The Interaction Between Groundwater Fluctuations and Nitrate Nitrogen Concentrations: case study in Latvia

A. Veinbergs, V. Vircavs, K. Abramenko, D. Lauva, Z. Dimanta, I. Vītola, and A. Gailuma
Latvia University of Agriculture. Dept. of Environmental Engeneering and water management. Jelgava, Latvia, 19 Akademijas Str., LV3001. e-mail: aarts@inbox.lv

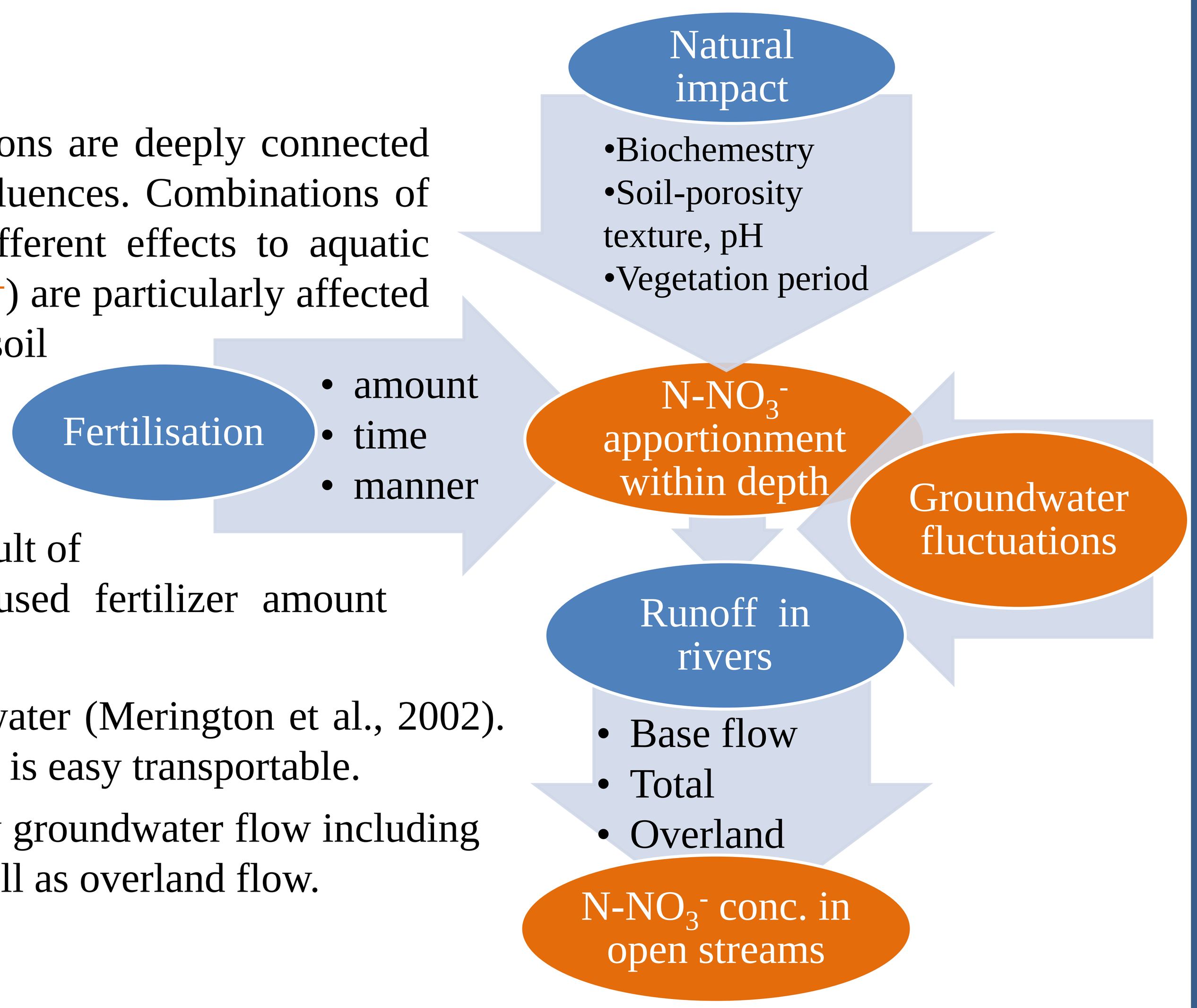
INTRODUCTION

Surface water hydrology and hydro-chemical conditions are deeply connected with processes in soil under natural and artificial influences. Combinations of environmental and antropogenic impact lead to different effects to aquatic environment. In Latvia, soil particles and nitrate (NO_3^-) are particularly affected by shallow groundwater fluctuations and runoff from soil to open streams because of typically humid climate conditions.

