Nitrogen Leaching from Meliorated Soil

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Stickstoffauswaschung aus entwässertem Boden

1. Introduction

Out of the total nitrogen added into soil with mineral fertilizers, plants get about 50 %, about 25 % is immobilized in soil, and about 25% is lost through leaching, denitrification and other mechanisms (AZAM et al., 1985). From the ecological viewpoint, nitrogen leaching has special importance because of its possible pollution of surface and ground water.

As nitrogen is predominantly leached in the form of nitrates since the soil does not adsorb these ions, the hazard of environmental pollution is generally related to the nitrate form of nitrogen, and less to its ammonium and nitrite forms. Excessive nitrate concentration in water may lead to

Zusammenfassung

Forschungsziel war es, beim Anbau von Ackerkulturen auf hydromelioriertem Gleyic Podzoluvisolboden in Mittelposavina den Einfluss von Entwässerungsvarianten mit unterschiedlichen Drainrohrabständen auf die Konzentration und die Menge des ausgewaschenen Stickstoffs zu erforschen. Die Messungen des ausgewaschenen Stickstoffs wurden bei vier Drainrohrvarianten mit verschiedenen Abständen durchgeführt (15 m, 20 m und 30 m).
In jedem Untersuchungsjahr wurde auf allen Varianten die gleiche Kultur angebaut und die gleiche Agrotechnik angewendet.
Die Ergebnisse zeigen, dass die Niederschlagsmengen während des Untersuchungszeitraumes wesentlich die Dynamik der Stickstoffauswaschung in allen untersuchten Varianten beeinflusst haben.
Die Gesamtmenge des Drainabflusses war sowohl innerhalb jedes Untersuchungsjahres zwischen den getesteten Varianten als auch zwischen den Forschungsjahren verschieden.
Im Jahre l996 schwankte der Drainabfluss von 77 $l.m^{-2}$ (oder 8.4 % von der Gesamtjahresniederschlagsmenge) bis 82 $l.m^{-2}$ (8,9 %); im Jahre 1997 von 13 $l.m^{-2}$ (1,6 %) bis 23 $l.m^{-2}$ (2,8 %) und im Jahre l998 von 185 $l.m^{-2}$ (18.5 %) bis 194 $l.m^{-2}$ (19.4 %).
Die maximale NO_3-N Konzentration überschritt in allen Varianten den Wert von 10 mg/l, während die jährlichen Durchschnittskonzentrationen niedriger oder höher als 10 mg/l waren.
Stickstoffkonzentrationen über 10 mg/l sind während der Regenzeiten und nach der Düngung registriert worden.
Die durchschnittliche Konzentration von NH_4-N war meistens höher als 0,1 mg/l, wobei der maximale Wert bis 2.9 mg/l stieg. Die Menge des ausgewaschenen Stickstoffs differierte nach Jahren und nach Untersuchungsvarianten. Im Jahr 1997 war der Gehalt an ausgewaschenem Stickstoff am geringsten. Die Mengen variierten zwischen 3.1 kg/ha (oder 1.8 % der gesamt zugeführten Stickstoffdünger-Menge) und 5.5 kg/ha (3.2 %). Der Anteil an ausgewaschenem Stickstoff war im Jahr 1998 am höchsten. Die Mengen streuten von 15.5 kg/ha (7.6 %) bis 19.8 kg/ha (9.8 %). Die Varianzanalyse ergab innerhalb der einzelnen Untersuchungsjahre keine statistisch signifikanten Unterschiede bei der Konzentration von NO_3-N und NH_4-N im Drainwasser. Auch hinsichtlich der Menge an ausgewaschenem Stickstoff treten zwischen den getesteten Drainrohr-Abstandsvarianten keine (auf dem Niveau P = 0,05 bzw. 0,01) signifikanten Differenzen auf.
Die Differenzen bei der Stickstoffauswaschung werden sowohl durch das Klima bzw. die Menge und die Verteilung der Niederschläge, als auch durch die angebauten Kulturen bzw. deren Entwicklung, durch die Fruchtfolge und durch Art sowie Zeitpunkt pflanzenbaulicher Eingriffe bedingt.

