Variations in the chemical composition of surface waters transported to the Baltic Sea with the Rega River in the years 1964-1975

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Surface waters
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Rega River

MICHAŁ FRIEDRICH and JAN WILAMSKI
Institute of Meteorology
and Water Management,
Słupsk

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Abstract

An attempt has been made to estimate the increase in pollutant levels of surface waters and of losses of fertilizer components during two periods differing in the intensity of fertilization. To do this, the results were utilized of hydrological-chemical investigations carried out in the Rega River watershed from January, 1964 to December, 1968 (1st period) and from May, 1973 to April, 1975 (2nd period).

1. Introduction

Precipitation and run-off constitute two main factors responsible for the migration of chemical components from drainage areas to rivers. The sources of the components in a drainage area are mineral fertilizers applied by farmers, cattle breeding, municipal waste waters, and industrial effluents. Intensification of agriculture, urbanization and industrial development all contribute to undesirable increase in the pollution of surface waters. Not only rivers, but also other water resources undergo pollution. In Poland, the Baltic Sea and some lakes are main reservoirs receiving surface waters. The run-off of chemical components, in particular nitrogen and phosphorus, from the drainage area causes losses of plant nutrients on the one hand and stimulates eutrophication on the other.

The local pollutions of rivers and water resources can be controlled and their impact on the environment can be regulated by designing appropriate waste-water treatment stations. On the other hand, monitoring of non-local pollutions, including mineral fertilizers, is extremely difficult. Even the most rational dispensing of the fertilizers, complying with agrotechnical schedules, is not in position to prevent migration of plant nutrients to surface waters.

The problem of pollutants run-off from the drainage area was studied, among others, by the following authors: Andrulewicz and Dubrawski [1], Borowiec and Skrzyczyński [2], Borowiec et al. [3–5], Chudecki and Duda [6], Januszkiewicz and Szarejko [9], Januszkiewicz [8], Korzeniewski [10], Wilamski [14, 15], Wilamski and Śliwa [16]. In some of the papers the authors studied also the consequences of polłution of the environment of the water resoures.

Intensification of the fertilization requires both the estimation of the increase of pollutant levels in surface waters and evaluation of nutrient losses by agriculture. An attempt of such estimation was made in this work by taking as an example the drainage basin of the Rega River. The results of hydrochemical investigations carried out in the years 1964–1968 and 1973–1975 in the Rega River drainage basin have been exploited here.

2. Materials and methods

The Rega River carries its waters directly to the Baltic Sea. The drainage area of the river is located in the hydrographic region XXXI/74 and 75. Its surface area measured downstream to the water gauge cross-section at Trzebiatów amounts to 2551.0 km^2, thus constituting 95% of the total area of the drainage basin (Fig. 1).

The drainage area of the Rega River lies on grounds ranked [13] to three climatic areas. These are: the Kołobrzeg Sea-coast (a narrow belt a few to more than ten kilometers in width along the Baltic Sea coast), the Gryfice-Nowogard area, and the Drawsko Lake District.

The precipitation index (P) calculated for the drainage area for the years 1901–1940 was 639 mm [11], whereas in the period 1951–1975 more – 670 mm (Table 1). Assuming, after Lambor [12], the climate of the Rega River drainage area can be considered as slightly to moderately humid.

Some more important factors influencing the hydrographic characteristics of the Rega River drainage basin downstream to the water gauge cross-section at Trzebiatów are listed below after [7]:

a) mean decline of the area (s)–18.5‰,

b) skewness coefficient (a)–0.36 $\left[a=\frac{(A_l-A_p)}{0.5(A_l+A_p)}\right]$,

where A_l and A_p are the areas of the left- and right-hand sides of the drainage basin, respectively [km^2],

c) density of stream network (D)–0.52 km/km^2,

d) mean altitude (h)–73.6 m a.s.l.,

e) area of arable grounds –49.6%,

f) area of greenland –13.1%,

g) area of lakes (γ)–1.46%,

h) degree of afforestation (λ)–26.8%,

i) afforestation development index (ε)–0.23.

The area occupied by the Rega River basin is filled mostly with postglacial formations, whereas in the protovalleys and in depressions with Holocene formations (peat). The parent rocks of the soils are boulder clays, almost exclusively carbonate free as well as boulder sands and valley sands. Arable grounds consist predominantly of leached brown soils and soils with gleyed top layers in bisegmental formations [5]. In forests, podzolic soils prevail with a slight contribution of top-gleyed soils and brown leached soils. The soils of greenland consist mostly of low peat. In depres-

