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ProEnvironment

ProEnvironment 8 (2015) 201 - 206

Original Article

Impact of Different Elements of Agricultural Landscape on the Removal of Nitrogen Forms from Ground Water

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Received 20 April 2015; received and revised form 15 May 2015; accepted 20 May 2015
Available online 20 June 2015

Abstract

The function of the elements of the agricultural landscape: two shelterbelts of different age and the composition of plants, and peatland for the control of the spread of nonpoint pollution in ground water between ecosystems were evaluated. In ground water under shelterbelts and adjoining cultivated fields, and peatland - pH, content of total nitrogen (N_{total}), nitrates ($N\text{-}NO_3^-$), ammonium ions ($N\text{-}NH_4^+$) and organic nitrogen ($N_{organic}$) were determined. The most significant removing of nitrogen compounds revealed peatland. Two shelterbelts of different age and composition of plants showed lower effectiveness than peatland in concentrations of these compounds in ground water. Moreover, both shelterbelts supplied ammonium to ground water. The manipulation of the rural countryside through the introduction of the shelterbelts and peatlands of different age and the composition of plants, leads to modification of biochemical soil condition and finally efficiency decrease of the nonpoint pollution content in ground water. Thus, we recommend the utilization of young shelterbelt and peatland as favorable element of the landscape for the control of the spread of nonpoint pollution between ecosystems in ground water.

Keywords: biogeochemical barriers, peatland, shelterbelt, nonpo ollution, nitrogen forms.int p.

1. Introduction

In agricultural landscape with high level of fertilization in cultivated fields, the elements of the landscape, which can protect water bodies against eutrophication, are of particular importance. Natural, compatible structures which assist in controlling matter cycles in agricultural landscape are of great importance for enhancement of a countryside resistant to degradation. Various plant cover structures like shelterbelts, peatlands, grasslands, stretches of meadows, hedges, riparian vegetation strips are of special interest. But the most important from the point of ecological engineering, is that the biogeochemical barriers exert controlling effects on nonpoint pollution.

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Shelterbelts and peatlands belong to the stable elements in the landscape, which (i) restrain soil erosion, (ii) improve microclimate for agricultural production, (iii) regulate water regime in soils and (iv) create refuge sites for wildlife. In addition, shelterbelts and peatlands show substantial ability to limit spread of chemical elements among the ecosystems in the agricultural landscape [6, 9, 15, 18, 21, 22]. Taking into account all positive functions of shelterbelts in rural areas, the Council of Europe Committee of Ministers in Recommendation No. R (94)6 of the Committee of Ministers to Member States for Sustainable Development and use of the Countryside with the Particular Focus on the Safeguarding of Wildlife and Landscapes [3] suggested the limitation of pollutions concentration and their spread into natural habitats and control non-specific sources of pollution, especially through simple and inexpensive means such as windbreaks, buffer zone, natural meadows and ponds.

In agricultural watersheds large amounts of migrating nutrients are usually leached from cultivated soils. The application of high doses of commercial fertilizers is one of the reasons for the elevated concentrations of nitrogen and other elements in water bodies of agricultural landscape [2, 4, 5, 19, 22].

Nitrogen forms pollution caused by using of inorganic fertilizers are especially a great threats for rural areas and led to the eutrophication of ground water.

Many physical, chemical, biochemical and biological processes, pathways and mechanisms control dispersion of these chemical compounds in soils and finally all these processes depend on the organic matter content and particularly on humic substances [8, 21, 23, 27].

The goal of this study was to evaluate the efficiency of two shelterbelts of different age and composition of plants, and peatland on the decrease of nitrogen compounds in ground water passing through these elements, in order to understand their role in functioning these structures of the landscape as biogeochemical barriers. The results obtained from the experiments should give a better insight into the functions of these elements of the landscape in countryside.

Furthermore, the results should recommend the element of the landscape, which the most efficient decreases nonpoint pollution.

2. Material and Method

The investigations were carried out in Dezydery Chłapowski Agroecological Landscape Park in Turew (40 km South-West of Poznań, West Polish Lowland, 16°45' E and 52°01' N).

