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Experimental studies of nitrogen fertilizers emissions from the catchment area

***Yu. Luzovitska** *(Ukrainian Hydrometeorological Institute)*, **N. Osadcha** *(Ukrainian Hydrometeorological Institute)*, **O. Ukhan** *(Ukrainian Hydrometeorological Institute)*

SUMMARY

The intensification of agriculture is closely related to the use of fertilizers, which has led to a significant increase in the pollution of waters. Globally, the share of diffuse water pollution has exceeded the role of point sources. Experimental studies on small plots were conducted to assess the impact of fertilizers on the nitrogen leaching from the catchment area during snowmelt event. Ammonium nitrate in dose of 300 kg per ha was applied to one of the plots. 18.6% of nitrogen compounds were additionally leached from the fertilized plot compare to the control one. In the undisturbed conditions the nitrogen emission is equally provided by surface flow and a subsurface flow, whereas upon applying fertilizers it is almost completely determined by a subsurface flow -97%. Obtained data showed that 96% of N water emission within agricultural area are provided by fertilizers. Due to good solubility the nitrate leaching from catchment was significantly higher in comparison with the ammonium form. The part of NO3- compounds in a surface flow was 42% in natural conditions and 2% on the fertilized plot. It was 58% and 98% correspondingly in a subsurface flow. Fertilizer application did not increase ammonium outcome from the catchment.

Introduction

Global population annual growth has exceeded 1% over the past 50 years. The world is faced with the challenges of providing resources, primarily food and water. Arable land area is limited and almost reached its limit. In particular, Ukraine has the highest rate of ploughed land in the world, which has reached 56% of the administrative territory and accounts for about 80% of agricultural lands. The solution was found in the intensification of agricultural production, consisting in a significant increase of mineral fertilizers application (*FAO and IWMI, 2017*). It followed an increase in water pollution with nutrients, nitrogen and phosphorus compounds, in water bodies everywhere. Society was faced with the need to resolve the contradiction between food supply and ecology.
Increased content of nutrients in water leads to uncontrolled production of higher aquatic plants and algae, resulting in undesirable imbalance of organisms in the water body and deterioration in water quality. This phenomenon is widely known as eutrophication or water "blooming" (*Dodds, 2002*; *Edmondson, 1995; Kazakova, 2015*).

Control of nutrients in water is one of the important factors to ensure the proper functioning of aquatic ecosystems and manage water quality. On the one hand, various regulations are being adopted, among which the Nitrate Directive and the Code of the best agricultural practices should be mentioned. On the other hand, methods and models are being developed to assess emission fluxes from the catchment area.
This work was aimed at experimental research of mineral fertilizers the leaching from the catchment area.

Method

Event-base field study was carried out at the research runoff plots (2.0 x1.0 m) covered by chernozem soils. The soil surface layer was removed to a freezing depth of 0.4 m (annual average value), a waterproof layer was laid and the soil surface layer was then returned. Plastic tubes for runoff collection were positioned near the surface and confining layer. These manipulations allowed us to separate physically the fast overland flow and the slow subsurface to establish the relative importance of different hydrological pathways for nitrogen emission. Plots were planted with grass in autumn.
During a winter a snow layer of 80 cm was accumulated. In March, an ammonium nitrate NH_4NO_3 in dose of 300 kg of active ingredient per hectare was applied to one of the plot. The second plot was used to control.
The water samples were permanently collected during the snowmelt lasted for 30 days. Mineral nitrogen was determined after prefiltration.

Results and Discussion.

Water runoff

An air temperature increase led to the formation of overland flow which sharply rose after the air temperature was over 0°C (Figure 1). The saturation of the soil moisture lasted 10 days, after that a subsurface runoff was formed.
During the snowmelt period, a water runoff with a volume of 1065.9 dm^3 was formed at the unfertilized plot № 1 and 1341.5 l dm^3 at the fertilized plot №2 which are 1065.9 dm^3 and 266 mm, respectively. Distribution between the surface and subsurface runoff at both plots were almost identical.

At the first plot runoff share of 56% surface flow and 44%subsurface flow, at the second plot 52% and 48%, respectively. An intensive increase discharge was observed after 384 hours from the beginning of the water runoff.

