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UNIT LOADS OF PHOSPHORUS AND NITROGEN DISCHARGED FROM THE DIFFUSE SOURCES OF THE SELECTED WATERSHEDS IN POLAND

Nitrogen and phosphorus discharges from the non-point sources have been investigated in 26 catchment areas characterized by different kind and degree of their land use and by differentiated geomorphological features. Based on the results of one-year and two-year cycles of investigations the unit discharged loads have been determined for nitrogen and phosphorus discharged from the watersheds. An attempt has been also made to define the factors governing the magnitudes of the loads.

1. INTRODUCTION

Definition of the real and potential hazard to the quality of surface water created by various pollution sources is of a basic importance not only for water protection but also for prediction of quality of the existing and planned water resources. One of the most important factors affecting quality of the surface waters and, in particular, the stagnant ones are the nutrients coming from point and non-point pollution sources. Their excessive load may rapidly accelerate the rate of eutrophication process, leading to a rapid deterioration of the quality of the waters, excluding eventually the possibilities of their use for economical purposes.

Technically it is simple to determine the loads of nutrients coming from point sources and to apply the adequate control methods. Depending on the given conditions the admissible surface loading of stagnant waters with nutrients may be, however, so low that all the protecting measures consisting in elimination of loads coming from point sources became insufficient. In such cases the loads coming from non-point sources should be analysed and controlled. And this is a much more complicated problem. By non-point pollution, in contrast to the point one, we mean all those pollutants which penetrate from the area examined into the receiving water body in a spatially more or less uniform way and which are more or less uniformly applied within the whole area.

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The non-point pollution sources include:

natural runoffs of nutrients resulting from erosion and washing of soil from catchment areas which are not affected by economical activity, loads imported by wind and atmospheric precipitations and resulting from biodegradation of vegetation, etc.;

supply of nutrients not related to the point sources of pollution, resulting from human activity, dependent on the extent and the kind of the catchment area use, especially resulting from the application of artificial fertilizers and pesticides.

Thus, non-point pollution sources include non-point supply of substances from soil and atmosphere. In the recent years the contribution of non-point sources to the total loading of waters with nutrients has substantially increased, owing to the intensification of agriculture and due to the increased pollution of atmosphere. The artificial fertilizers and manure, washed down from the catchment area in ever increasing amounts, create the more and more serious hazard for waters. The nutrient load from non-point sources depends on regional conditions, thus on such factors as climate, configuration of the terrain, hydrological conditions, types of soil and the land use in the given region. In many cases the impact of non-point sources, depending on local conditions, may became equivalent to that of point sources or even exceeds it. The magnitude of non-point pollution coming from a catchment area is characterized by the unit pollutant load expressed in kg/ha/year. It is calculated from the annual pollutant load and the area of the watershed.

In order to determine correctly the annual loads of pollutants from non-point sources and to establish the unit pollutant loads some serious methodical and technical difficulties should be as a rule overcome. The difficulties in the analysis of the measurement results are mainly due to the fact that of the whole complex of factors affecting the magnitude of the pollutant loads, a decisive role may be peformed by various factors, not single but, as a rule, in different configurations, depending on the local and real conditions. Therefore, very often the results and conclusions of many authors cannot be confirmed by the investigations conducted in other areas and under different conditions. As a result the data on the unit pollutant load established by various authors vary within a large range or show discrepancies which is also undoubtly due to the differences in the measurement methods applied and sometimes do not allow any comparison or generalization of the data presented by different authors. For this reason sometimes it would seem not advisable to apply the data outside the region for which they have been established and for conditions other than those under which the investigations had been performed.

On the other hand, due to high cost and time consumption as well as to many difficulties in conducting the investigations of this type, very often the real loads cannot be directly determined for the objects investigated and they should be estimated indirectly based on literature data and the watershed characteristics.

Non-point pollutions have become a problem to which more and more attention has been devoted in the recent 20 years (VOLLENWEIDER and DILLON [10]) and which has been the subject of more and more publications, since — according to general opinions — the exports indices can be established only by means of extensive investigations which would allow to grasp all the factors deciding upon their magnitudes. That is why there is a tendency to develop forecasting models; their construction and application require, however, the knowledge of the coefficients of discharge for the separate nutrients (DILLON and KIRCHNER [1]).

