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A regulated river ecosystem in a polluted section of the Upper Vistula*

1. Introduction and description of the study area

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A b s t r a c t — The Upper Vistula is to made navigable, hence a number of water stages damming the water are being built here. This section of the river is strongly polluted by industrial and municipal wastes from the Upper Silesian Industrial Region, Bielsko-Biała Industrial Region, and Oświęcim. The investigation was carried out at 6 stations located between kilometres 33 and 58 of the river course, differing in the type of bottom, flow rate, and depth.

K e y w o r d s: regulated river, pollution, geographic description.

1. Introduction

The economic programme "Wisła" originated in the seventies and included navigation-energetistic management of the riverbed, improving the capacity of retention in the basin, protection of the catchment area against pollution, tourist management of the territory, and intensification of agricultural production.

Within the framework of this programme the construction of water stages was planned on the riverbed from the mouth of the River Przemsza to the Martwa Vistula. So far, owing to limitation of the programme, only the construction of cascades has been realized in the Upper Vistula in the section from the Przemsza estuary to Niepołomice, thanks to which this section is to be changed into a navigable artery linking the Upper Silesian Industrial Region with Kraków.

Three water stages already existed here: Przewóz, built in 1954 for purposes of supplying water for the Nowa Huta foundry; Dąbie, built in 1961 for stabilization of the Vistula riverbed, apart from having

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a navigational function; and Łączany, built in 1961 in order to stabilize the water level in the Łączany Canal, which supplies water for the Skawina thermal power station. Further stages are currently under construction: Dwory, Smolice, Kościuszko, and Niepołomice (fig. 1).