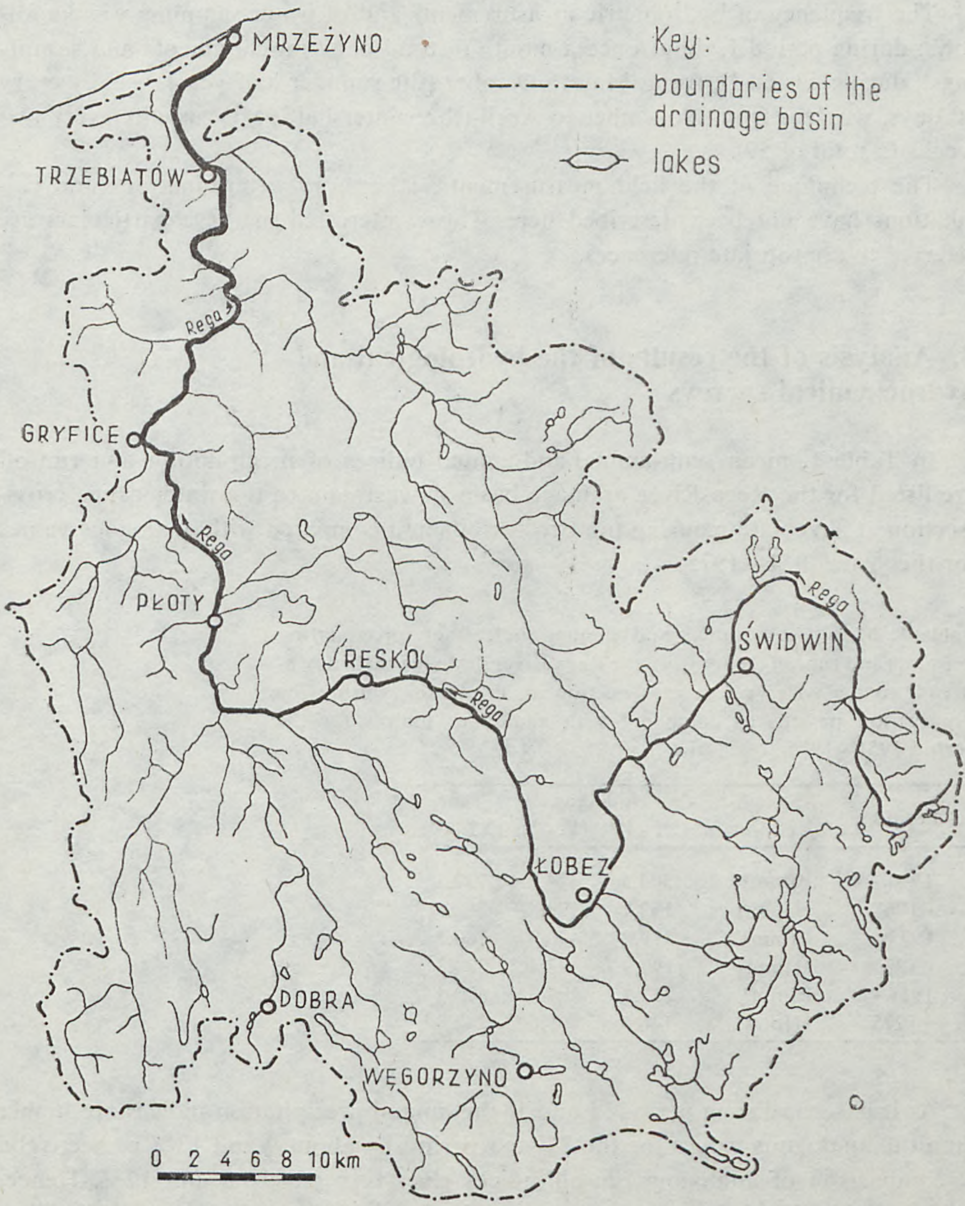


Fig. 1. Map of the Rega River drainage basin

sions, small fragments of variously cultivated black soils, mucks and mucky sands occur [5].

In this paper, the results of hydrochemical studies were exploited which were conducted in the Rega River from January, 1964 until December, 1968 (period I) and from May, 1973 till April, 1975 (period II).

The results were analyzed on the basis of [14, 16] – period I, and [2–5] – period II.

The frequency of hydrometric measurements and of water sampling was as follows: during period I, about once a month (a total of 52 measurements and samplings); during period II, from May to October (the summer half-year), usually every 10 days, whereas from November to April (the winter half-year), usually every two weeks (a total of 59).

The technique of the field measurements, laboratory determinations and calculations have not been described here. Those interested in these particulars are referred to appropriate references.

3. Analysis of the results of the hydrological and hydrochemical surveys

In Table 1, mean semi-annual and annual indices of precipitation and run-off are listed for the Rega River drainage basin downstream to the water gauge cross-section at Trzebiatów during the two periods and compared with analogous values for the years 1951–1975.

Table 1. Mean semi-annual and annual indices of precipitation (P [mm]) and run-off (H [mm]) in the Rega River drainage basin downstream to the water gauge cross-section at Trzebiatów during the observation periods as compared with analogous indices for the period 1951 - 1975

Period	Specification	Half-year (XI - IV)	Half-year (V - X)	Year (XI - X)
1964 -	P [mm]	304.5	424.6	729.1
- 1968	H [mm]	162.7	99.8	262.5
1973 -	P [mm]	319.8	440.9	760.7
- 1975	H [mm]	190.9	93.4	284.3
1951 -	P [mm]	273.3	397.0	670.3
- 1975	H [mm]	146.4	95.6	242.0

As it is seen, during periods I and II the annual precipitation indices are higher than the analogous values for the 25-year period by about 9 and 13% respectively. A comparison of analogous run-off indices gives respectively 8 and 17%. Hence, during period II, the mean annual precipitation index was by about 4% higher than during period I, whereas the run-off index was by about 8% higher. In parti-