2. UNIT LOADS OF PHOSPHORUS AND NITROGEN DISCHARGED FROM THE SELECTED CATCHMENT AREAS CHARACTERIZED BY DIFFERENT LAND USE

In 1973–1980 the department of water resources quality studies of the Institute of Meteorology and Water Management in Wrocław conducted the investigations on the magnitude of non-point pollution loads from 26 catchment areas differing in their characteristics and land use. Research programme included 3 types of catchment areas:

mountain watersheds (FLORCZYK [2]) represented by 9 partial catchment areas: 3 of the river Kamienna (western Karkonosze region), 2 from the river Morawka (Śnieżnik massive), and 4 of the upper river Bystrzyca (Owl Mountains),

submontane watersheds (FLORCZYK [3]) including 5 partial catchment areas of the river Piaseczna (Kaczawa Submontane),

lowland watersheds (GOŁOWIN, FLORCZYK [5]; FLORCZYK [3]) represented by 12 partial catchment areas (3 of the river Obrzyca–Lubuskie Lake District, 3 of the river Sama — Poznań Lake District, 2 of the upper river Noteć Wschodnia, 2 of the Rogalin–Gopło canal, and 2 of Kuśnierz being the tributary of Kujawskie Lake District).

The general location of the catchment areas is presented in fig. 1.

3. METHODS

Phosphorus and nitrogen loads coming from the catchment areas have been determined based on the results obtained from analyses of the samples of waters flowing through the cross-sections closing the partial catchment areas. The analyses have been performed systematically 2–4 times a month. While taking water samples the flow intensities were also measured. To determine the everyday water flow intensities in the cross-sections, the water-level indicators, overfalls and a vessel filling methods were applied depending on the water flow magnitude in a given stream. Water samples were analysed for total phosphorus and nitrogen contents.

Characteristics of the catchment areas examined have been made, based on the existing materials and the direct interview made in the area of interest. The characteristics of the partial catchment areas included: topography, morphology, hydrogeology, hydrography, climate and the way of land use. The data on land use created the basis for the estimation of the total phosphorus and nitrogen load produced and consumed in the catchment areas in a result of human economical activities. Loads produced were established

Fig. 1. Location of the basic watersheds being investigated

1 — the river Kamiena watershed, *2* — the river Morawka watershed, *3* — the river Bystrzyca watershed, *4* — the river Piaseczna watershed, *5* — the river Obrzyca watershed, *6* — the river Sama watershed, *7* — the Eastern Noteć watershed, *8* — watershed of Rogalin–Gopło canal, *8* — watershed tributary near Kuśnierz

Rys. 1. Lokalizacja badanych zlewni podstawowych

1 — zlewnia rzeki Kamiennej, *2* — zlewnia rzeki Morawki, *3* — zlewnia rzeki Bystrzycy, *4* — zlewnia rzeki Piasecznej, *5* — zlewnia rzeki Obrzycy, *6* — zlewnia rzeki Samy, *7* — zlewnia rzeki Noteci Wschodniej, *8* — zlewnia kanału Rogalin–Gopło, *9* — zlewnia cieku spod Kuśnierza

from the determined population density considering the indices defined by LIEBMANN [8] (3.0 g P/capita· day and 12 g N/capita·day) from the animal production volume, considering the indices established by VOLLENWEIDER [9] and HAMM [6] (a horse — 11.4 kg P/y and 76.8 kg N/y, a cow — 7.65 kg P/y and 70.2 kg N/y, a swine — 5.63 kg P/y and 18.93 kg N/y, a sheep — 1.50 kg P/y and 8.93 kg N/y, and a bird — 0.2 kg P/y and 0.55 kg N/y). The magnitude of phosphorus and nitrogen loads introduced by artificial fertilization were determined from statistical data established for the separate catchment areas. The determined magnitudes of annual loads of phosphorus and nitrogen produced and consumed were the basic data for the balance of the nutrient and for determining the unit nutrient loads produced and consumed in separate areas (in $t/km^2/y$). Majority of the selected catchment areas were examined in the closed, two-year cycles, only for some of them the programme was restricted to one year.

