ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 17, No. 6 2010

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IMPACT OF LAND USE METHOD IN A CATCHMENTS AREA ON THE DYNAMICS OF THE NITROGEN COMPOUNDS IN THE OUTFLOWING WATER

WPŁYW SPOSOBU UŻYTKOWANIA ZLEWNI NA DYNAMIKĘ ZWIĄZKÓW AZOTU W WODACH ODPŁYWAJĄCYCH

Abstract: Research on the impact of catchments land management on the concentration of the nitrogen compounds ($N\text{-}NO_3$, $N\text{-}NO_2$ and $N\text{-}NH_4$) in the runoff water was conducted in the years 2005–2007. An investigation was made into the water being discharged from the catchments areas located in the foothill terrains of the Malopolska region, which were utilised as forest, agricultural land and rural settlement. An analysis of the concentrations of investigated indicators proves that differences exist both among the studied sites as well as differences which occur within the sites between the winter and summer periods.

In the outflowing water from the catchment area used as forest, $N\text{-}NO_3$ concentration varied in the range of 0.124 to 9.024 mg · dm^{-3}. In the water discharged from the catchment area utilised as typical agricultural land, the concentrations of nitrates(V) were in the range of 0.145–10.397 mg · dm^{-3} and in the case of water flowing from the catchment area used as rural settlement, the concentrations were in the range of 0.934–11.487 mg · dm^{-3}. The concentrations of nitrates(III) in the outflowing water from the catchment area utilized as forest varied in the range of 0.003 to 0.146 mg · dm^{-3}, while in the water discharged from the typical agricultural area the concentrations were in the range of 0.020–0.404 mg · dm^{-3} However, in the case of the water flowing from the area of rural settlement nitrate(III) concentrations were in the range of 0.050–0.811 mg · dm^{-3}. The concentrations of $N\text{-}NH_4$ in water flowing from the catchment area used as forest, varied from 0.008 to 0.189 mg · dm^{-3}, and similarly ammonia concentrations in the water originating from agricultural land were at the level of 0.113–9.169 mg · dm^{-3} respectively. But in the case of water coming from the area of rural settlement they were in the range of 0.310–5.698 mg · dm^{-3}.

Keywords: catchments land use, nitrate compounds, water quality

Under natural conditions, the chemical composition of water is determined by substances of natural origin. Changes in water quality are caused by its contact with the atmosphere, land surface and underground layer. Apart from the leaching process of the rock and the soil, the significant impact on the ion concentrations in the surface water of

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agricultural catchments play anthropogenic impact eg the quantity of the compounds supplied on their surface, together with dry and wet precipitation as well as the transformations caused by anthropogenic activity, including land use method. It has been increasingly established that agricultural activity is also a source of water pollution [1]. The biogenic substances discharged into the water from agricultural areas, which determine the quality of these resources, can originate from spatial agriculture production as well as from the farm buildings [2, 3]. The objective of this work was to assess the impact of the method of using land in a catchments area on the concentrations of nitrogen compounds ($N\text{-}NO_3$, $N\text{-}NO_2$ and $N\text{-}NH_4$) in the water which drains these catchments.

Material and methods

The field studies were conducted from November 2005 to October 2007 within two meso-regions, eg the Bochenski and Wisnicki Foothills [4], in the Malopolska region, the district of Bochnia (Bochnia and Nowy Wisnicz commune) and the district of Brzesko (Brzesko commune). Based on results by the direct method the quality of the water was assessed and classified according to the regulations established by the Minister for the Environment [Official Journal No. 32 posit. 284 from March 1st 2004]. For this purpose three streams were chosen which drain the area eg agricultural land, rural settlements and forested areas, and from which water samples were subjected to physical-chemical analyses, determined nitrates(V), nitrates(III) and ammonia by the flow method of colorimetric analysis.

Catchment area with typical forest character (Site Zl)

The catchment area of 247.07 ha is located in the terrain of the Bochnia commune. The length of the principal stream is about 2.7 km. Its source is situated at an elevation of 330 m a.s.l. and the sampling point is at an altitude 260 m a.s.l. The principal part of the area (47.40 %) is characterized by slopes in the range of 5–10 %. The slopes above 15 % are represented in the small area of the catchment, and this area is mainly forestland. 75 % of the catchment area is used as a forest with pine trees being the dominant species. Agricultural land occupies 23 % of the basin and majority lies in upper part of the catchment area. In these forestlands brown leached, brown acid, podsols and gley soils can be found.

