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ANTHROPOGENIC CHANGES IN THE WATER CONDITIONS IN CRACOW (EAST-CENTRAL EUROPE) SINCE THE SECOND WORLD WAR

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Changes in the water conditions of Cracow brought about by human activity have occurred with great rapidity since the Second World War. Analysis of these changes seems to be justified by the fact that Cracow is an example of a city in which the trends in the water situation over recent years are typical of large Central European cities. The main changes in water conditions are: changes in the course of rivers, filling and covering over of river beds, the loss and creation of water reservoirs, changes in runoff and ice phenomena, and deterioration of water quality. Currently there are no rivers that meet drinking water quality standards in Cracow. Most municipal and industrial sewage has not been treated. Because of considerable contamination of surface and ground waters, more than half of the city's fresh water is pumped about 50 kilometers from a reservoir. The further development of Cracow and those regions that influence its waters should aim at an improvement, however modest, in the quality of water. The basis for modern protection of the water environment should be not only the building of waste treatment facilities but, more importantly, a proper economic development strategy for the city. It is also important to increase the ability of local authorities to enforce laws protecting water quality and to administer appropriate penalties for failing to observe these laws.

INTRODUCTION

Located in the southern part of Poland, Cracow is one of the largest and most beautiful cities of East-Central Europe (Figure 1). There are approximately six thousand historical monuments of art in Cracow. This explains why the city's historical-architectonic complex was chosen as one of the twelve most valuable sites in the world at the September 1978 UNESCO session in Washington.

Cracow's water conditions have been of crucial importance for centuries. The system of river networks and the location of wetlands have determined the territorial expansion of the city and the location of crafts industries. The early stages of development conformed to the existing water conditions; however, with economic and technical progress water conditions were gradually transformed.

Until the Second World War, Cracow's water conditions were the result of works begun in the medieval period. The Vistula River, Rudawa River, and parts of the Dluga Drwina River and Pradnik River had been regulated and embanked. As a result of regulation of the Vistula initiated in the nineteenth century, along with the exploitation of gravel and sand, the river channel was deepened by about 3 m. These activities led to a lowering of the groundwater level and former wetland areas of the city dried out. There were several millraces (on the Rudawa, Pradnik, and Dlubnia Rivers), as well as many ponds and fishponds in Cracow and near its boundaries. Some parts of the Vistula River valley were also partly drained.

Cracow was supplied with water from the Vistula River, then of good quality. It is known, however, that in the nineteen-thirties the Vistula already carried a certain amount of coal dust, chlorides, ammonium nitrate and organic compounds from the Silesia industrial region (Wrobel, 1990). Individual wells whose sanitary conditions left something to be desired were another source of water (Kleczkowski, 1974).

The intensive development of the national economy in the postwar period caused a sharp rise in demand for water. From 1949-60 this increase was nearly threefold, and in industrialized regions like Cracow, almost sevenfold. Several studies have examined Cracow's water condition. The most complete study is by J. Dynowski (1974), covering changes until the nineteen-seventies. Many studies cover changes in water quality and the

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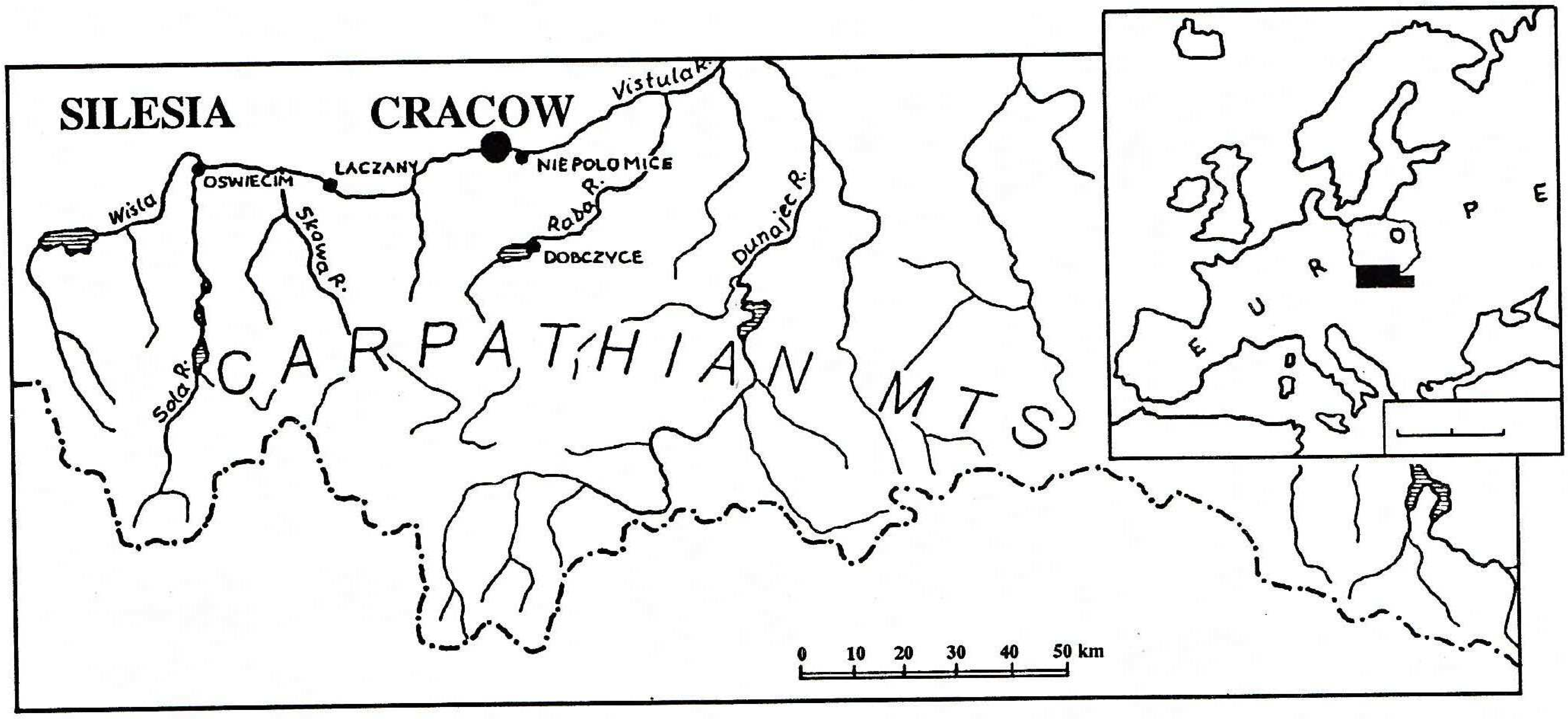