The quality of the waters analysed was and their nutrient loads were determined from the relations established between a nutrient concentration and the water flow or between the instantaneous nutrient load and the flow intensity. The latter method has been applied in the cases when no reliable relationship between the pollutant concentration and water flow has been obtained. In this case the annual nutrient loads being the basis for determining the unit nutrient loads were established from the daily water flow measurements in a tributary cross-sections. Based on the daily water flow and on a the relationship between the instantaneous nutrient load and water flow intensity the daily nutrient loads have been determined. The sum of the daily loads calculated for the one-year cycle of investigations was equal to the annual nutrient load. The unit nutrient load was obtained by dividing the annual load by the area of a watershed. From the data obtained, which are exemplified in fig. 2, it follows that the relationship between the nutrient load and

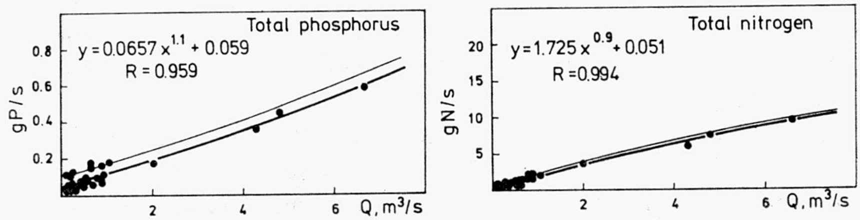

Fig. 2. Phosphorus and nitrogen loads versus flow intensity for the river Eastern Noteć in the cross-section of Mąkoszyn

Rys. 2. Zależności pomiędzy ładunkiem fosforu i azotu a natężeniem przepływu dla wód Noteci Wschodniej w przekroju Mąkoszyn

the water flow could be described by a modified version of a regression model RLQ (Krasnodębski and Dąbrowski, [7], Czapliński and Krasnodębski, 1978) called AREQ (Zięba [11]). In this model it is assumed that the relationship between the load and flow is described by the formula

$$L = a + bQ^{c_{\max}} + \varepsilon$$

where:

ε represents the influence of random factors,

$c_{\max}$ is the value of the exponent (from the sequence of the given exponents) for which the correlation coefficient is the highest,

the coefficients a and b of the regression curve are determined by the least squares method.

For the loads predicted in this way the upper limit of the confidence interval is calculated at the given confidence level $\alpha = 0.05$. This limit is calculated by classical method, i. e. by adding the product of the corresponding quantile of the Studet's distribution and the root of variance to the predicted value of the load.

Having at ones disposal the magnitudes of the daily water flows $x_1, \ldots, x_m$ and knowing the relationship between the load and flow determined from the above formula, the total annual load

$$\mathrm{TAL} = g \cdot \sum_{m=1}^{M} L(x_m)$$

is calculated (where $g = 0.0864$) when TAL is expressed in tons and flow intensity in m^3/s, and M is the number of days in the year.

The relationships between the loads of substances analysed and the flow have been established in each cross-section for the data set from the whole observation period, which was justified by the fact that the configurations of points did not show differences in the separate years, but formed a one common relationship.

4. GENERAL CHARACTERISTICS OF THE CATCHMENT AREAS

The watersheds selected for the investigations aimed at determining the magnitudes of phosphorus and nitrogen loads and assumed as being representatives appeared to be highly differentiated both morphometrically and with respect to the kind and intensity of their management.

The areas of the partial watersheds ranged from 0.9 km^2 to 306.0 km^2, i. e. 1.2 km^2–5.0 km^2 for river Kamienna, 14.3 km^2–17.5 km^2 for river Morawka, 0.9 km^2–128.9 km^2 for river Bystrzyca, 1.6 km^2–11.2 km^2 for river Piaseczna, 16.2 km^2–56.2 km^2 for river Obrzyca, 5.4 km^2–9.6 km^2 for river Sama, 189.9 km^2–306.0 km^2 for river Eastern Noteć, 27.7 km^2–58.5 km^2 for canal Rogalin–Gopło, and 32.8 km^2–42.8 km^2 for the tributary near Kuśnierz.

