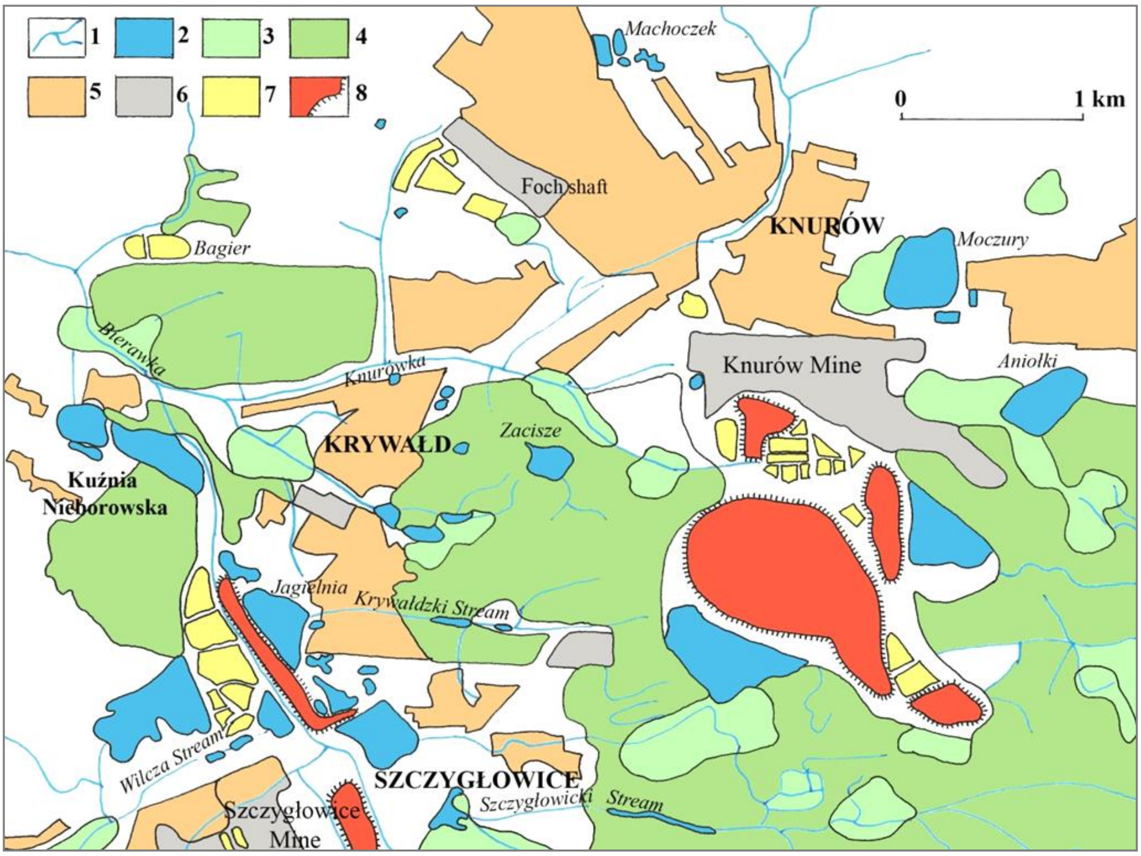

Fig. 5. Water reservoirs in the neighbourhood of Knurów in 2001
1 – rivers, 2 – water reservoirs, 3 – wetlands, 4 – forests, 5 – built-up areas, 6 – mining areas, 7 – settlement ponds, 8 – mining spoil heaps

5. Discussion

Like most of the water reservoirs in the Upper Silesian Coal Basin, the water reservoirs in the area around Knurów are of anthropogenic origin. They were formed primarily as a result of filling subsidence basins and excavations after the exploitation of raw mineral materials with water, as well as a being the result of the construction of various hydro-technical facilities (settling ponds, fire protection water reservoirs, etc.). Due to their oval shape and smooth edges the water reservoirs in subsidence basins are similar to natural ones in terms of their physiognomy. If the subsidence basin is formed in a river valley, the water reservoirs that are formed enable the flow-through. The reservoirs in the excavations after the exploitation of raw materials are characterised by steeper edges and a highly developed shoreline. Artificially created hydro-technical facilities have regular shapes and their edges are concreted or constructed using earthen levees.