Figure 1. Location of the study area.

problems of supplying Cracow with water (Fiszer, 1990; Kleczkowski, 1974; Pociask-Karteczka, 1989, 1992; Wrobel, 1990).

This paper is a continuation of research into the changes in Cracow's water situation over the centuries (Pociask-Karteczka, forthcoming). It is, however, more detailed, since changes in the water situation have occurred with great rapidity since the war.

The aim of the study is the presentation of the changes in the water situation of Cracow brought about by human activity since the Second World War. Analysis of these changes seems to be justified by the fact that Cracow is an example of a city in which the trends in the water situation over recent years are typical of large Central European cities.

ANTHROPOGENIC CHANGES IN THE WATER CONDITIONS

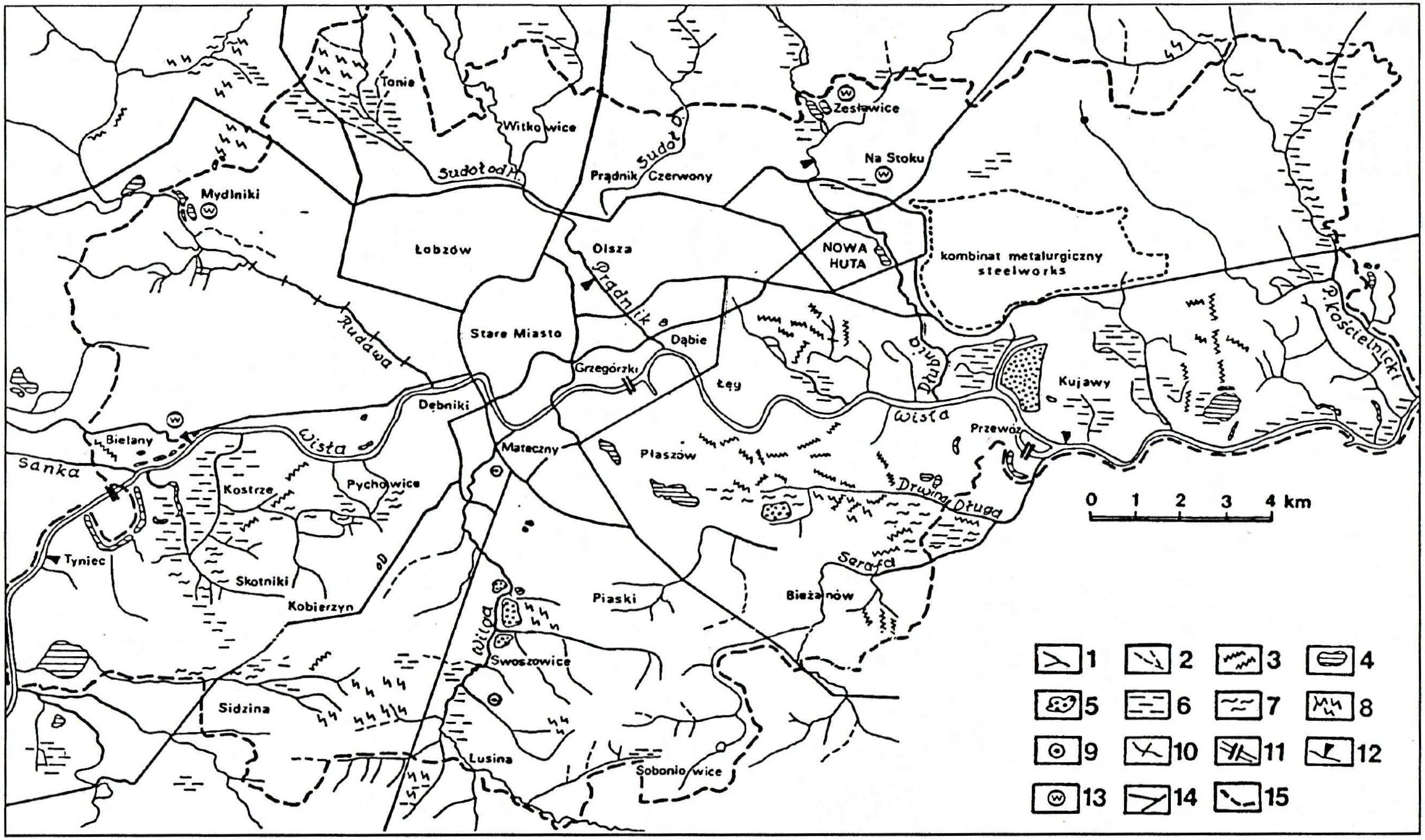
The territory of Cracow expanded along the valley of the Vistula, the main river flowing through the city, after the Second World War. It seemed that the city was turning towards the river and its tributaries, and also that water features were being integrated into the urban landscape. It turned out, however, that during the intense, unrestrained, and often chaotic development of construction and industry, the water network was not only exploited but also devastated. At present the area of the city is approximately 327 km^3, and the population approximately 750,000.

