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WATER RESOURCES OF POLAND AND THEIR STATE IN LUBLIN DISTRICT

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Summary. On the basis of statistical data of Census [Environmental… 2010], published and archive materials of the Institute of Meteorology and Water Management and Department of Hydrology of University of Maria Curie-Skłodowska water resources of Poland and their state in Lublin District were presented. The quantity and variability of water resources were analysed using data of precipitation, outflow, underground and surface retention, as well as quality of water and its consumption. Water resources, as the specific runoff, are in Lublin District lower by 1/3 than in Poland. Annual value of water resources per capita, as well for Poland as for Lublin District is almost identical.

Key words: water resources, outflow, Poland, Lublin District

INTRODUCTION

Evaluation of water resources is based on determination of precipitation falling onto the surface of particular country, the amount of outflow, and potential inflow of water, and the rational indicator of it is amount of water per capita. Water resources of the area are directly depended on natural environment factors, such as climatic conditions, geological structure, surface relief, soils, and land use. Climatic conditions are shaped by solar energy reaching the ground surface, distance from seas and oceans, surface relief, as well as altitude above sea level and pattern of mountains ranges. They decide the quantity of precipitation and evapotranspiration, as well as the outflow. Precipitation and proper water resources are not steadily distributed. Dry areas of the Earth occupy almost ¼ of continents, and permanent shortage of fresh water is observed in over the half of continents area. In some European countries, e.g. in Norway, Slovenia, Switzerland, Great Britain, Ireland, Austria, and in others, annual total precipitation exceeds 1000 mm. However, in Hungary, Poland, Romania, precipita-

tion rate is approx. 600 mm. Poland, together with Czech Republic and Belgium, is considered to the group of countries with the lowest water resources – approx. 1,500 m^3 per capita per year, while in Norway and Finland this index reach 20.000 m^3 per capita per year. Average value for Europe is 4.500 m^3 per year [Ciepielowski 1999].

MATERIALS

Data of Census for Poland [Environmental… 2010] and for Lublin District [Statistical… 2010] are the main basis for the paper. The quantity and structure of river outflow for Lublin District was calculated using data of the Institute of Meteorology and Water Management (years 1951–2005). Hydrometeorological and economic data were used for calculation of precipitation and runoff indices, as well as water resources per capita. Census materials were completed by archive information of Department of Hydrology of UMCS, considering conditions of water occurrence in Lublin District. Water quality data were analysed using materials of District Inspectorate of Environmental Protection [Report… 2010].

WATER RESOURCES IN POLAND

Nearly all the Polish territory is in the Baltic Sea basin (99.7%); only small parts belong to North Sea (0.1%) and Black Sea (0.2%) basins. Areas of the Odra and Wisła rivers occupy 89.6% of the Polish territory, and the rest in catchments of the rivers flowing directly into the Baltic Sea or to basins of the Niemen and Pregoła rivers [Fal and Bogdanowicz 2002].

Water resources of Poland are fed by precipitation and inflow of water from the abroad. In the average year about 190 km^3 of water comes from precipitation, and about 7 km^3 from surrounding countries. In 1901–2000 average precipitation for Poland was 628 mm, and runoff 175.2 mm, what is equal to 0.278 coefficient of runoff [Fal and Bogdanowicz 2002]. In average wet year precipitation in Poland changes from approx. 500 mm in the lowlands to over 1000 mm in mountains, what significantly influences the quantity of regional water resources.

Feeding area of the Polish rivers occupy territory of 351.028 km^2, the area bigger by 12.3% than Poland (mainly catchments of rivers flowing from Ukraine and Belarus). The average outflow of the Polish rivers in the last century (1901–2000) was 61.5 km^3 per year, including value of outflow from the Polish territory (53.9 km^3 per year). That value corresponds to outflow of 1,950 $m^3 \cdot s^{-1}$, runoff index of 175.2 mm, and specific runoff of 5.56 $dm^3 \cdot s^{-1} \cdot km^{-2}$ [Fal and Bogdanowicz 2002]. Extreme value of outflow was observed in the second half of the last century. The highest outflow, 89.9 km^3, was recorded in 1981, and the lowest one, 37.6 km^3, in 1954; so annual irregularity of outflow of Polish rivers was 2.4.

Atmospheric waters are retained in rocks, lakes, ponds and reservoirs, and some part of them directly flows to the rivers. According to data in Hydrogeological atlas of Poland [Paczyński 1995], annual value of renewable groundwater resources in useful aquifers is estimated as approx. 18 km^3. Disposable groundwater resources of useful aquifers are estimated as 15 km^3 per year [Paczyński 2002].