Turew landscape (17000 ha) has been an area of long-term investigations on agricultural landscape ecology [11, 12]. The infiltration rates of upland soils range from few to several cm h^{-1} and can be classified as having moderate or moderately rapid infiltration rates. Therefore, the water from rain or snow thaw can easily infiltrate beyond the depth of plant roots and then transport dissolved chemicals to ground water.

This area, from Polish climatic conditions, is warm, with an annual mean temperature of 9°C. Therefore, thermal conditions are favorable for vegetation growth. The growing season, with air temperatures above 5°C, lasts 225 days. On average, it begins in the middle of March and until end of October. Intensively agriculture is observed in this region. Cultivated fields are represented by 70%, 12% meadows.

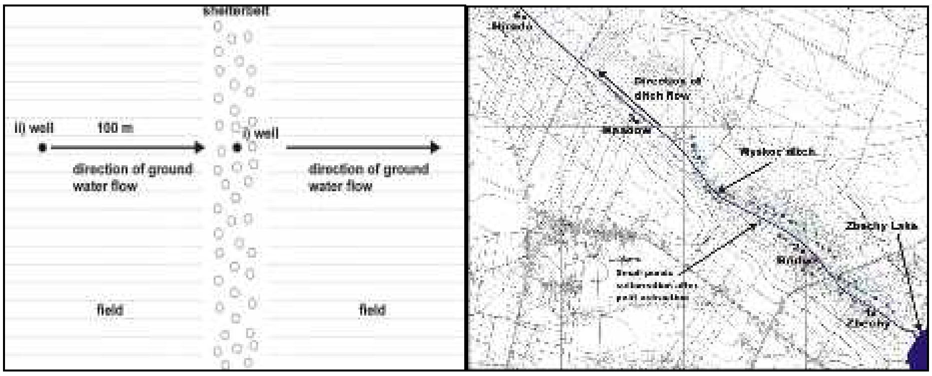

Figure 1. Investigated area – a) scheme of the young and old shelterbelts; b) peatland

All the investigated shelterbelts were introduced on *hapludalfs* soils.

Ground water was taken from the wells located: (i) on the middle of shelterbelts, (ii) on the adjoining cultivated fields (100 m from the shelterbelts) (Fig. 1a).

The other research site was a transect of peatland 4.5 km long. The investigated four chosen points marked as 1 Zbechy, 2 Bridge, 3 Meadow and 4 Hirudo were located along to Wyskoć ditch (Fig. 1b).

Peat-moorsh soils were described and classified according to Polish hydrogenic soil classification [17] and Word Reference Base Soil Resources [26].

Ground water samples were taken from the wells located on investigated peatland.

The pH, N_{total} (Kjeldahl method), $N\text{-}NO_3^-$ and $N\text{-}NH_4^+$, (chromatographic method), and $N_{organic}$ content in ground water samples were evaluated [20].

3. Results and Discussions

All the ground water samples have neutral properties to slightly basic. pH of ground water under young and old of shelterbelts and adjoining cultivated fields were neutral and ranged from 6.65 to 7.57 (Table 1). The pH values of the peatland ground water ranged from 6.40 to 7.52 (Table 1). The application of fertilizers is not the only measure which increases inland water pollution. Decomposition of soil organic matter owning to tillage activities also contributes to the release of various chemical compounds from soil [9, 18, 19, 22, 25]. The intensity of organic matter decomposition plays important role in determining a control capacities of the shelterbelts. The study on nitrogen release during decomposition of biomass has showed that when in a stand of old trees the litter accumulated to 641g m^{-2}, then during the decomposition processes 15.3 gN m^{-2} or 153 kgN ha^{-1}, were released in the period from March to October [1]. Such amount of released nitrogen is equal to a high dose of nitrogen fertilizer application. Under such conditions the subsurface output of mineral nitrogen with ground water was by 60% higher than input of nitrogen with ground water seeping from cultivated field. When a large amount of plant debris is accumulated then under conditions promoting biomass decomposition shelterbelt can turn from sink to source spreading nitrogen in the landscape. The practical implication of this study is efficient control of nitrogen spreading with ground water. It can be ensured when accumulating litter is removed from shelterbelt. The network of shelterbelt will operate with much greater firmness. If even one shelterbelt turn from sink to source of nitrogen discharge, then other shelterbelts will limit nitrogen pollution.