Schlagworte: Auswaschung, Stickstoff, Wasser, Gleyic Podzoluvisol.

Summary

The research object was to investigate the influence of different pipe drainage systems on the concentration and quantity of nitrogen leached in the production of agricultural crops on hydroameliorated Gleyic Podzoluvisol in the central Sava Valley. Nitrogen leaching was investigated in four different variants of drainpipe spacing (15 m, 20 m, 25 m and 30 m). The same crop was grown and the same agricultural practices applied in all trial variants and in all trial years.

The results achieved indicate that the quantity of precipitation in the trial period had a substantial influence on the dynamics of nitrogen leaching in all trial variants. Differences in the total quantity of drainage discharge were recorded both between the tested variants in each trial year and between trial years. In 1996 drainage discharge ranged from 77 $l.m^{-2}$ (8.4 % of total annual precipitation) to 82 $l.m^{-2}$ (8.9 %), in 1997 from 13 $l.m^{-2}$ (1.6 %) to 23 $l.m^{-2}$ (2.8 %), and in 1998 from 185 $l.m^{-2}$ (18.5 %) to 194 $l.m^{-2}$ (19.4 %).

Maximum concentrations of NO_3-N were over 10 mg/l in all variants, while the average NO_3-N concentrations were either lower or higher than 10 mg/l. NO_3-N concentrations over 10 mg/l were recorded during rainy periods, after fertilizer application. The average NH_4-N concentration was generally higher than 0.1 mg/l, while its maximum value went up to 2.9 mg/l.

Quantities of leached nitrogen varied per years and per trial variants. The lowest nitrogen leaching was recorded in 1997, the quantities ranging from 3.1 kg/ha (1.8 % of the total nitrogen added with fertilization) to 5.5 kg/ha (3.2 %). The highest leaching occurred in 1998, the N quantities ranging from 15.5 kg/ha (7.6 %) to 19.8 kg/ha (9.8 %).

Analysis of variance did not render any statistically significant differences in drainage water concentrations of NO_3-N and NH_4-N for any of the trial years, and neither in the quantity of leached nitrogen between the tested variants of pipe drainage spacing, at P = 0.05 and 0.01.

Different quantities of leached nitrogen were conditioned by the climate, that is, the quantity and distribution of precipitation, crops grown, that is, crop development stages in crop rotation, as well as by the agricultural practices and the time when each particular practice was applied.

Key words: leaching, nitrogen, waters, Gleyic Podzoluvisol.

eutrophication of watercourses or, if such water is used for human consumption or stock watering, it may cause methemoglobinemia in infants and animals (PRATT and JURY, 1984).

Nitrogen quantity that will be taken out of arable areas with drainage water depends on a number of factors such as, for example, the kind and rate of nitrogen fertilizer applied, soil physical properties, crops sown, quantity and distribution of precipitation, etc.

Different systems of detailed drainage may affect the quantity of leached nitrogen. BAKER and JOHNSON (1971) and VANČURA and KUNC (1988) have established that drainage systems increase the transport of nitrates in agricultural soil. Drainage systems and nitrogen leaching have been the subject of many studies, among which are: JANI and KLAGHOFER (1975), FÖRSTER (1984), BOCKEN (1987), GOSS et al. (1987), ŠOŠKIĆ et al. (1987), ROSSI et al. (1991), MILBURN and RICHARDS (1994), WEBSTER et al. (1999), and VIDAČEK et al. (1999).

In view of the above facts, this study was aimed at determining the concentration and leaching of nitrate and ammonium forms of nitrogen in drainage waters from hydroameliorated soils in the central Sava Valley, since 161,530 ha of underground drainage systems have been built in Croatia (MARUŠIĆ, 1995).

This research is an extension of that done by ŠIMUNIĆ et al. (1993 and 1996), TOMIĆ et al. (1994), and KLAĆIĆ et al. (1998).