There are 7,081 lakes (bigger than 1 hectare), which area is 2.809.8 km^2 [Choiński 2006], and total capacity is 33 km^3. Dam reservoirs, constructed on rivers, diminish regularity of outflow and increase surface retention. There are 138 various-capacity water reservoirs, 95 of them exceed capacity of 2 hm^3. The sixty biggest reservoirs, which are the most important for water management, influence significantly the level of disposable resources. Only 10 of them exceed the capacity of 100 hm^3. Total capacity of reservoirs is 4 km^3 that is approx. 6.5% of annual outflow. However, capacity of several biggest reservoirs, under management of regional boards of water management decides the regulation of river outflow [Strategy… 2005, Environmental… 2010].

Regional variability of water resources can be described as specific runoff, understood as amount of water in litres, outflowing during one second from one square kilometer ($dm^3 \cdot s^{-1} \cdot km^{-2}$). Specific runoff in Karpaty and Sudety Mountains exceeds 10 $dm^3 \cdot s^{-1} \cdot km^{-2}$, and in Tatry even 50 $dm^3 \cdot s^{-1} \cdot km^{-2}$. In the upland part of Poland, specific runoff is 4–8 $dm^3 \cdot s^{-1} \cdot km^{-2}$, and in lake districts 5–12 $dm^3 \cdot s^{-1} \cdot km^{-2}$. In lowland part specific runoff changes from 2 to 4 $dm^3 \cdot s^{-1} \cdot km^{-2}$, the lowest values are observed in Kujawy and in the northern part of Wielkopolska [Stachy and Biernat 1987].

High variability of river discharges is the main reason for inefficient management of outflowed water. Significant part of water is uselessly drained during high surface runoffs. As amount of disposable resources Kaczmarek [1978] assumed amount of outflowing water that could be supplied to consumers during 95% of time in the year. According to this criterion, outflow of Polish rivers was estimated as 22 km^3. The similar value of disposable resources can be calculated as groundwater outflow in the year of lowest outflow. Considering values of biological discharge for the Polish rivers at the level of 15 km^3 per year, disposable resources for Poland, as non-returnable usage, are 7 km^3 per year. That value would increase to 9-10 km^3 per year after regulation of rivers and increase of reservoir and soil retention.

In 2009 it was taken 10.8 km^3 of water, including 1.6 km^3 from groundwater resources for municipal, industrial, and agriculture purposes. Part of used water return to the rivers, where the quality of water is shaped mainly by point and diffuse sources of pollution. In 2009, almost 9 km^3 of sewages were returned to the environment, mainly to the rivers. Approx. 75.5% of sewages can be stated as heat waters – chemically clean. The share of treated sewages is 23.0%, and untreated – 1.5%. Results of classification of ecological and chemical state of rivers show low quality of river waters [Environmental… 2010]. According to present five-class quality classification, waters of I class were not found, and of II class were found very rarely.

WATER RESOURCES IN LUBLIN DISTRICT

The area of Lublin District is 25,122.5 km^2 [Statistical… 2010], it is located in the central part of the interfluve of the Wisła and Bug rivers. It occupies several geographical regions: Lublin Upland and Lublin Polesie, Roztocze (within the borders of Poland), as well as small areas of Mazowsze Lowland and Podlasie in the northern part, and Sandomierz Basin and Pobuże in the south. The river density in the lowland part of the district is very high, with many peatlands and permanent wetlands and lakes [Michalczyk and Wilgat 1998]. The rivers are rather short, fed by groundwater resources, and abundant springs [Michalczyk 2001].

The Wisła and Bug rivers, the most abundant rivers, constitute the western and eastern border of the district, and have their feeding areas outside the Lublin District. Because of their location on the outskirts of region, the Wieprz river is the hydrographic axis of district. The longest rivers are: the Chodelka and Kurówka (tributaries of the Wisła), the Tyśmienica and Bystrzyca (tributaries of the Wieprz), the Huczwa, Włodawka and Krzna (tributaries of the Bug river).

There are over 70 water reservoirs in Lublin District that could be considered as natural lakes. The deepest lake is Piaseczno – 38.8 m [Wilgat 1954]. Most of lakes are in the region of Łęczna-Włodawa Lake District. The largest one of the Lake District is Lake Uściwierz (area of 284 hectares), and areas of three other lakes (Łukie, Białe Sosnowickie, Białe Włodawskie) are within the range of 100–150 hectares. The capacity of only two lakes (Białe Włodawskie and Piaseczno) is over 10 ml m^3 each. The total capacity of natural lakes is about 80 ml m^3 [Wilgat *et al*. 1991], and concerning lakes changed into artificial reservoirs even over 100 ml m^3. Surface retention is enlarged by artificial reservoirs, with the biggest one in Nielisz (capacity of 19.5 ml m^3). According to publication Programme of water management of Lublin District, water reservoirs occupy 41.2 km^2 area, and collect 79.1 ml m^3 of water. The area of fishing ponds is 66.0 km^2.