The average slop of the terrain ranges from 2.5‰ to 218‰. The highest slopes (22‰–218‰) are characteristic of mountain regions, while the lowest slopes occur in lowland ones of the river Eastern Noteć.

The index of the compactness of the catchment area varies from 0.45 to 1.69; the values below 1.05 occurring in lowland regions, those within 1.15–1.68 in the mountain ones and from 1.07 to 1.69 in the submontane watersheds.

The coefficient of the river system density in the separate catchment areas varies from 0.35 km/km^2 (river Obrzyca) to 10.0 km/km^2 (river Kamienna). The variability of this parameter is the following: for mountain catchment areas it ranges from 0.93 km/km^2 to 10.0 km/km^2, for submontane ones from 0.62 km/km^2 to 1.55 km/km^2, and for lowland regions from 0.35 km/km^2 to 1.94 km/km^2.

The percentage of arable lands ranges from 47% to 96%, except for the river Kamienna's watershed, two partial catchment areas of the river Morawka watershed and one of that of the river Bystrzyca where no arable lands exist. The highest percentage of arable lands is stated in the partial catchment area of the river Sama and the canal Rogalin–Gopło (about 96% of arable lands); the lowest one in the mountain regions of the river Bystrzyca watershed (ca 48% of arable lands). In the remaining catchment areas the percentage of arable lands varies from 64.5% to 91.1%.

The percentage of forest within the examined regions is exceptionally differentiated, ranging from 0.2% to 100%. The highest afforestation (97%–100%) occurs in the river Kamienna watershed and in one partial catchment area of the river Bystrzyca region, the lowest one in the watershed of the river Sama. The lowest degree of afforestation is characteristic of submontane and lowland catchment areas, where the forests occupy 0.2% to 37% of the total watershed area.

Weathering soils occur in the partial catchment areas of the rivers Kamienna and Morawka, sandy clay and rocky soils in those of the river Kamienna. Brown earth together with podsol prevail in the watershed of the rivers Piaseczna and Obrzyca. The podsol dominates in the watershed of the river Sama. The catchment areas of the river Eastern Noteć are covered mainly by sandy soild of different types and podsols with a portion of black earth. Within catchment areas of the Rogalin–Gopło canal the prevailing soils are black earth, degraded black and grey earths, whereas within those of the tributary near Kuśnierz the prevailing soils are podsol and pseudopodsol with a high ratio of degraded balck and grey earths.

The arable lands are occupied by 4 grain crops, potatoes and industrial and fodder crops. Except for mountain afforested areas these crops take 6.6%–76.6% of the arable areas of which wheat covers 12.1%–72.2%. The highest percentage of the grounds occupied by fodder and industrial crops (chiefly sugar beetroots) is found in the river Piaseczna's watershed. The index of the population density ranges within 0–167 inhabitants/km^2. Non-settled areas are found chiefly in the mountain afforested regions. The population densities of the watersheds of the rivers Bystrzyca, Piaseczna, Obrzyca, and Sama are highly differentiated amounting to 0–163 inhabitants/km^2, 0–167 inhabitants/km^2, 10–64 inhabitants/km^2, and 12–123 inhabitants/km^2, respectively.

The catchment areas situated in the river Eastern Noteć watershed are characterized by the density population index equal to 84 inhabitants/km^2, in those of the Rogalin–Gopło canal this index ranges within 59–91 inhabitants/km^2, and in the tributary near Kuśnierz — 47 inhabitants/km^2.