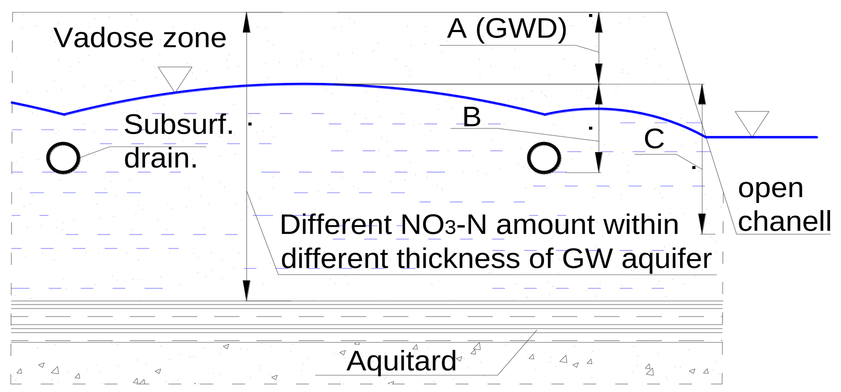
There is different amount of nitrate nitrogen ($N\text{-}NO_3^-$) in soil within depth. The characteristic amount is a result of natural sources as well as greatly dependent on used fertilizer amount (Gustafson, 1983).

$N\text{-}NO_3^-$ has anionic form and high solubility within water (Merington et al., 2002). This is the main reason why $N\text{-}NO_3^-$ from soil to rivers is easy transportable.

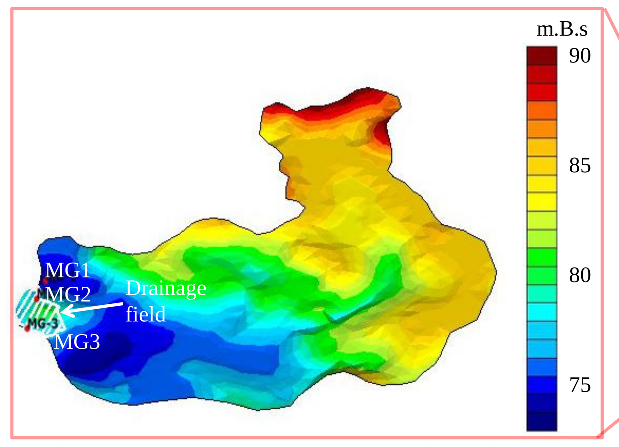
$N\text{-}NO_3^-$ from soil to rivers is commonly transported by groundwater flow including base flow and subsurface drainage pipe transport as well as overland flow.



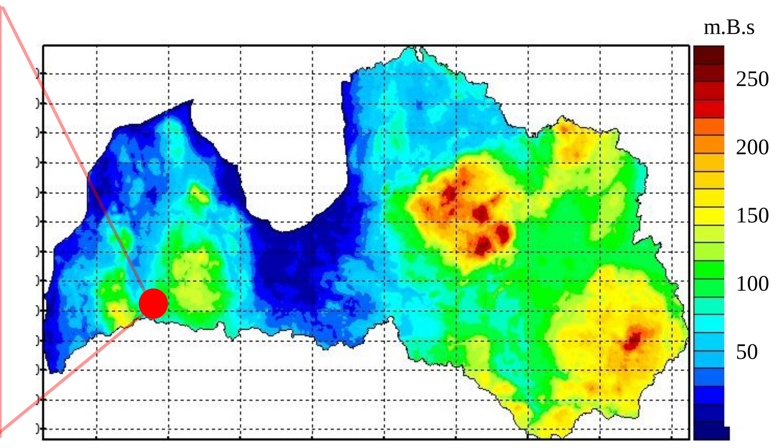
METHODOLOGY



1.fig: Groundwater flow from aquifer



2.fig: Mellupīte small catchment with drainage field and groundwater wells (MG1, MG2 and MG3)