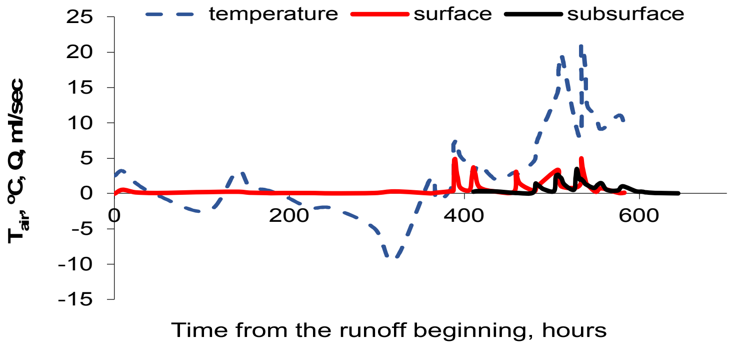

Figure 1 *Air temperature and water discharges at the plot №1.*

Nitrogen emission

The nitrogen response in the natural plot was equal to 0.5 g or 1.4 % of N content in the contact layer, while under fertilizer conditions it reached 11.7 g or 12.8% of N total reserve. Compare to natural conditions fertilizer application led to the growth of nitrogen leaching by 25 times.
Data obtained showed that fertilizers contribute 96% of N pollution in discharge water in the arable areas. Due to the water emission the inefficient losses of the applied N fertilizers amounted to 18,6%.
The inorganic nitrogen ability to form easily soluble f compounds contributes to their high migration capacity in the soil and subsequent scattering in the landscape.
This feature indicates that none component of the chemical composition of natural waters is able to limit the accumulation of these components, and with increasing mineralization, the NH_4^+, NO_2^- and NO_3content will also increase. The solubility of NH_4NO_3 at a temperature of 18 - 20 ° is 1920 g kg^{-1}, and for KNO_3 reaches 3067 g kg^{-1} (*Krainov, Zakutin, 1993*).
Different pathways contributed to the nitrogen emission. On the unfertilized area, the emission was almost equally shared between the surface and subsurface runoff. Whereas on the fertilized plot № 2 the subsurface flow was dominate and responsible for the 97% of inorganic nitrogen leaching (Figure 2).

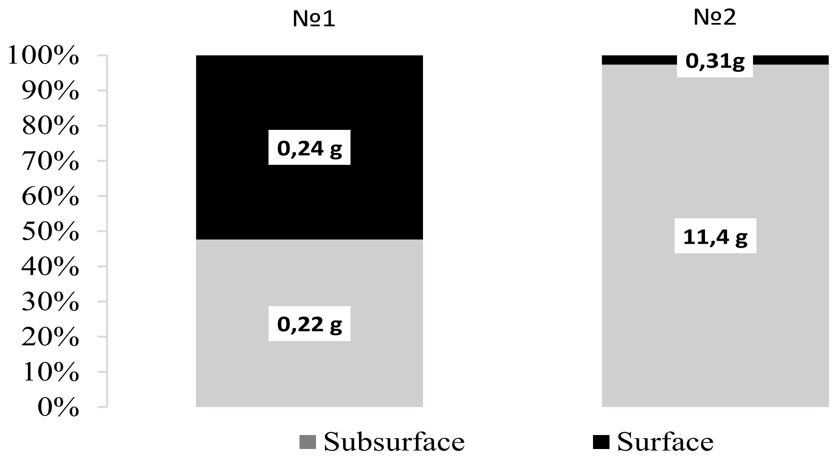

Figure 2 *Share of the surface and subsurface flow in inorganic nitrogen leaching from unfertilized (№1) and fertilized plot (№2).*

In our opinion, this difference is due to the opposite behaviour of nitrate and ammonium compounds of nitrogen. It was mentioned above that nitrogen nitrate forms are well soluble compounds, while ammonium nitrogen shows a high ability to sorption on fine soil particles, represented by clay minerals. The activity of ammonium ion exceeds the activity of potassium, sodium, lithium. This means that ammonium is capable of their displacement in the process of ion exchange.
Humic substances, which are the dominant component of the soil organic part, also have a high ability to absorb ammonium (*Krainov and Zakutin, 1995*). Ammonium compounds due to exchange absorption accumulates in the soil. While nitrate ions form good soluble salts mainly with calcium and magnesium and are easily transported into the depth of the soil profile and also outside the soil ecosystem (*Klechkovsky and Petersburg, 1967*). According to (*Akhmetyeva et al., 1991*) 93% of ammonium is sorbed from the soil solution by loams, while only 55-60% by sands. The mineral part of soil in the studied plots was mainly represented by montmorillonite, which is the reason for the high volume of ammonium fixation (*Sokolov, 1973*). This is the reason why nitrate form dominates in the composition of soluble nitrogen compounds at both plots.
The differences in the ratio of nitrate and ammonium forms are founded between the faster surface and slower subsurface flow (Figure 3).