Catchment area with typical rural settlement character (Site Zz)

The catchment area covers s 598.21 ha. The length of the main stream is about 4.5 km. In the terrain of the basin, land slopes within the range of 5 to 10 % are prevalent (37.58 %), however, the land with slopes (10–15 %) occupies 25.53 %. 71 % of the catchment area is used for agriculture, mainly for grain crops. 19 % of the catchment area is covered by forestlands which have pine and beech trees as a dominant species and these are located in the southern part of the basin. A large number of built-up areas belonging to the town of Jadowniki are located in the lower part of the catchment area.

In the agricultural areas brown leached soils, brown acid proper and podsols soils can be found.

Catchment area with typical agricultural character (Site Zr)

The catchment area is 130.25 ha. The length of the main stream, whose source is situated at an elevation of 320 m a.s.l., amounts to about 2.7 km. The water sampling point is located at an altitude of 220 m a.s.l. The prevailing part of the basin area (81.56 %) consists of the terrain with slopes in the range of 0–10 %. 93 % of the catchment area is used for agriculture. The major part, which constitutes 81 % of the catchment area, is occupied by arable lands. The catchment area is covered mostly by brown proper soils. The remaining part is made up of brown acid soils and podsols.

Results and discussion

Nitrates(V)

The distribution analyses of nitrate(V) concentrations in the water of the studied sites, confirm that differences exist among the sites in relation to each other, as well as the fact that differences exist within each site over particular months of the period in which this study took place. During the time of research, nitrate(V) concentrations registered in outflowing water from the catchment area used for agriculture (Zr), were at the level 0.145–10.397 mg · dm^{-3}. In the case of water flowing from the catchment area used as rural settlement (Zz), $N\text{-}NO_3$ concentration levels in the whole research period, were in the range of 0.934–11.487 mg · dm^{-3}. Whereas, the average concentrations of $N\text{-}NO_3$ in the outflowing water from the catchment area used as forest (Zl) amounted to 2.63 mg · dm^{-3} and varied in the range of 0.124 to 9.024 mg · dm^{-3}. The highest values were recorded in February and March, however, it was during the summer period that the lowest concentrations of $N\text{-}NO_3$ were predominant. Over the whole investigation period, this water was seen to contain lower levels of $N\text{-}NO_3$ concentration than the water being discharged from the area with a typical agricultural character (Tables 1, 2).

Nitrates(III)

Nitrate(III) concentrations, which in this period of research were recorded in outflowing water from the area with a typical agricultural character (Zr), vary in the range of 0.020–0.404 mg · dm^{-3}. The highest levels of $N\text{-}NO_2$ concentrations were observed over the period from May to September, with the lowest levels being recorded in the winter months. In the case of water coming from the terrain where a typical rural settlement (Zz) is located the levels of concentration over the whole research period were in the range of 0.050–0.811 mg · dm^{-3}. The distribution of the concentrations in particular months was similar to that for the water draining the agricultural terrain. The water flowing from the rural settlement area was characterised by a significantly higher concentration of $N\text{-}NO_2$. And in the water discharged from the catchment area used for forest (Zl), $N\text{-}NO_2$ concentration varied in the range of 0.003 to 0.146 mg · dm^{-3}. In the

whole research period, water flowing off the catchment area used for forest was characterized by low levels of $N\text{-}NO_2$ concentrations, lower than in the water discharged from typical agricultural land and rural settlements (Tables 1, 2).

Ammonia

In this period of research, the concentrations of ammonia ($N\text{-}NH_4$) recorded in the catchment area used as typical agricultural land, (Zr) were at the level of 0.113–9.169

Table 1

The statistical significance of the average concentrations of biogenic chemical indicators in water flowing from the areas: typical agricultural (site Zr), rural settlement (site Zz) and forest (site Zl)

Treatment	Mean	*SD*	Remainder	Student *t*-test	*p*
Nitrates(V)					
Zr	4.21	2.85	2.56**	–3.019	0.004
Zz	6.77	3.02			
Zr	4.21	2.85	1.58	1.942	0.058
Zl	2.63	2.80			
Zz	6.77	3.02	4.14**	4.929	0.000
Zl	2.63	2.80			
Nitrates(III)					
Zr	0.14	0.11	0.13*	–2.515	0.015
Zz	0.27	0.23			
Zr	0.14	0.11	0.10**	4.202	0.000
Zl	0.04	0.04			
Zz	0.27	0.23	0.23**	4.824	0.000
Zl	0.04	0.04			
Ammonia					
Zr	3.00	2.94	1.14	1.741	0.088
Zz	1.86	1.31			
Zr	3.00	2.94	2.93**	4.888	0.000
Zl	0.07	0.05			
Zz	1.86	1.31	1.79**	6.707	0.000
Zl	0.07	0.05			

