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Wody opadów atmosferycznych jako źródło składników biogennych dla zbiornika goczałkowickiego*

Rainfall waters as a source of biogenous components for the reservoir at Goczałkowice

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Abstract — The results of 198 analysis of rainfall waters in a 3 year cycle of investigations (1973 to 1975) were presented. The investigations showed that a high annual amount of rainfalls (812 mm) brings with them into the reservoir at Goczałkowice considerable amounts of nutrient compounds (13.2 kg N/ha per year and 0.23 kg $P—PO_4$/ha per year). This makes 9 per cent N and 11.2 per cent $P—PO_4$ of the total inflow of these components into the reservoir. Apart from it, the rainfall waters from Goczałkowice contain other compounds necessary for the development of plankton algae.

In research on the sources of biogenous components flowing into surface waters more and more attention is paid to the rainfalls since these contain, among other components, nitrogen and phosphorus compounds, i.e. substances contributing to water eutrophization.

The content of nitrogen compounds in the rainfalls varies from amounts lower than 0.2 mg N/l to a few milligrams nitrogen in 1 litre. Tamm (1958) found at Bogesund (Sweden) 0.2 to 0.9 mg $N—NH_4$/l, while Peukert (1976) found in the rainfalls in the southern regions of the GDR as much as 3.40 mg $N—NO_3$/l, most of the data being encompassed in the interval 0.45 to 1.13 mg $N—NO_3$/l. For the region of Giessen the mean content of nitrogen compounds was 7 mg N/NH_4, NH_3/l (Scharrer, Fast 1951).

According to Miller (1955), the annual charges of nitrogen brought in with rainfalls vary from 2 to 22.5 kg/N/ha. It should be noted that for

* Praca wykonana w problemie węzłowym 10.2.

highly industrialized regions the above given values can be much higher: e.g., in the vicinity of Essen the annual amounts of nitrogen brought by rainfalls were 43 kg N/ha (Gericke, Kurmies 1957 — cit. after Krummenacher 1976). Krummenacher (1976) determined 31.5 kg N/ha of rainfall origin within a year in Switzerland in the vicinity of the Lake Alpnacher.

The content of phosphorus compounds in the rainfall waters is considerably lower, since their amounts vary from trace amounts to some hundred micrograms in 1 l. Tamm, to whom reference has been made above, found 30 to 100 μg P/l in the rainfalls. Peukert (1976), on the other hand, reported values higher than 650 μg P—PO_4/l, but the mean content of phosphates in 158 rainfall water samples investigated by him was 108 μg P—PO_4/l.

The annual amounts of phosphorus in the rainfalls cited by Vollenweider (1968) equal 0.15 to 0.50 kg P/ha for Sweden and about 0.40 kg P for the territory of France. The rainfalls falling on the Lake Alpnacher brought annually 0.63 kg P/ha (Krummenacher 1976).

In Poland Chojnacki (1967a, b, c, 1968, 1970), in his investigations on rainfall waters, carried out over a couple of years, found that in agricultural regions the annual inflow of nitrogen compounds in the rainfalls was about 10 kg/ha, whereas in industrial areas and in the high mountains over 20 kg/ha. The annual inflow of phosphorus by this way did not usually exceed 0.5 kg/ha and 6 kg/ha of potassium. According to Początek (1975) in the towns of Wrocław and Milicz 4.19 kg P—PO_4/ha of rainfall origin were found in a year.

Thus, considerable amounts of chemical compounds are brought with rainfalls into the soils and waters. According to Chalupa (1960) the phosphorus present in the rainfall waters is a source of its supply into the trophogenic layers of oligotrophic and thermically stratified reservoirs (Hofmann 1972), since rainfall water happens sometimes to be lighter and stays in the surface layers.

In the light of the above presented data there arises the question, what is the chemical composition of the rainfalls coming into the reservoir at Goczałkowice, and what are really these quantitative magnitudes (charges)?