2. Materials and methods

The object of the research done in the 1996–1998 period on hydroameliorated Gleyic Podzoluvisol in four different variants of drainpipe spacing (15 m, 20 m, 25 m and 30 m) was to determine:

- concentrations of nitrate and ammonium forms of nitrogen in drainage water;

- total leaching of nitrogen with drainage water;
- whether there is a significant difference in the concentrations of nitrate and ammonium forms of nitrogen in drainage water and in nitrogen leaching between different drainpipe spacings (using the analysis of variance);

The trial was set up on the experimental amelioration field "Jelenščak"- near Kutina, on the soil type hydroameliorated Gleyic Podzoluvisol. The trial involved variants of drainpipe spacing of 15 m, 20 m, 25 m and 30 m. All variants were combined with contact hydraulic material – gravel (Ø 5–25 mm) and were done in four replications. Drainpipes were 95 m long, diameter 65 mm, average drop 3 ‰, and average depth 1 m, discharging directly into open canals. Pipes were plastic (PVC)- annular- ribbed and perforated.

The same crop was grown and the same agricultural practices were applied in all pipe drainage variants in each trial year (Table 1).

Drainage discharge was measured continually by means of automatic electronic gauges – limnimeters. Limnimeters were set up in each variant, at the drainpipe outlet into the open canal.

Sampling of drainage water was done each day during the discharge period. An water sample was made for laboratory analyses.

APHA methods were applied to determine the NO_3^- and NH_4^+ concentrations in the laboratory (APHA, 1992).

The total annual quantity of nitrogen leached was estimated on the basis of monthly values, that is, average monthly concentration of NO_3-N, or NH_4-N, average monthly quantity of drainage discharge, days/month of drainage discharge, and the drained area.

Data were statistically processed by means of the analysis of variance.

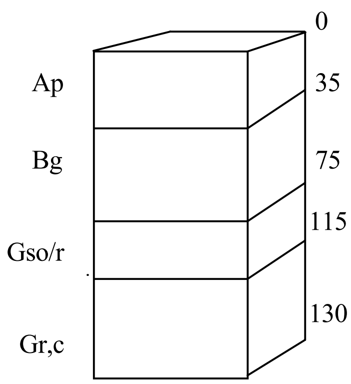
3. Results

To facilitate interpretation of research results, the site factors – soil and climate – were taken into consideration.

3.1 Soil properties

Drained Gleyic Podzoluvisol is located in the Sava river valley, on level relief (slope < 1‰), at an average altitude of 96.4 m a.s.l. Before the trial was set up, the area was utilised as a pasture, which was in association with swamp vegetation (*Salix* sp., *Juncus* sp. etc.).

Genetic texture of the soil profile with major hydropedological indicators is presented in Figure 1, while the major physical and chemical properties are given in Table 2.



1. Soil type: Gleyic Podzoluvisol, drained, medium deep
2. Main mode of soil moistening: surface and ground water
3. Vertical hydraulic conductivity: 35–75 cm = 0.011 m/day (very low) 75–115 cm = 0.011 m/day (very low)
4. Layering of soil profile: Ap - Bg - Gso/r - Gr,c
5. Depth to impervious horizon, D in m: ca.2 m
6. Mean rise of groundwater level, measured from soil surface: ca. 75 cm.

Figure 1: Genetic texture of Gleyic Podzoluvisol
Abbildung 1: Die genetische Textur des Gleyic Podzoluvisols

Table 1: Agricultural practices and application terms for crops grown during the trial period
Tabelle 1: Landwirtschaftsarbeiten und Fristen im Pflanzenbau während der Versuchsperiode

Year	Crop	Sowing	Fertilization		Protection		Harvest
			Quantity (kg N/ha)	Date	Quantity (l/ha)	Date	
1996	Maize	May 22	115 N 30 N	May 20 July 8	Primextra (6 l/ha)	May 23	Nov. 16
1997	Maize	May 6	121 N 54 N	May 5 June 24	Primextra (6 l/ha) + Racer (1l/ha)	May 9	Oct. 18
1998	Wheat	Oct. 19	109 N 54 N 40 N	Oct. 15 Feb. 25 April 7	Lontrel (4l/ha) Deut (1l/ha)	Mar. 13 May 8	July 7