The river network

Changes in the river network caused by human action consist primarily of changes in the course of rivers and the filling and covering over of river beds.

The Vistula River flows through Cracow from west to east. Its length within the city is 41.2 km, including 18 km in which it is the city boundary (Figure 2). Its course is meandering. After the Second World War the course of the river within the city was shortened by 4.3 km as a result of excavating new channels with weirs and locks at places where the river formerly curved.

The building of weirs and locks is connected with a program aimed mainly at adapting the Vistula River for navigation. The first lock and weir were built in Przewoz in 1954 (Figure 2). The damming of the river in Przewoz raised the ground water level 1.5 m above the weir and lowered it 0.5 m below it (Dynowska, 1992). Above the weir there was drowning of land which resulted in the hindering of ground water exchange and a significant decrease in the quality of ground water. The next weir and lock were built seven years later in Dabie (Figure 2). The goals of this project included counteracting bottom erosion by the Vistula River within Cracow, which threatened bridge construction. The weir and lock in Dabie caused a return in this part of the city to earlier hydrogeological conditions, that is, a raising of the ground water level that had previously been lowered due to bottom erosion. However, a significant part of the city was drowned. This was counteracted by barriers of wells.



1. permanent stream
2. periodic stream
3. drainage ditch
4. lakes
5. industrial reservoir
6. wet area
7. terrain with artificial drainage system
8. drained area
9. mineral springs
10. gully control step
11. weir
12. water level gauge
13. water treatment plant
14. main streets
15. border of the city

Figure 2. Contemporary water network in Cracow.

Another weir and lock (Kociuszko) was sited in the Tyniec region and opened in 1989 (Figure 2). So far, bands of ditches around the crown of the dam have protected nearby terrain from drowning (Hennig, 1991).

The *Rudawa River* flows through Cracow as an old millstream that runs to the Premonstratensian convent (Figure 2). Another artificial branch of the Rudawa River, the "Royal Millstream," which was still flowing towards the city at the end of the Second World War, has been filled in with sediment with the exception of its upper segment. It is worth remembering that this millstream had filled an important role in the life of the city from medieval times, since it supplied water to the city water-supply service called "rurmus". With the filling and covering over of this millstream, a monument to the city's well-built medieval waterworks was destroyed.

The *Pradnik River*, known in Cracow as the Bialucha, was regulated after the Second World War and its channel was deepened. As a result of this work, an accelerated accumulation of alluvial material in its channel occurred in subsequent years. The Pradnik millstream was cut off and its channel largely filled in. Aside from this, the outlet segment of one of the tributaries of the Pradnik River, known as the Dominican Sudol Stream, was also covered over. Work is underway at present to cover over a large segment of another tributary of the Pradnik River, known as the Modlnica Sudol Stream (Figure 2).

The *Dlubnia River* is another, larger tributary of the Vistula River. The course of the Dlubnia River has not been significantly altered since the war. However, an old millstream running to the Cistercian monastery has been cut off, as have been two branches near the mouth. The *Koscielnicki Stream* for some distance forms the administrative boundary of Cracow. Its course has not been changed, thanks doubtless to its peripheral location in relation to the center of the city. The *Wilga River* was straightened and embanked in the 1.2 km segment near its mouth, due to the backup above the lock in Dabie. The *Drwina Dluga* flows almost entirely within the city, with the exception of the short segment near its mouth (Figure 2). Its channel was deepened in 1957 and at present it functions as a canal carrying off partly treated municipal and industrial sewage.

In summary, the river network within the Cracow city limits is 14% shorter now than it was before the war (Deutsche Heereskarte, 1934).

Lakes, ponds, and wetlands

The growth of Cracow and the desire for new lands for architecture, construction and (in the peripheral districts) for cultivation has fostered the filling in of ponds and old river beds, as well as wetlands (Figure 2).

The 11 ponds in Debniki and Polwies Zwierzyniecka have been used as building sites and those in Prokocim and Przegorzaly as allotment gardens. Much of the old Vistula River bed in the regions of Koscierz and Przewoz has been adapted for cultivation. Another factor in accelerating the disappearance of old river beds has been the eutrophication of waters, which are rapidly covered over by aquatic vegetation. An example of exceptionally destructive and devastating human activity is to be found in the ponds in the upper part of the Serafa basin in Soboniowice, in the southern part of the city. Until recently there were several ponds there connected by waterfalls along a stream. Today, as a result of drilling carried out in exploration for salt deposits, only one pond remains. There is now a city dump nearby, and water from the Wieliczka salt mine is pumped into the pond.

