NITRATE MONITORING RESULTS IN AGRICULTURAL CATCHMENTS

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Abstract

The paper deals with monitoring results of nitrate nitrogen (NO_3^--N) run-off in three small agricultural catchments in Latvia (Berze, Mellupite, and Vienziemite) during the period of 1995 - 2007. Continuous flow measurements and water sampling were carried out in two scales – catchment and drainage field. Water quality data was analyzed statistically to identify outliers at various intensity agricultural production systems. The results indicated that with increase of agriculture intensity outlying values are higher and scattered from the rest of the data set thereby the risk of NO_3^--N leaching is higher. It can be explained by application of different rates of organic and inorganic fertilization. To analyze water discharge data, cumulative distribution was used. The results show that main part of the water discharge is observed from late autumn to spring, whereas in summer period it is low and stable. The dependence of NO_3^--N concentrations on the discharge is expressed by Spearman's correlation coefficient - at catchment scale it is 0.37 in Vienziemite site, 0.39 - in Berze, and 0.44 in Mellupite. Calculated correlation coefficients are statistically reliable.

Key words: nitrate nitrogen concentration, agricultural catchments, discharge.

Introduction

Agriculture is one of the major sources of nitrogen that contributes to the eutrophication of the inland waters and the Baltic Sea (Jansons et al., 2003; Kyllmar, 2004; Šileika et al., 2006).

Other consequence of nitrogen losses from agriculture could be the increase of nitrate concentration in the surface and groundwater. This can result in the poor water quality from both private wells and municipal water sources that are used for water supply. EC Directive 91/676/EEC (Nitrate Directive) aims to protect waters against pollution caused by nitrates from agricultural sources and prevent further such pollution. Member States which apply the action programmes throughout their national territory shall monitor the nitrate content of waters (surface water and groundwater) at selected measuring points which make it possible to establish the extent of nitrate pollution from agricultural sources. Monitoring to control the effectiveness of action programmes means assessment of the impact of changes in agricultural practices on nitrate losses to surface and ground waters firstly at the whole catchment, secondly at the micro-catchment, and thirdly at the field level (Draft guidelines for..., 2003).

For the assessment of agricultural pollution to water bodies, an agricultural run-off monitoring programme in Latvia was implemented in three small agricultural catchments (Berze, Mellupite, and Vienziemite). Measures of the action programmes to reduce NO_3^--N pollution are not yet implemented in monitoring catchments.

Surface water quality in agricultural catchments depends on both natural conditions and human impact. Therefore the hydrologic and weather conditions, spatial and temporal variability, differences in land use and land management practices should be taken into account when analysis of water quality data is carried out (Iital, 2005).

Materials and Methods

Study areas represent different geographical regions in the western (Mellupite), central (Berze), and north-eastern (Vienziemite) parts of Latvia. In study areas are varied soils and agricultural practices. Continuous flow measurements and water sampling were carried out in two levels – catchment and drainage field. Composite water samples based on flow proportional procedure and manual samples were collected monthly. Water analyses of NO_3^--N were carried out in Latvian Institute of Aquatic Ecology according to standard method (LVS 339:2001). Main characteristics of monitoring sites are presented in Table 1.

Table 1

Main characteristics of monitoring sites

Monitoring site / Scale	Area, ha (% arable land)	Soil	Flow measurement sampling method	Intensity of agricultural system
Berze Small catchment	368 (98)	Silty clay loam	Modified Crump V-weir, data logger Flow prop. sampling	Intensive
Drainage field	77 (100)		Triangular weir, data logger Flow prop. sampling	
Mellupite Small catchment	960 (69)	Loam, clay loam	Crump weir, data logger Flow prop. sampling	Moderate intensive
Drainage field	12 (100)		Triangular weir, data logger Flow prop. sampling	
Vienziemite Small catchment	592 (78)	Sandy loam	Combined profile weir, data logger Manual sampling	Low input farming
Drainage field	67 (100)		Triangular weir, data logger Manual sampling	

The Berze catchment is characterized by relatively intensive crop production as compared to the present farming conditions in Latvia. The landscape is flat lowland and 98% of the catchment soils are cultivated. Due to high natural soil fertility, winter wheat and rape have become the main crops in the Berze catchment. The share of arable crops has increased up to 80-90%. Farmers use modern equipment, and rather intensive technology for Baltic conditions, e.g. a fertilizer application in some fields has reached 160 kg N ha^{-1} $year^{-1}$.