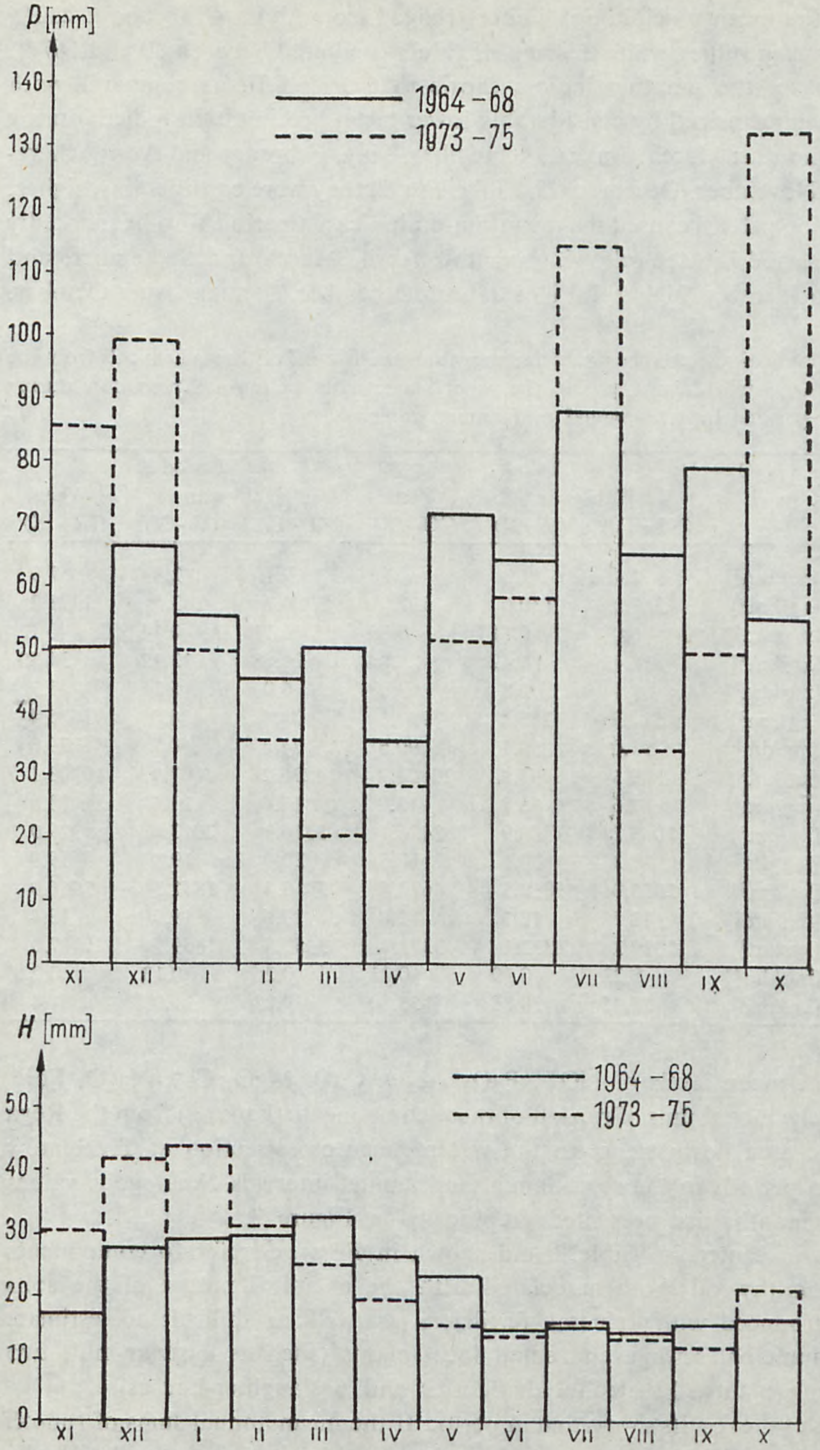


Fig. 2. Mean monthly indices of precipitation (*P*) and run-off (*H*) in the Rega River drainage basin downstream to the water gauge cross-section at Trzebiatów

cular months the mean precipitation indices ranged from about 48 to about 232% of the 25-year mean values, while the run-off values oscillated between 80 and 167%.

An analysis of the monthly indices shows that period II, as compared with period I, was characterized by considerably lower mean precipitation indices during the following months: March, August, September, May, February and April, whereas in October, November, December and July (Fig. 2) they were considerably higher. This precipitation pattern caused the mean run-off indices in period II to be markedly lower than in period I in the following months: April, March and September, and they were considerably higher in November, December, January and October.

Table 2. Mean levels of selected chemicals and mean sums of run-off of these chemicals from the Rega River drainage area downstream to the water gauge cross-section at Trzebiatów during the observation periods in semi-annual and annual intervals

Specification		Period I Half-year (XI - IV)	Period I Half-year (V - X)	Period I Year (XI - X)	Period II Half-year (XI - IV)	Period II Half-year (V - X)	Period II Year (XI - X)
NO_3^-	[mg/dm^3]	2.4	1.3	2.0	9.1	2.8	7.0
	[kg/km^2]	387.3	130.6	517.9	1729.7	263.5	1993.2
P_2O_5	[mg/dm^3]	0.08	0.11	0.09	0.11	0.14	0.12
	[kg/km^2]	12.42	11.42	23.84	21.68	13.12	34.80
K_2O	[mg/dm^3]	3.1	2.8	3.0	6.0	5.2	5.7
	[kg/km^2]	510.9	283.8	794.7	1139.4	486.0	1625.4
CaO	[mg/dm^3]	91.0	90.1	90.6	74.6	60.7	70.0
	[kg/km^2]	14809.3	8994.9	23803.7	14235.2	5667.9	19903.1
MgO	[mg/dm^3]	12.6	13.8	13.0	17.4	21.6	18.8
	[kg/km^2]	2045.2	1380.9	3426.1	3316.9	2013.0	5329.9
Cl^-	[mg/dm^3]	17.3	18.1	17.6	20.0	19.8	19.9
	[kg/km^2]	2815.0	1812.5	4627.5	3815.4	1851.5	5666.9
Na_2O	[mg/dm^3]	12.5	13.3	12.8	17.6	19.9	18.4
	[kg/km^2]	2039.3	1332.1	3371.4	3357.5	1859.5	5217.0
Fe^{3+}	[mg/dm^3]	0.23	0.19	0.21	0.26	0.13	0.22
	[kg/km^2]	36.95	18.85	55.80	49.23	11.91	61.44

Table 2 lists mean levels of NO_3^-, P_2O_5, K_2O, CaO, MgO, Cl^-, Na_2O, Fe^{3+} (mg/dm^3) and the mean sums of run-off of these components (kg/km^2) from the Rega River drainage area downstream to the water gauge cross-section at Trzebiatów during the two periods in the semi-annual and annual intervals. Analogous values for particular months are presented graphically in Figure 3.

The values presented in Table 2 and shown in Figure 3 refer to components leached out from the soil, both associated with the chemical nature of the soils and those introduced with mineral fertilizers as well as difficult to estimate amounts of municipal sewage and small local plants (such as a sugar-mill, two starch-producing plants, 12 alcohol distilleries and 6 slaughter-houses).

An analysis of the results shows that in period II the mean annual sums of run-off of the chemicals and their mean annual levels were higher than in period I. An exception provides CaO, probably owing to the use of various methods to assay this component. In period I the complexometric method [16] was employed, whereas in period II the spectrophotometric method [3]. A similar tendency of variation of the mean levels and run-offs of the chemicals has also been observed for hydrological half-years and for the overwhelming majority of months.