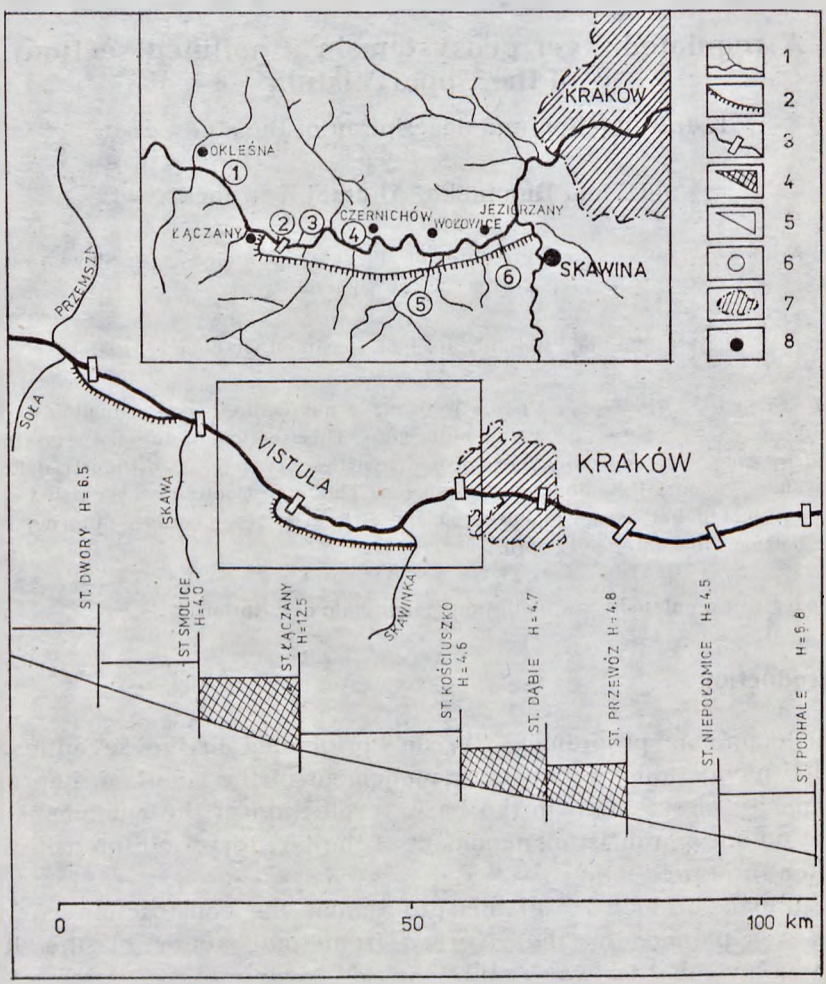

Fig. 1. The Upper Vistula, showing cascade building and stations on the investigated river section. 1 — rivers; 2 — canal; 3 — water stages, dams; 4 — water stages built; 5 — water stages under construction and planned; 6 — stations; 7 — cities; 8 — towns and villages

The cascade building in this section of the Upper Vistula will change its physiographic character. From a small shallow river with a rapid current it will change into a series of extensive and fairly deep reservoirs with a slow water current. At present, the waters of the Vistula

here are strongly polluted with municipal and industrial wastes, hence the question arises as to how the building of cascades in such a polluted river as the Upper Vistula, will affect its waters. So far opinion is divided. Most Polish hydrobiologists postulate that their construction will impair the quality of the water and the oxygen balance in the river (Mańczak 1970, Turoboyski, Pudo 1979, Schmager 1982, 1985). On the other hand, some authors believe that the sedimentation of suspension in the reservoirs will contribute to a reduction in pollution (Wróbel, Szczęsny 1983). These opinions were chiefly based on hydrochemical studies carried out by laboratories dealing with environmental control, but in a smaller measure on hydrobiological investigations.

The tradition of hydrobiological investigations of the Upper Vistula dates back 50 years and of ichthyobiological studies more than 100 years. The hydrobiological studies were initiated by Starmach (1938). Apart from the seston which was the basic subject of this work, he also gave hydrochemical description of the Vistula and some information concerning other organisms found in the river in 1933. Later, hydrochemical studies of the Upper Vistula were carried out by Kotulski (1962) and Bombówna, Wróbel (1966), of seston, periphyton, and microbenthos by Turoboyski (1956, 1962), Kyselowa, Kysela (1966), Starzykowa (1972), Hanak-Schmager (1974), and Pudo (1977), and of macrofauna by Zięba, Zaćwilichowska (1966). Laboratory experiments concerning the effect of artificial aeration of the physico-chemical and bacteriological properties and bioseston of the Upper Vistula above the water stage at Łączany were also carried out (Schmager 1986).

Ichthyological studies in the 100-year-old tradition were initiated in the Upper Vistula by Maximilian Siła-Nowicki, Nestor of Polish zoology and fish culture (Nowicki 1882, 1883, 1889). Further studies in this field were carried out by Starmach (1948), Bieniarz, Epler (1972), and Epler, Bieniarz (1973). Apart from the above-mentioned works, an enormous number of results were obtained concerning the sanitary condition of the Upper Vistula; nevertheless, only to a slight degree were they taken into account in comprehensive reports on the state of water purity in Poland (Florczyk et al. 1971, 1972, Jarmolińska et al. 1981, Dojlido, Woyciechowska 1983).

The above studies did not, however, include the effect of cascade building. Therefore, a group of workers of the Institute of Freshwater Biology of the Polish Academy of Sciences undertook hydrochemical, hydrobiological, and fishery investigations in the Upper Vistula, on the section of the existing water stage at Łączany. The aim of the study was
— to predict the effect of cascade building on the water quality and biocenosis of the Vistula,
— to determine the role of the more important elements of biocenosis

in the self-purification processes of the river, and
— to compare biocenoses in the hydrologically unchanged river section and in the Łączany reservoir.