The Mellupite catchment represents average farming conditions and can be considered as typical for the present agriculture in Latvia. Several large farms are using intensive agricultural technology, whereas a few farms are producing only for self-consumption with low fertilization rates and without pesticides. The average use of mineral fertilizers ranges from 10 to 40 kg N ha^{-1} $year^{-1}$.

The landscape in the Vienziemite catchment is rather hilly for Baltic conditions. Soil, slopes, and market conditions are less favorable for agriculture and only two farms in the catchment are producing something for market. Almost no fertilizers (only 4 –5 kg N ha^{-1} $year^{-1}$) are applied in Vienziemite. Most of the farmland was abandoned land or low productivity grassland during the measurement period. The Vienziemite catchment is a typical example of low - input agricultural land use, and can be used as a reference site for diffuse pollution (Jansons et al., 1999).

Two different types of graphs and two tests are used to visualize and evaluate water quality and quantity data. Box plots (Figure 1) are used for graphical presentations of the NO_3^--N concentration data. The box plots represent the rank-sum test results and show the 25th, 50th, and 75th percentiles as calculated using robust log-probability regression. Side-by-side box plots are convenient for determining differences in medians and similarity in spreads (Warner, 2000). As well as box plots could be used to calculate and show outliers of monitored data set. These are observations which values are quite different from the others in the data set, and often cause concern or alarm. Outliers can have one of three causes: (i) a measurement or recording error; (ii) an observation from a population not similar to that of most of the data, e.g. a flood caused by a dam break rather than by precipitation; (iii) a rare event from a single population that is quite skewed (Helsel and Hirsch, 2002).

The statistical properties of water quality data (concentrations of nutrient) are usually not normally distributed, and they often reflect a seasonal pattern because they are influenced by water discharge (Iital, 2005). Therefore to test normality of water quality and discharge data, the Kolmogorov–Smirnov test (K–S test) was used.

Spearman's rank correlation procedure was used to identify monotonic (but not necessarily linear) correlations among constituents, providing a measure of the intensity of association between two variables. Spearman's correlation coefficient is the linear correlation coefficient computed on the ranks of data instead of actual values. This coefficient ranges from -1 to +1; a negative coefficient indicates that the higher ranks of one variable are related to the lower ranks of the other variable. The closer the absolute value of r_s is to 1, the greater is the correlation between the two variables. A small r_s value, however, can still be significant, depending on the associated p value. If this p value is less than the significance level ($p<0.05$), then the null hypothesis of no correlation (or $r_s=0$) is rejected, and the correlation coefficient computed is considered statistically significant (Warner, 2000).

A cumulative distribution curve of the monthly mean values was used to show high and low water discharge periods.

Results and Discussion

The observed concentrations of NO_3^--N have rather remarkable variability in all monitoring sites, as well as in monitoring scales (Figure 1). High mean and maximum NO_3^--N values in the Berze catchment (mean – 6.8 mg l^{-1}) and drainage field (mean – 10 mg l^{-1}) levels can be explained by the intensity of agricultural production, and increased use of fertilizers. Compared to Berze in Mellupite monitoring catchment less fertilizers are used therefore NO_3^--N concentrations (mean 2.7 mg l^{-1} in the catchment and mean 6.5 mg l^{-1} in the drainage field) are fairly stable and close to mean value. In the Vienziemite site, NO_3^--N concentrations are low and can be assumed to be close to the natural levels, and there are no difference in the concentration in drainage field (mean - 0.83 mg l^{-1}) and catchment (mean - 0.86 mg l^{-1}) scales. NO_3^--N mean concentrations in the studied catchments do not exceed the levels established by the Nitrate Directive (i.e., 11.3 mg NO_3^--N l^{-1}).

