Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2020, 10(3), 197-200, doi: 10.15421/2020_154

ORIGINAL ARTICLE

Effect of the water regime, crop rotation and fertilizers in biogenic matters leaching into ground water and surface water

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Received: 12.06.2020. Accepted 28.07.2020

The purpose of our work was to establish features of formation of filtration processes and to define prevention measures towards the nutrients leaching from drainage soils into the ground waters. Our researches were carried out on typical drained floodplain soils of Panfil Research Station, Institute of Agriculture of National Academy of Agrarian Science (floodplain of Supiy River, Yahotyn district, Kiev region, Ukraine) in 2016-2018. The arable layer of peatlands had high level of decomposition (50-60%) with gross nitrogen contamination of 1.9%, phosphorus – 0.4, potassium – 0.17 and sodium – 7.1%, which is typical for the forest-steppe zone. The drying and humidifying system was satisfactory. Research on nutrient washing into ground water was carried out on various agricultural lands, during and out of crop rotation. iltration water was taken from water measurement wells, from drainage canals and directly from the Supi River twice a year (in autumn and spring) on sites with different fertilisation schemes. We found that in the fields with perennial grasses without mineral fertilizers 4.9 mg L^{-1} of NO_3 was washed out, 11.7 mg of K_2O, and 130 mg of CaO; on the fertilized fields it were 4. 2-19.4, 12.8-22.2, and 122-148 mg L^{-1} respectively; on the annual crop fields without the fertilizers a total of 9.2 mg L^{-1} of NO_3, 16.8 of K_2O and 134 mg L^{-1} of CaO were leached, whereas it were 14.3-19.6, 21.2-34.4 and 138-161 mg L^{-1}on the annual crop fertilized fields in the humid years. We observed a similar dependence in the dry 2018 year. Our observations of nutrient wash-out showed that on the fields with perennial grasses and annual crops (winter rye and corn) there were much more wash-out of nitrate and ammonium nitrogen, mobile phosphorus and potassium in autumn compared to spring for average from 2016-2018. In addition, the autumn drainage water contains more carbonates and had higher content of Na_2O (up to 48.7-51.3 mg L^{-1}). We did not register the dependence of nutrient washing into the ground water on the cultivated crops. At the same time, a significant amount of calcium and magnesium was washed out from perennial and annual crop fields in spring.

Key words: Nutrients leaching; Crops; Soil; Ground water; Surface water

Introduction

A significant anthropogenic impact on the river basins has led to a significant imbalance in nature relationships that have existed in the biosphere for millennia (Cheshko, 2005; Yatsik, 1997). This situation requires scientists and producers are to develop effective and scientifically grounded measures for balanced use of land and water resources, including the river basins (Degodyuk, Degodyuk, 2006; Locksmith, 2013; Slyusar et al., 2018a, 2018b).

Rational use of drained organogenic soils of humid zones is connected with development and mastering of sustainable development model for agrarian sector. The core object here is a soil with related processes - degradation of organic soil, leaching of nutrients into ground waters, their contamination with products of peat bog decomposition and with chemicals used for crop cultivation (Belolipsky, Polulyakh, 2018; Warnemuende et al., 2007; Yevtushenko, Dudnik, 2016; Lal, 2007). This problem is particularly significant in the arid land reclamation zone, where changes in water-air regime, in heat and nutrient regimes and in inner microbiological processes occur, which together with infiltration lead to contamination of groundwater and river water (Truskavetsky, Tsapko, 2016; Truskavetskii, 2014; Scuman, 1975). It was established that the quantity and composition of soluble substances and the hydrochemical regime of surface waters are formed under the strong influence of physical and geographical conditions and economic activities. Intensive mineralization of organic matter and application of mineral fertilizers on drained peatlands was accompanied by accumulation of various chemical compounds in them. This under certain water conditions caused their leaching from the soil into the drainage waters, which resulted in partial loss of plant nutrients and was accompanied by contamination of groundwater and river waters. This also increases of nutrient and mineral content in water bodies and rivers, decreases their sanitary condition, promotes growth of algae and aquatic vegetation and transfrorms them into wetlands (Degodyuk, Degodyuk, 2006; Yevtushenko, Dudnik, 2016; Lal, 2007; Lopushnyak, 2015). All this testifies the importance of researches on prevention the mineral matter leaching in ground waters for the river basins of humid zones (Ladika et al., 2015; Ushkarenko et al., 2013; Cheshko, 2005; Yatsik, 1997; Yatsik, Shevchek, 2006).