The nitrogen ions occurred predominantly in ground water of our investigations. The significant decrease of the concentration of N_{total} was observed. The content of N_{total} in ground water passing through adjoining cultivated fields towards shelterbelts was reduced 18% at young and 39% at old (Table 1). The highest content of N_{total} was determined in the beginning of peatland (marked Zbechy) and equaled 11.81±0.74 mg l^{-1}. A decrease of the content of N_{total} with increase of the distance from the edge of the peatland was measured along 4.5 km of the peatland, equal to 26% (Table 1).

Yearly mean contents of $N_{organic}$ in ground water between shelterbelts and adjoining cultivated fields decrease by 6% at young shelterbelt, and significantly increase by 29% under old shelterbelt (Table 1). Furthermore, the amount of $N_{organic}$ decreases with an increase of the distance of the peatland.

The decrease of organic compounds including nitrogen in their structures was equal to 29% (Table 1). In general, nitrate concentrations are the highest in ground water nearest the land surface when nitrogen sources are present [7]. The concentration of $N\text{-}NO_3^-$ by 20% at young and by 60% at old was reduced.

However, shelterbelts did not reduce content of $N\text{-}NH_4^+$.

The amounts of $N\text{-}NH_4^+$ in ground water increased 0.70% under young shelterbelt, and 41% under old shelterbelt (Table 1). The $N\text{-}NO_3^-$ anion is practically not exchanged by soil colloids. These differences result mainly from the action of a complex set of biological factors involving the plant's uptake, denitrification processes, and the release of gaseous products including NO, N_2O and N_2. The nitrates may convert to $N\text{-}NH_4^+$, which could be volatilized as NH_3.

Table 1. Contents of chemical compounds in ground water under young and old shelterbelts soils and adjoining cultivated fields soils, and peatland soils

Number	Location of sampling place	pH	N_{total} [mg l^{-1}]	$N_{organic}$ [mg l^{-1}]	$N\text{-}NO_3^-$ [mg l^{-1}]	$N\text{-}NH_4^+$ [mg l^{-1}]
			Young shelterbelt			
1	field	6.65-7.41	21.83±2.03	0.62±0.03	19.78±1.63	1.43±0.23
2	shelterbelt	7.05-7.57	17.84±0.94	0.58±0.01	15.82±1.14	1.44±0.19
	(-)decrease/(+)increase		-18.3%	-6.4%	-20.0%	+0.7%
			Old shelterbelt			
1	field	6.73-7.33	10.74±1.11	0.66±0.05	8.43±0.79	1.65±0.18
2	shelterbelt	6.69-7.36	6.52±0.51	0.85±0.04	3.35±0.34	2.32±0.21
	(-)decrease/(+)increase		-39.3%	+28.8%	-60.3%	+40.6%
			Peatland			
1	Zbechy	6.51-7.06	11.81±0.74	5.92±0.72	0.93±0.15	4.95±0.23
2	Bridge	6.78-7.52	11.34±0.61	6.19±0.84	0.63±0.09	4.52±0.57
3	Meadow	6.40-7.46	10.38±0.29	6.69±0.41	0.66±0.11*	3.03±0.24
4	Hirudo	6.89-7.44	8.76±0.39	4.22±0.67	1.01±0.20	3.53±0.47
	(-)decrease/(+)increase		-25.8%	-28.8%	-29. 6%*	-28.7%

*first 3.4 km [illegible] f the transect

We noticed significant disparity of the concentrations of ammonium under two shelterbelts. The higher concentration for ammonium ions in ground water was observed under older *Robinia pseudacacia* shelterbelt (2.32±0.21 mg l^{-1}) than under young shelterbelt (1.44±0.19 mg l^{-1}) (Table 1). Some ammonium ions are absorbed by roots system as well as retained by the base exchanges complex. The observed lack of the decrease in $N\text{-}NH_4^+$ ions concentrations when ground water is passing through root systems of the old "*Robinia pseudacacia*" shelterbelt should be related, therefore, to inputs of ammonium ions from decomposing organic matter. Several biological processes, conversions and pathways could lead to the formation of NH_3. The dissimilatory nitrate reduced in which NH_3 is used for the production of biomass. However, the biomass after mineralization could release ammonium ions. Moreover, dissimilatory reduction of nitrates, which in denitrification releases gaseous forms of nitrogen, and in dissimilatory reduction of nitrate to ammonium releases $N\text{-}NH_4^+$ ions under anaerobic conditions [24]. In addition, very small amounts of $N\text{-}NH_4^+$ ions can be exuded from tree roots, as shown experimentally by Smith [16] in case of birch, beech and maple trees.