Table 2: Major properties of drained Gleyic Podzoluvisol
Tabelle 2: Wichtigere Eigenschaften des Gleyic Podzoluvisol-Bodens

Depth, cm	Content of particles, %		Porosity, %	Capacity, %		Permeability, m/day	pH		Humus, (%)	mg/100 g soil	
	Silt	Clay		Water	Air		H_2O	1M KCl		P_2O_5	K_2O
0–35	47	46	48	44	4	0.011	6.7	5.3	3.0	5.9	7.6
35–75	45	48	49	45	4	0.010	6.5	5.2			
75–115	55	39	46	42	4	0.011	7.9	7.1			
115–130	63	25	49	45	4		8.1	7.2			

The soil has silty clayey texture to the depth of 0.75 m. The clay content of this soil section is in the range of 46–48 %, and the silt content is 45–47 %. The soil depth of 0.75–1.15 m is of lighter texture. The silt component preponderates in soil texture (55 %), while the clay content decreases (34 %). Soil texture at depths over 1.15 m is silty loamy. The soil is porous with the total pore volume of 48–49 %. Soil water capacity is 42–45 %. Air capacity is low – 4 %. Vertical hydraulic conductivity is very low (0.011 m/ day).

3.2 Climatic characteristics

The three-year mean precipitation amounted to 909.4 mm, while the annual precipitation ranged from 807.3 $l.m^{-2}$ (1997) to 999.2 $l.m^{-2}$ (1998). The primary precipitation maximum was recorded in the autumn period and the secondary maximum generally in late spring. The three-year mean air temperature was 10.7 °C, while the mean annual air temperature ranged from 10.3 °C (1996) to 11.1 °C (1998). According to the said climatic elements, the region had an average three-year humid climate (Kf = 85.0), while the mean several-months climate ranged from perhumid (I, XI and XII), humid (II, III, IX and X), semihumid (IV and VII), to semiarid (V, VI and VIII). According to the mean three-year and mean annual air temperatures, the region had moderately warm climate (mean air temperatures between 8 °C and 12 °C). According to the average of mean monthly air temperatures, one month had nival climate (XII), two had cold climate (I and II), two moderately cold (III and XI), two moderately warm (IV and X), three warm (V and IX), and three months hot climate (VI, VII and VIII).

Note that, for the needs of this work, fluctuations of precipitation and drainage discharge have been studied in great detail, in terms of their daily and decade values. Results from Table 3 point to a relatively high precipitation, which had a substantial effect on the nitrogen leaching dynamics.

3.3 Hydrological relations

Drainage discharge and duration are important indicators of pipe drainage efficiency in draining excess water from

Table 3: Total monthly and annual precipitation and its mean values ($l.m^{-2}$), 1996–1998
Tabelle 3: Die Gesamtmenge der Monats- und Jahresniederschläge ($l.m^{-2}$), 1996–1998

Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Σ
1996	54.3	31.5	40.6	69.7	70.7	30.6	90.5	82.5	191.0	46.3	134.9	79.0	921.6
1997	43.8	54.5	25.5	45.4	73.3	81.3	102.8	62.8	29.8	76.0	126.5	85.6	807.3
1998	65.3	5.3	57.5	59.2	103.2	107.1	121.3	86.5	173.5	119.8	51.3	49.2	999.2
$\bar{x}$	54,5	30,4	41,2	58,1	82,4	73,0	104,9	77,3	131,4	80,7	104,2	71,3	909,4

Table 4: Mean monthly and mean annual air temperatures (°C), 1996–1998
Tabelle 4: Die Monats- und Jahresdurchschnittswerte der Lufttemperaturen (°C), 1996–1998

Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	$\bar{x}$
1996	-0.6	-0.8	3.4	10.8	17.4	20.7	19.8	20.5	13.5	12.0	8.7	-1.4	10.3
1997	-1.1	4.1	6.5	7.3	16.7	20.0	20.3	19.8	15.8	8.7	6.0	2.9	10.6
1998	3.3	5.5	5.0	10.3	15.2	20.0	22.2	21.9	16.0	12.2	3.7	-2.6	11.1
$\bar{x}$	0.5	2.9	5.0	9.5	16.4	20.2	20.8	20.7	15.1	11.0	6.1	-0.4	10.7