Economic activity in Cracow has caused the loss of some water reservoirs, while creating others. Many new water reservoirs have come into being in *excavations* left by gravel quarries on the Vistula terraces (Plaszow, Podgorze, Przylasek Rusiecki). Their number and size continues to grow as a result of the ongoing exploitation of this building material. In recent years a very deep excavation-type reservoir has formed in the former stone quarry in Zakrzowek. It is being filled with water from numerous springs flowing out of the Jurassic limestone. On the outskirts of Cracow there are also two *retention reservoirs* on the Dlubnia (Figure 2). The first of them was formed in the nineteen-sixties in order to provide Nowa Huta with water. After twenty-five years it was half silted, and therefore a second reservoir was opened in 1989 while deposits were removed from the first. Now both reservoirs are filled with water. Water from the Dlubnia also flows into a reservoir in Nowa Huta from which it is pumped to the metalworks. This reservoir also has a recreational function. New reservoirs of the *cut meander* type have been formed in bends of the Vistula River cut off from the main channel by the excavation of new channels with locks (Przewoz, Tyniec).

There was an old network of *drainage ditches* in the wetlands of Cracow. As more and more new territory, including wetlands, was incorporated into the city, land reclamation work was undertaken. This most commonly consisted of drainage by surface ditches (Tonie, Szidzina) or *draining of ground water* (Tonie, Plaszow). In some areas (the Kostrze-Pychowice band of meadows) this work led to excessive drainage and of typical meadowland soils (Komornicki, 1974).

RUNOFF

Human economic activity that involves the transfer of water from one basin to another, the building of hydrotechnical constructions or the irreversible use of water in industry or agriculture can cause changes in the

Table 1. Mean Annual Runoff of the Vistula River and Its Tributaries in Cracow, 1973-87

water gauge	mean runoff (m^3/sec)	regression coefficient
Wisla-Tyniec	98.1	-2.037 *
Rudawa-Balice	2.43	-0.092 *
Pradnik-Olsza	1.08	-0.022
Dlubnia-Zeslawice	1.10	-0.037

* significance of regression for the significance level 0.05

regime and magnitude of runoff. On the basis of analyses of the *magnitude and frequency of floods* from 1860 to 1980, one can state that the magnitude of infrequently occurring flows has increased since the Second World War: the value of water over the century 1861-1960 was 2160 m^3/sec. while in the period 1931-80 it grew to 2680 m^3/sec. The velocity of the flow also increased. At the beginning of the century it took an average of 44 hours for the flood to cover the segment from the mouth of the Skawa to the mouth of the Raba. After the Second World War this period decreased by three hours, while recently the velocity is twice what it was at the turn of the century. Furthermore, the concentration time decreased. These changes have been brought about primarily by human activity, including the regulation of the river channel and changes in land use. Deforestation has doubtless contributed to greater changes in flow. Regulation of the river through the bypassing of bends, which involves not only the shortening of the river but also increasing its gradient, has contributed to increasing the concentration of floodwaters (Punzet, 1972, 1985).

Changes in the runoff of the Vistula and its tributaries from 1973 to 1987 (this is the period for which data is available) show a similar tendency: in this period the mean annual runoff of all the rivers has decreased slightly, but in the cases of the Vistula River and the Rudawa River there has been a significant decrease (Table 1). Precipitation hardly changed over these fifteen years. There has been a similar tendency in mean monthly flow over the years (Table 2). Over the fifteen years in question the average monthly flows of the rivers in question have fallen in spite of the fact that precipitation in specific months has risen, with the exception of February, July, and the autumn months. Only in the case of the Vistula River has there been a tendency to an increase of flow in May, June, and August. The decrease in the mean annual runoff of these rivers at a time when precipitation has not changed or has even increased somewhat could be caused by an increasing consumptive use of water in the industrial, municipal, and agricultural sectors. It is difficult, however, to assess the degree to which these changes are natural or anthropogenic.

THERMAL AND ICE PHENOMENA IN THE VISTULA RIVER

The beginning of disturbances to the natural thermal regime of the Vistula River occurred at the end of the sixties as a result of the opening of the power plant in Skawina (1957). The discharge of warm water from the plant's cooling system has caused a heating of the waters of the Vistula River by approximately 7.5 degrees Celsius (Turoboyski, 1963). In the segment from Tyniec to Bielany, below the discharge, the water of the Vistula River cools somewhat: in winter the fall in the average monthly temperature of the waters of the Vistula amounts to 0.6 to 2.3 degrees Celsius, and in summer from 0.6 to 1.8 degrees (Pociask-Karteczka, forthcoming). The rise in temperature and above all the pollution of the water (salinization) have caused the disappearance of ice on the Vistula River. Brash ice (debris ice) has appeared only sporadically since 1959. In the winter of 1979, for example, it lasted for only eight days (Pociask-Karteczka, forthcoming). Earlier, before the opening of the power plant, the ice cover typically appeared at the beginning of January and lasted through the first ten days of February. On occasion, however, it lasted much longer, as in 1929 when it lasted for 80 days and its thickness reached 27 cm. In 1963, with similar temperatures, only brash ice on the Vistula River (Golek, 1957).