Method

The rainfalls were collected in a plastic container situated near the reservoir at Goczałkowice. Its catching area was about 0.25 m^2, so that even small rainfalls provided amounts of water sufficient for analysis (2 mm rainfall gave 0.5 l water).

The following indices were determined in the rainfall water: calcium, manganese, sodium, potassium, and chlorides (after Golterman 1969), ammonia nitrogen, nitrites, nitrates, phosphates, and iron (after Just, Hermanowicz 1955). 198 analysis of rainfalls were carried out.

The magnitudes of chemical compound charges were calculated by multiplying the existing concentrations of the investigated component by the amount of rainfalls expressed in m^3/ha.

Investigations on rainfalls were carried out in the years 1973 to 1975.

Investigation territory

The reservoir at Goczałkowice is the basic source of pipe water supply for the biggest municipal-industrial agglomeration in Poland, i.e., the Upper Silesian Industrial District. It is situated in the sub-Beskid Mts agricultural region in the vicinity of a big industrial center, the Province of Katowice. Close to the reservoir (4 km from the Czechoslovak border) at the Moravian Gate the foundary of Trzyniec is situated. The Moravian Gate opens the way for the winds blowing frequently in the direction of the reservoir (Pasternak 1964).

It follows from the above data that industrial dust and gas waste emission from the industrial works of the Province of Katowice and of Trzyniec as well as wind erosion of the soil can be a source of rainfall water pollution.

On the other hand, a fairly large amount of rainfalls characteristic of the submontane regions (in the investigated period 1973 to 1975 643; 899; 893 mm rainfall were recorded, respectively) will exert considerable influence on the chemical compound concentration (dilution).

Investigation results and discussion

Mean investigation results of the chemical composition of the rainfall waters from Goczałkowice are plotted in Table I. It follows from these investigation results that among the mineral nitrogen compounds the rainfall waters contained the greatest amounts of ammonium salts. The concentration of the ammonium form of nitrogen varied from 0.174 to 5.78 mg N/l and the mean ammonia concentration for the whole investigation period was 1.457 mg N/l. In summer the contents of ammonium salts in the water were slightly higher. Junge (1963), cited after Choj-

Tabela I. Średnie wyniki badań składu chemicznego wód opadowych (w mg/l) z Goczałkowic z lat 1973-1975

WN - współczynnik nieregularności = max. wartość / min. wartość

Table I. Mean investigation results of the chemical composition of rainfall waters (in mg/l) at Goczałkowice for years 1973-1975

WN - coefficient of irregularity = max. value / min. value

Składnik Component	Średnia ważona Weighted mean			Wahania Variations		WN
	rocznie annual	latem summer IV-IX	zimą winter X-III	max.	min.	
Ca	2.97	2.54	3.66	13.97	0.36	38.8
Mg	1.42	1.42	1.42	7.82	0.02	391
Fe	0.071	0.067	0.078	0.276	0.000	-
Cl	1.76	1.51	2.17	12.25	0.71	17 25
$N\text{-}NH_4$	1.457	1.593	1.238	5.78	0.174	33.2
$N\text{-}NO_2$	0.006	0.006	0.006	0.034	0.000	-
$N\text{-}NO_3$	0.162	0.132	0.212	1.05	0.01	105
$P\text{-}PO_4$	0.028	0.031	0.025	0.30	0.000	-
K	0.46	0.44	0.52	2.5	0.000	-
Na	0.46	0.32	0.78	2.1	0.000	

nacki (1970), found that ammonia passes into the atmosphere for the most part from the soil (fertilization of alcalic soils with ammonium salts); this most probably accounts for the larger amounts of that form of nitrogen in the rainfall waters during the summer period. Ammonium nitrogen constituted about 89.7 per cent of the mean content of all mineral nitrogen compounds.

Next came the nitrates. The nitrate concentration ranged within the limits from 0.01 to 1.05 mg $N—NO_3$/l and the mean nitrate concentration in the rainfall water was 0.162 mg N/l.

The last place among the mineral forms of nitrogen was occupied by nitrites; these occurred in the amounts from the analytical zero to 0.034 mg $N—NO_2$/l.