Fig. 6. „Aniołki" water reservoir near the „Knurów" hard coal mine (*E. Jaruchiewicz*)

Fig. 7. "Knurów V" water reservoir near the mining spoil heap (*E. Jaruchiewicz*)

The importance of water reservoirs in the landscape of the Upper Silesian Coal Basin has been the subject of research since the 1970s – 1980s (JANKOWSKI & WACH, 1980; CZAJA & DEGÓRSKA, 1988; JANKOWSKI, 1991, 1999; PEŁKA-GOŚCINIAK & SZCZYPEK, 1995; TOKARSKA-GUZIK & ROSTAŃSKI, 1996; CZYLOK & RAHMONOV, 1998; RZĘTAŁA, 2008a,b; MADOWICZ, 2001; KAMIŃSKI ET AL., 2003; CZYLOK & BARYŁA, 2003; DULIAS, 2003b, 2005, 2008a,b; MACHOWSKI & RZĘTAŁA, 2006; BŁOŃSKA ET AL., 2008; JARUCHIEWICZ, 2008; MACHOWSKI, 2010, FAJER ET AL. 2014). The research shows that over the past 200 years, but especially in the last half-century, numerous changes in the distribution and number of anthropogenic water reservoirs have taken place. Initially, mainly ponds for fish breeding and for the collection of water for the purposes of ponds for water mills were created. In the second half of the 19th century, a particularly large number of water reservoirs were formed after surface and shallow exploitation of zinc and lead ores as well as clay rocks, limestones and dolomites. Their number is highly variable in time, therefore their role in the landscape is diverse. In some of the old excavations and subsidence basins water is present periodically – in spring and autumn, setting a specific rhythm to the development of vegetation. The environs of Radzionków in the Bytom Plateau can be held up as an example of change in the number of water reservoirs (CZAJA & DEGÓRSKA, 1988). Over 30 years their numbers varied in the range between 62 and 146, and at the end of the 20th century many of them were filled, thus their number decreased 3-fold. By comparison, in the first half of the 19th century 18 water reservoirs existed in the city of Bytom, whereas at the end of 19th century there were 143, in the 1960s – 258, and in 1989 – as many as 321 (JANKOWSKI, 1991). Similar changes in the number of water reservoirs are observed in other parts of the Upper Silesian Coal Basin (JANKOWSKI ET AL., 2003; RUMAN, 2004; MACHOWSKI & RZĘTAŁA, 2006; DULIAS, 2008a,b). In the study area in the environs of Knurów the trends of changes in the number of water reservoirs are similar – between 1884 and 2001 their number increased 25-fold, while at the same time their total surface area increased more than 8-fold (Tab. 1).

The formation of overflows and new water reservoirs results in gradual change to the existing terrestrial ecosystems to wetland and littoral ecosystems. Species of plants characteristic of the bottom and mid-water as well as species inhabiting the water surface and the shoreline zone start to occur. For example, on the banks of the large Rybnik Reservoir water, bulrush and reed phytocenoses, and – further from the shore – riparian shrubs and trees have developed (PEŁKA-GOŚCINIAK & SZCZYPEK, 1995). Smaller bodies of water do not generally show a high relationship between their genetic type and the composition of their plant communities (BŁOŃSKA ET AL., 2008). The diversity of the vegetation depends, to a greater extent, on the age of the reservoir, its depth and the manner in which it is used as well as on the physico-chemical properties of the water and the fluctuations in their water level (TOKARSKA-GUZIK & ROSTAŃSKI, 1996). *Phragmitetum australis* is the most common plant community. On the basis of studies on vegetation surrounding several water reservoirs in the city of Katowice it was found that the reservoirs in the excavations after the exploitation of raw materials are characterised by a small number of plant communities, and the vegetation belts there are relatively narrow (BŁOŃSKA ET AL., 2008). Around the water bodies in the subsidence basins the vegetation belts are wider, but are usually composed of concentrations of *Phragmites australis* or *Typha latifolia*. Similar observations were made in the study area and with respect to other water reservoirs (e.g. KOSTECKI, 1974; DULIAS, 2008b). The most common species of plants around the anthropogenic water reservoirs include *Phragmites australis*, *Typha latifolia, Ceratophyllum demersum*, *Elodea canadensis, Potamogeton natans*, *Lemna sp., Acorus calamus*, *Sagittaria sagittifolia*, *Myriophyllum verticillatum*, *Alisma plantago-aquatica* and *Glyceria aquatica*. (STRZELEC, 1993; BŁOŃSKA ET AL., 2008; JARUCHIEWICZ, 2008).