QUALITY OF SURFACE WATER

Deterioration in water quality is the most unfavorable result of human activity. We can assume that at the conclusion of the Second World War the Vistula River met the 1st class of Drinking Water Quality Standards, as it did before the war. However, in the nineteen-fifties there was already a change of the natural water type from

Table 2. Anthropological Component in Chemical Composition of Water in the Vistula River (after Kaminski, Wrobel 1991)

Chemical component	Kamienica	Wisla	Anthropological component
	(mg/l)		%
chlorides	4.7	815	99.4
sulphates	16.8	177	90.5
sodium	1.6	466	99.6
calcium	31.9	113	71.8
magnesium	6.7	56.7	88.2

calcium-carbonate to sodium-chloride as a result of the water from the Silesian mines that entered the Vistula River by way of the Przemsza. From that time on the pollution of the Vistula rose steadily until, after 1980, it jumped drastically as a result of the opening of four new mines in Silesia (Figure 3). At this time the pollution reaching the Vistula above Laczany increased, while between Laczany and Niepolomice (the segment including Cracow) the amount of pollution reaching the Vistula declined somewhat. This means that the Cracow region's share in the overall amount of pollution entering the Vistula River was less and less.

Aside from the Przemsza River, pollution is carried into the Vistula River by the Biala River (effluents from the Bielsko-Biala region), the Gostynia River (effluents from Czulow) and the Wlosienica River (effluents from Oswiecim). These rivers carry industrial waste above all. The Sola River and the Skawa River also carry a certain

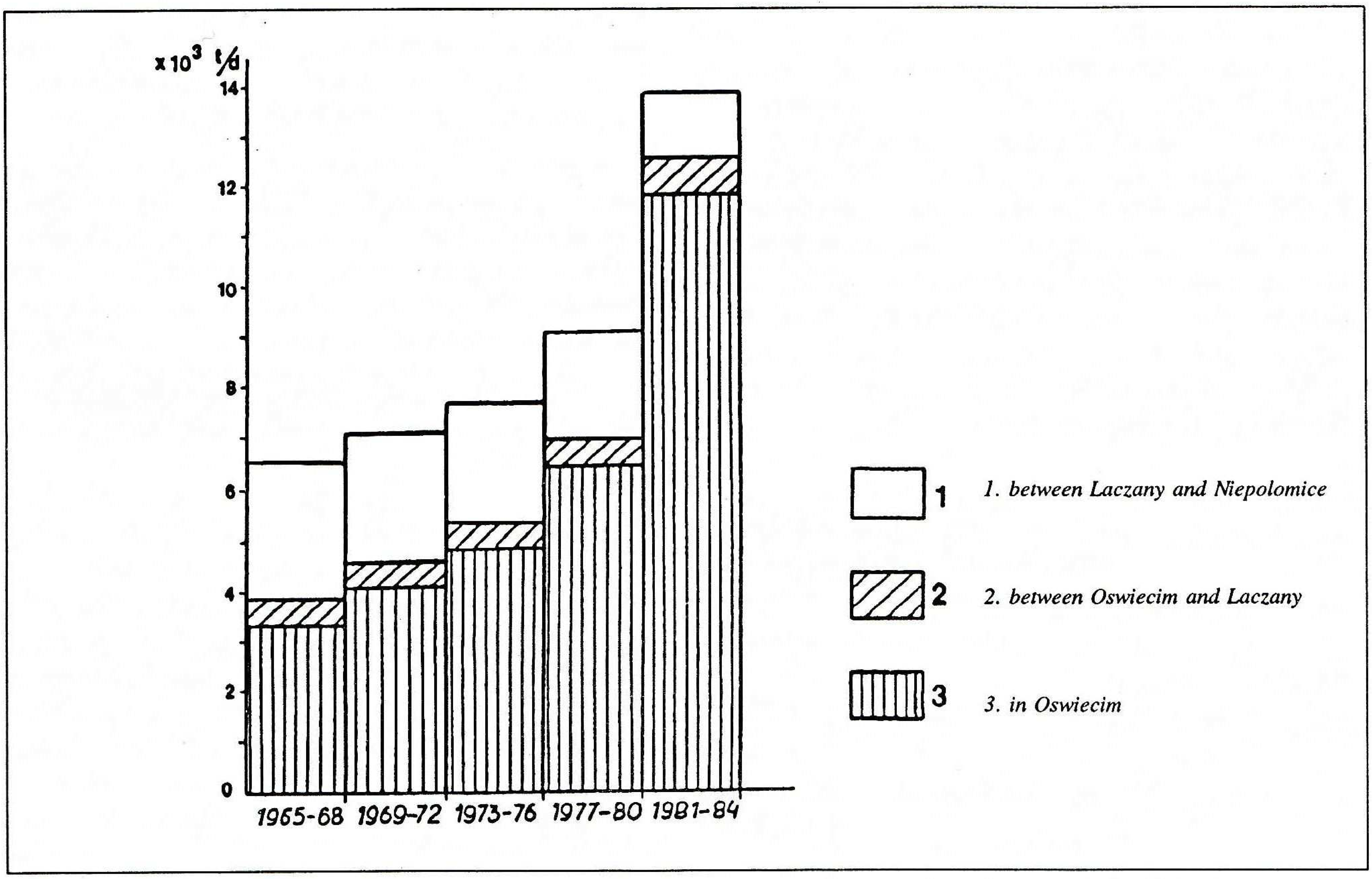


Figure 3. Dry Residue in Water of the Vistula River, 1965-84 (after Materialy Urzedu Miasta Krakova, 1992).