The following studies were carried out: the chemical composition of water (Kasza 1988), evaluation of water fertility using the method of algal tests (Bednarz 1988), the study of bacteria (Starzecka 1988), seston (Bednarz, Żurek 1988), sessile algae (Kwandrans 1988), Ciliata (Grabacka 1988), macrobenthos (Dumnicka, Kownacki 1988), and ichthyofauna (Włodek, Skóra 1988). A synthesis of the investigation and conclusions will be presented by Kownacki (1988). Moreover, Dr Małgorzata Schmager from the Kraków Section of the Institute for Physical Planning and Municipal Economy took an active part in the work (Schmager 1988). The investigation made it possible to predict the trend of changes of river ecosystems and self-purification processes after the building of cascades in the Upper Vistula.

2. Description of the Upper Vistula

The Czarna and Biała Wisełka streams flow down the slopes of Mount Barania Góra in the Silesian Beskid range, their confluence originating the River Vistula, which from this point has the character of a montane river and then, from Ustroń to the Goczałkowice Reservoir, of a sub-montane one. About 80% of the water fed to the Goczałkowice reservoir is taken by a water supply system and directed to the region of Silesia. This water returns to the Vistula in the form of wastes through a left-side tributary, the River Przemsza (fig. 2). The junction of the Vistula and Przemsza is taken as kilometre 0 and the sector above the confluence is called the Mała Wisła (Little Vistula), while that between the mouths of the Rivers Przemsza and San is called the Upper Vistula.

In the section from Przemsza to Łączany the Vistula has the character of a lowland river with a gradient of 0.3‰. It winds through a valley 3—8 km wide. The river bottom is sandy, in places of stagnant water covered with mud; the banks are regulated.

At kilometre 38 of the river course the water stage at Łączany was built. The preliminary total capacity of the reservoir was 4.5 million m^3; however, it is by now considerably reduced owing to the rapid accumulation of mud. In 1981—1982 the reservoir was dredged. The barrier, 6 m in height, dams up a 14-kilometer section of the river. In this cross-section the mean daily discharge reaches 6.7 million m^3 (Wróbel, Szczęsny 1983) and with an average flow the water exchange in the reservoir takes place during 16 hrs. A navigable-energetistic Łączany-Skawina channel flows out of the reservoir and connects the Vistula with its right-side affluent, the Skawinka. About 20 m^3 sec^{-1} water is derived from the