These quantitative proportions between the three forms of nitrogen are also corroborated by the investigation results obtained by Chojnacki (1970).

The range of the quantitative occurrence of phosphates in the rainfall water (Table I) varies from 0.00 to 0.30 mg $P—PO_4$/l. The mean concentration of phosphates was 0.028 mg $P—PO_4$/l, while a higher phosphate concentration was recorded in the rainfall water in the summer period than in winter. It should be added that phosphate concentrations in the rainfalls falling on the reservoir at Goczałkowice (0.028 mg $P—PO_4$/l) were higher than their mean concentration in the water of the reservoir (0.008 mg $P—PO_4$/l) and in its main tributary the River Vistula (0.014 mg $P—PO_4$/l), and that phosphorus is a macrocomponent limiting the growth and development of the phytoplankton of the reservoir at Goczałkowice (Kasza 1977).

Tabela II. Roczne i okresowe ilości niektórych składników w kg/ha w opadach atmosferycznych oraz wielkość opadu w mm.
x - za okres 1.VII.1973 do 30.VI.1974 (opad 744 mm)

Table II. Annual and periodical amounts of some components in kg/ha in the rainfalls and rainfall magnitude in mm. x - for the period from 1 July 1973 to 30 June 1974

Składnik Component	Średnie Mean 1973-1975	1973			1974			1975		
		rocznie annual	latem summer IV-IX	zimą winter X-III	rocznie annual	latem summer IV-IX	zimą winter X-III	rocznie annual	latem summer IV-IX	zimą winter X-III
Ca	24.06	26.74	14.48	12.26	21.52	9.90	11.62	23.92	13.89	10.03
Mg	11.54	11.09	6.63	4.46	10.86	6.92	3.94	12.66	7.87	4.79
Fe	0.58	0.55	0.27	0.28	0.59	0.41	0.18	0.59	0.32	0.27
Cl	14.30	16.20	8.12	8.08	12.49	5.85	6.64	14.20	8.78	5.42
$N\text{-}NH_4$	11.82	10.27	6.46	3.81	12.41	8.39	4.02	12.78	9.12	3.66
$N\text{-}NO_2$	0.06	0.03	0.02	0.01	0.08	0.05	0.03	0.06	0.03	0.03
$N\text{-}NO_3$	1.31	1.02	0.47	0.55	1.35	0.60	0.75	1.57	0.91	0.66
$P\text{-}PO_4$	0.23	0.16	0.09	0.07	0.27	0.19	0.08	0.27	0.18	0.09
K x	3.44									
Na x	3.39									
Opad Rainfall	812	643	392	251	899	547	352	893	566	327

The concentration range of electrolites in rainfalls (Table I) was as follows: calcium 0.36 to 13.97 mg Ca/l; manganese 0.02 to 7.82 mg Mg/l; sodium 0.00 to 2.1 mg Na/l; potassium 0.00 to 2.5 mg K/l; chlorides 0.71 to 12.25 mg Cl/l, and the mean concentration of these ions calculated for the whole investigation period was: 2.97 mg Ca/l; 1.42 mg Mg/l; 0.46 mg Na/l; 0.46 mg K/l; 1.76 mg Cl/l. As a rule a higher concentration of these compounds was found in winter.

On comparing the ion composition of the rainfall waters with the electrolite contents in waters, even in the oligotrophic ones, we can clearly see that the amounts of Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, and Cl^{-} in the rainfalls are lower, and are not a rich source of inflow of the above mentioned electrolites.

The annual and periodical charges of components brought with the rainfalls on the surface area of 1 ha are given in Table II. In a three year investigation cycle the range of annual charge variations in ammonium salts was within the limits 10.27 to 12.78 kg N—NH_4/ha, in nitrate salts 1.02 to 1.57 kg N—NO_3/ha, and in nitrite salts 0.03 to 0.06 kg N—NO_2/ha. The ammonia nitrogen charges constituted on the average 89 per cent of the total amount of mineral nitrogen. The total charges of phosphates brought with the rainfalls oscillated within the limits 0.16 to 0.27 kg P—PO_4/ha.