The water reservoirs which were formed in forest areas are characterised by the occurrence of dead tree trunks within their borders. However, around these reservoirs, in marshy woods protected and rare species of plants occur frequently as a result of spontaneous re-naturalization (JĘDRZEJKO, 1987; HOLAK, 1996; TOKARSKA-GUZIK & ROSTAŃSKI, 1996, MACHOWSKI, 2010). These include, among others, *Equisetum telmateia* Ehrh., *Nymphaea alba* L., *Nuphar luteum*, *Hydrocharis morsus-ranae* L., *Butomus umbellatus* L. and *Lemna gibba* L.

The study area is also inhabited by natural curiosities. The location of water chestnut (*Trapa natans* L.) in the water reservoirs in Kuźnia Nieborowska is considered particularly valuable (MRÓZ, 1995). Moreover, the environs of the "Bagier" settling pond are inhabited by *Ruppia maritima* L., a species that is considered to be in danger of extinction in Poland.

Due to their landscape value many anthropogenic water reservoirs are used for recreational purposes. This applies above all to the water bodies located in excavations after the exploitation of stowing sands, e.g. Pogoria I, II and III, Kuźnica Warężyńska, Sosina, Balaton, Dzierżno Małe, Rogoźnik, Morawa (RZĘTAŁA, 2008b; DULIAS, 2010; CZYLOK & TYC, 2014). On the basis of interviews with inhabitants within the environs of Knurów it was found that the formation of anthropogenic water reservoirs is generally positively perceived, providing that it does not cause material damage by flooding residential buildings, roads and farmlands,. These are popular places for short-term recreation – walking, cycling trips, and most of all fishing.

The studies carried out show a cause-and-effect-relationship of landscape transformation in the mining area in the eastern part of the Upper Silesian Coal Basin. Water reservoirs in the environs of Knurów were formed as a result of the pond management pursued in the 19th and 20th century, but most of all as a consequence of more than a century of hard coal mining, (and to a lesser extent – sand and clay mining), which resulted in the formation of subsidence basins and pits filled with water. Over 130 years in the study area a significant increase in the water surface – from approximately 30 ha at the end of the 19th century to nearly 250 ha at the beginning of the 21st century was recorded. The large concentration of water reservoirs in this region is expressed by the lake (water reservoir) density index that was at 4.42% for the Knurów community, which is the second largest index – after that of Dąbrowa Górnicza – among the cities of the Katowice agglomeration, and its high value is comparable to the value in the environs of the young-glacial areas in the north of Poland (RZĘTAŁA, 2000). The role of the newly created water reservoirs in the landscape primarily involves the transformation of the existing terrestrial ecosystems into wetland ecosystems. The agro-forestry landscape of the late 19th century was transformed into a typically anthropogenic landscape with a dominant share of water reservoirs, settling ponds and mining waste disposal sites. Changes in the vegetation cover can be considered favourable since the analysed area is currently characterised by greater biodiversity.

References

Absalon D., Jankowski A.T., Leśniok M. 2001. *Komentarz do mapy hydrograficznej 1:50 000*, ark. Gliwice, GUGiG.

Błońska A., Serwon K., Wika S. 2008. Wpływ genezy wybranych zbiorników antropogenicznych Katowic na szatę roślinną ich obrzeży. *Kształt. środ. geogr. i ochr. przyr. na obsz. uprzem. i zurb.,* 39: 5-16.

Clark G. 1963. *Grimes Graves*. Her Majesty`s Stationery Office. London.

Czaja S., Degórska V. 1988. Geneza i czasowe zmiany zbiorników wodnych w rejonie Radzionkowa i Bytomia. *Geogr. Stud. et dissert.*, 12: 7-15.

Czylok A., Baryła J. 2003. Wczesne stadia sukcesji roślinnej w wyrobisku po eksploatacji piasku w Kuźnicy Warężyńskiej. *Przyroda Górnego Śląska*, 31: 11-12.

Czylok A., Rahmonov O. 1998. The initial stages of succession with variegated horsetail *Equisetum variegatum* Schleich in wet sands of surface excavations. [in:] Szabó J., Wach J. (eds.) *Anthropogenic aspects of geographical environment transformations*. Debrecen-Sosnowiec: 81-86.