The unit phosphorus loads coming from inhabitants, agriculture, and animal husbandry varies from 0 to 55 t P/km^2/y, while in the non-settled areas of the river Bystrzyca it is equal to 0.9–1.1/t P/km^2. In the partial catchment areas of the rivers Piaseczna, Obrzyca, Sama, and Noteć it ranges within 2.2–4.3 t P/km^2/y, 1.9–3.9 t P/km^2/y, 30–35 t P/km^2/y, and 3.1–4.3 t P/km^2/y, respectively. The most uniform phosphorus loads are stated for the unit catchment areas of the river Bystrzyca (except for the forest regions), those of the river Eeastern Noteć, Rogalin–Gopło canal and the underflow of Kuśnierz. The unit nitrogen loads vary from 0 to 132 t N/km^2/y, the highest one occurring in the partial catchment areas of the river Sama (97–132 t N/km^2/y). The unit nitrogen loads in Noteć watershed is only slightly differentiated and for the river Eastern Noteć it amounts to about 12.7 t N/km^2/y, for the Rogalin–Gopło canal — ca 16.5 t N/km^2/y, and for the river tributary area of Kuśnierz — 15.0 t N/km^2/y. In the catchment areas of the river Obrzyca nitrogen loads varies from 6.0 to 15.6 t N/km^2/y, in those of the river Piaseczna from 9.7 to 40.0 t N/km^2/y, and in the catchment grounds of the river Bystrzyca (arable lands included) it ranges within 4.0–5.4 t N/km^2/y.

The highest contribution to the total phosphorus loads falls to the agriculture as a result of artificial fertilizers use, next the animal husbandry, and finally the population. In case of nitrogen load the highest ratio cames from animal husbandry, then from the agriculture, and finally from inhabitants. In general it may be assumed that agriculture and animal husbandry perform the greatest part in the generation of the nutrient loads within the watersheds.

5. UNIT LOADS OF NUTRIENTS

The data presented in table may suggest that the magnitudes of unit loads of nitrogen do not depend so much on the land use within a given catchment area (expressed in percentage of forests and arable lands) but they rather do on the type of the catchment area (mountain, submontane, lowland). The highest unit loads – up to 27.3 kg N/ha/y are found within the mountain regions, irrespectively of the degree of their afforestation and the percentage of arable land. The lowest nitrogen unit loads (0.6–7.8 kg N/ha/y) were

Table

Unit loads of nutrients (P and N) discharged from the catchment areas of a different land use
Wartości współczynników jednostkowego odpływu substancji biogennych (P i N) ze zlewni o różnym zagospodarowaniu

Type of watershed	Basic watershed	Number of watershed	Percentage of arable lands %	Percentage of forets %	Unit loads of nutrients	
					kg P/ha/y	kg N/ha/y
Mountain	river Kamienna	3	—	98–100	0.265–0.393	17.4–27.3
	river Morawka	2	0.7–0.8	60–75	0.267–0.442	16.6–23.6
	river Bystrzyca	1	—	97	0.106	10.9
	river Bystrzyca	3	47–49	43–45	0.109–0.540	7.1–23.3
Submontane	river Piaseczna	5	65–91	5–34	0.044–0.628	2.6–18.4
Lowland	river Obrzyca	3	57–79	12–38	0.040–0.528	0.6–5.9
	river Sama	3	77–96	0–10	0.014–0.300	1.8–4.8
	river Eastern Noteć	2	80–81	10–11	0.081–0.094	1.7–2.0
	river tributary near Kuśnierz	2	83–85	11–13	0.171–0.193	3.0
	Rogalin–Gopło canal	2	95–96	1–1.4	0.550–0.635	6.0–7.8

found for the lowland regions. The submontane areas created the intermediate group (2.6–18.4 kg N/ha/y) characterized by almost the same morphometric parameters, hydrological conditions and kind of subsoil (the main catchment areas of the river Piaseczna). For this group the relationship between the unit nitrogen load and the percentage of arable grounds is expressed by the equation

$$y = 0.131 \times 10^{-8} \times x^{5.19}$$

with the correlation coefficient equal to 0.985, where:

y – unit nitrogen load in kg N/ha/y,

x – the percentage of arable land.

For lowland catchment areas this relationship is some different ($y = 0.912 \times 10^{-5} \times x^{2.88}$) and the correlation coefficient being much lower (0.720). For mountain regions such a relationship has not been established.