Predominant part of district, in Lublin Upland and Roztocze, is considered as Lublin chalky hydrogeological region, with the main groundwater aquifer in rocks of the Upper Cretaceous, locally also in Tertiary and Quaternary deposits [Paczyński 1995]. Abundant groundwaters are of a very good quality, exploited for municipal and economic purposes. There are many springs of high yield in the zone of carbonate rocks occurrence in the upland part of district [Michalczyk 1986, 2001]. The chemical composition of spring waters is natural, typical for groundwaters not influenced by human impact. Analysed for environmental monitoring purposes quality indices correspond to highest and high class of quality. Natural spring waters of high content of iron in Nałęczów are considered as the most valuable.

The northern part of the district is within the hydrogeological regions of Podlasie and Mazowsze Lowland, where groundwaters are maintained in porous Tertiary and Quaternary deposits, and deeper – in Cretaceous rocks [Malinowski 1984, Michalczyk and Wilgat 1998]. However, groundwaters of low abundance

occurred in different-size grainy Quaternary deposits, on Tertiary krakowieckie loams of Sandomierz Basin belong to Podkarpacie hydrogeological region.

Groundwaters of the useful aquifers are of a very good quality. These are two-ion water HCO_3-Ca (sometimes three-ion waters HCO_3-Ca-Mg), of slightly alkaline reaction or neutral, and slightly mineralized. There are several milligrams of chlorides and sulphates per one liter and some content of manganese in chemical composition of water. Increased content of iron, sometimes exceeding the requirements for drinking water, is found in some areas. Quality of groundwaters meets the physico-chemical and bacteriological criteria for municipal purposes.

Hydrogeological and hydrological conditions of Lublin District are favorable for existence of wetlands, where intensified peatland process took place. It was stated that about 2 thousand peatlands of various size of total area of 140 thousand hectares and the total capacity of approx. 2 milliards m^3 exists [Borowiec 1990]. It gives the 5th position of Lublin District in Poland.

The quantity of water resources is directly depended on precipitation. The average total precipitation for Lublin District changes in the range from 520 mm in the northern part to 670 mm in Roztocze. Lublin District is characterized by low value of outflow, specific runoff is lower by 1.5 $dm^3 \cdot s^{-1} \cdot km^{-2}$ than average value for Poland (5.5 $dm^3 \cdot s^{-1} \cdot km^{-2}$). In 1951–2005 the average specific runoff for Lublin District was only 3.95 $dm^3 \cdot s^{-1} \cdot km^{-2}$, for lowland part 3.48 $dm^3 \cdot s^{-1} \cdot km^{-2}$, and for the upland one 4.13 $dm^3 \cdot s^{-1} \cdot km^{-2}$. These values were similar in 1951–1990 [Michalczyk and Wilgat 1998]. Surface water resources, except the border rivers, are very poor, characterized by high seasonal and annual diversity. In the lowland part of the district shortages of water for agriculture purposes are stated [Wojciechowski 1965], what indicates the necessity of water retention. Characteristic values of outflow from Lublin District, calculated on the basis of hydrometric materials of IMGW for years 1951–2005 (without border rivers discharges), are summarized in Table 1. These are water resources as average outflow, underground outflow and outflow for dry and wet year. Water resources per capita in different hydrological conditions are also presented, those for district (1.450 m^3) and country (1.440 m^3) are similar.

Table 1. Characteristic values of outflow for Lublin District and specific runoff per capita

Outflow	Outflow	Specific runoff	Water resources per capita
	$m^3 \cdot s^{-1}$	$dm^3 \cdot s^{-1} \cdot km^{-2}$	$m^3 \cdot rok^{-1}$
Average annual	99.3	3.95	1.450
Underground	64.4	2.56	940
In dry year	49.1	1.97	720
In wet year	191.9	7.64	2.800

In Lublin District unsteadily distribution of surface and underground water resources results from terrain and climatic conditions. Average outflow from the upland part is almost 50 $m^3 \cdot s^{-1}$, and from the Polesie and Mazowsze part is 40 $m^3 \cdot s^{-1}$. In the urban areas there is conflict between local water resources and economic water needs.