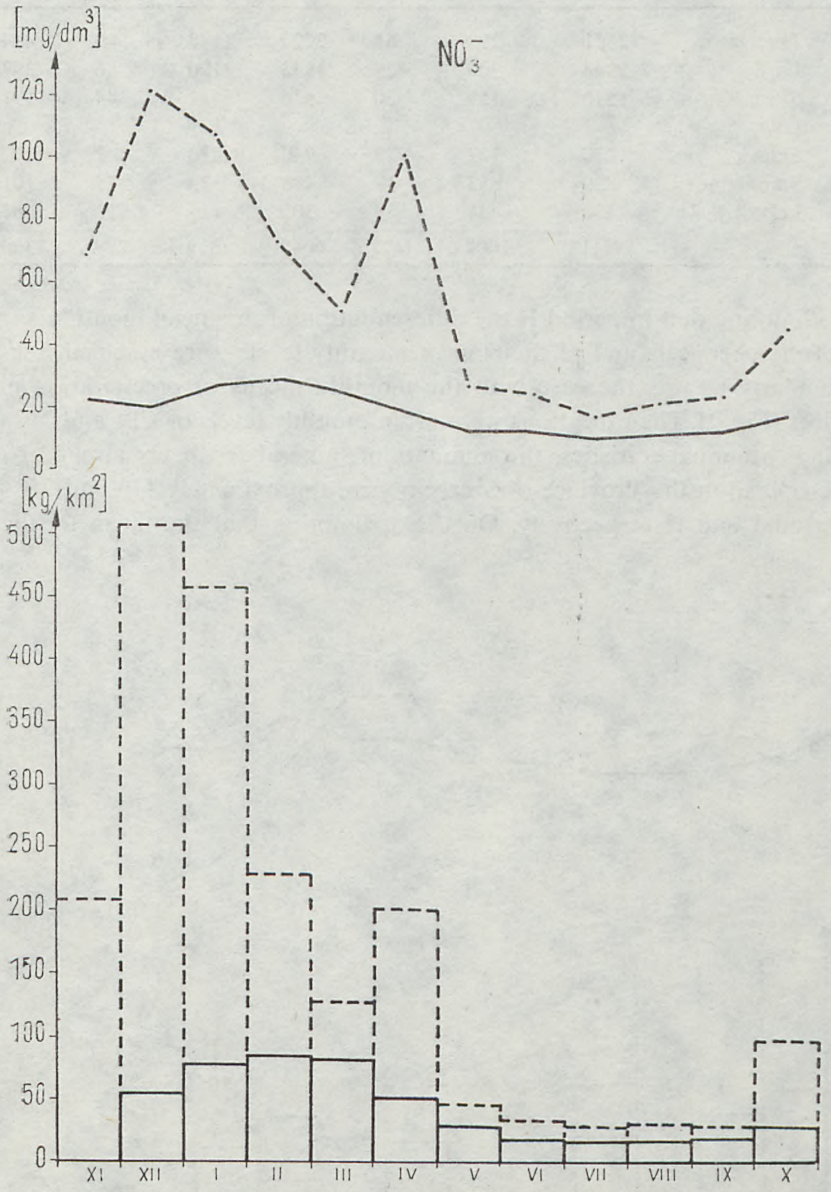


Fig. 3. Denotation as in Fig. 3. p. 75. Mean monthly levels and run-off sums of selected chemicals in the water gauge cross-section of the Rega River at Trzebiatów periods: 1964 - 68 (continuous line), 1973 - 75 (dashed line)

Table 3. Mean annual transport of the components of mineral fertilizers from larger drainage areas of the Western Sea-coast rivers

River	Profile	Area of the drainage basin [km²]	Volume of transport [tones per year] Period I			Period II		
			NO_3^-–N	P_2O_5	K_2O	NO_3–N	P_2O_5	K_2O
Rega	Trzebiatów	2551	298	61	2027	1148	89	4146
Parsęta	Bardy	2944	309	59	1943	1190	86	3974
Wieprza	Stary Kraków	1510	159	30	936	612	44	1914
Słupia	Słupsk	1470	122	29	940	470	42	1923
Łupawa	Smołdzino	830	83	17	498	320	25	1019
Łeba	Lębork	436	31	9	305	119	13	624
Total		9741	1002	205	6649	3859	299	13600

It is worth noting that in period II the differentiation of the mean monthly sums of run-off of the chemicals and of their mean monthly levels were much higher in period I, similarly as was the case with the monthly means of precipitation and run-off indices (Fig. 2). The exceptions were mean monthly levels of Cl^- and Na_2O.

According to annual statistics, the amounts of mineral fertilizers applied to 1 hectare of cropland in the Province of Szczecin were approximately 110 and 250 kg NPK in period I and II respectively. On the assumption that the mean fertilizer

