# STUDY ON USE OF ARTIFICIAL WATER RESERVOIRS IN SILESIAN UPLAND (SOUTHERN POLAND) AS ELEMENT OF CULTURAL LANDSCAPE

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Abstract

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In result of industry and urbanisation development in upper Silesia some thousands artificial water reservoirs were originated. It caused many changes in the environment identified with transformation of cultural landscape. Management of them is unusually essential task promoted in support intentional and harmonious modelling of the neighbourhood (landscape architecture). Results of carried out field (level geodetic circuit) and laboratory (INAA, ICP, XRF) investigations allowed to state some regularities designating the importance of water reservoirs in landscape. Water quality in reservoirs is the basic factor deciding of character of their use as well as of management of littoral zone. The delicious indices of qualitative state of reservoirs waters are results of complex investigations on bottom deposits. Ranges of levels of trace elements occurrence in bottom deposits usually stray from levels of geochemical background. Temporal changes in trace elements content simultaneously indicate the largest transformations in water environment identified with period of socialistic economy and spontaneous nature regeneration which was typical for last a dozen or so years of marked economy development.

*Key words*: Silesian upland, heavy metal, water reservoir, monitoring, bottom deposits

## Introduction

In Silesian upland in result of industry and industrialisation development some thousand water reservoirs were originated (they are relatively new elements of cultural landscape of the given region) of total area reaching tens km$^2$. It caused many changes in the environment, identified with transformation of cultural landscape as well as with many phenomena and processes, which earlier did not occur in this area (e.g. formation of new sedimentation basins, development of shore processes, swamping, changes in species composition of vegetation, changes in topoclimate). Management of these reservoirs is extremely essential task, promoting intended and harmonious modelling of the neighbourhood (landscape architecture), and the ambivalent direction of scientific considerations is estimation on their influence on the neighbouring environment. Negative aspects of functioning of artificial water reservoirs (e.g. flooding, eutrophication, abrasion, and silting, uncontrolled shore management) are worth special attention, because they have direct connection with the loss of aesthetic values in the neighbourhood and formation of wasteland zones. There are relatively many examples in this respect in Silesian upland, although they are not such spectacular as in the case of large Siberian water reservoirs (Ovchinnikov et al., 2002) where the size of shore washing in some places reaches even 200 meters for the period of exploitation, at annual mean reaching a dozen or so meters per year and length of abraded shores, measured in hundred and thousand km.

## Area of investigation

Silesian upland (3.9 thousand km$^2$), in result of complex changes in the natural environment, caused by industry concentration (especially mining) and significant population degree, belongs to the most transformed areas in Poland in respect of human impact (Fig. 1). These changes also refer to the water environment, what is among others revealed in transformation of surface hydrographic net, degradation of underground water quality and impoverishment in local water resources.

Among some thousand water reservoirs occurring in the area of Silesian upland (Fig. 1), the decided majority is unintentional result of economic activity. They are most often located in subsidence depressions of different size (derivative of underground deposit exploitation). Together with reservoirs formed in result of resource surface exploitation and used in coal mining as stowing material as well as dam reservoirs formed at the upland borders, they create the largest water complex in southern Poland.

## Methods

Investigations realised gave the base to draw conclusions on regularities determining the role of water reservoirs in landscape of Silesian upland, pointing simultaneously at the possibilities of their further management. The base of cameral investigations was the analysis of both topographic maps on the scales 1:10 000 and 1:25 000 as well as aerial photos, and bases of consideration were results of analyses of bottom deposit as a good indicator of features of the neighbouring environment.

Sampling was carried out by means of pipe samplers, and laboratory determinations were made by means of: areometer or sieve-areometer – granular composition; instrumental method of neutron activation analysis (INAA) – occurrence of some elements (Au, As, Br, Co, Cr, Sb, U), by method of atom emission spectrometry with plasma excitation from alloy (ICP) – occurrence of elements: Ba, Sr, V, by means of ICP method after complete sample solution – occurrence of some elements (Cu, Pb, Zn, Ag, Ni, Cd), by method of X-ray fluorescence analysis (XRF) – occurrence of element Pb.