Table 5: Monthly and total annual drainage discharge ($l.m^{-2}$) per variants
Tabelle 5: Die Monats- und Jahresgesamtmenge der Drainabflüsse nach Varianten

Variant	Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
*R 15	1996					0	0	0	4	36	24	16		80
*R 20						0	0	0	4	34	21	18		77
*R 25						0	0	0	3	35	21	23		82
*R 30						0	0	0	1	31	27	21		80
R 15	1997					5	6	2	0	0	0	10	50	13
R 20						8	6	4	0	0	0	9	46	18
R 25						11	8	3	0	0	0	10	51	22
R 30						10	8	5	0	0	0	9	48	23
R 15	1998	45	9	10	17	30	16	0						187
R 20		47	8	10	18	32	15	0						185
R 25		47	7	12	18	32	17	0						194
R 30		46	9	11	19	34	17	0						193

LEGEND:
R-15 Drainpipe spacing 15 m
R-20 Drainpipe spacing 20 m
R-25 Drainpipe spacing 25 m
R-30 Drainpipe spacing 30 m

Table 6: Monthly and total duration of drainage discharge (days) per variants
Tabelle 6: Die Monats- und Jahresgesamtdauer der Drainabflüsse (in Tagen) nach Varianten

Variant	Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total
R 15	1996					0	0	0	4	20	11	11		46
R 20						0	0	0	4	22	15	15		56
R 25						0	0	0	4	22	19	15		60
R 30						0	0	0	4	24	19	16		63
R 15	1997					7	10	4	0	0	0	14	23	21
R 20						8	10	4	0	0	0	14	26	22
R 25						9	14	5	0	0	0	15	28	28
R 30						10	14	6	0	0	0	18	31	30
R 15	1998	31	9	17	7	20	8	0						129
R 20		31	8	18	8	21	8	0						134
R 25		31	10	21	10	24	10	0						149
R 30		31	11	21	9	25	12	0						158

soil. Systems with higher discharge and its shorter duration are more efficient. It would be impossible to estimate the quantity of leached nitrogen in the tested pipe drainage variants without determining the quantity and dynamics of drainage discharge. Values of the said indicators for different drainpipe spacings are presented in Tables 5 and 6.

It can be seen from Table 5 that there are certain differences in the quantity of drainage discharge, both between the tested variants in each year and between the trial years. In 1996, drainage discharge ranged from 77 $l.m^{-2}$ (8.4 % of total annual precipitation) to 82 $l.m^{-2}$ (8.9 %), in the second year from 13 $l.m^{-2}$ (1.6 %) to 23 $l.m^{-2}$ (2.8 %), and in the last year from 185 $l.m^{-2}$ (18.5 %) to 194 $l.m^{-2}$ (19.4 %). The largest quantities of discharge in all variants were recorded in the autumn-winter and spring periods, when evaporation is the lowest, precipitation is the most abundant and there is no plant cover on soil, or plants are in their initial development stage. In our opinion, there are several reasons for these differences in drainage discharge, primarily the different total annual quantity and distribution of precipitation, the crop grown and its different water requirements (evapotranspiration), as well as the different efficiency of each particular pipe drainage system. KLAŠIĆ et al. (1998) report an average drainage discharge of 246 $l.m^{-2}$ or 22.5 % of total precipitation (1094 $l.m^{-2}$).

Table 6 shows that there are also monthly and yearly differences in the duration of drainage discharge between the tested pipe drainage systems. In 1996, drainage discharge lasted from 46 to 63 days, in the second year from 21 to 30 days, and in the last trial year from 129 to 158 days. Duration of drainage discharge increases with the width of drainpipe spacing and with the quantity of precipitation and vice versa, narrower spacing and less precipitation cause shorter drainage discharge. We relate the duration of drainage discharge to the efficiency of each particular pipe drainage system and to all other factors mentioned for drainage discharge. The foregoing allows the conclusion that narrower drainpipe spacing is more efficient in these edaphic conditions, which is especially expressed in more humid years. PETOŠIČ et al. (1998) report that the variant involving drainpipe spacing of 10 m rendered the best results in terms of drainage discharge intensity.