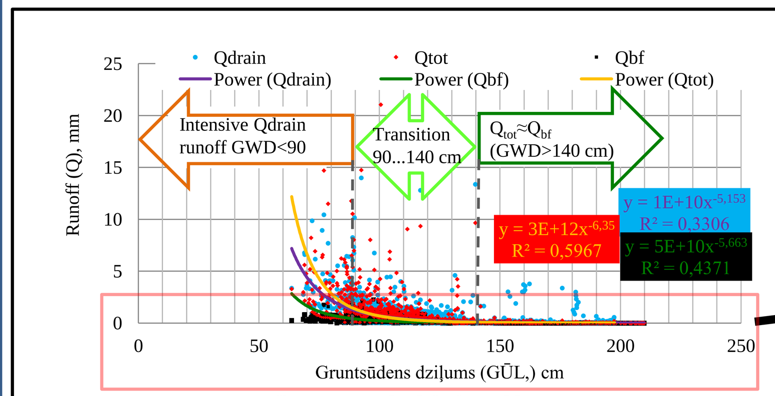


3.fig: The location of monitoring sation Mellupite in Latvia

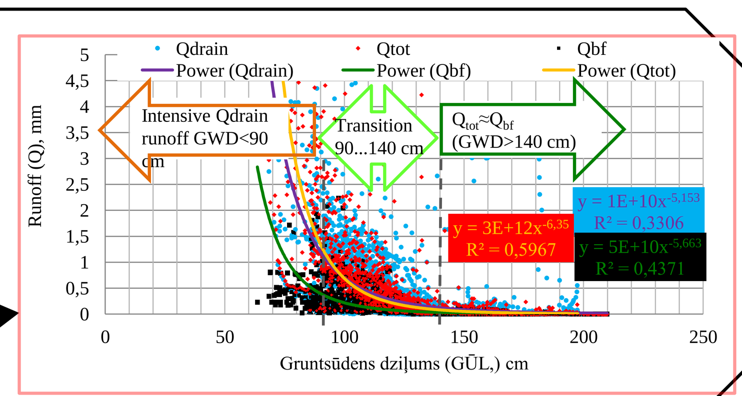
There are differences in all the groundwater aquifer –the part the dominant flow with $N\text{-}NO_3^-$ is forms from. Subsurface drainage runoff mainly transports water solution from soil layer B, river from layer C (1. fig.).

In Mellupīte small catchment (2. fig. and 3. fig.) $N\text{-}NO_3^-$ concentrations within 2006-2010 are estimated by analyzing Groundwater depth (GWD) fluctuations (observed in groundwater well MG1). Only one groundwater well observations are used because the fluctuations in all the three wells correlates (R2>75) even the altitude difference of earth surface is ≈5 m. Three GWD periods (1.GWD>140; 2. 90<GWD<140; 3. GWD<90) are divided by analyzing values of $N\text{-}NO_3^-$ probability curves (6. fig.,7. fig., 8. fig. and 9. fig.) and changes of runoff distribution in components - total runoff from small catchment (Q_{tot}), base flow from small catchment (Q_{bf}) and drainage runoff from drainage field (Q_{drain}) (4. fig. and 5. fig). Base flow (Q_{bf}) is calculated by FORTRAN program "Base Flow index" (BFI) (Wahl, K. L., and Wahl, T. L., 1995). 68% of Mellupīte small catchment are drained artificially – mainly with subsurface drainage. This affects the GWD, by increasing the groundwater runoff intensity. In hydrograph it's shows as a pike values. As the BFI separates the pike values, the difference between total runoff and base flow, is strongly related with subsurface drainage runoff (Q_{drain}). If the GWD is deep, $N\text{-}NO_3^-$ is mainly transported by base flow, while GWD becomes more shallow, drainage runoff becomes dominant.