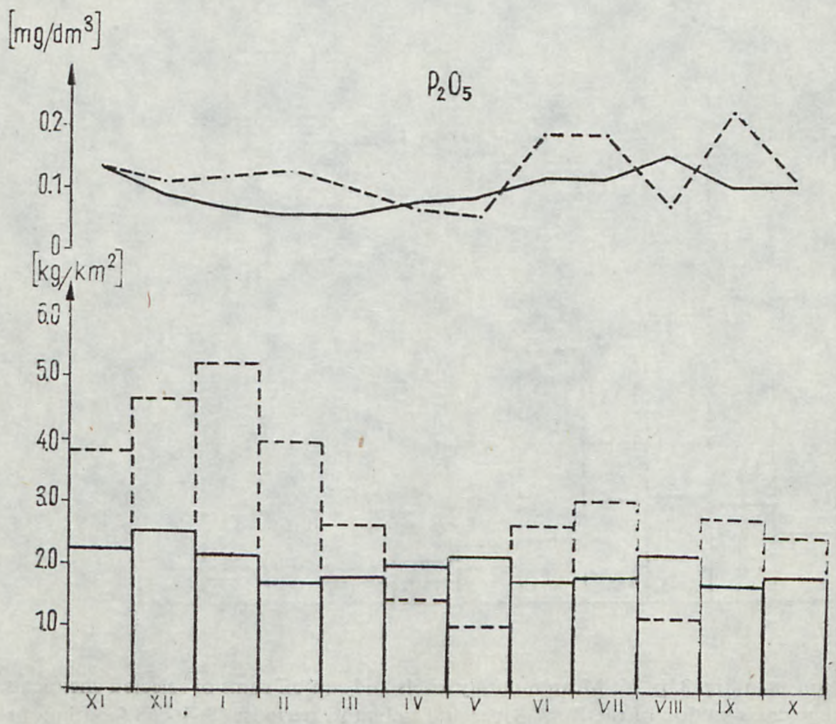
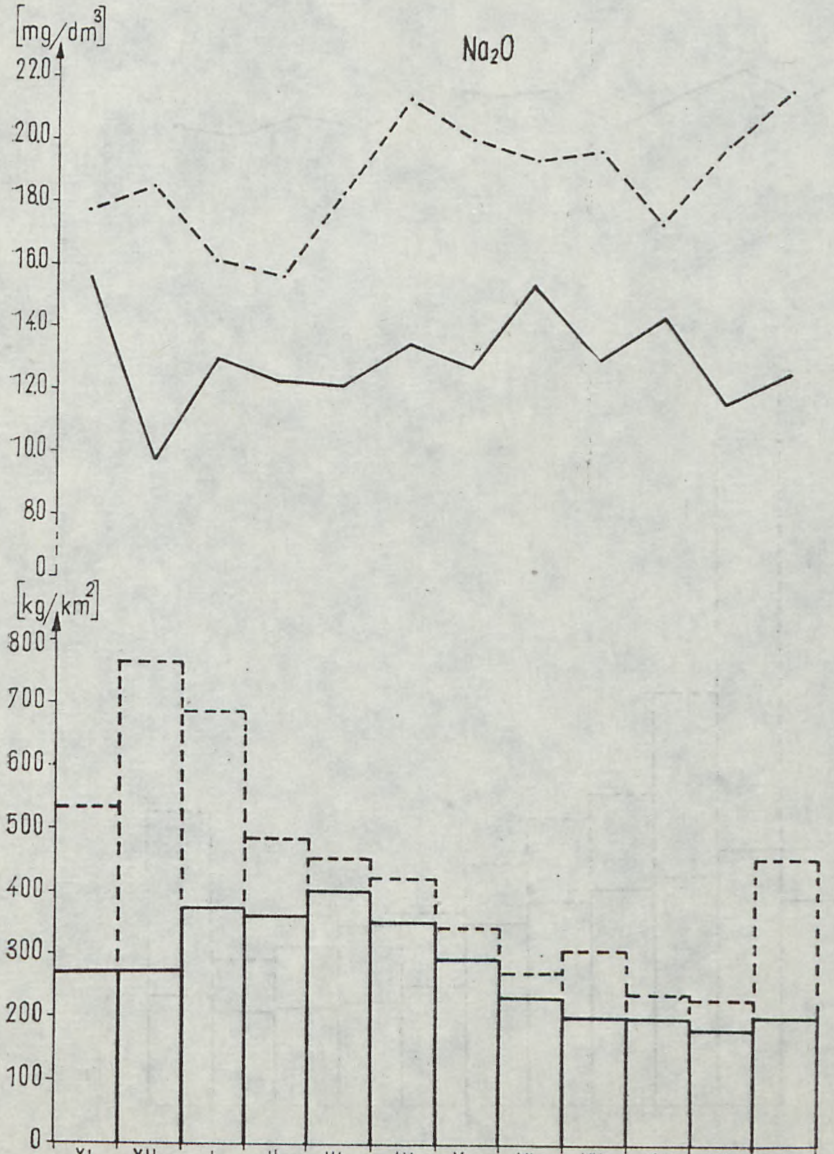


Fig. 3. Denotation as in Fig. 3. p. 75

load applied to croplands in the Rega River drainage basin was similar to that in the whole Province of Szczecin, mean NPK values applied to 1 km² of the area were calculated, which amounted to approximately 9000 and 21 000 kg NPK for periods I and II respectively.

This analysis shows that in the Rega River basin the increase in the fertilizer load by about 130% in period II relative to period I was accompanied by an increase in the mean annual levels and sums of run-off of the chemicals. The highest increase was noted for nitrates, NO_3^- (in concentration by 250% and in run-off by 285%),