Table 3. Sewage Disposals (10^3 m^3/yr) of Some Plants in Cracow in 1992 (after Materialy Urzedu Miasta Krakowa, 1993)

Plant	Total	Cleaned
MPWiK dla dzielnic: Krowodrza, Podgorze, Srodmiescie	86.11	0.11
MPWiK dla Nowej Huty	27.85	0
Huta im. Sendzimira	28.40	28.40
Elektrocieplownia "Leg"	3.82	3.82

amount of waste, including municipal sewage (Atlas zanieczyszczen rzek w Polsce [Atlas of Polish River Pollution] 1981, 1983, 1986). Effluents reaching the Vistula River from outside Cracow contain phenols, cyanides, rhodanic acids, coal sediments, oils, lubricants, fats, tars, sulphur lye, heavy metals, calcium sulfate, magnesium, and iron (Dynowski, 1974). The large amount of sewage disposal flowing into the Vistula from outside Cracow indicates the tremendous anthropogenic pressure to which the Cracow segment is subjected. In the case of calcium ions and soda it amounts to 99% (Table 3).

However, pollutants from the Cracow region also flow into the Vistula River. They enter it directly or by way of tributaries. The majority of wastes are treated only partially or not at all. Companies like the Polfa Pharmaceutical Factory, the Tobacco Industry Factory and the Polmos Spirits and Yeast Industry Factory dump their wastes into the city sewage system. They reach the Vistula River through the Drwina Dluga River, which carries partially treated waste from the Municipal Waterworks and Sewage Company. The water in this river is foul-smelling and almost black, with fatty spots (Materialy Urzedu Miasta Krakowa, 1988).

The unfavorable influence of Cracow's industrial and residential infrastructure on the quality of water can be seen most clearly in the case of the Vistula's tributaries. The amount of pollution in the water of these tributaries is much less at the point where they enter the city limits than at their mouths. The worst pollution from Cracow flows into the Dlubnia River and the Wilga River. Sewage disposal from the Metalworks in Nowa Huta enter the Dlubnia, while leachate pollution from the sediment dumps of the former *Solvay* Soda Works enter the Wilga River. In 1976-92, the content of residues and chlorides in the water of the Wilga below the waste-pipe and sediment dumps was often dozens or even hundreds of times greater than above this point (Figure 4). The least harmful influence of Cracow on water quality is found in the Rudawa River and the Pradnik River.

Research in recent years has pointed to atmospheric precipitation as an additional source of river pollution. The mineralization of precipitate water in Cracow is higher than outside the city. In view of its widespread character, this phenomenon can cause serious changes in the chemistry of Cracow's surface waters (Fiszer, 1990).

A highly unfavorable phenomenon is the *eutrophication* of water, which increased greatly after the war.

Table 4. Quality of Surface Water in the Cracow Voivodeship (Province) in 1992 (after Materialy Urzedu Mista Krakowa,1993)

criterium	*% of rivers in classes*			
	I	II	III	out of classification
physicochemical	1.8	23.2	27.9	47.1
bacteriological	-	-	3.5	96.5
general	-	-	3.5	96.5