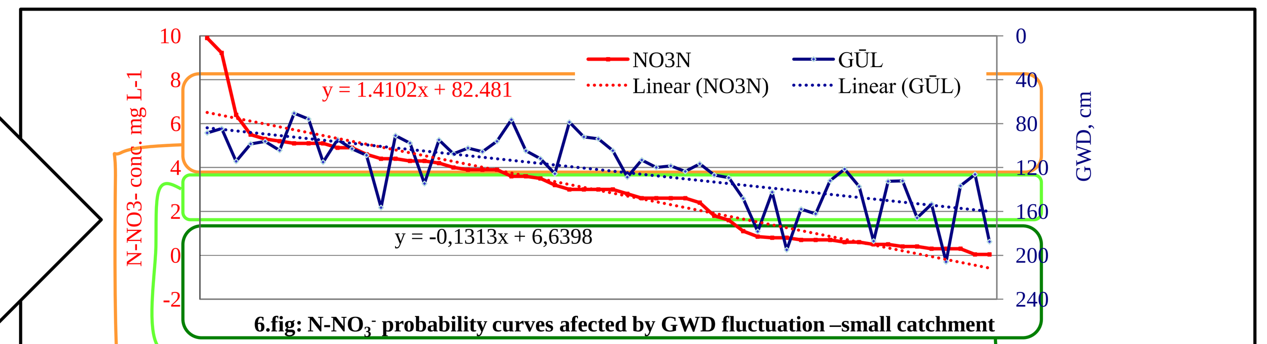
RESULTS AND DISCUSSION



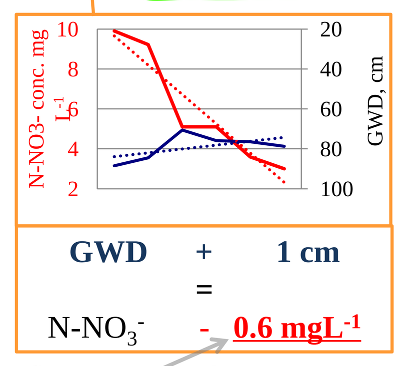
4.fig: Qtot and Qbf afected by GWD



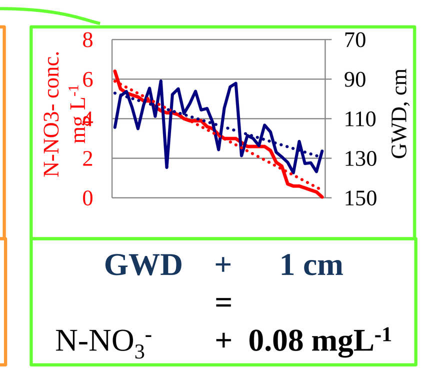
5.fig: Qtot and Qbf affected by GWD



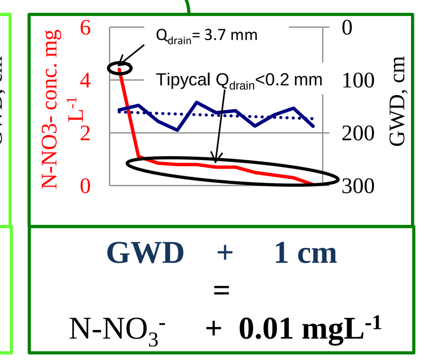
6.fig: $N\text{-}NO_3^-$ probability curves afected by GWD fluctuation –small catchment