The purpose of our work was to establish features of formation of filtration processes and to define prevention measures towards the nutrients leaching from drainage soils into the ground waters.

Materials and Methods

Our researches were carried out on typical drained floodplain soils of Panfilska Research Station of NSC Institute of Agriculture of NAAS (floodplain of Supiy River, Yahotyn district, Kiev region) in 2016-2018. The arable layer of peatlands had high level of decomposition (50-60%) with gross nitrogen contamination of 1.9%, phosphorus – 0.4, potassium – 0.17 and sodium – 7.1%, which is typical for the forest-steppe zone. The drying and humidifying system was satisfactory. Research on nutrient washing into ground water was carried out on various agricultural lands, during and out of crop rotation. iltration water was taken from water measurement wells, from drainage canals and directly from the Supi River twice a year (in autumn and spring) on sites with different fertilisation schemes.

The agrotechnics implemented to the experimental plots were corresponded to standard recommendations and included minimum tillage, application of moderate doses of mineral fertilizers and crop rotation. The experiments were conducted in three replications according to the developed scheme. Soil moisture was determined by thermostatic weight method. The content of nitrate ammonium in drained waters and soil was determined with disulfophenolic acid according to GOST 4725-2007; the content of ammonium nitrogen was determined by the extraction of potassium chloride solution according to DSTU ISO/TE 14256-1:2003; the content of mobile compounds of phosphorus and potassium - by flame photometry of coal ammonium extraction according to Machigin method and DSTU 4114-2002. Yield accounting was carried out in crop maturity at each site. Mathematical processing of the results was carried out by dispersion analysis (Yeshchenko et al., 2005; Ushkarenko et al., 2013).

Results and Discussion

An important factor in the formation of the water regime in river floodplains is weather and soil-climatic conditions, which will determine filtration processes during the year (Locksmith, 2013; Slyusar et al., 2018b; Yatsik, Shevchek, 2006). Our analysis of meteorological parameters (Table 1) shows that these parameters have been subject to significant changes. The wettest period was April-October 2016 with 418 mm of precipitation at a rate of 362 mm, while in other years the amount of precipitation was significantly lower and air temperatures in all years of study were 0.9-2.5°C above the norm.

Table 1. Meteorological parameters during experiments.

Month	T,°C				Rainfall, mm			
	2016	2017	2018	norm	2016	2017	2018	norm
April	12.4	10.2	12.3	8.3	26.0	28.1	12.0	35.0
May	15.3	14.9	17.4	15.0	127.0	25.5	33.0	49.0
Jun	20.1	20.1	19.0	18.1	70.0	8.0	62.0	62.0
July	22.1	20.6	21.2	19.4	25.0	65.4	78.0	69.0
August	20.9	22.3	21.9	18.6	60.0	23.0	5.0	66.0
September	14.7	16.5	16.8	13.6	11.0	15.2	34.0	46.0
Octobe	6.4	8.2	10.0	7.5	98.5	96.0	16.0	35.0
Mean Apr-Oct	16.0	16.1	16.9	14.4	418.0	261	240.0	362.0

For many years of observations we have revealed that groundwater occurrence and moisture dynamics of the active soil layer essentially depend not only on drying and irrigating system, but also on precipitation and thermal regime. During our studies, the groundwater level was highly correlated with the amount of precipitation (see also Slyusar et al., 2018b, 2018c). In wet conditions, the water level was closer to the soil surface, especially in the first half of vegetation (Table 2), and in dry conditions it was inversely dependent. We registered the same dependence with soil humidity, but the humidity of active soil layer rarely decreased in 0-50 cm layer of beyond lower optimal humidity (40% from full moisture capacity) (Slyusar et al., 2018c; Truskavetsky, Tsapko, 2016).