Czylok A., Tyc A. 2014. Sand mining areas in the Dąbrowa Basin and their restoration. [in:] Dulias R., Prokop P. (eds.) *Land degradation and reclamation in the Silesian Upland and the Polish Carpathians*. Univ. of Silesia, Polish Academy of Sciences, IGU Comm. on Land Degradation and Desertification (COMLAND), Sosnowiec, Kraków: 72-75.

Denimal S., Bertrand C., Mudry J., Paquette Y., Hochart M., Steinmann M. 2005. Evolution of the aqueous geochemistry of mine pit lakes – Blanzy-Montceau-les-Mines coal basin (Massif Central, France): origin ofsulfate contents; effects of stratification on water quality. *Applied Geochem.*, vol. 20, 5: 825-839.

Drecker P., Genske D.D., Heinrich K., Nol. H.P. 1995. Subsidence and wetland development in the Ruhr district of Germany. *Land Subsidence*, IAHS Publ., 234: 413-421.

Dulias R. 2003a. Subsidence depression in Upper Silesian Coal Basin. [in:] Mentlik P. (ed.) *Geomorfologický sborník*, 2: 11-16.

Dulias R. 2003b. Rola niecek osiadania w krajobrazie obszarów górniczych na przykładzie Górnośląskiego Zagłębia Węglowego. [in:] Śmigielska M., Słodczyk J. (eds.) *Geograficzne aspekty globalizacji i integracji europejskiej*. PTG, Uniw. Opolski, Opole: 37-41.

Dulias R. 2005. Wpływ eksploatacji piasków podsadzkowych na krajobraz dolin rzecznych w Kotlinach – Dąbrowskiej i Biskupiego Boru. *Kształt. środ. geogr. i ochr. przyr. na obsz. uprzem. i zurb*., 36: 17-29.

Dulias R. 2008a. Changes in landscape in the neighbourhood of Żabie Doły in the Silesian Upland. *Anthropogenic aspects of landscape transformations*, 5: 13-19.

Dulias R. 2008b. Wpływ górnictwa węglowego na zmiany krajobrazu w zlewniach Dębinki I Pniówki na Płaskowyżu Rybnickim. *Dokum. Geogr.*, 37: 144-149.

Dulias R. 2010. Landscape planning in areas of sand extraction in the Silesian Upland, Poland. *Landsc. Urban Plan*., 95: 91-104.

Dulias R., Rudnicka M. 2000. Typy brzegów antropogenicznych zbiorników wodnych na obszarze między Sosnowcem, Katowicami i Mysłowicami. *Kształt. środ. geogr. i ochr. przyr. na obsz. uprzem. i zurb.,* 30: 7-14.

Eary L.E. 1999. Geochemical and equilibrium trends in mine pit lakes. *Applied Geochem.*, 14, 8: 963-987.

Fajer M., Waga J.M., Degórska A., Machowski R. 2014. Stop 1.8. "Żabie Doły" landscape-nature protected complex as an example of renaturation of post-industrial areas. [in:] Dulias R., Prokop P. (eds.) *Land degradation and reclamation in the Silesian Upland and the Polish Carpathians*. Univ. of Silesia, Polish Academy of Sciences, IGU Comm. on Land Degradation and Desertification (COMLAND), Sosnowiec, Kraków: 59-63.

Holak E., Kania E., Wrona A. 1996. Rzadkie i chronione gatunki roślin naczyniowych w wybranych antropogenicznych zbiornikach wodnych położonych w obrębie Bytomia, Jaworzna, Czerwionki-Leszczyn, Zabrza i Knurowa. [in:] Rosik-Dulewska C., Gołubowicz J. (eds.) *Gospodarka terenami zniszczonymi działalnością człowieka*. PAN, Inst. Podstaw Inż. Środowiska, Zabrze: 147-150.

Jankowski A.T. 1991. Występowanie antropogenicznych zbiorników na terenie Bytomia w okresie 1881-1989. *Kształt. środ. geogr. i ochr. przyr. na obsz. uprzem.i zurb*., 3: 21-29.

Jankowski A.T. 1999. Antropogeniczne zbiorniki wodne na obszarze Górnego Śląska. *Acta Univ. Nicolai Copernici*, XXIX, *Nauki Mat. Przyr*., 103: 129-142.