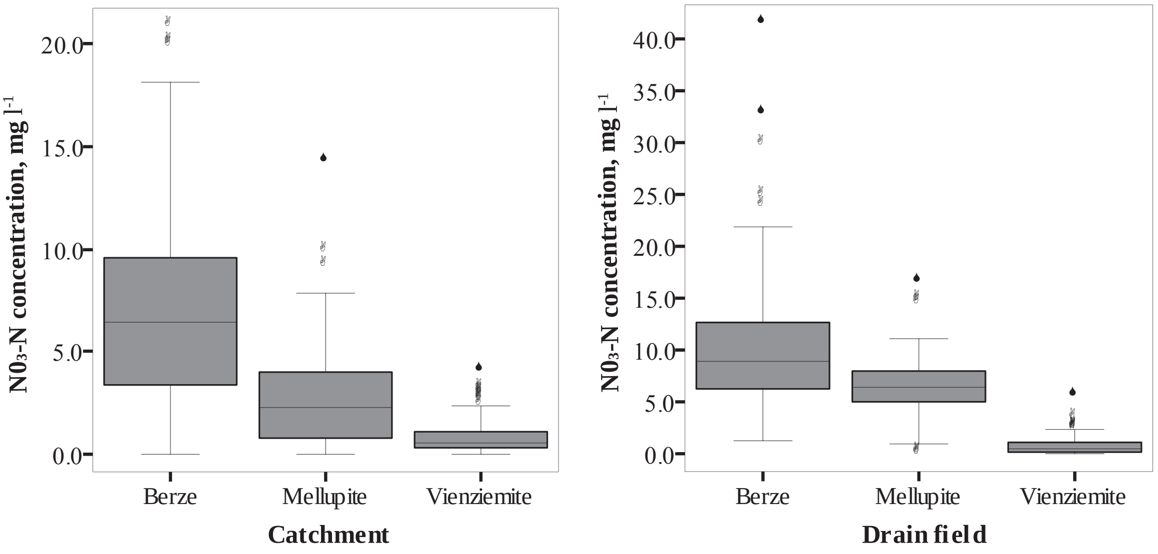

Figure 1. Concentrations of NO_3^--N in the catchment and drainage field scales: minimum, mean, maximum, and outlying values.

The observed NO_3^--N concentrations were higher in the drainage field outlets compared with concentrations in the streams. The drainage water as it moves from the root zone to the underlying drainage pipes has higher nutrient concentrations, and nitrogen removal / retention started there due to aeration, intake, and mixing with the surface run-off. Relatively slow flow processes and more favorable conditions for retention can contribute to the nutrient decrease in streams (Jansons et al., 1999).

It should also be noted that some values of the observed concentrations can be considered as extreme values, which are statistically different from the other data set. They are most likely due to extreme natural conditions such as intense rainfall over a short period, fast snow melting, etc. In fact, outliers are the maximum values that have been fixed during the study period, and it is obvious that these values have an impact not only on the instantaneous concentration in water, but also on the calculated total NO_3^--N losses.

Cumulative distribution of discharge shows the time periods of intensive water flow, which also affects the NO_3^--N losses. Similar trends can be seen in all monitoring sites and in both field and catchments' monitoring scales. Most of the water discharge occurred during spring flood, snowmelt in winter, and rainy period in the fall (Jansons et al., 2003; Deelstra et al., 2004; Kutra, 2006). The results show that main water discharge occurs during the period from October to May, while during the summer months, discharge is low and stable. Highest water discharge is measured in Vienziemite monitoring site, while the lowest is in Berze. Differences in discharged volumes are associated with the regional distribution of rainfall and local water balance. In the study period, the average rainfall in Vienziemite catchment area was 702 mm, in Mellupite 636 mm, and in Berze 581 mm.