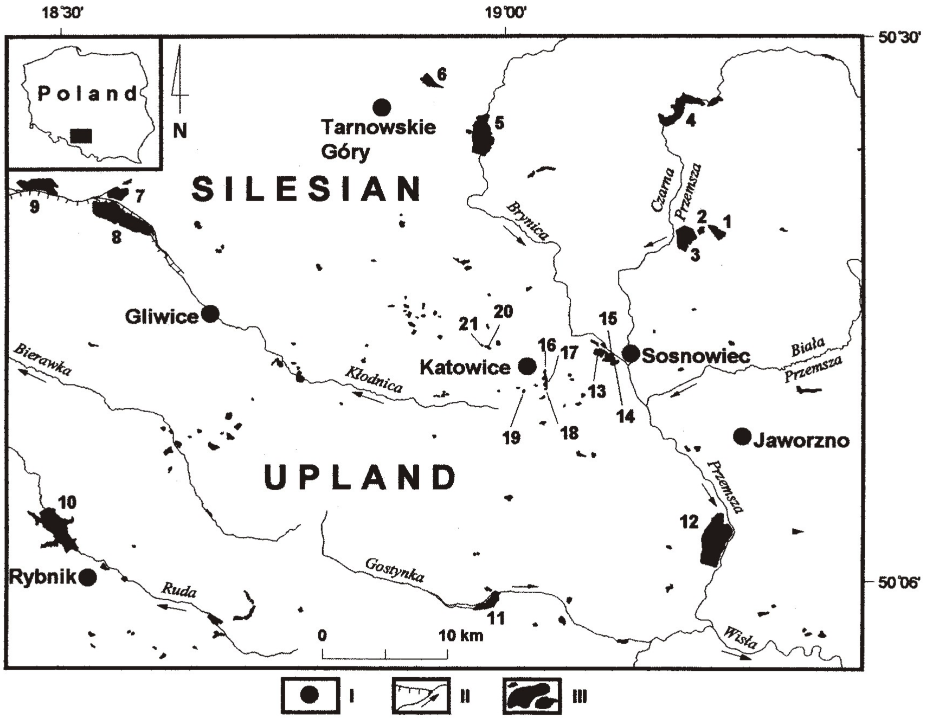


Fig. 1. Location of the research area: I – towns, II – watercourses and canals, III – water reservoirs: 1 – Pogoria I, 2 – Pogoria II, 3 – Pogoria III, 4 – Przeczyce, 5 – Kozłowa Góra, 6 – Chechło, 7 – Dzierżno Małe, 8 – Dzierżno Duże, 9 – Pławniowice, 10 – Rybnicki, 11 – Paprocany, 12 – Dziećkowice, 13 – Morawa, 14 – Gliniak, 15 – Hubertus, 16 – Łąka, 17– Kajakowy, 18 – Kąpielisko, 19 – Grünfeld, 20 – Maroko I, 21 – Maroko II.

Level circuits, situation-height plans in littoral zone and landscape profiles were made at use of tachymeter "Dahlta 020". Bathymetric recognition was carried out with applying echo sounder Ultra III 3D, tachymeter and GPS.

## Results and discussion

Trace element contents in bottom deposits of artificial water reservoirs in Silesian upland are significantly varied. It results from the existence of natural (e.g. deposit lithology) and anthropogenic conditions, identified with different forms of management of their catchment areas. Striking examples of different influence of conditions make data for some larger water reservoirs in respect of capacity and area (Table 1).