Table 2. Ground water levels on experimental fields, cm from soil surface.

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Mean
2016	54	56	71	99	144	158	141	103
2017	52	78	112	139	165	147	130	118
2018	53	80	102	97	107	119	103	94
Mean	53	71	95	112	139	141	125	105

Analysis of nutrient leaching towards the soil year humidity and groundwater level showed slight correlation with year humidity (Table 3). Obviously, the nutrients were mainly in the active soil layer (0-50 cm) and the soil moisture was formed by capillary water, which was replenished from regulating ditches during dry vegetation periods. In addition, the capillary moisture flow from the lower layers transported nutrients to the surface soil layer, which was used by cultivated crops. Such process was observed in arid and humid years, but in the humid years less additional water was supplied from the main canal, which leveled the impact of year moisture on the nutrient transport. Water migration determined a high nutrient content in dried (regulating) canals and the river during the humid years. This migration contributed to the increase of capillary soil moisture during dry vegetation periods, whereas during wet periods there was an intensive filtration, which facilitated the migration of nutrients to dehydrated canals and river water.

An important factor in soil and river water pollution is the presence of various biochemical substances in soil [2, 6, 14]. Our analysis of soil nutrient content has shown that the degree of soil contamination depends significantly on the way drained soils are used, weather conditions and the amount of chemicals introduced into the soil during crop cultivation (Table 3). Ca and Mg compounds leached from the active soil layer were the highest, regardless of the doses and types of mineral fertilizers and weather conditions (142-161 and 33.9-125.8 mg, respectively). Nitrate and ammonia nitrogen leaching rate was smaller and they were 2.0-32.4 mg and 1.2-16.2 mg per 1 liter of drained water. Such dependence is related to the fact that mobile forms of nitrogen were intensively used by cultivated plants, which contributed to the impoverishment of the active soil layer. Also we registered that significant amount of Na_2O was leached, namely 21.8-65.0 mg L^{-1}. Mobile forms of phosphorus and potassium were leached in lesser amounts compared to other mineral elements and their compounds (it were 1-2.2 and 9.7-22.4 mg L^{-1} of water). The perennial grass mixtures had special importance for the drainage organogenic soils, as they prevent the intensive mineralization of organics and excessive accumulation of mobile compounds of nutrients and first of all mobile nitrogen compounds, which can be easily leached into ground waters.

Table 3. Effect of year humidity on nutrients leaching to the ground water in autumn, Suliy river floodplain, per L of drainage water.

Fertilizer pattern	2016					2017					2018				
	$N\text{-}NO_3$	P_2O_5	K_2O	Ca	$Na\text{-}NO_3$	$N\text{-}NO_3$	P_2O_5	K_2O	Ca	$Na\text{-}NO_3$	$N\text{-}NO_3$	P_2O_5	K_2O	Ca	$Na\text{-}NO_3$
Perennial grasses without reseeding															
Non-fertilized	4.9	1.75	11.7	132	43.4	11.7	2.0	11.8	89	39.0	2.0	1.0	10.2	118	40.5
$N_{45}P_{45}K_{60+60}$	18.9	1.37	12.8	124	46.2	29.5	1.2	15.9	122	37.7	26.9	1.2	13.9	118	38.0
$N_{45}P_{84}K_{90+60}$	19.4	1.2	22.2	148	44.4	28.0	1.0	12.5	124	37.1	12.1	1.1	9.6	116	35.7
$N_{45}P_{138}K_{173+120}$	4.2	2.28	14.6	122	42.0	12.2	1.0	16.5	98	36.2	11.0	1.6	11.0	117	38.3
Annual crops															
Non-fertilized	9.2	2.2	16.8	134	48.4	-	1.0	7.0	120	38.4	12.3	1.0	9.0	123	42.5
$P_{45}K_{120}$	18.5	2.5	21.2	138	49.2	-	1.0	7.2	126	39.2	27.2	1.2	11.4	128	48.2
$P_{115}K_{55}$	19.6	2.5	34.4	161	51.2	-	1.0	8.6	147	45.7	26.1	1.2	27.1	165	49.3
$P_{100+166}K_{127}$	14.3	2.4	25.0	142	51.0	-	1.1	7.7	128	38.4	24.1	1.8	20.8	128	40.0
Supiy River	2.5	1.0	13.7	104	53.0	-	0.4	11.2	96	37.2	2.1	1.3	12.3	83	44.1
Drainage canal	2.5	1.0	15.6	106	52.0	-	1.1	15.0	82	38.4	2.2	1.2	11.6	95	51.0
Hip_{05}	0.08	0.09	1.4	5.6	2.1										