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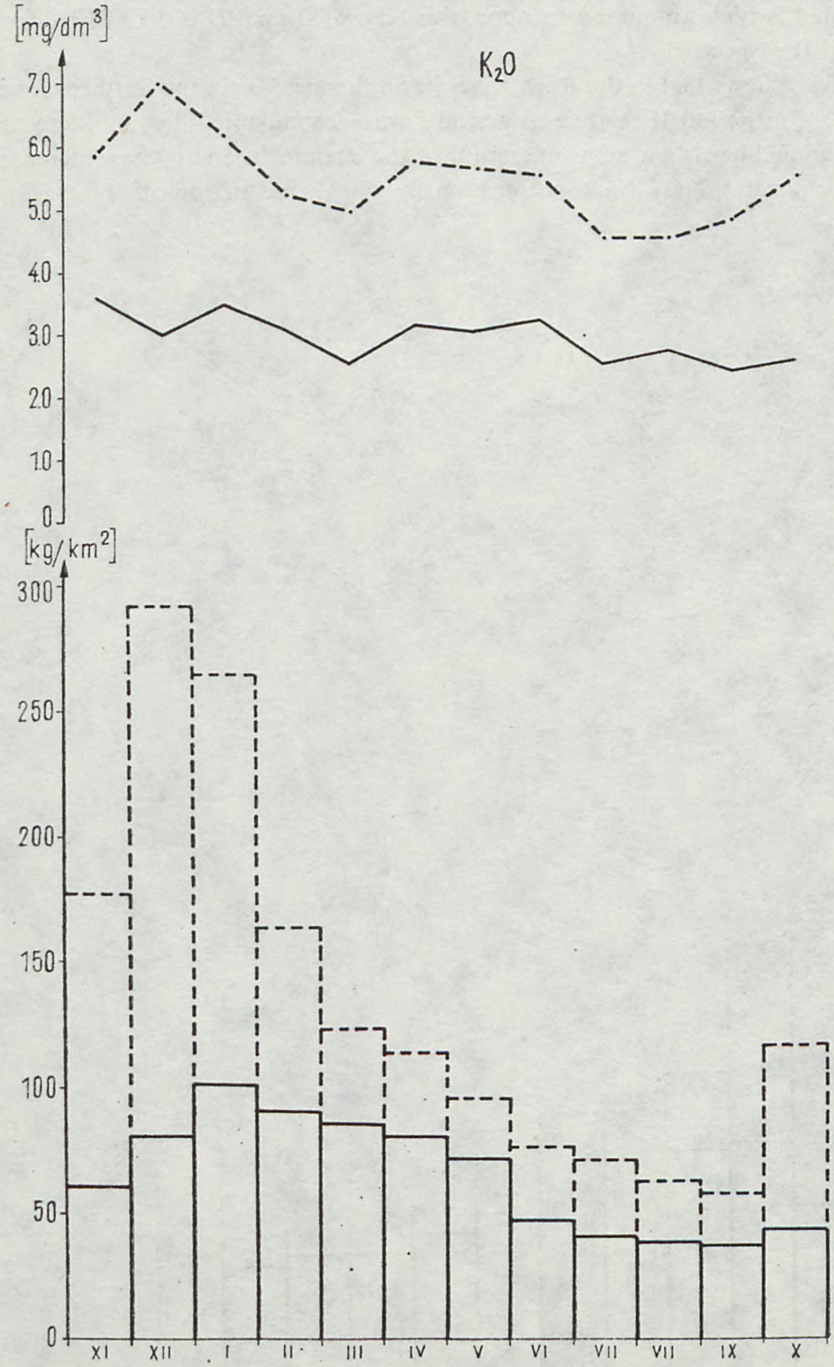

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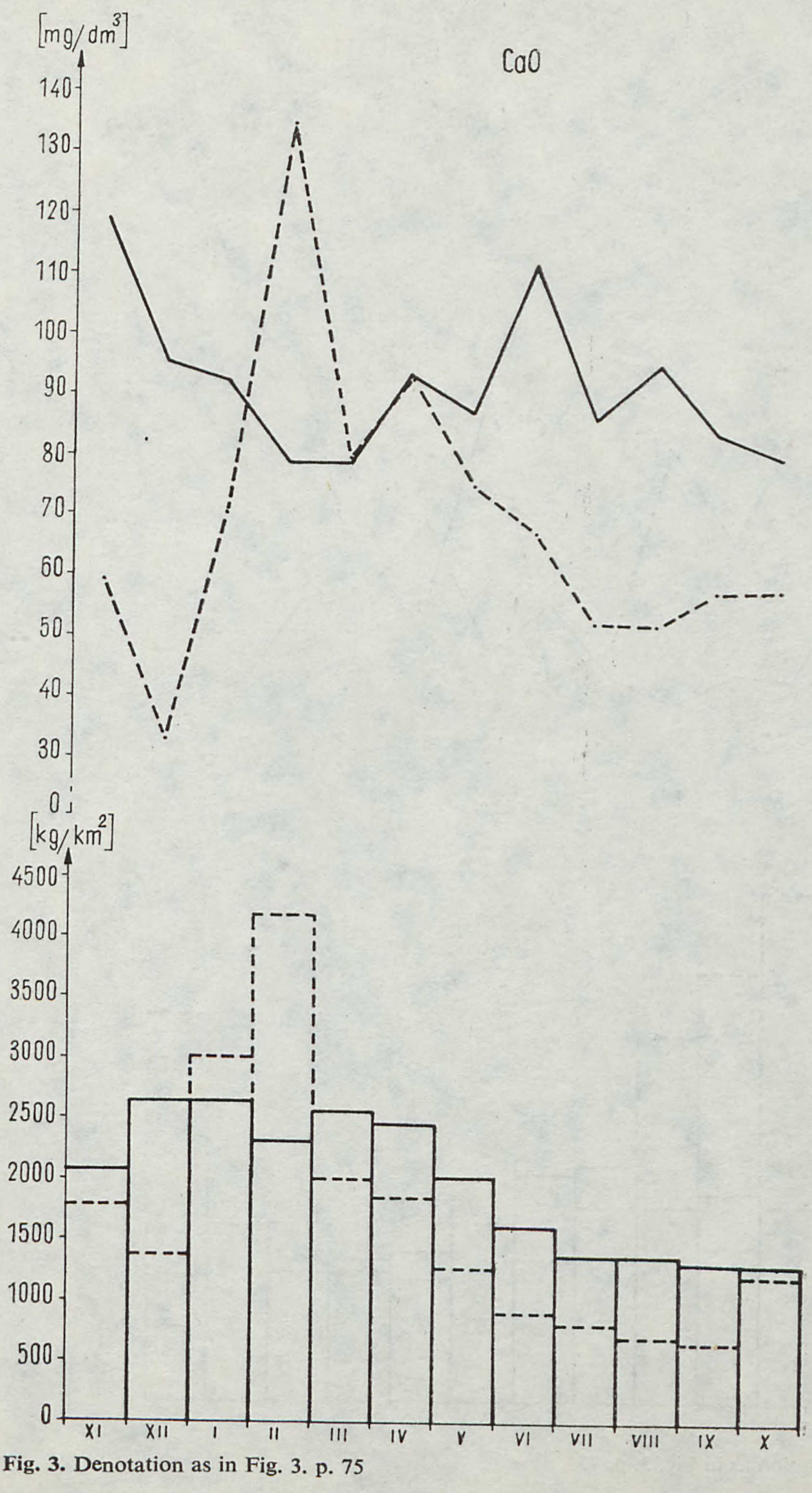