The annual and seasonal amounts of biogenous substances in the rainfall waters were in the majority of cases dependent on the sum of rainfalls from those periods. Namely, the more rainfalls the more chemical compounds penetrated with them into the soils and waters. Thus, e.g., the dry summer of 1973 differed greatly with respect to the amount of

Tabela III. Ocena rocznych ilości niektórych składników wnoszonych wraz z opadami na 1 ha (w kg) wg 4-stopniowej skali Chojnackiego (1970).
x - za okres 1.VII.1973 do 30.VI.1974

Table III. Estimation of annual amounts of some components brought in with rainfalls per 1 ha (in kg).
x - for the period from 1 July 1973 to 30 June 1974

Składnik Component	Średnia Mean 1973-1975	Ocena ilości wg Chojnackiego (1970) Estimation of the amounts acc.to Chojnacki (1970)	
Ca	24.06	b. duża very great	>20
Mg	11.54	b. duża very great	>4
Cl	14.30	b. duża very great	>10
$N\text{-}NH_4$	11.82	dość duża fairly great	10-15
$N\text{-}NO_3$	1.31	mała small	<2
$P\text{-}PO_4$	0.23	średnia average	0.2-1.0
K x	3.44	średnia average	1-4
Na x	3.39	średnia average	1-5

substances brought with the rainfalls (in kg/ha) when compared with the averagely wet years 1974 and 1975.

The variation range of annual calcium, manganese, and chloride charges was respectively: 21.52 to 26.74 kg Ca/ha; 10.86 to 12.66 kg Mg/ha; and 12.49 to 16.20 kg Cl/ha, while the charges of sodium and potassium determined in a year cycle were of the order 3.39 kg Na/ha and 3.44 kg K/ha.

The estimation of the annual amount of compounds falling with rainfalls onto the surface area of 1 ha is presented in Table III; the 4 grade scale used by Chojnacki (1970), was applied.

As it follows from that table, the amounts of ammonia nitrogen falling onto 1 ha of the reservoir at Goczałkowice in the amount of about 12 kg are fairly large in comparison with the data for the whole country. Only in the mountains and in the highly industrialized territories Chojnacki found greater amounts of it. On the other hand, the amounts of nitrate nitrogen in the rainfalls from the territory of Goczałkowice are small (1.31 kg/ha) in comparison with the rainfalls for the whole country. The amounts of phosphates brought in with rainfalls equal on the average 0.23 kg $P—PO_4$/ha; these being amounts of average values in the scale of the whole country.

Attention should be drawn to the very high amounts of calcium and manganese in the rainfalls at Goczałkowice. These were magnitudes characteristic of industrial territories.

In the obtained balance of nutrient substances in the reservoir at Goczałkowice (Kasza 1978) the above mentioned elements supplied with

rainfalls constitute a considerable percentage of the total amount of the components flowing into the reservoir. Thus, nitrogen constitutes 9 per cent, phosphates 11.2 per cent, and total P 4.9 per cent of the biogenous salts penetrating into the reservoir. For the sake of information it may be added that 36 to 46 tonns of mineral nitrogen and 0.5 to 0.86 tonns of phosphorus from phosphates comes into the reservoir at Goczałkowice with the rainfalls.