Explanations: Zr – catchment area used as typical agricultural land, Zz – catchment area used as a rural settlement and agricultural land, Zl – catchment area used as forest, *SD* – standard deviation, *p* – probability level, * – statistically significant at $p < 0.05$, ** – statistically significant at $p < 0.01$.

Table 2

The average seasonal levels of factors indicating the quality of water discharged from catchment areas of various usages

Parameters	Treatment	Period					
		XII–II	III–V	VI–VIII	IX–XI	XI–IV	V–X
Nitrates(V) [mg · dm^{-3}]	Zr	6.10	4.57	3.43	2.76	5.10	3.22
	Zz	6.98	7.10	6.89	6.11	7.00	6.54
	Zl	4.40	3.35	1.68	1.07	4.04	1.22
Nitrates(III) [mg · dm^{-3}]	Zr	0.079	0.115	0.215	0.138	0.071	0.203
	Zz	0.085	0.225	0.531	0.229	0.093	0.441
	Zl	0.060	0.046	0.032	0.015	0.043	0.033
Ammonia [mg · dm^{-3}]	Zr	0.270	4.850	5.490	0.235	0.364	2.256
	Zz	1.076	2.651	1.650	1.773	0.810	1.452
	Zl	0.027	0.025	0.041	0.142	0.08	0.052

Explanations as in Table 1.

mg · dm^{-3}. The lowest levels were observed during the winter months, and the highest in the summer periods. In the case of water flowing off an area of rural settlement (Zz), the concentration levels varied in the range of 0.310–5.698 mg · dm^{-3} over the whole investigation period. But in the catchment area which is used as forest (Zl), N-NH_4 concentrations in the water varied in the range of 0.008 to 0.189 mg · dm^{-3}. And over the whole research period this water was characterized by manifold lower concentration levels of N-NH_4 than in the water being discharged from the terrain used as typical agricultural land (Tables 1, 2).

Visibly higher concentration levels of nitrates(V), nitrates(III) and ammonia in water flowing from the typical agricultural area can be recognized as being the result of agricultural activity, however, we should also link the higher concentration levels in the water coming from rural settlement areas with inappropriate wastewater management. The distinct increase in chemical compound concentrations in water flowing off the terrain where a compact built-up area is located, when compared with water from typical agricultural and forested areas is confirmed by research conducted by Pijanowski and Kanownik [5–7]. Also Koc et al [8, 9] when analysing the concentrations of selected chemical compounds in water coming from rural settlement and forest areas found that rural settlement played a dominant role in providing chemical compounds to the water. This finding supports the results obtained in this work. Rajda and Natkaniec [10] when comparing selected compounds in the water flowing from a catchment area characterised by typical agricultural and rural settlements confirmed that rural settlements increased their concentrations particularly in the case of N-NO_2, N-NH_4 and P-PO_4. Quality analysis by the direct method proved that the factors which lowered the water quality the most were biogenic compounds. In the case of water draining typical agricultural land its quality was decreased the most by ammonium and nitrate(III) – to