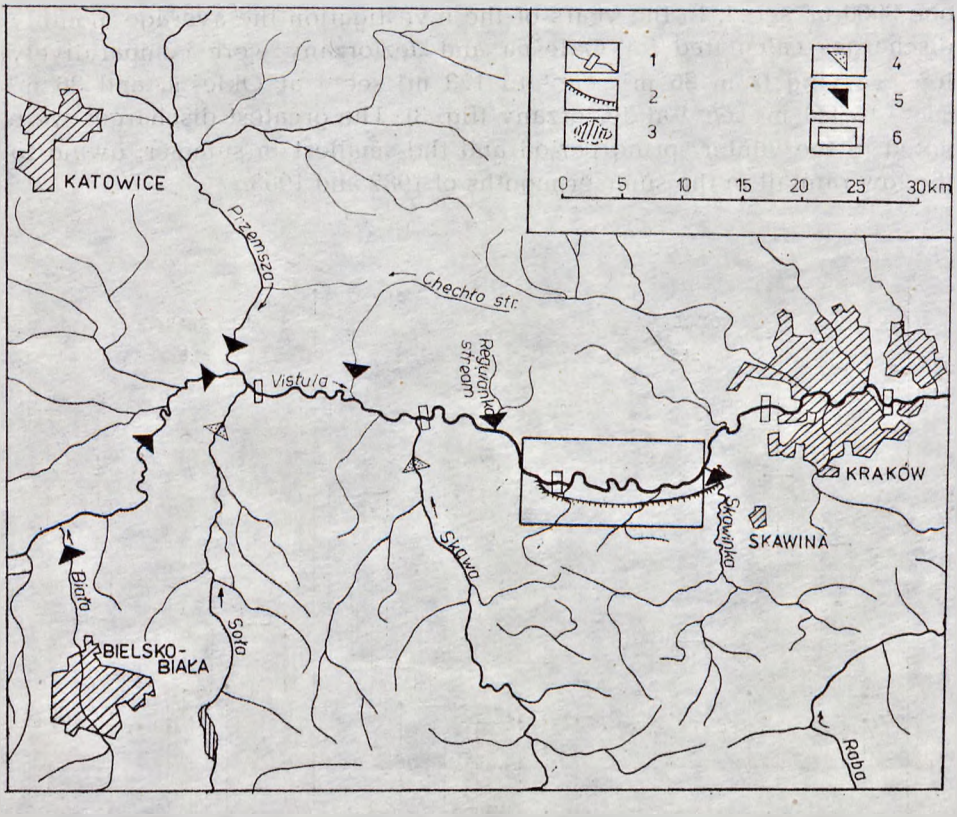

Fig. 2. The Upper Vistula basin, the chief sources of pollution (according to the Polish Norm of water purity classes) and of the investigated river sector. 1 — dams, water stages; 2 — canal; 3 — towns; 4 — waters of purity class III; 5 — waters outside purity classes; 6 — study area

channel, directed to the Skawina electric power station, heated, and discharged back to the Vistula.

Below Łączany the Vistula still shows traits of a lowland river. From Wołowice (kilometre 53 of the river course) to Kraków it flows across the calcareous territory of the Kraków Upland. In this sector it has a stony bottom, is widely spread, and forms numerous rapids, so that it resembles a sub-montane river. The construction of water stages at Dąbie and Przewóz changed the Vistula in the Kraków region into a slow-flowing deep river. Below Kraków the valley again widens and the river assumes the character of a large lowland river.

The Upper Vistula receives all the Carpathian tributaries, characterized by a very great variation in water level. Hence, the water discharges are very variable, e.g., at the Łączany stage the minimum flow is 12.5 m^3 sec^{-1}, the average annual flow 77.8 m^3 sec^{-1}, and the maximum

one 2060 m^3 sec^{-1}. In the years of the investigation the average monthly discharges calculated for Oklesna and Jeziorzany were comparatively low, varying from 36 m^3 sec^{-1} to 123 m^3 sec^{-1} at Okleśna and 36 m^3 sec^{-1} to 151 m^3 sec^{-1} at Jeziorzany (fig. 3). The greatest discharges were noted in the winter-spring period and the smallest in summer, owing to the low rainfall in the summer months of 1982 and 1983.