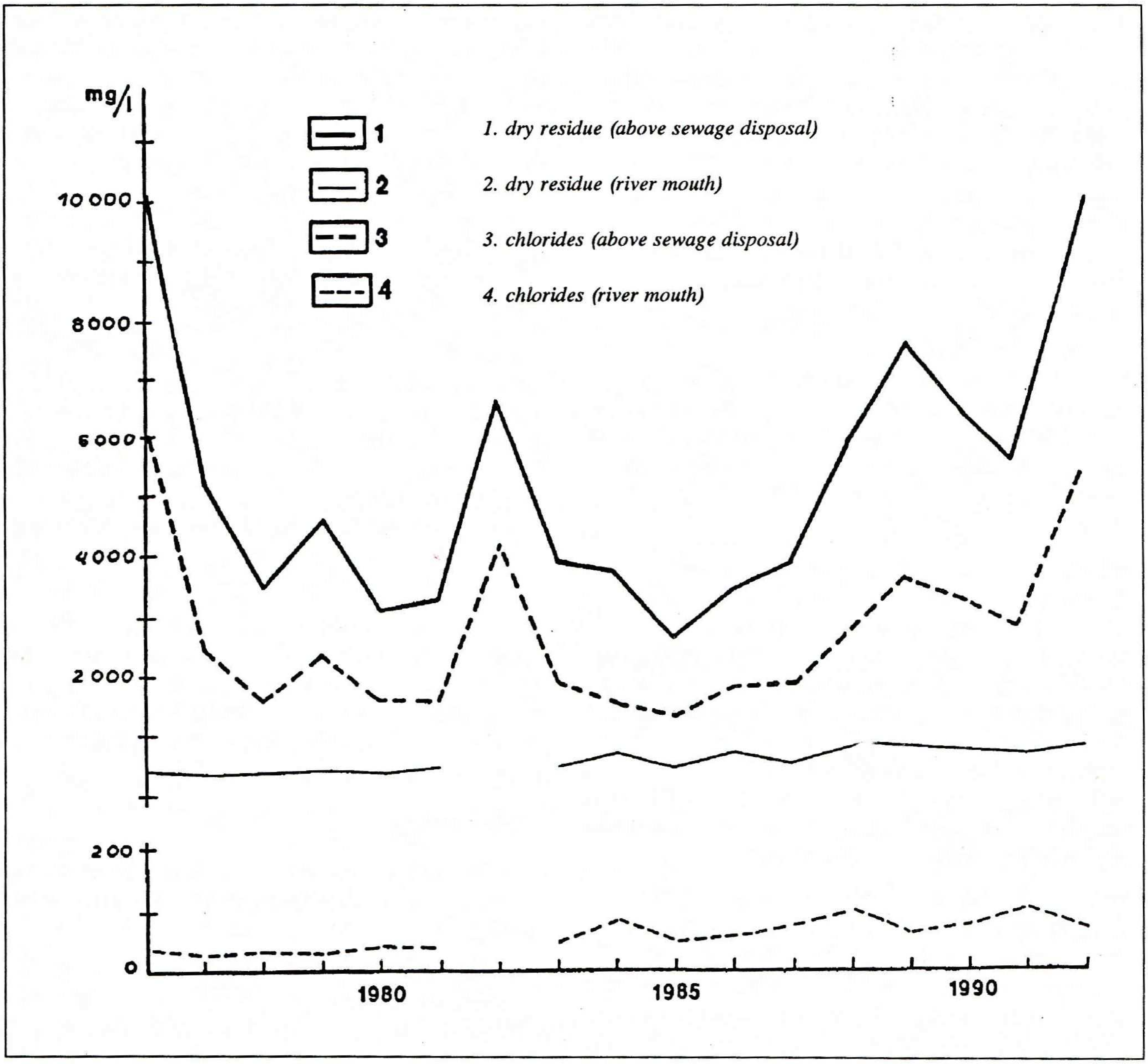


Figure 4. Dry residue and chlorides in water of the Wilga River above and below the city sewage disposal, 1976-92 (after Materialy UrzeduMiasta Krakowa, 1993).

It results from the inflow of more and more municipal and industrial wastes containing phosphorus and microelements as well as of agricultural runoff containing nitrogen compounds and plant growth stimulants. Hydrotechnical construction on the Vistula River, especially the locks in Dabie, intensifies eutrophication. Before the construction of the locks, a high concentration of suspended organic carbon particles hindered the growth of algae. After the construction of the lock, the sedimentation of the suspension made the water cleaner, which facilitated the rampant growth of algae and underwater plants. In the summer the plants die and decay in the tributaries of the river, with a negative effect on its sanitary and aesthetic state (Wrobel, 1991).

According to assessments of water quality following general criteria, carried out in 1992 by the Environmental Protection Inspectorate, there is no water that meets the 1st class of Drinking Water Quality Standards in Cracow, and most of the water falls beyond classification. Of the 524.1 km of water tested in the rivers of the Cracow province, only 3.5% met the standards for 2nd class (Table 4).

GROUNDWATER QUALITY

At the end of the nineteen-fifties, the chemical composition of the water in most of the wells of Cracow was natural. The bacteriological state of some wells was the only disquieting factor. At present, the quality of well water within the Cracow city limits is poor. It is potable only after boiling. It is often made unpotable by the presence of nitrates, manganese, iron and heavy metals as well as its general hardness and bacteriological state. It sometimes turns out that the high iron content is not caused by human factors, but rather by the natural presence of iron in the water-bearing Pleistocene strata. Chlorinators are installed in wells to make the water drinkable (Pociask-Karteczka, forthcoming).

The poor quality of groundwater in Cracow also results from the deposition of airborne pollutants on the soil and their migration to groundwater, and especially to the first horizon of the groundwater. Highly polluted Vistula water can also supply the groundwater. Additional large amounts of contaminants reach the groundwater from industrial dumps.

The contamination of mineral waters in Cracow is an extremely negative phenomenon. Mineral waters of the sulfate variety have been used since the beginning of the nineteenth century. At present they are exploited for natural medicinal purposes and home consumption, which has led to a depletion of the resource. However, a much more unfavorable phenomenon is the pollution of these waters with man-made substances. Tritium, a by-product of thermonuclear explosions, has been found in the water at Mateczny. As exploitation increases there will be more use of younger groundwaters that are potentially threatened by atmospheric and soil pollution.

Mineral water was discovered in Lusina in 1952, and in Mistrzejowice in 1975. In recent years several new wells have been drilled within the city limits and fitted with spigots to give city residents free access to the water. This is a praiseworthy initiative, since Cracow's mineral waters have a medicinal effect for many illnesses, including such diseases as arteriosclerosis, cancer, toxic poisoning, and conditions of the nervous system.

SUPPLYING CRACOW WITH WATER

At the end of the Second World War, Cracow drew all its water from the only existing waterworks, in Bielany (Figure 2). Originally, this plant used an intake on the Vistula River. In view of the pollution of the river, this intake has been closed since the mid-1980s and the plant has used water from an intake on the Sanka River as well as groundwater. Six and a half million m^3 of water are treated each year.