3.4 Yield of crops

The mean values of crop yields, in dependence on the drainpipe spacing variant, are presented in Table 7.

As can be seen from Table 7, maize participated in the crop rotation in two years, winter wheat in one year. Yields of the same crops differed in different trial years due to various factors, such as genetic characteristics of the cultivars, or hybrids, drilling date, total fertilizer applied, topdressing pattern in the growing season, the harvest/picking time (Table 1), different quantities and distribution of precipitation during the growing season (Table 3). Yields of the same crops differed in different drainpipe spacing variants. As a rule, the highest yields were achieved in the drainpipe spacing variant of 15 m, and the lowest in that involving 30 m spacing, which the authors attribute to the efficiency of particular drainage systems (TOMIĆ et al., 1994; ŠIMUNIĆ, 1995).

Analysis of variance, done separately for each trial year, rendered highly significant differences ($p < 0.01$) between yields of particular crops in dependence on the drainpipe spacing in all trial years.

Duncan's test revealed that maize yields were significantly higher in drainpipe spacing variants of 15 m in both trial years. In 1998, winter wheat yield was not significantly different between drainpipe variants of 15 m and 20 m.

Accordingly, satisfactory yields can be achieved under the agroecological conditions of the central Sava valley with the drainpipe spacing of 15 m. Drainpipe spacing of 20 m, supplemented by repeated vertical deep loosening, may give satisfactory results in years when the drainage system is adequately maintained. Hence, drainpipe spacing of 20 m is recommended for Gleyic Podzoluvisol, along with appropriate and regular maintenance of the drainage system and application of vertical deep loosening of soil (TOMIĆ et al., 1994; ŠIMUNIĆ, 1995; PETOŠIĆ et al., 1998).

3.5 Concentration of nitrate nitrogen in drainage water

Translocation, that is, leaching of NO_3-N depends primarily on the soil water-permeability and its water content, namely on the soil type and its structure. Since the nitrates bind poorly to colloid soil particles, it is important to determine the dynamics of their leaching. Results on the nitrate concentration in drainage water are presented per variants in Table 8.

It can be seen from Table 8 that maximum concentrations of NO_3-N in all variants during the three-year trial

Table 7: Duncan's Multiple Range test of the mean values of crop yields (t/ha) in dependence on the drainpipe spacing variant
Tabelle 7: Der Duncan's Multiple Range-Test der Durchschnittswerte der Erträge nach Abständen der Drainrohre

Variant	Dry grain yield (t/ha)					
	Maize (1996)		Maize (1997)		Winter wheat (1998)	
R 15	5.82	a	8.44	a	3.85	a
R 20	5.34	b	8.02	b	3.89	a
R 25	4.92	c	7.80	b	3.28	b
R 30	4.35	d	7.27	c	3.09	b

Values marked by the same letter are not significantly different according to Duncan's test ($p > 0.05$)

Table 8: Average, minimum and maximum concentrations of NO_3-N (mg/l) in drainage water, per variants
Tabelle 8: Die Durchschnitts-Mindest- und Höchstwerte des NO_3-N-Gehaltes (mg/l) im Drainwasser nach Varianten

Variant	1996			1997			1998		
	Average	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.
R 15	8.67	4.16	13.05	19.76	7.66	32.10	12.06	1.13	29.59
R 20	9.36	4.54	15.81	19.76	9.77	30.78	9.85	1.16	25.37
R 25	8.58	5.14	13.34	19.48	8.07	32.43	8.25	1.75	20.02
R 30	8.51	4.76	12.91	18.83	9.24	28.79	10.09	1.58	24.30

period exceeded the concentration of 10 mg/l, which is maximal admission concentration of nitrates in water. The average highest maximum concentration for all variants was recorded in 1997 (28.79 mg/l to 32.43 mg/l), and the average lowest concentration in 1996 (12.91 mg/l to 15.81 mg/l).