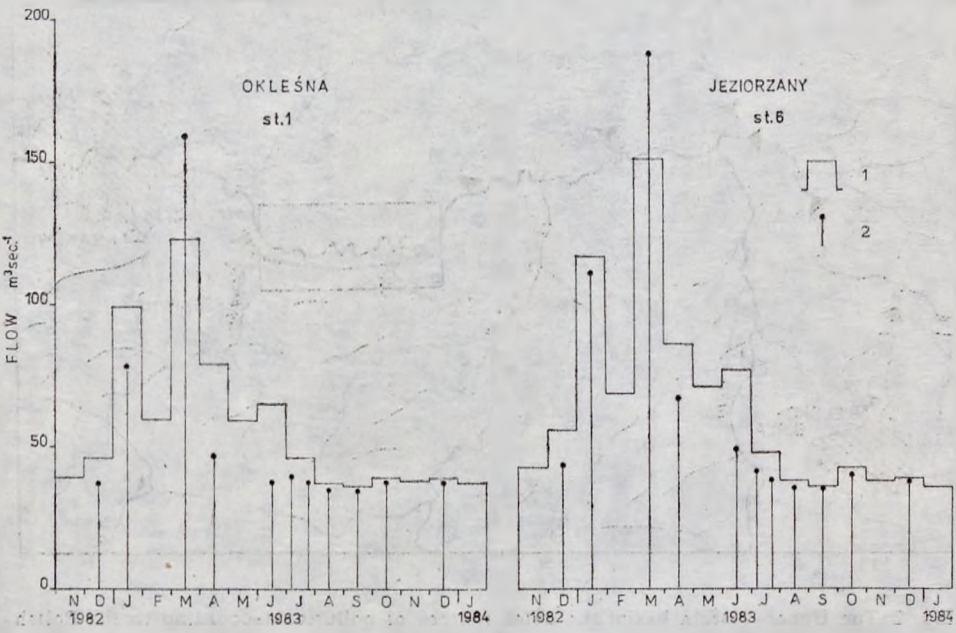

Fig 3. Water flow at Stations 1 and 6 in the period of investigation. 1 — average monthly flow; 2 — flow on the sampling day

The investigated section of the Upper Vistula is very strongly polluted. According to Polish norms (Norma przemysłowa — Industrial Norm, 1975), its water is outside the purity classes and is unsuitable even for industrial purposes (Jarmolińska et al. 1981). In 1978 the surface waters of the Upper Vistula basin received 1.47 million m^3 of sewage, this constituting 32% of wastes produced in Poland and 44.5% of wastes in the Vistula basin. From the total amount of sewage 62% were industrial wastes less subject to decomposition in the processes of river self-purification. About 58% of wastes undergoes purification, of which amount 72% is treated only mechanically, barely 15% biologically and 13% chemically (Bolesta 1982). Besides, the Upper Vistula is salinated by waters from collieries of the Rybnik Coal Region and the Upper Silesian Industrial Region.

This strong pollution of the River Vistula above Kraków is caused

by some of its affluents (fig. 2) bringing in industrial and municipal sewage. The greatest amounts of wastes are carried by
— the River Biała: pollution from plants of textile (wool), chemical, and heavy industry in Bielsko-Biała and waters from the depths of hard coal mines;
— the River Gostynia: wastes from paper mills at Czułów, motor-works at Tychy, and waters from the depths of hard coal mines;
— the River Przemsza constitutes a great sewage drain for the Upper Silesian Industrial Region, from numerous foundries, collieries, and large towns, including Katowice;
— the River Włosienica drains wastes from chemical works at Oświęcim;
— the River Regulanka brings in wastes from chemical works at Alwernia;
— the Rivers Soła and Skawa carry slightly cleaner waters (purity class III).

The condition of the River Vistula is additionally deteriorated by industrial and municipal wastes from Kraków and Nowa Huta.

3. Description of stations

The investigation was carried out on a 25-kilometre section of the Upper Vistula between kilometres 33 and 58, at 6 stations (fig. 1).
Station 1 — Okleśna, at kilometre 33 of the Vistula course, above the water stage at Łączany. The riverbed about 80 m wide, the banks regulated, the left one about 70 cm high and covered with grass; the right bank flat and overgrown by purple willow. The bottom covered with sticky black mud. Depth to 1.2 m.
Station 2 — Łączany, at kilometre 38 of the river course, within the water stage at the right bank, near the dam. Depth to 1.5 m, the bottom muddy and overgrown by algae in shallower places. The resevoir about 2 km wide.
Station 3 — Łączany, about 200—300 m below the water stage, nearer the right bank. The riverbed about 100 m wide, in the upper part the bottom covered with large stones, only in places sandy; in the lower part sandy, here and there muddy. In the upper sector the banks form a scarp, in the lower one they are fairly low and overgrown with purple willow. The current variable, turbulent in the stony sector an laminar below. The current rate depends upon the amount of water released from the reservoir. Depth to 70 cm.
Station 4 — Czernichów, kilometre 45 of the Vistula course. The riverbed about 80 m wide, the right bank low and sandy, the left one undermined, about 1 m high, covered with grass. The bottom muddy, in places sandy, at low water levels a stony sandbank is exposed. Depth 10—70 cm.
Station 5 — Wołowice, kilometre 53 of the river course. The riverbed