T a b l e 1. Mean concentrations of selected elements in bottom deposits of selected water reservoirs in the Silesian upland

| Element | | Geochemical background * | Water reservoir | | | | | |
|---|---|---|---|---|---|---|---|---|
| Name | Symbol | | Pogoria I | Pogoria III** | Przeczyce ** | Świerkla-niec** | Dzierżno Małe | Dzierżno Duże** |
| | | [ mg/kg ] | | | | | | |
| Antimony | Sb | 0.03 – 2.00 | 3.53 | 1.30 | 3.47 | 3.30 | 1.93 | 6.70 |
| Arsenic | As | 1.0 – 13.0 | 19.3 | 10.7 | 25.7 | 41.0 | 12.3 | 22.0 |
| Barium | Ba | 50 – 800 | 678.7 | 432.7 | 493.3 | 1080.0 | 450.7 | 1230.5 |
| Bromine | Br | 1 – 10 | 5.3 | 2.0 | 12.7 | 10.5 | 18.3 | 6.00 |
| Cesium | Cs | 0.5 – 10.0 | 10.0 | 8.6 | 7.3 | 5.1 | 4.6 | 8.9 |
| Chromium | Cr | 5 – 120 | 132.3 | 104.7 | 78.3 | 74.0 | 68.3 | 123.0 |
| Zinc | Zn | 10 – 120 | 1276.0 | 185.7 | 1282.3 | 1729.0 | 351.3 | 512.5 |
| Zirconium | Zr | 20 – 220 | 487.3 | 484.7 | 381.7 | 352.5 | 204.00 | 105.0 |
| Cadmium | Cd | 0.05 – 0.35 | 15.27 | 0.93 | 11.70 | 18.05 | 2.53 | 9.30 |
| Cobalt | Co | 0.1 – 20.0 | 22.0 | 15.7 | 14.3 | 16.0 | 15.0 | 22.5 |
| Copper | Cu | 2 – 60 | 44.0 | 20.0 | 33.0 | 60.0 | 22.0 | 60.5 |
| Nickel | Ni | 5 – 90 | 50.0 | 33.7 | 27.0 | 26.5 | 24.7 | 33.0 |
| Lead | Pb | 3 – 40 | 239 | 51 | 599 | 479 | 72 | 88 |
| Silver | Ag | 0.050 – 0.250 | 1.13 | 1.00 | 0.83 | 0.60 | 0.80 | 1.25 |
| Strontium | Sr | 20 – 600 | 105.8 | 105.7 | 109.3 | 100.0 | 304.0 | 218.5 |
| Uranium | U | 0.45 – 4.00 | 4.20 | 3.97 | 3.07 | 5.30 | 2.83 | 3.65 |
| Vanadium | V | 10 – 130 | 110.3 | 86.7 | 53.7 | 66.0 | 59.7 | 82.5 |
| Gold | Au | 0.002 – 0.007 | 0.025 | 0.010 | 0.014 | 0.013 | 0.014 | 0.068 |

*Explanation:*

a) symbol (*) at the "geochemical background" notion detonet values given for all kinds of sedimentary rocks listed by Kabata-Pendias, Pendias (1993)

b) underlined values are values that exceed the geochemical background for sedimentary rocks

c) symbol (**) – according to Rzętala (2003)

Pogoria I and Pogoria III are reservoirs located in the zone of influence of metallurgical plant and urban built-up area, supplied with water from the catchment, built of sandy Quaternary deposits and Triassic and Carboniferous deposits. Catchment of Przeczyce reservoir is built of the Mesozoic ore-bearing deposits and it has agricultural character. Similar geological composition and agricultural-forest type of land use is typical for the area of alimentation of Kozłowa Góra water reservoir. Industrial-agricultural character is typical for terrains (built mainly of Triassic and Quaternary deposits), drained by tributaries of Dzierżno Małe water reservoir. Highly industrial kind of land use is typical for the catchment of Dzierżno Duże water reservoir, where the Carboniferous deposits predominate.

The essential problem of trace element concentrations in bottom deposits is the exceeding of geochemical background level, defined by many research workers, among others by Kabata-Pendias, Pendias (1993). It is especially visible in relation to contents of zinc, cad-