According to data of Census [Environmental… 2010] water use in 2009 for national economy in Lublin District was 344.7 hm^3, including industry (113.4 hm^3 – 32.9%), agriculture and forestry (162.7 hm^3 – 47.2%), and exploitation of water supply system (68.7 hm^3 – 19.9%). High water intake of surface waters for agriculture purposes, mainly filling pond and industrial ones, is sharply visible in structure of intake and consumption of water.

Rivers of Lublin District are mainly fed from groundwater resources, with dominant carbonates in chemical composition. Average concentration of carbonates is within the range of 200–300 mg $CaCO_3 \cdot dm^{-3}$, and reaction is about 7.6–8.2. River waters, fed from Quaternary aquifer, have lower content of carbonates, not exceeding 150 mg $CaCO_3 \cdot dm^{-3}$. Researches of Inspectorate of Environmental Protection in Lublin, conducted in 2010 as network of monitoring of rivers in Lublin District show good ecological state for 20%, moderate for 75%, and poor for 5% of sample sites.

CONCLUSIONS

The territory of Poland is characterized by relatively low water resources in Europe, which results from the rate of precipitation and evapotranspiration and their seasonal diversity. The average outflow from Polish rivers in the years 1901–2000 was 61.5 km^3, however from the Polish territory was 53.9 km^3. That value is equal to runoff index 175.2 mm and to specific runoff 5.56 $dm^3 \cdot s^{-1} \cdot km^{-2}$. The river outflow, considered as runoff index, as well as per capita, is one of the lowest in Europe.

Lublin District occupies territory of the upland and lowland part of Poland, what results in conditions of occurrence and resources of water, and above all diversification of water network density (rivers, lakes, ponds, and wetlands). The average specific runoff for Lublin District is 3.95 $dm^3 \cdot s^{-1} \cdot km^{-2}$, for the upland part 4.13 $dm^3 \cdot s^{-1} \cdot km^{-2}$, and in Polesie and Mazowsze 3.48 $dm^3 \cdot s^{-1} \cdot km^{-2}$. Those average values are lower by 1.5 $dm^3 \cdot s^{-1} \cdot km^{-2}$ than average for Poland, and by twice lower than average for Europe.

In the average year outflow from Lublin District is almost 100 $m^3 \cdot s^{-1}$, with the high share of groundwater resources (64.8%). In dry year outflow is half the average, and in wet – twice as average. Average resources per capita are 1.450 m^3, which is comparable to those for Poland; however, concerning Europe is one of the lowest. Water management with low water resources should be directed for maintained the quality and quantity of water. Economic use of water should be based on the constitutional principle of sustainable development.

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ZASOBY WODNE POLSKI I ICH STAN W WOJEWÓDZTWIE LUBELSKIM

Streszczenie. Obszar Polski cechuje się w skali europejskiej stosunkowo niskimi zasobami wód, co wynika z wielkości opadów i parowania oraz ich sezonowej zmienności. Średni odpływ rzekami polskimi w okresie 1901–2000 wynosił 61,5 km^3, natomiast z obszaru Polski odpływało 53,9 km^3. Wielkość ta odpowiada warstwie odpływu 175,2 mm i odpływowi jednostkowemu 5,56 $dm^3 \cdot s^{-1} \cdot km^{-2}$. Średni odpływ jednostkowy z województwa lubelskiego wynosi 3,95 $dm^3 \cdot s^{-1} \cdot km^{-2}$, jego wielkość w części wyżynnej osiąga 4,13 $dm^3 \cdot s^{-1} \cdot km^{-2}$, a w mazowiecko-poleskiej 3,48 $dm^3 \cdot s^{-1} \cdot km^{-2}$. Wskazane zasoby wodne są w wartościach średnich niższe o 1,5 $dm^3 \cdot s^{-1} \cdot km^{-2}$

od wartości średniej dla Polski i ponaddwukrotnie niższe od średniej dla Europy. W roku średnim odpływa z terenu województwa lubelskiego prawie 100 $m^3 \cdot s^{-1}$, z tego duża część pochodzi z zasobów podziemnych – 64,8%. W roku suchym ilość odpływającej wody zmniejsza się o połowę, a w roku mokrym wzrasta dwukrotnie. Średnie zasoby wody liczone w ciągu roku na jednego mieszkańca wynoszą 1450 m^3, co jest wartością porównywalną z sytuacją rejestrowaną w Polsce. W odniesieniu do krajów europejskich są to jedne z najniższych zasobów wodnych.

Słowa kluczowe: zasoby wody, odpływ, Polska, województwo lubelskie