Highly diversified values of the unit phosphorus load do not show any close dependence either on the kind of catchment area or on the way of land use. A relationship between the unit phosphorus load and the percentage of arable land has been obtained only for submontane and lowland regions (excluding the results for 2 catchment areas of the river Sama). This relationship, with the correlation coefficient equal to 0.602, is given by the equation

$$y = 0.312 \times 10^{-7} \times x^{3.58}.$$

The highest unit loads, exceeding 0.500 kg P/ha/y, have been established both for some mountain, submontane and lowland catchment areas, the lowest ones (below 0.100 kg P/ha/y) being determined for submontane and lowland regions. The unit loads of nutrient, presented in tab. 1, have been determined assuming the following runoff coefficients: 3723–19779 m^3/ha/y for mountain rivers, 654–3802 m^3/ha/y for submontane rivers, and 393–2078 m^3/ha/y for lowland rivers. The unit loads of the nutrients from the diffuse sources depend first of all on meteorological and hydrological conditions. They depend to a high extent on the intensity of water runoff; this statement is among other confirmed by the high values of correlation coefficients obtained for regression equations describing these relationships.

The annual loads of nutrients discharged from partial catchment areas and calculated on the basis of two-year research cycle are substantially diversified, the differences stated are distinctly correlated with the annual water runoff. They increase with the increasing water runoff. It has been also found that the average annual concentration of these nutrients in the runoff water were kept on the same level, independently of the runoff magnitude. Almost the same values of the average nutrient concentrations even at the higher their annual loads prove that the intensity of the nutrients washout from the soil is the main factor influencing the magnitude of their annual loads from the given catchment area, thereby deciding upon the values of their unit loads. Thus, it follows that depending on the hydrological characteristics the unit loads of nutrients discharge from selected catchment area may be substantially different from the year to the year, though the way of the land use is the same. Therefore it is necessary to determine the magnitudes of the unit loads of nutrients for all the characteristic hydrological years, i. e. for the dry one, the average and the wet.

The search for the relationships between the morphometric parameters and indices characterizing the degree of economical utilization of watershed areas have shown a distinct character of the mountain forest regions. Although they are loaded only with a natural loads of the nutrients, they are characterized by the values of the unit nutrient loads higher or equal to those determined for the watersheds with the intensive agricultural activity. This phenomenon should be ascribed to a high extent to the nutrients loads coming from atmospheric precipitation. The investigations on the nutrient contents in the rain water which were conducted in the watershed of the river Kamienna have shown that quantities of the nutrients imported into a catchment area amount to about 2.1 kg P/ha/y and to about 42.4 kg N/ha/y. In the case of mountain regions covered with forests it has been stated that hydrological conditions exert a distinct effect on the unit loads of nutrients which explicitely depends (fig. 3) on the unit water runoffs (expressed in $m^3/km^2/y$).

Excluding the results obtained for mountain aforested regions, a distinct relationship between the unit loading of the catchment area with phosphorus and nitrogen and the coefficients of these nutrients discharge has been stated. As it follows from figs. 4 and 5, three separate relationships may be distinguished for the three following groups of watersheds, i.e. the mountain ones, the most of the lowland ones used for agricultural purposes, and for that of the river Sama. The detailed analysis of the characteristics of

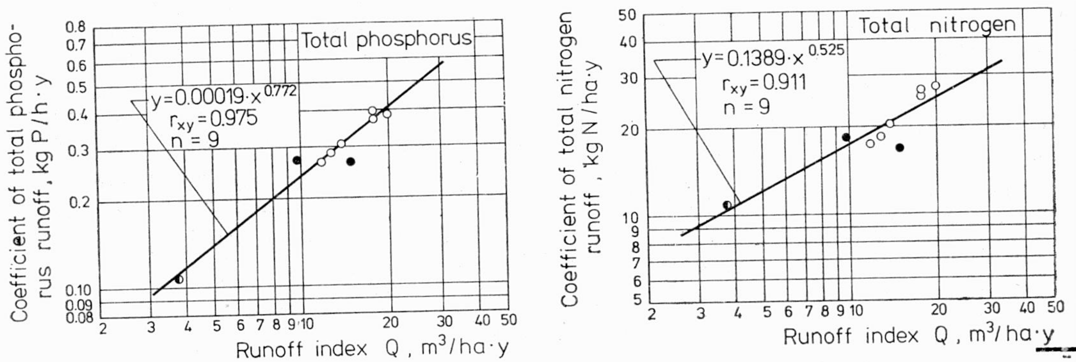

Fig. 3. Unit water runoff versus phosphorus and nitrogen unit loads discharged from mountain aforested regions