Average values of NO_3-N concentrations (for all variants) in 1996 were below 10 mg/l, while the by far highest average concentrations were recorded in 1997 (18.83 mg/l to 19.76 mg/l). In 1998, average concentrations were below 10 mg/l in two variants, and above 10 mg/l in the other two.

Similar results for drainage water were obtained in a three-year study done by JANI and KLAGHOFER (1975) in Petzenkirchen (Lower Austria). They determined an average NO_3-N concentration of 14. 3 mg/l. FÖRSTER (1984) estimated an average concentration of NO_3-N in drainage water of 24.5 mg/l–38.3 mg/l in northwestern Germany. ŠOŠKIĆ et al. (1987) recorded an average NO_3-N concentration of 9.4 mg/l–12.9 mg/l on agricultural areas of the pilot farm "Ježevo" (Upper Sava Valley). KLAČIĆ et al. (1998) recorded an average NO_3-N concentration lower than 10 mg/l, and the maximum one up to 30 mg/l.

Fluctuation of NO_3-N concentration in the three-year period is presented in Figure 2.

It can be seen from Figure 2 that the maximum NO_3-N concentrations of all variants were determined in the spring or in the autumn, after sowing and basic tillage or top-dressing, which generally coincided with primary or secondary precipitation maxima.

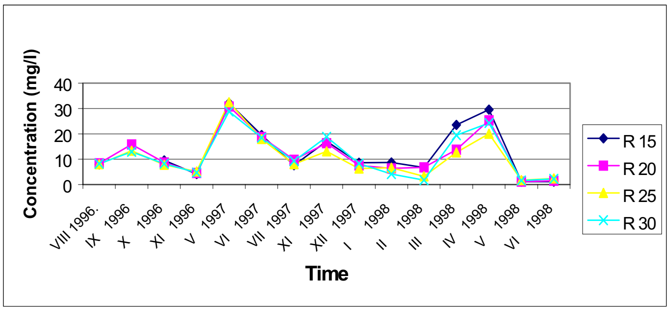


Figure 2: Fluctuation of NO_3-N concentration in drainage water, 1996–1998
Abbildung 2: Die Fluktuation des NO_3-N-Gehaltes im Drainwasser

Compared to nitrates, ammonia is less leached due to its ability to bind to the colloid soil particles. It is therefore less dangerous for the environment.

Results referring to ammonia concentrations are given in Table 9.

Table 9 shows that the maximum NH_4-N concentration for all variants was the lowest in the first trial year, while the highest maximum concentration was recorded in 1998.

It was only in 1996 that the average and the maximum (in three variants) NH_4-N concentration were lower than 0.4 mg/l, while it exceeded this value in variant from 15 m (1996) and in all variants in the remaining two years.

FÖRSTER (1984) recorded an average concentration of NH_4-N in drainage water from 0.59 mg/l to 1.52 mg/l. ŠOŠKIĆ et al. (1987) determined an average NH_4-N concentration from 0.7 mg/l to 0.8 mg/l.

It was determined by the analysis of variance that there were no statistically significant differences in drainage water concentrations of NO_3-N and NH_4-N in any of the trial years between the tested variants of drainpipe spacing, at P = 0.05 and 0.01.

The foregoing points to the conclusion that drainage water is exceeded maximal admission concentration of nitrates and ammonia in one part of the year and it constitutes hazard to open watercourses.

3.6 Quantity of nitrogen leached

The quantity of nitrogen leached is in linear correlation with the quantity of drainage discharge (ŠOŠKIĆ et al., 1987). Hence, the largest quantities of leached nitrogen were recorded in years with the highest drainage discharge, and with highest precipitation. Table 10 presents the total quantity of leached nitrogen and its percentage relative to the total nitrogen added with fertilization.