T a b l e 2. Mean concentrations of selected heavy metals in bottom deposits of selected water reservoirs in the Silesian upland (after: Jankowski et al., 2002)

| Water reservoir | Zinc (Zn) | Lead (Pb) | Cadmium (Cd) | Copper (Cu) |
|---|---|---|---|---|
| | [ mg/kg ] | | | |
| Gliniak | 31600 | 4100 | 327 | 338 |
| Huberus | 29800 | 3980 | 249 | 475 |
| Morawa | 12120 | 3960 | 115 | 249 |
| Grünfeld | 205 | 48 | 4 | 23 |
| Maroko I | 3820 | 906 | 258 | 208 |
| Maroko II | 2180 | 454 | 13 | 145 |
| Kąpielisko | 1940 | 165 | 13 | 23 |
| Kajakowy | 5780 | 584 | 49 | 53 |
| Łąka | 2800 | 547 | 19 | 80 |

mium and lead (Table 1). Decidedly larger level of bottom deposit pollution refers to water reservoirs, located in the direct neighbourhood of industrial terrains (e.g. non-ferrous metals works) or being the receivers of precipitation sewage from terrains of urban built-up areas or communication infrastructure (Table 2). There are situation treated as ecologically menacing in the context of – signalled for many years – increase in acidification of the environment in relation to decrease in alkaline influence of atmosphere dust pollution. So the possible increase in the environment acidification is the real hazard, which can be identified with uncontrolled increase in mobility of metals, which are presently cumulated in bottom deposits.

One should expect, that in ever case under consideration the ecological state of water reservoir – expressed at least in qualitative state of bottom deposits – is the reason of corrections in object use and changes in management of its neighbourhood, thereby landscape transformations on the local scale. Therefore the essential problems of landscape transformation in the reservoir neighbourhood are most often processes running even tens kilometres from its shoreline. Conditions of landscape transformations in the reservoir neighbourhood have more rarely autochthonous character. To show these processes some examples of landscape evolution in reservoir neighbourhoods are worth considering, pointing simultaneously at possibilities of application character of investigations on trace element content in bottom deposits as the alternative for frequent, time- and capital-consuming monitoring of more dynamic water environment.

Area, where presently water reservoirs Dzierżno Duże and Dzierżno Małe occur, for past tens years was characterised by landscape transformations – from water-logged landscape of valley bottoms, forested in some places, through landscape connected with surface sand exploitation and developing here aeolian processes, up to landscapes typical for stagnating water. The consequence of reservoir supply with water from industrial-agricultural catchment (Dzierżno Małe) and industrial one (Dzierżno Duże) is bad qualitative state of water environment of these reservoirs. In result of it the development of recreation function in the case of Dzierżno Małe water reservoir is importantly hindered, and Dzierżno Duże water reservoir and its borders remains as unmanaged, although the direct neighbourhood of both objects has features typical for landscape of high level of aesthetics.

Significant example of changing in time importance of stagnant waters retention in the landscape is Kozłowa Góra water reservoir, which was planned in area of wastelands of former Russia-Prussia borderland, used at the very most in direction of agriculture and forest economy. This reservoir was formed in the years 1933–1939 for military purposes and made an element of system of permanent and field fortifications (e.g. fighting shelters, anti-tank barrier, artillery stations) of Fortified Area "Silesia". Therefore this reservoir was an element of fortified landscape. In the first post-war years (1948–1951) in connection with permanent water deficit in the upper Silesian Region, this reservoir was adapted to fulfil the function of drinking–supply water reservoir through building of Water Treatment Station. Thus, in the period of socialistic economy, this reservoir was an element of landscape subordinated to function of water supply with all deciding consequences, e.g. limitation of recreation and limitation of some sectors accessibility inclusive. Decrease in water demand in the period of market economy (liquidation of unprofitable industrial plants, water saving) caused the limitation of water intake work and undertaking activities adapting the reservoir to use it in a wider way in recreation, tourism and education. Therefore it is possible to expect the new type of cultural landscape – post-agrarian and post-industrial to form. Signs of large dynamics of environmental changes in central part of the Brynica valley as well as the indicator of anthropogenic activity are transformations of landscape from natural and quasi-natural to cultural with enclaves of natural and typical cultural landscapes of: forest, meadow, agricultural, park, military-defensive, industrial and municipal, and recently more and more clearly connected with the sphere of services and identified with the development of recreation and tourism (Fig. 2).