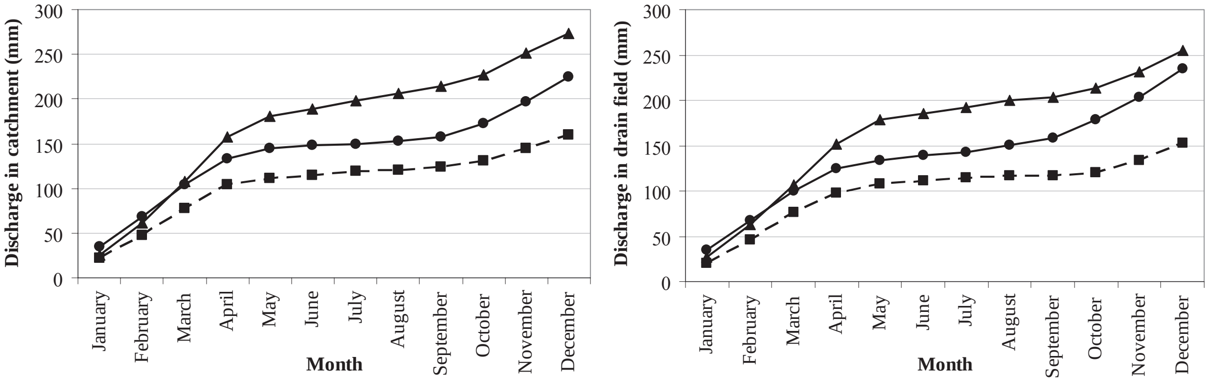

Figure 2. Cumulative distribution of discharge (mm) in different monitoring scales:
■ - Berze, ● - Mellupite, ▲ - Vienziemite.

In general, nitrogen losses from arable land have a good correlation with water discharge from the catchment area and main losses occur with surface and drainage runoff during the high runoff periods (Iital, 2005). Monthly concentrations of NO_3^--N in Berze catchment support the above - mentioned statement (Figure 3). Mean values are higher during spring flood and rainy period in the fall. Extreme values in summer can be explained by rainfall that follows dry periods.

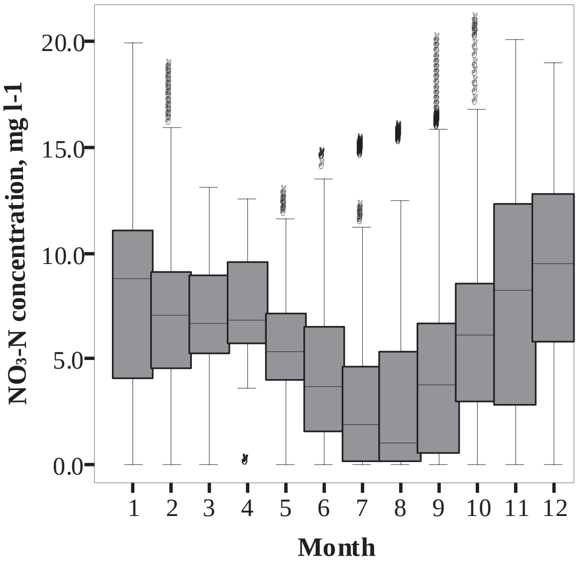

Figure 3. Minimum, mean, maximum, and outlying monthly concentrations of NO_3^--N in Berze catchment scale:
1 – January, 2 – February, 3 – March, 4 – April, 5 – May, 6 – June, 7 – July, 8 – August, 9 – September, 10 – October, 11 – November, 12 – December.

Also Spearman's correlation coefficients (r_s) between NO_3^--N concentrations and discharge show rather close relationship. In the small catchment scale in Berze monitoring site, $r_s = 0.39$ ($p = 0.00$), in Mellupite - $r_s = 0.44$ ($p = 0.00$), and in Vienziemite - $r_s = 0.37$ ($p = 0.00$); p value indicates that the given correlation coefficients are statistically reliable.

Conclusions

The results of the study show large variations in NO_3^--N concentration depending on land use and management practices. With increase of agriculture intensity, resulting in increase of nitrogen inputs in the catchments' area, mean and maximum NO_3^--N concentrations are higher in Berze and Mellupite monitoring sites.

Water discharge in all study catchments mainly occurs during the period from October to May, while during the summer months discharge is low and stable. Higher water discharge usually determines higher NO_3^--N losses, because more water infiltrates through the soil profile, resulting in a higher nitrate leakage, especially in drainage systems. Thus, specific agricultural practices and mitigation measures should be implemented to decrease the pollution risk caused by the meteorological conditions that are prevailing during the autumn/winter period.

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