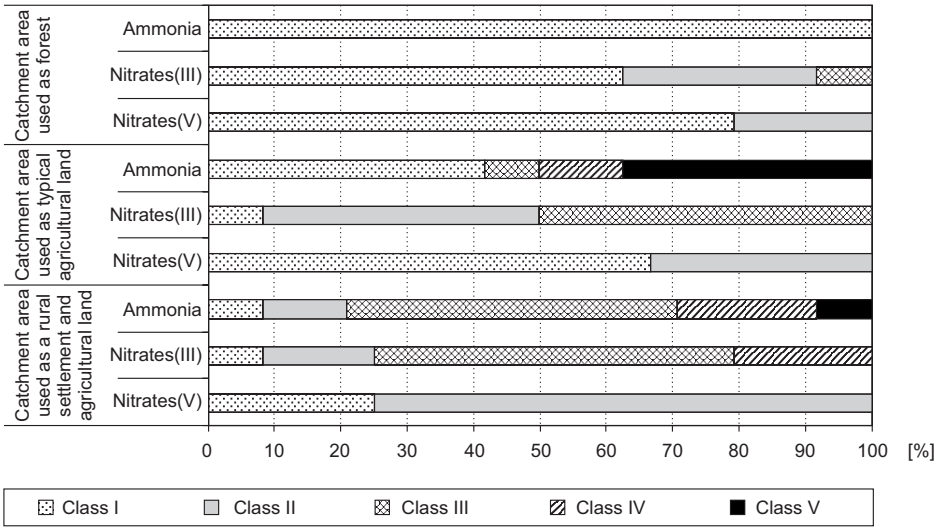

Fig. 1. Distribution of the frequency [%] of biogenic indicators of the quality of water flowing from the studied areas, characteristic for each class

the 4th class of water cleanness. The quality of water in streams flowing from the wooded areas was determined by biogenic compounds (maximum level of the 2nd class). And on the basis of a direct quality assessment of single water samples, it was found that only water flowing from forestland can be qualified as being of the 1st class of cleanness (Fig. 1).

Conclusions

1. The land use method has a significant impact on the concentration of nitrogen compounds in the surface water. Decisively, the lowest contents of investigated indicators in runoff water from a forest confirm the fact that wooded land establishes a biological barrier which limits the migration of nitrogen compounds to the surface water.

2. The principal source responsible for increasing the nitrogen compound concentration in the surface water of rural areas are pollutants originating from settlement areas. This is caused mainly by inefficient wastewater management.

3. This research has also shown the occurrence of seasonal changes in the investigated indicators over particular months, seasons as well as over a half-year period. The reduction in the concentration levels of respective compounds, together with the beginning of the growing season can be explained by the increased absorption of chemical elements by the vegetation cover.

4. On the basis of water classification, it can be assumed that increasingly its quality is being lowered by the proximity of rural settlement areas, subsequently by typical agricultural land and is most definitely least affected by forest. The significant impact

on the decrease in water quality in typical agricultural areas, particularly in rural settlements, is shown by biogenic indicators.

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WPŁYW SPOSOBU UŻYTKOWANIA ZLEWNI NA DYNAMIKĘ ZWIĄZKÓW AZOTU W WODACH ODPŁYWAJĄCYCH

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Abstrakt: Badania wpływu sposobu zagospodarowania zlewni na stężenia związków azotu ($N\text{-}NO_3$, $N\text{-}NO_2$ i $N\text{-}NH_4$) w wodach odpływających prowadzono w latach 2005–2007. Analizie poddano jakość wód odpływających z położonych w terenach podgórskich woj. małopolskiego zlewni o użytkowaniu: leśnym, rolniczym i osadniczo-rolniczym.

Analiza stężeń badanych wskaźników pozwala stwierdzić ich zróżnicowanie zarówno pomiędzy badanymi obiektami, jak również w czasie, głównie między okresem zimowym a letnim. W wodach odpływających z terenu zlewni o użytkowaniu leśnym stężenia $N\text{-}NO_3$ wahały się w przedziale od 0,124 do 9,024 mg · dm^{-3}. W wodach odpływających z terenu zlewni o użytkowaniu typowo rolniczym stężenia azotanów(V) mieściły się w granicach 0,145–10,397 mg · dm^{-3}, a w przypadku wód odpływających ze zlewni o użytkowaniu osadniczo-rolniczym w przedziale 0,934–11,487 mg · dm^{-3}. Stężenia azotanów(III) w wodach odpływających ze zlewni o użytkowaniu leśnym wahały się w przedziale od 0,003 do 0,146 mg · dm^{-3}, w wodach odpływających ze zlewni o użytkowaniu typowo rolniczym w granicach 0,020–0,404 mg · dm^{-3}, natomiast w przypadku wód odpływających z terenu o użytkowaniu osadniczo-rolniczym w przedziale 0,050–0,811 mg · dm^{-3}. Stężenia $N\text{-}NH_4$ w wodach odpływających z terenu zlewni o użytkowaniu leśnym wahały się od 0,008 do 0,189 mg · dm^{-3}, w wodach odpływających z terenu zlewni użytkowanej rolniczo kształtowały się na poziomie 0,113–9,169 mg · dm^{-3}, a w przypadku wód odpływających z terenu o użytkowaniu osadniczo-rolniczym w przedziale 0,310–5,698 mg · dm^{-3}.

Słowa kluczowe: użytkowanie zlewni, związki azotu, jakość wód