The following example of landscape transformation under the influence of changes in land use refers to water reservoirs Pogoria I and II, which were formed at excavations after surface sand exploitation. Before the beginning of sandy deposit exploitation in area presently occupied by Pogoria I forest landscape predominated and within present reservoir Pogoria III swamping and waterlogged areas, typical for valley bottom, occurred. After exploitation finishing and reservoirs formation the process of shaping of new type of cultural landscape connected with recreation started. Of large importance for the shaping of landscape is the process of spontaneous nature regeneration after former disturbances caused by surface exploitation. It is assisted by human activities, which tend to restore some values of landscape. Analyses of concentrations of trace elements in bottom deposits also show the part flowing water reservoirs play in accumulation of pollutants. A spectacular example is data concerning the Pogoria I and Pogoria III reservoirs, i.e. the first and the last objects on the Pogoria stream (along its course). What is worth noticing is the fact that concentrations of heavy metals in bottom deposits of the first reservoir are frequently many times higher that those of the Pogoria III reservoir. The Pogoria I reservoir therefore serves the function of a peculiar "water treatment plant" for the flowing stream. With it is con-

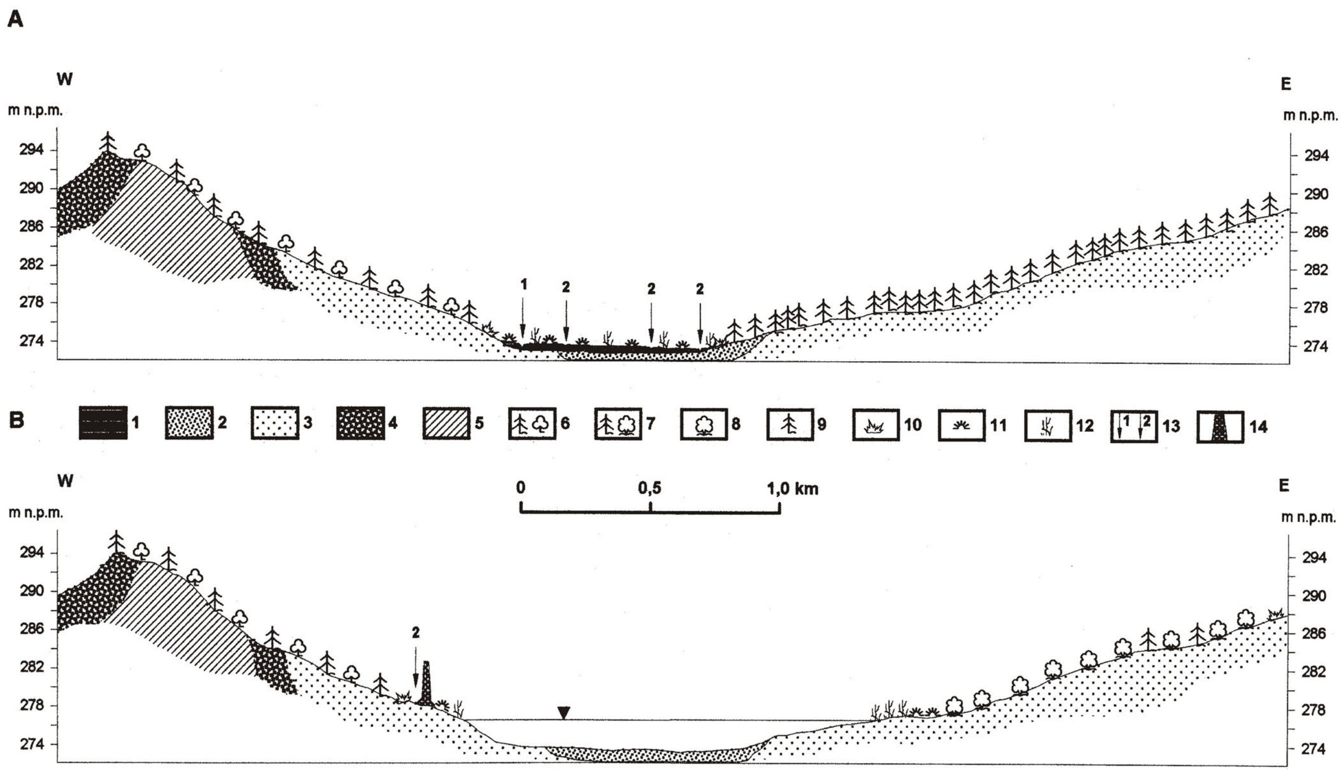


Fig. 2. Cross-profile through the Brynica valley in the neighbourhood of Kozłowa Góra water reservoir (top figure – the early part of the 20th century, bottom figure – the end of the 20th century): 1 – peats (Holocene), 2 – sands and gravels of medium accumulation terraces (Pleistocene), 3 – glacial sands and gravels (Pleistocene), 4 – sands, red and mottled clays (Lower Triassic), 5 – shales, sandstones and black coal (Carboniferous), 6 – park vegetation, 7 – mixed forest, 8 – leafy forest, 9 – coniferous forest, 10 – dry meadow, 11 – water-logged meadows, 12 – rush plants, 13 – surface streams (1 – Brynica, 2 – remaining streams), 14 – lateral dam crown.

nected the hazard of worsening in ecological state of water reservoir and forced landscape transformation together with wastelands in the neighbourhood of Pogoria I water reservoir, and this way the increase in recreation importance of reservoir Pogoria III.

As it was above mentioned, the highest concentrations of trace elements in bottom deposits concern small water reservoirs being the receivers of precipitation sewage (Maroko I, Maroko II, Kajakowy, Kąpielisko, Łąka) or being in the zone of influence of linear and area pollution sources of industrial genesis (Gliniak, Hubertus, Morawa). The last of above mentioned reservoirs, functioning near non- ferrous metals works, serves recreation despite of high level of heavy metals contamination, although the landscape of its surrounding is determined as “zinc desert” in respect of poor vegetation cover. The scale of anthropopression influence on character of use of especially small water reservoirs is documented by pond Grünfeld. It is isolated before the pollutant inflow and devoid of arduous forms of management. It favours spontaneous shaping of landscape in its neighbourhood, which is valuable enough to protect this object by means of one of legal forms of nature protection (Jankovski et al., 2002).