7.fig: $N\text{-}NO_3^-$ conc. when GWD<90 cm



8.fig: $N\text{-}NO_3^-$ conc. when 90<GWD<140 cm

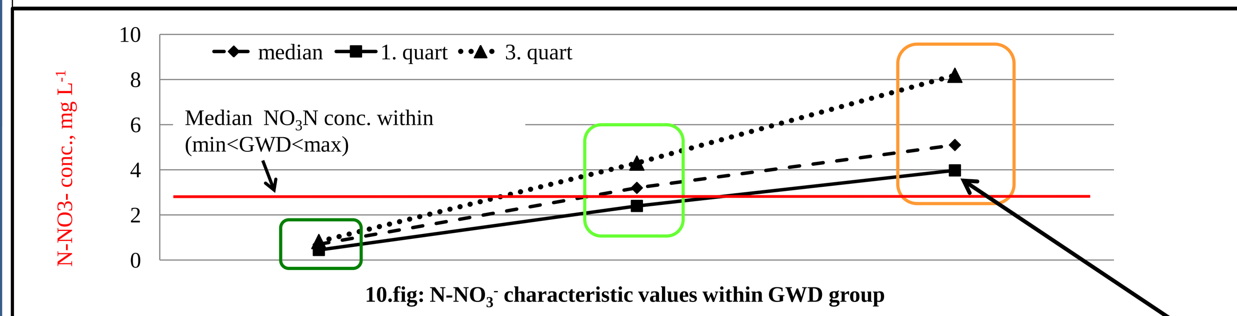


9.fig: $N\text{-}NO_3^-$ conc. when GW>140 cm

Trends of total runoff from small catchment (Qtot) and from drainage field (Qdrain) within groundwater depth (GWD) fluctuations are at a close range. But the base flow in small catchment (Qbf) is more different (4. fig. 5. fig.). Such results suggest that the pike values in runoff hydrograph mainly are the result of drainage runoff. When the groundwater is deep, the Qbf≈Qtot. In case the GWD decreases, the distribution of Qbf and Qdrain is changing and the drainage runoff becomes more dominant. In the same time the dominant depth of soil layer (B and C shown in 1. fig.), mainly influenced by runoff, is changing sharply. It also sharply affects the leaching of $N\text{-}NO_3^-$.

As it was previously stated, three GWD periods (5. fig. 6. fig.) are divided :

1. $Q_{tot}≈Q_{bf}$ – the leaching of $N\text{-}NO_3^-$ affected by Qbf (7. fig.);
2. Transition period – the drainage runoff starts (8. fig.);
3. Intensive Qdrain – the leaching of $N\text{-}NO_3^-$ dominantly is affected by Qdrain (9. fig.).



10.fig: $N\text{-}NO_3^-$ characteristic values within GWD group

Low GWD group = Low $N\text{-}NO_3^-$ conc. and it's amplitude	Middle GWD group = Middle $N\text{-}NO_3^-$ conc. and it's amplitude	High GWD group = High $N\text{-}NO_3^-$ conc. and it's amplitude

➢High GWD influence. However the trend is opposite as it is recognized in other GWD periods (8.fig. 9.fig.)

But...

Highest $N\text{-}NO_3^-$ conc. Minimum (10. fig.)

In general GWD fluctuations has the same trend as $N\text{-}NO_3^-$ conc. cumulative curve (6. fig.). Also the higher GWD class the higher $N\text{-}NO_3^-$ conc. and its amplitude is estimated (10. fig.). However in every GWD group there are different respons reaction of $N\text{-}NO_3^-$ conc. within changes of GWD (7. fig. 8. fig. 9.fig.).

CONCLUSIONS

In general: GWD decreases (becomes more shalow) → increases runoff – base flow Q_{bf} and latter Q_{drain} → increases $N\text{-}NO_3^-$ concentration

In details:

➢The trend of Qtot and Qdrain within groundwater depth (GWD) fluctuations is at a close range. But Qbf is more different (4. fig. 5. fig.):
- ➢ According to mentioned, pike values, separated by program BFI, are similar to Qtot-Qbf≈Qdrain;

➢The main part of Qtot (figure 1.):
- ➢ forms from soil layer C when the base flow is dominant (Qbf≈ Qtot). It is defined when GWD greater than140 cm ;
- ➢ forms from soil layer B when the drainage runoff becomes dominant.

➢When GWD greater than140 cm, $N\text{-}NO_3^-$ conc. forms from soil layer C;

➢When GWD decrease and drainage runoff becomes dominant, $N\text{-}NO_3^-$ forms from soil layer B;

➢If GWD group is higher (groundwater is more shallow), the higher is (10. fig.):
- $N\text{-}NO_3^-$ conc;
- $N\text{-}NO_3^-$ conc. and amplitude;
- changes of $N\text{-}NO_3^-$ conc. mgL^{-1} per 1 cm GWD.

➢If $Q_{tot}≈Q_{bf}$ (GWD>140), $N\text{-}NO_3^-$ conc. are affected more slightly than in other GWD groups (7.fig., 8. fig. 9. fig);

➢The different (negative) trend is recognized when the GWD<90 (7. fig.) The reason could be decrease of $N\text{-}NO_3^-$ amount in active root zone. However the quality of data for this period is poor.

References
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contact information:
Institution: Latvia University of Agriculture
Project contact person: Artūrs Veinbergs
Address: 19 Akademijas Str., LV-3001, Jelgava, Latvia
E-mail: aarts@inbox.lv
Web page : www.llu.lv/lif