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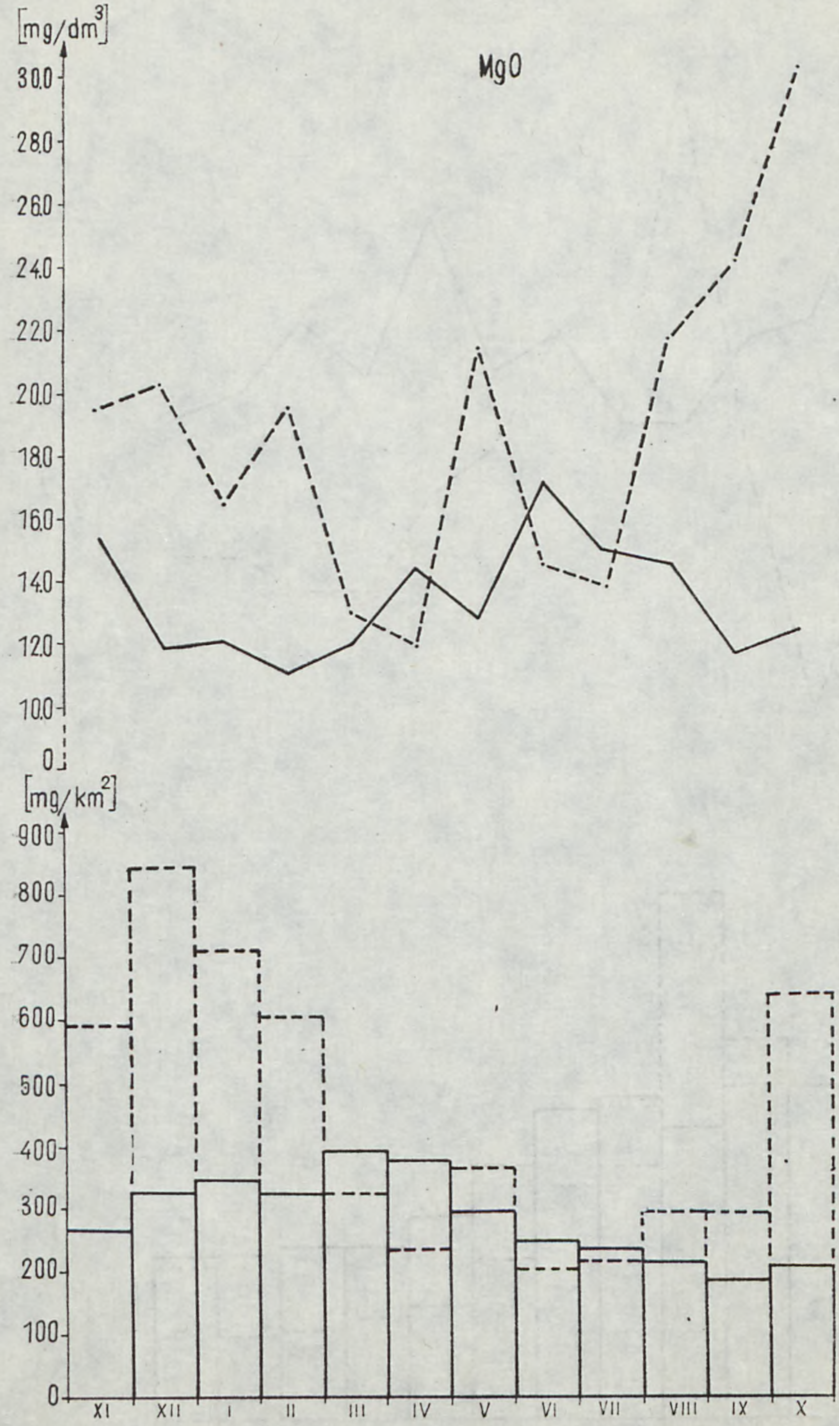

Fig. 3. Denotation as in Fig. 3, p. 75

followed by potassium, K_2O (by 90 and 105% resp.). Increases in the mean annual levels and sum of run-off by 33–45% and by 46–56% respectively was observed for phosphorus (P_2O_5), sodium (Na_2O) and magnesium (MgO). The least pronounced increases were found for iron (Fe^{3+}) and chlorine (Cl^-) – in concentration by 4 –13% and in run-off by 10–22%. The mean annual sum of run-off of the NPK components in period I was 935.44 kg/km² (116.9 kg/km² $NO_3^- - N$; 23.84 kg/km² P_2O_5; 794.7 kg/km² K_2O), whereas in period II the sum was 2110.3 kg/km² (450.1 kg/km² $NO_3^- - N$; 34.80 kg/km² P_2O_5; 1625.4 kg/km² K_2O). This comparison shows