Rys. 3. Zależność pomiędzy jednostkowym odpływem wód a wielkością współczynników odpływu i azotu dla górskich zlewni leśnych

the separate catchment areas has shown the distinct differences in the type of subsoil and hydrogeological conditions. It should be noted that each distinguished group include catchment areas of similar characteristics of their subsoil. Thus, it may be assumed that the obtained curves represent the relation characteristic of the following catchment areas: 1) non-impermeable subsoil, 2) intermediatory permeable subsoil, 3) readily impermeable subsoil.

The same classification, including three identical groups of watersheds has been obtained for the relationship between the loads of the nutrients originating and consumed in a catchment area and that discharged from it (the loads are expressed in tons of P and N/y). These relationships of a very high significance level show that the volume of phosphorus and nitrogen runoffs from the catchment areas being investigated depends also on the total volume of load contained within the catchment area. In case of phosphorus the highest losses were stated for mountain catchment areas (1.2%–3.7%). For submontane watersheds they range from 0.2% to 1.7%, most of the result obtained osscillate within 1%. For lowland regions the phosphorus losses vary from 0.005% to 1.6%, in most cases not exceeding 0.7%.

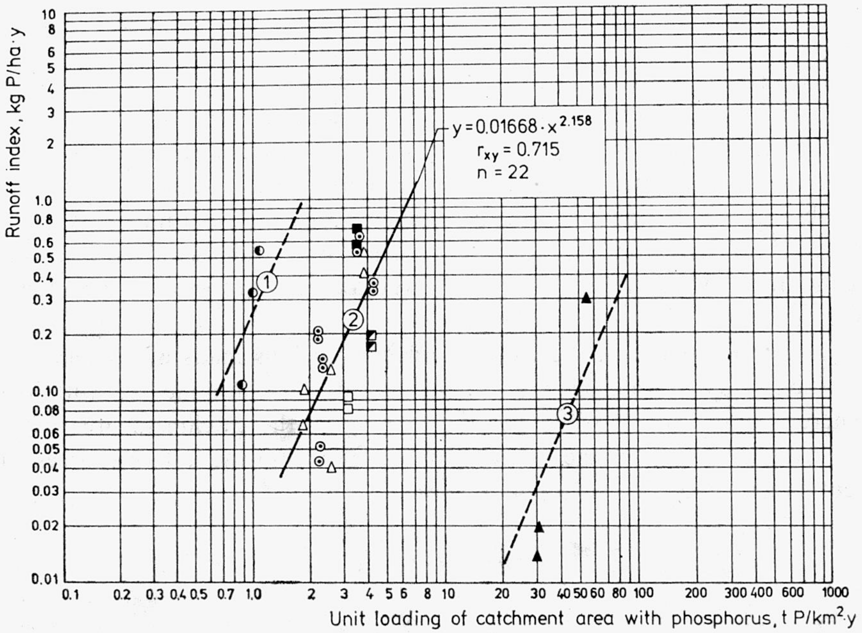

Fig. 4. Coefficient of catchment area loading with phosphrous versus unit load discharged

Rys. 4. Zależność pomiędzy współczynnikiem obciążenia zlewni a współczynnikiem odpływu z niej fosforu