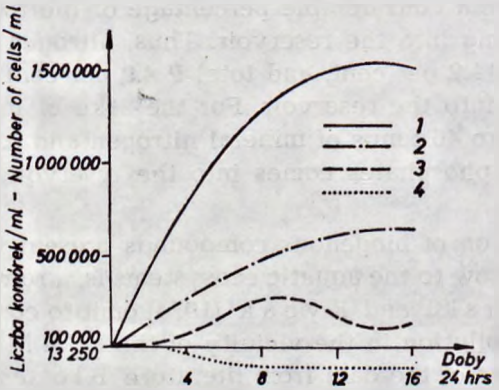
The participation of biogenous compounds present in the rainfalls in their complete inflow to the aquatic ecosystems is, a rule negligibly small. And so, e. g., Górski and Ryback (1974) omit to consider this source, finding that air pollution in the vicinity of the Lake Mikołajskie is very small. On the basis of the data from literature Florczyk et al. (1976) determined the magnitude of the N and P charges coming into the reservoir at Lubachów (about 50 ha) with the rainfalls as charges of the order 0.66 per cent N and 0.53 per cent P. Such a low percentage value of those components in the total balance results from a much greater abundance of nitrogen and phosphorus in the main tributary, the River Bystrzyca, than in the tributaries of the reservoir at Goczałkowice and a small surface area of the reservoir at Lubachów (about 50 ha) with respect to its capacity (8 millions m^3). For the sake of information it can be mentioned that the reservoir at Goczałkowice is a big shallow reservoir since its average depth is about 5 m, its surface area 3200 ha, and its capacity 168 millions m^3.

According to Hofmann (1972) the participation of phosphorus from rainfalls constitutes in the reservoir at Saidenbach only 2.2 per cent of the total amount supplied by the tributaries. This reservoir differs from that at Goczałkowice by its much smaller area (146 ha) and 3 times greater depth and capacity of the order 22.4 mln m^3.

These high amounts of nitrogen and phosphorus from rainfalls coming into the reservoir at Goczałkowice result among others from the great surface area of the reservoir in relation to its capacity and from the inflow of rather poor waters from the main tributary, the River Vistula. It should also be taken into consideration that the waters of the reservoir at Goczałkowice are exchanged within a year 2 to 3 times and that the share of rainfall waters constitutes 9 per cent in the total water balance of the reservoir at Goczałkowice (Kasza 1978).

There arises the question whether rainfalls falling down immediately on the surface of the reservoir at Goczałkowice and bringing in considerable amounts of these basic biogenous compounds can contribute to acceleration of the eutrophization process of its waters.

The investigations carried out in the Laboratory of Water Biology of the Polish Academy of Sciences (fig. 1) show that the waters from the melting snow at Goczałkowice are sufficiently rich and possess all the nutrient compounds necessary for the development of the plankton algae



Ryc. 1. Wpływ wody ze stopionego śniegu na rozwój *Selenastrum* sp. (wg S t a r m a c h i in. (1976), częściowo zmienione). 1 — pożywka Chu-10; 2 — Kraków—Śródmieście; 3 — Goczałkowice; 4 — Kraków—Nowa Huta

Fig. 1. Influence of water from melting snow on the development of *Selenastrum* sp. (after S t a r m a c h et al. (1976), partly changed). 1 — nutrient solution Chu-10; 2 — Cracow-City; 3 — Goczałkowice; 4 — Kraków—Nowa Huta

(S t a r m a c h et al. 1976). The production of the biomass of the phytoplankton can be, thus, theoretically calculated basing on the magnitude of the factor being in the minimum amount. As it has already been mentioned phosphorus is a macroelement limiting the development and growth of the algae in the reservoir at Goczałkowice. Since from 1 mg PO_4 one can theoretically obtain 25.6 mg of organic substance (S t u m m — after P e u k e r t 1976), hence, considering the amounts of phosphates brought in annually with the rainfalls 23 mg P—PO_4/m^2 (Table II), i.e.