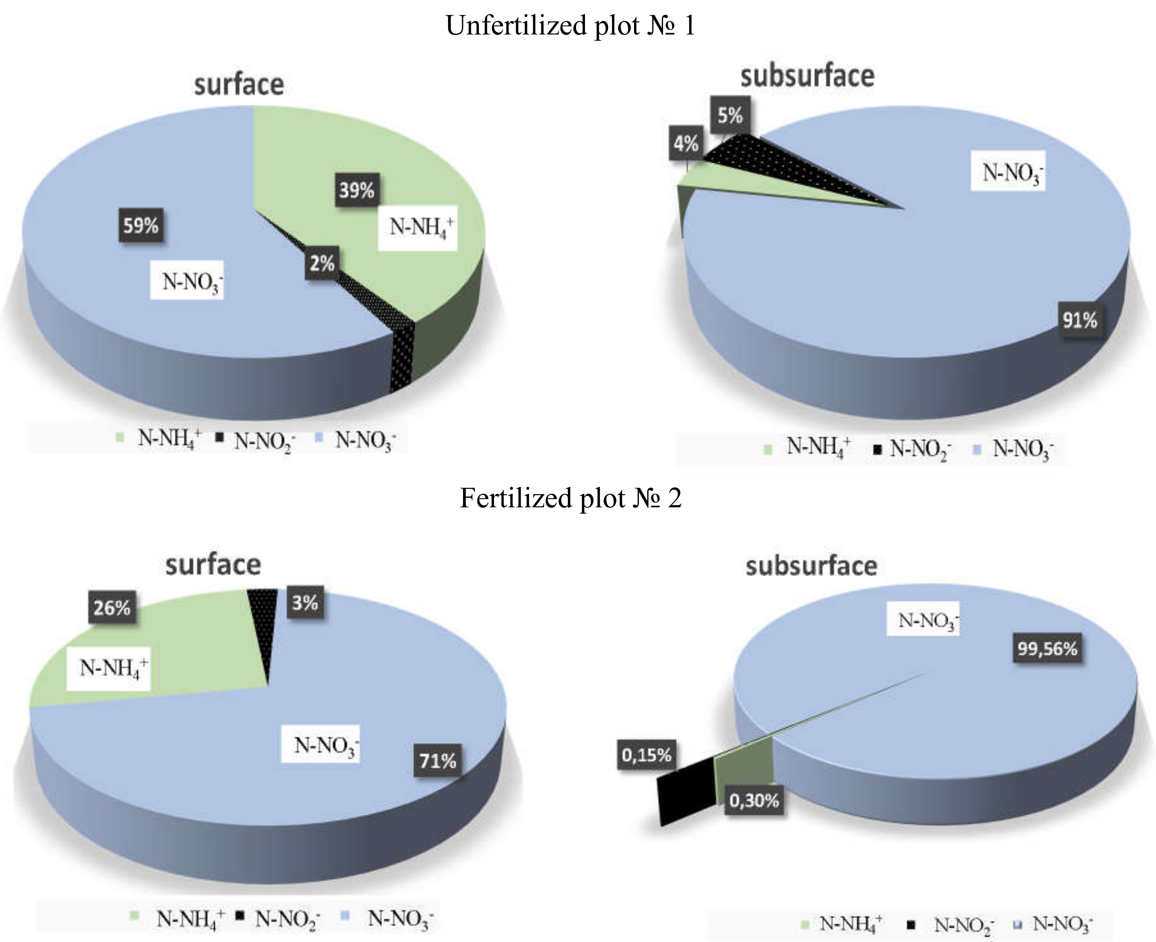

Figure 3 *Share of the nitrogen inorganic forms in surface and subsurface flow.*

During snowmelt event totally 140 mg of nitrates were discharged with the surface runoff, and 198 mg with the subsurface runoff on the unfertilized plot 1. The share of the nitrate forms in the total nitrogen emission with surface runoff was 39%, while in the subsurface runoff this value reached 91%.

Fertilizer application on the plot № 2 contributed to a significant increase of nitrogen leaching from the catchment. Totally 248 mg of nitrogen was discharged with the surface runoff, and 11 336 mg with the subsurface flow. Nitrate salts accounted for 71% in the total emission of nitrogen compounds with surface runoff, while the subsurface discharge was completely formed by nitrate forms of nitrogen. Totally 124 mg of ammonium nitrogen was received from the fertilized plot, which is comparable to the unfertilized one. At the same time, the share of ammonium nitrogen in the surface runoff of the unfertilized plot was higher and amounted to 59%, while in the fertilized one it was almost 2 times less. In connection with sorption processes, the proportion of ammonium forms of nitrogen in the subsurface flow is much lower. It was 4% on the unfertilized site, and where fertilizers were applied - 0.3%.

The obtained results showed that fertilizer application did not increase ammonium outcome from the catchment. In general, chernozems are characterized by lower ammonium saturation compared to other soil types (*Sokolov, 1973*). Plants mostly absorb an average of 50 - 60% of nitrogen from nitrogen fertilizers, about 15 - 30% is converted into organic form and 10 - 20% is lost from the soil as gaseous (*Klechkovsky and Petersburg, 1967*).

Conclusions

The nitrogen response in the unfertilized plot during snowmelt event was 0.5 g or 1.4 % of total N fund in the contact layer, while under fertilizer conditions nitrogen emission reached 11.7 g or 12.8% of N total reserve. Compare to natural conditions fertilizer application led to the growth of mineral nitrogen leaching by 25 times.

The nitrogen emission from the natural catchment is provided by surface flow and a subsurface flow equally. On the contrary, under fertilizer conditions, N transferring is almost completely determined by a subsurface flow - 97 %. From the obtained data it follows that 96 % of N pollution in discharge water within agricultural area are provided by fertilizers. The inefficient losses of the applied N fertilizers with water flow amounted to 19%.

Due to good solubility the nitrate leaching from catchment was significantly higher in comparison with the ammonium form. The part of NO_3^- compounds in a surface flow was 42% in natural conditions and 2% on the fertilized plot. It was 58% and 98 % correspondingly in a subsurface flow. Fertilizer application did not increase ammonium outcome from the catchment.

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