Peatland significantly decreased the content of $N\text{-}NO_3^-$ in ground water. The concentration of $N\text{-}NO_3^-$ decreased with an increase of the distance from the edge of the peatland. The highest yearly mean content of $N\text{-}NO_3^-$ was measured at the beginning of the transect and was equal to 0.93±0.15 mg l^{-1}; the lowest was determined in Meadow equal to 0.66±0.11 mg l^{-1}, representing the 3.4 km length of the transect. The decrease of the $N\text{-}NO_3^-$ throughout the whole transect was equal to 30% (Table 1).

In addition, the decreases of $N\text{-}NH_4^+$ concentrations were similar to $N\text{-}NO_3^-$. Ammonium ions quantities decreased with an increase of the distance from the edge of the peatland. Throughout the entire peatland the decrease $N\text{-}NH_4^+$ was equal to 29% (Table 1).

Our results are in line with Ryszkowski and Kędziora [13]. Their investigations showed, that nitrate concentrations decreased substantially when ground water outgoing from cultivated fields seeped under shelterbelts. Authors present the concentration of nitrates ions ranged from 0.3 to 8.4 mg l^{-1} under shelterbelts and ranged from 12.6 to 94.2 mg l^{-1} under adjoining cultivated fields, besides that, the content of ammonium ions ranged from 1.1 to 4.5 mg l^{-1} under shelterbelts and ranged from 1.4 to 2.5 mg l^{-1} under adjoining cultivated fields. Concentrations of incoming nitrates with ground water dropped by 75.6 to 97.7% of input in six objects composed of cultivated fields and adjoining shelterbelts or pine and birch forest patches. Depending on the length of study, the number of samples in different series of measurements numbered from 11 to 89 covering all seasons of the year. In contrast to nitrate the ammonium ions behave entirely different. In three cases of six studied, their concentration increased under shelterbelts and in the other three the decrease was small amounting only by 15.4 to 22.3% of input. In cultivated fields nitrates distinctly dominated over ammonium ions in ground water. The results of Ryszkowski et al. [14] and Ryszkowski [10] suggested, that during wet and warm years significant degradation of litter in afforestation is observed. The nitrogen compounds created as results of this process are the reason of significant input of nitrogen into the soil and ground water.

Peatland also seems to be a very effective element of the landscape for removal of nitrogen compounds from through-flowing waters when the N_{total} is in the form of nitrate rather than $N\text{-}NH_4^+$ or dissolved $N_{organic}$. The data show that peatland as an element of the landscape limits the dispersion of different compounds in ground water. This element of the rural area plays a significant function in the purification processes [21].

4. Conclusions

The study revealed decrease of N_{total} and $N\text{-}NO_3^-$ at all investigated biogeochemical barriers. The order of N_{total} and $N\text{-}NO_3^-$ removers were: old shelterbelt (39%, 60%), peatland (26%, 30%) and young shelterbelt (18%, 20%), respectively (Table 1).

Furthermore, $N\text{-}NH_4^+$ was removed from ground water only by peatland biogeochemical barrier, 29%. However, old and young shelterbelts increase $N\text{-}NH_4^+$ the contents in ground water for 41% and 0.7%, respectively (Table 1). Peatland is an efficient biogeochemical barrier, which is natural part of the landscape, reducing concentrations of 26% N_{total}, 30% $N\text{-}NO_3^-$ and 28% $N\text{-}NH_4^+$ in ground water (Table 1).

The study showed the impact of the age and composition of plants on the removing of compounds by shelterbelts. In addition this process depends on catabolic or anabolic conversions in organic matter and preferences of plants for the uptake of chemicals. The results show that manipulation of plant cover in agricultural landscape is an important factor to control the quality and quantity of chemical substances in ground water that may appear some unwanted effects on the migration of chemicals among ecosystems.

Acknowledgement: This work was supported by a grant No. 2013/09/B/NZ9/03169 founded by founded by the Polish National Sciences Centre. Thanks are extended to Teresa Stachecka for technical support.

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