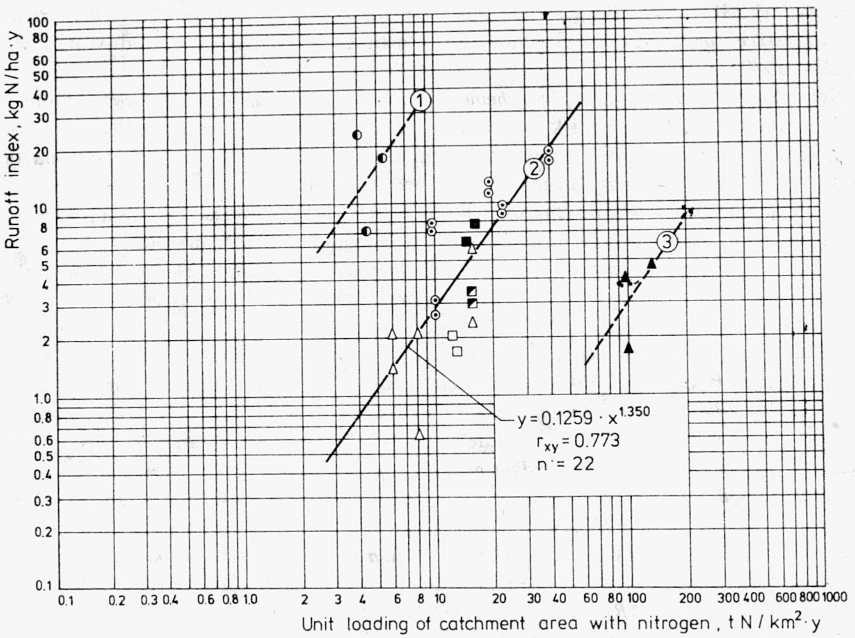

Fig. 5. Coefficient of catchment area loading with nitrogen versus unit load discharged

Rys. 5. Zależność pomiędzy współczynnikiem obciążenia zlewni a współczynnikiem odpływu z niej azotu

6. CONCLUSIONS

1. The investigations conducted in 26 partial catchment areas, characterized by different morphometric parameters, differentiated types of soil, subsoil, and the way of land use, have shown that the volume loads of nutrients discharged from the diffuse sources within the watersheds depend first of all on meteorological and hydrological conditions, type of subsoil, and the loading of the catchment area with the nutrients.

2. There is no correlation between the percentage of arable lands and the concentrations of the nutrients in the runoff water as well as their unit loads discharged from the catchment areas.

3. It has been stated that the annual and instataneous loads of phosphorus and nitrogen in the rivers examined are the function of water flow and increase with its increase.

4. There is a relationship between the loading of the catchment area with the nutrients and the unit loads of the nutrients discharged from the diffuse sources within the catchment areas of a similar type of subsoil.

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WSPÓŁCZYNNIKI JEDNOSTKOWEGO ODPŁYWU FOSFORU I AZOTU Z WYBRANYCH ZLEWNI OBSZARU POLSKI

Zbadano odpływ fosforu i azotu w 26 zlewniach charakteryzujących się różnym rodzajem i stopniem zagospodarowania oraz zróżnicowanymi cechami geomorfologicznymi. Na podstawie wyników badań wykonanych w cyklach rocznych i 2-letnich określono jednostkowe współczynniki odpływu fosforu i azotu oraz dokonano próby określenia czynników decydujących o wielkości tego odpływu.

BEIWERTE DER SPEZIFISCHEN PHOSPHOR- UND STICKSTOFFABFLÜSSE VON AUSGEWÄHLTEN FLUSSEINZUGSGEBIETEN POLENS

Untersucht wurden die abfliessenden Phosphor- und Stickstoffmengen an 26 Einzugsgebieten, die auf verschiedene Weise und mit differenzierter Intensität genutzt werden und sich geomorphologisch voneinander unterscheiden. Anhand der Versuche, die in Jahres- und 2-jährigen Zeitperioden durchgeführt wurden, sind die spezifischen P- und N-Mengen berechnet worden. Es wurde zugleich ein Versuch gemacht, die beeinfliessenden Faktoren eindeutig zu bestimmen.

КОЭФФИЦИЕНТЫ УДЕЛЬНОГО СТОКА ФОСФОРА И АЗОТА ИЗ ИЗБРАННЫХ БАССЕЙНОВ ТЕРРИТОРИИ ПОЛЬШИ

Исследован сток фосфора и азота в 26 бассейнах, характеризующихся различным видом и степенью освоения, а также дифференцированными геоморфологическими особенностями. На основе результатов исследований, проведенных в годовых и двухлетних циклах определены удельные коэффициенты стока фосфора и азота, а также была предпринята попытка определить факторы, решающие величину этого стока.