The rapid rise in the need for water has made it necessary to seek other sources. The water treatment plant in Mydlniki, drawing on an intake on the Rudawa River as well as deep wells, was opened in 1955. This plant supplies 23 million m^3 of water per year. Since 1964, water from the Dlubnia River has been piped to the water treatment plant Na Stoku and thence to users in Nowa Huta. This plant processes approximately 14 million m^3 per year. Nowa Huta also receives water from the water works in Mistrzejowice, whose deep wells yield 1.5 million m^3 per year. The supplies of deep well water have declined over the years, so that of the large number of wells, only nine are currently in use. Cracow's yearly water requirement is estimated at 100 million m^3, of which 45% is supplied by the above-mentioned intakes and water treatment plants. The rest of the requirement is met by water from an intake on the Raba River, with a reservoir at Dobczyce, in operation since 1985. The water is processed on site and pumped to Gorzkow at a rate of approximately 64 million m^3 per year (2 m^3/sec), whence it flows by gravity towards Cracow. Since the opening of the intake on the Raba River the quality of water in Cracow's water system has improved significantly. There is a plan to meet an increase in Cracow's consumption by transferring water from the Dunajec River to the Raba River above the reservoir in Dobczyce, and allow the flow from the reservoir to reach a maximum of 6 m^3/sec.

A certain part of the water requirement is met by domestic wells used by residents of the outlying districts. At the beginning of the nineteen-seventies, approximately 70% of the city's population depended on such wells. Some industrial establishments also have their own groundwater intakes (Dynowski, 1974).

CONCLUSIONS

After the Second World War, Cracow's water situation worsened significantly as a result of human economic activity.

Long-term postwar plans for land use in Cracow envisaged benefiting from the city's hydrographical network for recreation and aesthetic purposes. In the country's postwar program of accelerated industrialization, however, these plans never came to fruition. In fact, the opposite occurred. The growth of industry, housing construction, and changes in land use led to highly unfavorable -- and often irreversible -- changes in the water situation. Many river channels were filled in or canalized, many ponds and pools were eliminated, and the Vistula River and some of its tributaries (the Wilga River and the Drwina River) became examples of the transformation of rivers into sewage canals.

The most unfavorable result of this activity is the constantly increasing pollution of surface and underground waters. For this reason, fresh water is transported from regions distant from the city in order to meet residential and industrial needs. Rivers have lost their natural chemical and thermal characteristics because, neither in Cracow nor along the banks of the Vistula River and its tributaries up river from the city, has the growth of industry and the expansion of residential areas been accompanied by the development of sewage processing plants. Additional diverting of water, hydrotechnical construction, straightening of river beds, and the consumptive use of water in industry have contributed to changes in the flow regimes of rivers, and above all of the Vistula River. There is a greater frequency of floods and an increase in the concentration time of flood. On the other hand, there has been a decrease in the annual flow of the Vistula and its tributaries despite an unchanging level of precipitation. A proper water management policy ought to aim at the protection of local waters in order to facilitate their exploitation, rather than at bringing water in from more and more distant catchment areas. Furthermore, to avoid changes in runoff, it is important to have proper land use and rational exploitation of the sediments in riverbeds.

Major changes have appeared in Cracow's water network. More and more watercourses are being covered over. Postwar plans to make use of such water sites as rivers and reservoirs for recreation and scenic purposes have been realized only to a small degree or incorrectly. In new residential districts of high-density multifamily dwellings, where the water network could constitute one of the few recreational elements, lakes and ponds are neglected or simply filled in.

Neglect of water management is not only a barrier to further economic development, but a threat to the health of the city's population. In the case of Cracow, the critical size in relation to the environmental capacities of the water system was passed long ago. The further development of Cracow and those regions that influence its waters should aim at an improvement, however modest, in the quality of water. The basis for modern protection of the water environment should be not only the building of waste treatment facilities but, more importantly, a proper economic development strategy for the city. It is also important to increase the ability of local authorities to enforce laws protecting water quality and to administer appropriate penalties for failing to observe these laws.

It should also be remembered that counteracting unfavorable, anthropogenic changes in water conditions would make it possible to avoid often irreversible changes to other elements in the geographical environment, like the microclimate, soil and vegetation.

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accompanied by the development of sewage processing plants. Additional diverting of water, hydrotechnical construction, straightening of river beds, and the consumptive use of water in industry have contributed to changes in the flow regimes of rivers, and above all of the Vistula River. There is a greater frequency of floods and an increase in the concentration time of flood. On the other hand, there has been a decrease in the annual flow of the Vistula and its tributaries despite an unchanging level of precipitation. A proper water management policy ought to aim at the protection of local waters in order to facilitate their exploitation, rather than at bringing water in from more and more distant catchment areas. Furthermore, to avoid changes in runoff, it is important to have proper land use and rational exploitation of the sediments in riverbeds.

Major changes have appeared in Cracow's water network. More and more watercourses are being covered over. Postwar plans to make use of such water sites as rivers and reservoirs for recreation and scenic purposes have been realized only to a small degree or incorrectly. In new residential districts of high-density multifamily dwellings, where the water network could constitute one of the few recreational elements, lakes and ponds are neglected or simply filled in.

Neglect of water management is not only a barrier to further economic development, but a threat to the health of the city's population. In the case of Cracow, the critical size in relation to the environmental capacities of the water system was passed long ago. The further development of Cracow and those regions that influence its waters should aim at an improvement, however modest, in the quality of water. The basis for modern protection of the water environment should be not only the building of waste treatment facilities but, more importantly, a proper economic development strategy for the city. It is also important to increase the ability of local authorities to enforce laws protecting water quality and to administer appropriate penalties for failing to observe these laws.

It should also be remembered that counteracting unfavorable, anthropogenic changes in water conditions would make it possible to avoid often irreversible changes to other elements in the geographical environment, like the microclimate, soil and vegetation.

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