Jankowski A.T., Wach J. 1980. Uwagi o zbiornikach antropogenicznych na terenie GOP i jego obrzeżenia. [in:] *Przeobrażenia środowiska geograficznego w obszarach uprzemysłowionych i zurbanizowanych*. Mat. VII Symp. polsko –czechosł., Uniw. Śląski, Sosnowiec: 65-75.

Jankowski A.T., Rzętała M. 1996. Zmiany ilościowo-jakościowe zbiorników wodnych w warunkach silnej antropopresji. *Zesz. Nauk. Akad. Roln.*, 289: 117-120.

Jankowski A.T., Machowski R., Molenda T., Nitkiewicz-Jankowska A., Rzętała M. 2003. Quantitative-qualitative characteristics and bases of water reservoirs revitalisation in the area of the Hummock of Tarnowskie Góry. *Limnol. Rev*., 3: 95-100.

Jaruchiewicz E. 2008. Krajobrazowe znaczenie zbiorników wodnych w okolicach Knurowa. *Kształt. środ. geogr. i ochr. przyr. na obsz. uprzem.i zurb*., 39: 17-25.

Jędrzejko K. 1987. Szata roślinna w krajobrazie terenów przemysłowych Wyżyny Śląskiej. [in:] *Problemy geograficzne górnośląsko-ostrawskiego regionu przemysłowego*. Mat. symp. polsko-czechosł., IDN IKN, WNoZ Uniw. Śląski, Sosnowiec-Katowice: 49-56.

Kamiński A., Rzętała M., Szczypek T. 2003. Rola zbiorników wodnych w kształtowaniu krajobrazu. [in:] Szczypek T., Rzętała M. (eds.) *Człowiek i woda*, PTG Oddz. Katowicki, Sosnowiec: 54-63.

Kapfer M. 1998. Assessment of the colonization and primary production of microphythobentos in the litoral of acidic mining lakes in Lusatia (Germany). *Water, Air and Soil Pollution*, vol. 108, 3-4:331-340.

Klimaszewski M. 1972. *Geomorfologia Polski*, t. 1. PWN, Warszawa.

Kostecki M. 1974. Jakość wody w niewielkich zbiornikach pochodzenia przemysłowego na terenie GOP. *Gosp. Wodna*, 10: 381-384.

Koziełek A. 1990. *Knurów i Krywałd. Kronika na tle historii Ziemi Gliwickiej*. Tow. Miłośników Knurowa, Katowice.

Ligęza J. (ed.) 1970. *Ziemia rybnicko-wodzisławska*. Wyd. Śląsk. Katowice.

Machowski R. 2010. *Przemiany geosystemów zbiorników wodnych powstałych w nieckach osiadania na Wyżynie Katowickiej*. Wyd. Uniw. Śląskiego, Katowice.

Machowski R., Rzętała M. 2006. Geneza, liczebność, funkcje oraz perspektywy użytkowania zbiorników wodnych na obszarze Pagórów Jaworznickich. *Geogr.. Stud. et dissert.*, 28: 127-139.

Madowicz A. 2001. Zalewiska poeksploatacyjne w Jastrzębiu Zdroju jako nowy element krajobrazu. [in:] Myga-Piątek U. (ed.) Krajobraz kulturowy. Idee, problemy, wyzwania. WNoZ Uniw. Śląski, Oddz. Katowicki PTG, Sosnowiec: 57-61.

Mapa topograficzna 1:25 000, ark. Knurów, WODGiK, 1986.

Mapa topograficzna 1:25 000, Rybnicki Okręg Węglowy, ark. 3, 1960.

Martinec P., Schejbalová B., Hortvík K., Maníček J. 2005. The effects of coal mining on the landscapes of the Ostrava Region. *Moravian Geogr. Reports*, 13: 13-26.

McCullough C. D., Lund, M. A. 2006. Opportunities for sustainable mining pit lakes in Australia. *Mine Water and the Environ.*, 25: 220-226.

Messtischblätter, Herausgeggeben von der Preußischen Landesaufnahme, 1:25 000, Reichsamt für Landesaufnahme, Berlin 1884.

Mirek Z., Piękoś-Mirkowa H., Zając M. 2002. *Flowering plants and pteridophytes of Poland. A checklist*. W. Szafer Instit. of Botany, Polish Acad. of Sci., Kraków.

Mróz B. 1995. Ostoja orzecha wodnego w Kuźni Nieborowickiej. *Zesz. Knurowskie*, 7: 32-37.