about 100 m wide. The left bank low with a stony sandbank, the right one high, overgrown with purple willow. The bottom composed of stones of different size, here and there of gravel and sand; stones covered with a thin layer of mud only at the bank and at low water level. Thick cover of algae noted on stones, especially in spring and summer. Long filaments of *Cladophora* sp. noted. Depth 20—70 cm.
Station 6 — Jeziorzany, kilometre 58 of the Vistula course. The riverbed over 100 m wide. The left bank flat with a large stony sandbank, the right one low but undermined. The bottom stony, at low water level muddy. Depth to 70 cm.

Several reasons dictated the choice of stations. First of all, above the reservoir at Łączany the Vistula receives a load from all the larger sewage channels and from the slightly purer affluents Soła and Skawa (purity class III). However, in the sector from the Łączany water stage to the mouth of the River Skawinka, which conducts heated waters and wastes from the Skawina power station, neither any greater loads of wastes nor larger rivers which might basically affect the quality of water are drained to the Vistula. Secondly, in this sector the river to a great degree has preserved its natural hydrological character, though the water itself is very strongly polluted. Thirdly, the construction of the Łączany reservoir, which constitutes a part of the planned cascade, made it possible to compare biocenoses and biological processes in this type of reservoir and in the river and to evaluate the role of the reservoir in self-purification processes.

4. Polish summary

Ekosystem uregulowanego i zanieczyszczonego odcinka Górnej Wisły

1. Wstęp i opis terenu badań

Program kompleksowej zabudowy Wisły przewiduje powstanie arterii żeglugowej w jej górnym biegu. W tym celu buduje się szereg stopni wodnych podpiętrzających wodę (ryc. 1), co zmieni fizjograficzny charakter rzeki. Z niedużej, płytkiej rzeki o szybkim prądzie powstanie ciąg szeroko rozlanych i stosunkowo głębokich zbiorników z wolnym przepływem wody. Obecnie Wisła na tym odcinku prowadzi wody silnie zanieczyszczone przez ścieki komunalne i przemysłowe z kilku ośrodków przemysłowych i dużych miast. Zachodzi więc pytanie, jak kaskadowa zabudowa zanieczyszczonej rzeki, jaką jest Górna Wisła, wpłynie na jakość jej wody, przebieg procesów samooczyszczania i strukturę biocenoz. Dla uzyskania odpowiedzi na to pytanie opracowano: skład chemiczny wody oraz ocenę żyzności wody metodą testów glonowych, bakterie, seston, glony osiadłe, orzęski, makrobentos i ichtiofaunę Wisły w rejonie stopnia wodnego w Łączanach. Badania te pozwoliły przewidzieć, w jakim kierunku zmienią się ekosystemy rzeczne i procesy samooczyszczania po wybudowaniu kaskad na Górnej Wiśle.

Do badań wybrano odcinek Wisły między 33 a 58 km jej biegu (przyjmując za km 0 połączenie się Wisły z Przemszą). Powyżej tego odcinka dopływają do Wisły

wszystkie większe ścieki (ryc. 2) i nieco czyściejsze dopływy, natomiast na badanym odcinku nie ma dopływu większych ładunków ścieków ani dopływu rzek mogących w zasadniczy sposób zmienić jakość wody. Poniżej zbiornika w Łączanach rzeka zachowała jeszcze w znacznej części swój naturalny hydrologiczny charakter, chociaż sama woda jest bardzo silnie zanieczyszczona. Usytuowanie stanowisk powyżej zbiornika (st. 1), w samym zbiorniku (st. 2) i poniżej zbiornika (st. 3—6) pozwoliło na porównanie biocenoz i procesów biologicznych w tego typu zbiorniku i nie zmienionym odcinku rzeki Stanowiska różniły się typem dna, szybkością prądu i wielkością przepływu (ryc. 3).

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