Tabela IV. Zawartość fosforanów i azotu mineralnego (mg/l) w wodach spływających po powierzchni z terenów bezpośredniej zlewni zbiornika goczałkowickiego

Table IV. Phosphate and mineral nitrogen content (mg/l) in the water flowing down the surface from the territories of the direct catchment area of the reservoir at Goczałkowice

Miejsce poboru Sampling station	$P-PO_4$	$N-NO_3$	$N-NH_4$
Las Forest	0.001	0.785 - 0.800	1.40 - 1.45
Użytki zielone Grean areas	0.014 - 0.030	7.89 - 8.003	0.35 - 0.39
Grunty orne Arable ground	0.026 - 0.033	2.44 - 8.00	0.35 - 0.39
Drogi Roads	0.029 - 0.042	0.875 - 7.52	0.55 - 0.70
Rów odwadniający Drainage ditch	0.010	4.55	2.67
Drany Drain pipes	0.020	2.20	0.38

70.53 mg PO_4 the annual production of the plankton biomass would equal 1.80 g/m². When, however, due reference is made to the amounts of phosphorus brought in with rainfalls from April till the end of September the theoretically possible production of the biomass would be 1.20 g/m².

Further, long-term rainfalls falling down directly on the catchment area of the reservoir and flowing down the surface, by washing down, bring into it additional amounts of nutrient compounds.

Analyses of the water flowing directly into the reservoir from various territories of the catchment area (Table IV) were carried out in August 1977. In most cases they disclosed a higher concentration of these compounds (especially nitrogen) than that in the water flowing into it with the river water (K a s z a 1978).

Conclusions

1. Upon comparing the amounts of components brought in with rainfalls with C h o j n a c k i' s data (1970) for the whole country it can be concluded that the chemical composition of the rainfall waters differs slightly from the composition typical of agricultural regions and is partly formed by industrial and agricultural pollutions.

2. A higher mean content of mineral nitrogen (1.665 mg N/l) and phosphorus (0.028 mg P—PO_4/l) in the rainfall water than in the water of the reservoir at Goczałkowice (0.95 mg N/l, 0.008 mg P—PO_4/l) in the same investigation period and the magnitudes of participation of these two nutrient compounds of rainfall origin in their total inflow into the reservoir (9 per cent N, 11.2 per cent P—PO_4) suggest that rainfalls can contribute to a periodical increase in water fertility in the reservoir at Goczałkowice (e.g. during heavy rains) and by the same to the progress of the eutrophization process, the more so because these rainfalls contain all the components necessary for the development of the plankton algae.

STRESZCZENIE

Zbiornik goczałkowicki, usytuowany w podbeskidzkim rejonie rolniczym w sąsiedztwie wielkiego ośrodka przemysłowego województwa katowickiego i w niedalekiej odległości od Huty „Trzyniec", narażony jest na wnoszenie do niego dużych ilości substancji chemicznych wraz z wodami opadów atmosferycznych, tym bardziej, że dla tego terenu podgórskiego charakterystyczne są sumy opadów ponad 800 mm rocznie.

Badane opady atmosferyczne zawierały stosunkowo znaczne ilości związków azotowych głównie w formie amonowej (tabela I). Również średnie stężenia fosforanów w wodach opadowych (28 µg P—PO_4/l) były wyższe od koncentracji w zbiorniku go-

całkowickim (8 µg P—PO_4/l) i w głównym dopływie Wiśle (14 µg P—PO_4/l). Roczne i sezonowe ilości składników (tabela II) wnoszonych wraz z opadami w większości przypadków zależne były od sumy opadów z tych okresów.

Na podstawie porównań ilości składników w opadach atmosferycznych z terenu Goczałkowic z wieloletnimi wynikami badań przeprowadzonymi przez Chojnackiego na obszarze całej Polski stwierdzono, że skład chemiczny wód opadowych nieznacznie odbiega od typowego dla rejonów rolniczych, jest kształtowany po części przez zanieczyszczenia przemysłowe i rolnicze.

Opady atmosferyczne wnoszą do zbiornika goczałkowickiego spore ilości składników pokarmowych (13,2 kg N/ha · rok i 0,23 kg P—PO_4/ha · rok), co stanowi w ogólnym dopływie tych składników do zbiornika 9% N, 11,2% P—PO_4 i 4,9% P—ogól.

Badania przeprowadzone przez Starmacha i in. (1976) wykazały, że wody ze stopionego śniegu z Goczałkowic są wystarczająco zasobne i posiadają wszystkie składniki potrzebne do rozwoju glonów planktonowych.

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