## Conclusions

The studies show that bottom deposit is a good indicator of the neighbouring environment features (Goldberg et al., 2000; Van den Berg et al., 2000). By giving evidence for the part natural and anthropogenic factors play in shaping their physical-chemical properties, they provide an excellent “record” of phenomena and processes that occur in the geographical environment of the catchment and the neighbourhood of the reservoirs. This also emphasises their importance as an excellent indicator of ecological changes and interpretation of the degree of their contamination may bring much better economic results than expensive studies of water environment (Rzętała et al., 2002). Analyses of heavy metal concentrations in bottom deposits should therefore be one of basic monitoring elements for activities concerning reclamation and revitalisation of water reservoirs and their direct neighbourhood (Jankowski et al., 2002).

Water quality in reservoirs is the basic factor deciding of character of their use as well as of management of littoral zone. The delicious indices of qualitative state of reservoir waters are results of complex investigations on bottom deposits. Ranges of levels of trace elements occurrence in bottom deposits usually stray from levels of geochemical background. Temporal changes in trace elements content simultaneously indicate the largest transformations in water environment, identified with period of socialistic economy and spontaneous nature regeneration which was typical for last a dozen or so years of marked economy development. Economical, social and political conditions additionally modify the role of water reservoirs in the formation of cultural landscape, what allows dividing some characteristic stages in their functioning.

Water reservoirs functioning in the period of early capitalistic economy in the majority of cases underwent liquidation in the period of socialistic economy because they did not meet production requirements and in result of activities negating idea bases of the former epoch. Many water reservoirs were originated in the period of socialistic economy documenting the superiority of industrial and municipal tasks being in conflict with ecological rules. In the period of political system-economical transformation, and especially of market economy, the successive adaptation of existing reservoirs to fulfil many functions with special regard to tourist-recreation tasks took place. Flood-control function considered in programs of small retention development should be acknowledged as stabile in conception and unchanging in time.

*Translated by the authors*

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