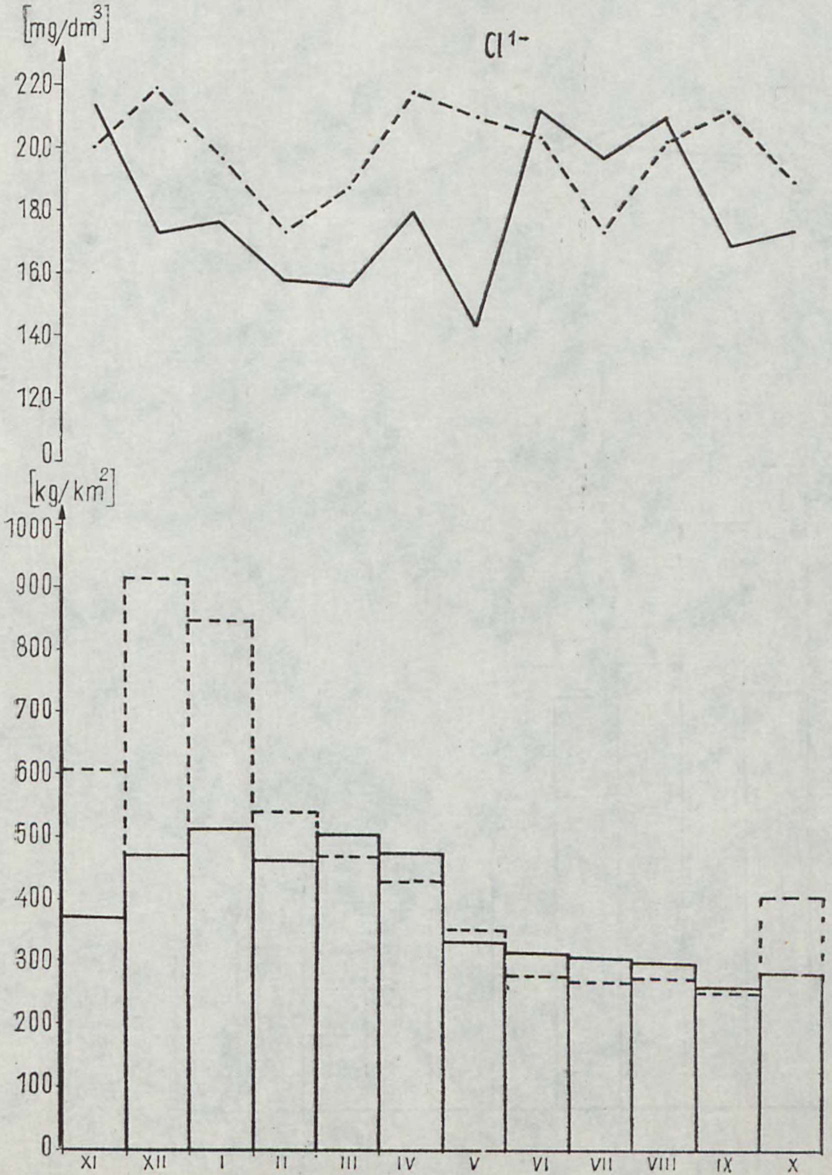

Fig. 3. Denotation as in Fig. 3. p. 75

that the mean annual sum of run-off of NPK constituted approximately 10% of the NPK applied to 1 km² of the drainage area in the form of mineral fertilizers.

In Table 3, the mean annual transport of the fertilizers' components is shown in both periods from larger drainage areas of the rivers of the Western Sea-coast. The values for the Rega River were calculated on the basis of the mean annual sums of run-off listed in Table 2. For the remaining rivers the mean annual transport was calculated as follows: for period I – by utilizing the results published in [16]; for period II – by assuming that the increase in the mean annual run-off of the compo-

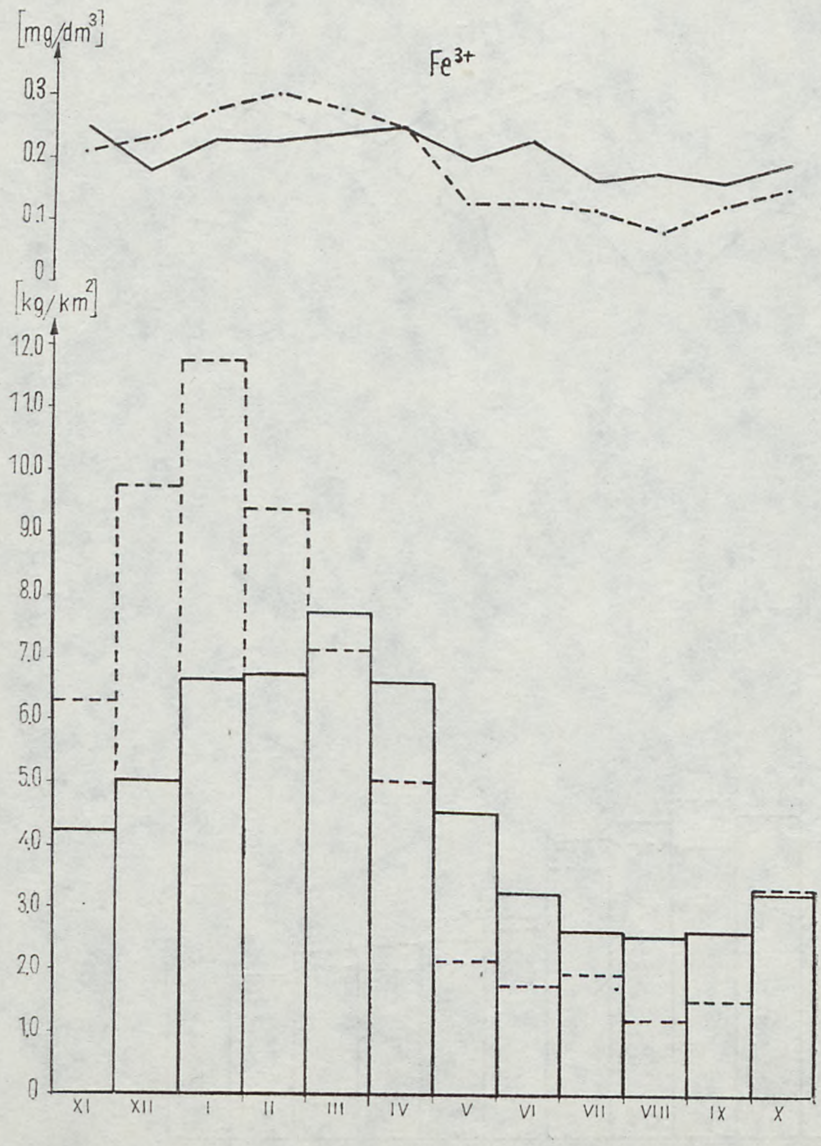

Fig. 3. Denotation as in Fig. 3, p. 75.

nents was the same as in the Rega River drainage area. Hence, the values of the ransport reported for these rivers must be considered as rough estimates.

Table 3 shows that in period II the annual transport of the components from the area (9741 km^2) was as follows: 3859 tons of NO_3^--N, 299 tons of P_2O_5 and 13 600 tons of K_2O. Assuming that on the remaining area of the Western Sea-coast the mean annual sums of run-off of the components in period II matched the mean values from the analyzed area (*i.e.* 396.2 kg/km^2 NO_3^--N; 30.7 kg/km^2 P_2O_5; 1396.2 kg/km^2 K_2O) one may estimate the total annual transport of these components from the whole Western Sea-coast (19 788 km^2) to the Baltic Sea. The calculations gave approximately 7800 tons of NO_3^--N, 600 tons of P_2O_5 and 27 600 tons of K_2O.

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