We found that in the fields with perennial grasses without mineral fertilizers 4.9 mg L^{-1} of NO_3 was washed out, 11.7 mg of K_2O, and 130 mg of CaO; on the fertilized fields it were 4. 2-19.4, 12.8-22.2, and 122-148 mg L^{-1} respectively; on the annual crop fields without the fertilizers some 9.2 mg L^{-1} of NO_3, 16.8 of K_2O and 134 mg L^{-1} of CaO were leached, whereas it were 14.3-19.6, 21.2-34.4 and 138-161 mg L^{-1}on the annual crop fertilized fields in humid years.

A similar dependence was observed in the dry 2018 year (Table 3). Observations of nutrient wash-out showed that on sowings of perennial grasses and annual crops (winter rye, corn) much more wash-out of nitrate and ammonium nitrogen, mobile phosphorus and potassium in autumn compared to the average for spring 2016-2018. In addition, the autumn drainage water contains more carbonates and had higher content of Na_2O (up to 48.7-51.3 mg L^{-1}). We did not register the dependence of nutrient washing into the ground water on the cultivated crops. At the same time, a significant amount of calcium and magnesium was washed out from perennial and annual crop fields in spring. We believe that the amount of leached nutrients in irrigation and drainage canals was almost the same, the difference was several percent, which can be attributed to the errors of sampling and analysis. At the same time, we observed much more leaching rate in wet 2016 than in dry 2018. Thus, NO_3 content in the river and channel was 2.5 mg L^{-1}, K_2O – 13.7-15.6, Ca – 144-106 mg L^{-1} of drainage water in humid 2016, and it was 2.1-2.2, 12.3-11.6, 83-95 mg L^{-1} of drainage water, respectively, in arid 2018. The content of nutrients in drainage and irrigation canals was different. Thus, the content of Ca was almost the same in spring and autumn, the content of Mg increased in autumn water; no difference was found for mobile forms of nitrogen; the content of phosphorus was almost the same, and the content of K_2O and Na_2O increased from spring to autumn. We found that the content of nutrients in river waters did not exceed MAC for fishery bodies of water, excluding compounds Mg (MAC - 40 mg L^{-1} of water), the content of which in the studied waters was up to 91 mg L^{-1} and acidity of water (normal value pH 6.5-8.0), which often amounted to 7.5-8.7. The content of other nutrients in water also did not exceed MAC for fishery waters. We did not apply athe fertilizers when growing crops on drained lands, and it is obvious that a significant part of compounds is found in vivianite layers of organic soil and its underlying layers.

Conclusion

Mineral compounds leaching from active layer of organic drained soil is largely connected with water regime, weather conditions, cultivated crops and scheme of fertilization. We found that it was leached by 1.2 times more of nitrate nitrogen and K_2O and 1.4 times more of CaO in humid years compared to dry years. We supposed that much more nutrients were washed out into ground and river waters in humid years than in arid ones, and the cultivation of perennial grass mixtures significantly prevents the depletion of minerals into the ground waters. In fact, the application of mineral fertilizers determines their increased content in groundwater and river waters.

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Citation:
Slyusar, I.T., Solyanik, O.P., Serbenyuk, V.O., Viryovka, V.V., Tarasenko, O.A. (2020). Effect of the water regime, crop rotation and fertilizers in biogenic matters leaching into ground water and surface water. *Ukrainian Journal of Ecology, 10*(3), 197-200.