Pełka-Gościniak J., Szczypek T. 1995. Próba oceny wpływu antropogenicznych zbiorników wodnych na krajobraz Górnego Śląska. [in:] *Przeobrażenia środowiska geograficznego w przygranicznej strefie górnośląsko-ostrawskiej*. Mat. symp. polsko-czeskiego, WNoZ UŚ, PK CKKRW, Sosnowiec: 91-99.

Ruman M. 2004. Zmiany liczby i powierzchni sztucznych zbiorników wodnych na terenie Gliwic od połowy XIX wieku. [in:] Jankowski A.T., Rzętała M (eds.) *Jeziora i sztuczne zbiorniki wodne – funkcjonowanie, rewitalizacja i ochrona*, WNoZ UŚ, Pol. Tow. Limnol., PTG O. Katowice, Sosnowiec: 193-202.

Rzętała M. 1998. Zróżnicowanie występowania sztucznych zbiorników wodnych na obszarze Wyżyny Katowickiej. *Geogr.. Stud. et dissert.*, 22: 52-67.
Rzętała M. 2000. Wybrane problemy eksploatacji i ochrony zbiorników wodnych na obszarze województwa śląskiego. [in:] Jankowski A.T., Myga-Piątek U., Ostaficzuk S. (eds.) *Środowisko przyrodnicze regionu górnośląskiego-stan poznania, zagrożenia i ochrona.* WNoZ, UŚ, Oddz. Katowicki PTG, Sosnowiec: 117-131.
Rzętała M. 2008a. *Funkcjonowanie zbiorników wodnych oraz przebieg procesów limnicznych w warunkach zróżnicowanej antropopresji na przykładzie region górnośląskiego*. Wyd. Uniw. Śląskiego, Katowice.
Rzętała M. 2008b. Ocena znaczenia turystyczno-rekreacyjnego zbiorników wodnych na przykładzie regionu górnośląsko-ostrawskiego). *Kształt. środ. geogr. i ochr. przyr. na obsz. uprzem. i zurb.,* 39: 94-105.
Rzętała M.A. 2003. *Procesy brzegowe i osady denne wybranych zbiorników wodnych w warunkach zróżnicowanej antropopresji (na przykładzie Wyżyny Śląskiej i jej obrzeży*). Wyd. Uniw. Śląskiego, Katowice.
Salwa J. 1995. Próba oznaczenia czystości wód według Indeksu Viborga. *Zesz. Knurowskie*, 7: 39-45.
Solarski M., Pradela A. 2010. Przebieg zjawisk lodowych w zbiorniku wodnym w niece osiadania w sezonie zimowym 2008/2009. *Kształt. środ. geogr. i ochr. przyr. na obsz. uprzem. i zurb.,* 42: 70-79.
Strategia rozwoju gminy miasta Knurów. Zał. do Uchwały RM Knurów, Nr XXXI/430/2005 z dn. 20 stycznia 2005.
Strzelec M. 1993. Zbiorniki zapadliskowe – szczególne środowisko dla życia ślimaków wodnych w Górnośląskim Okręgu Przemysłowym. *Kształt. środ. geogr. i ochr. przyr. na obsz. uprzem. i zurb.,*9: 31-36.
Stupnicka E. 1997. *Geologia regionalna Polski*. Wyd. Uniw. Warszawski, Warszawa.
Tokarska-Guzik B., Rostański A. 1996. Zapadliska górnicze w aglomeracji katowickiej, ich znaczenie i możliwości zagospodarowania. [in:] Rosik-Dulewska C., Gołubowicz J. (eds.) *Gospodarka terenami zniszczonymi działalnością człowieka*. PAN, Inst. Podstaw Inż. Środowiska, Zabrze: 147-150.
Topographische Karte 1:25 000, ark. Orzesche, Golleow, Gleiwitz, Kieferstadtel. Berlin 1881-1884.
Weiller M., Wolny E. 1995. Charakterystyka wód wybranych akwenów na terenie Krywałdu. *Zesz. Knurowskie*, 7: 26-31.
Werner F., Bilek F., Luckner L. 2001. Impact of regional groundwater flow on the water quality of an old post-mining lake. *Ecol. Eng.*, 17, 2-3: 133-142.
Ziemońska Z. 1979. Rola zbiorników wodnych antropogenicznego pochodzenia w uprzemysłowionym obszarze Wyżyny Śląskiej. *Folia Geogr., Ser. Geogr.-Physica*: 123-136.