Table 9: Average, minimum and maximum concentrations of NH_3-N (mg/l) in drainage water, per variants
Tabelle 9: Die Durchschnitts-Mindest- und Höchstwerte des NH_3-N-Gehaltes (mg/l) im Drainwasser nach Varianten

Variant	1996			1997			1998		
	Average	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.
R 15	0.20	0.00	0.46	0.65	0.00	1.60	1.90	0.00	2.87
R 20	0.02	0.00	0.05	0.54	0.00	1.30	1.33	0.00	2.92
R 25	0.07	0.00	0.13	0.81	0.00	1.46	1.53	0.00	2.47
R 30	0.02	0.00	0.05	0.62	0.00	1.42	1.58	0.00	2.45

Table 10: Quantity of nitrogen leached per pipe drainage variants (kg/ha) and percentage of nitrogen leached relative to the total N added with fertilization
Tabelle 10: Mengen des ausgewaschenen Stickstoffs nach Varianten und Anteil des ausgewaschenen Stickstoffs in Bezug auf die Düngungsstickstoffmenge

Variant	1996		1997		1998	
	kg/ha	% relative to total N fertilization	kg/ha	% relative to total N fertilization	kg/ha	% relative to total N fertilization
R 15	8.2	5.7	3.1	1.8	19.8	9.8
R 20	8.4	5.8	4.1	2.3	16.8	8.3
R 25	7.8	5.4	5.5	3.2	15.5	7.6
R 30	7.3	5.0	5.2	2.9	17.22	8.5

The quantity of NO_3-N and NH_4-N leached was calculated according to the following formula:

$$A = 0.0864 \frac{nQK}{F}$$

A = NO_3-N and NH_4-N leached in the drainage period (kg/ha);
n = Number of days of drainage discharge;
Q = Quantity of drainage discharge (l/sec.);
K = Concentration of NO_3-N and NH_4-N (mg/l);
F = Size of drained area (ha)

It can be seen from Table 10 that the quantity of nitrogen leached varied per years and per trial variants. The lowest nitrogen leaching was recorded in 1997, the quantities ranging from 3.1 kg/ha (1.8 % of the total nitrogen added with fertilization) to 5.5 kg/ha (3.2 %). The highest leaching occurred in 1998 – from 15.5 kg/ha (7.6 %) to 19.8 kg/ha (9.8 %). Our results on the quantities of nitrogen leached in different pipe drainage variants are in agreement with the results obtained by SKAGGS and GILLIAM (1987) and KLAŠIĆ et al. (1998). Different quantities of leached nitrogen are conditioned by the climate, namely the quantity and distribution of precipitation, crops grown, that is, their development stages in the crop rotation, as well as by the agricultural practices and the time of their application.

It was determined by the analysis of variance that there were no statistically significant differences between the tested variants of drainpipe spacing in the quantity of nitrogen leached in a particular year, at P = 0.05 and 0.01.

4. Discussion

The problem of nitrogen leaching on hydroameliorated soils has been addressed by a number of researchers: JANI and KLAGHOFER (1975), FÖRSTER (1984), BOCKEN (1987), GOSS et al. (1987), ŠOŠKIĆ et al. (1987), ROSSI et al. (1991), MILBURN et al. (1994), WEBSTER et al. (1999), and VIDAČEK et al. (1999). Since it is not capable of binding to the colloid soil particles, nitrogen carried in water may cause eutrophication of watercourses or, if its quantities in drinking water are excessive, it may cause methemoglobinemia in infants and animals (PRATT and JURY, 1984).

Results on the quantity of nitrogen leached from hydroameliorated Gleyic Podzoluvisol, in dependence on drainpipe spacing, are in agreement with the results of SKAGGS and GILLIAM (1987), ŠOŠKIĆ et al. (1987), BOCKEN (1991), GOSS et al. (1987), ROSSI et al. (1991), MILBURN and RICHARDS (1994), ŠIMUNIĆ et al. (1993), and KLAČIĆ et al. (1998) and they point to the fact that the quantity of nitrogen leached in these parts is strongly influenced by the distribution of precipitation, time of mineral fertilizer application, rates of added mineral fertilizers, and the phenological stage of the crop. With regard to the percentage of leached nitrogen from the basic and pre-sowing fertilization in the total nitrogen leached, the change of the established practice of combining the basic and pre-sowing fertilization should be considered, and the pre-sowing fertilization should involve less nitrogen.

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