Effect of Water Table Rise on Migration and Transformation Law of Nitrate under The Condition of Rainfall in Saturated -Unsaturated Soil Layer

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Abstract: In this experiment, we simulated the migration and transformation law of nitrate under the condition of water table rise caused by rainfall in Changping District of Beijing. Two types of experimental apparatus were used in the experiment to simulate the distribution of NO_3^--N, NO_2^--N and NH_4^+-N, which were named soil column 1 and soil column 2. Soil column 2 was under the condition of rainfall and soil column 1 was for comparison. It took 50.3 hours for the experiment during which simples were taken and tested. The test items were the concentration of NO_3^--N, NO_2^--N and NH_4^+-N. The results indicated that (1) In unsaturated zone, the influence of leaching caused by rainfall on the concentrations of NO_3^--N and NH_4^+-N were significant. The decreasing range could reach to 95.9% and 90% which means that it was easily to lead to the contamination of groundwater. In saturated zone, NO_3^--N concentrations were mainly influenced by dispersion and could achieve balance between the dilution and dispersion with the increase of rainfall. The increasing range of NO_3^--N concentration was large, and the value could reach to 675%. In addition, the NH_4^+-N concentration had a slight trend of decrease. (2) Under the condition of rainfall, NO_3^--N concentrations increased in saturated zone, decreased in the path of water table rise and unsaturated zone. The NH_4^+-N concentrations had a decreasing trend in saturated-unsaturated zone. (3) NH_4^+-N concentrations in medium sand were more easily influenced by leaching from rainfall than those in silt.

Introduction

Groundwater is an important water supply source of human. With the increase of chemical fertilizer used in agriculture, the nitrogen contamination of groundwater is becoming more and more serious. The nitrogen contamination is always a threat to human health [1]. As for the nitrogen contamination on groundwater, domestic researchers pay more attention to the influencing factors of migration and transformation in groundwater-soil system [2-11]. But there must be water table fluctuations

according to the change of seasonal and natural conditions. Usually, rainfall can lead to the rise of water table and the change of unsaturated zone to saturated zone in the water table path which means changes of soil properties, such as water content and saturation [12-14]. In order to simulate the migration and transformation law of contamination more precisely, it is necessary to take these factors in to consideration. In recent years, some foreign scholars conducted some studies on migration and transformation law of nitrate in the artificial wetland system and under the water table fluctuation conditions [15]. S.Sasikala et[16] simulated the removal effect of TN and NH_4^+-N (below the artificial wetland system surface) under the steady and fluctuant water table conditions by laboratory experiment. Chris C.Tanner et.[17] simulated the removal effect of NO_3^--N, NO_2^--N and NH_4^+-N by artificial wetland system under the conditions of steady water table, fast frequency and slow frequency water table fluctuation. As an influence factors on nitrate migration and transformation, rainfall can easily pass through the unsaturated zone and lead to the contamination of groundwater by leaching. It is rare that simulating the effect of water table rise on migration and transformation law of nitrate on the condition of leaching in China.

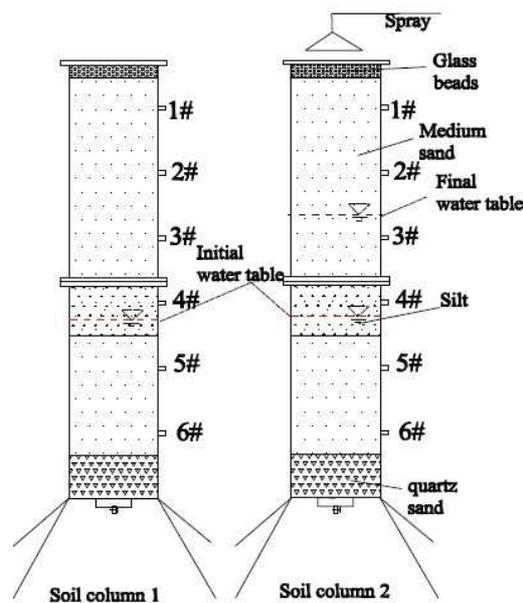**Materials and Method**

Experimental apparatus

Figure 1   Experimental apparatus

This experiment compared the migration and transformation of nitrate under two different conditions, rising water table caused by rainfall and steady water table without recharge, by laboratory experiment. The main components in this region are medium sand and silt, and the silt exists in the form of interlayer. Figure 1 shows the apparatus used in this experiment to test the temporal and spatial distribution of nitrate and its conversion product , NO2--N and NH4+-N. Soil column 1 simulates the condition of steady water table and soil column 2 simulates the condition of rising water table caused by rainfall. Both of the two soil columns are filled with two layers of medium sand and a layer of silt which is put in the middle of the column and is 40cm away from bottom of the soil column. On the top of the soil column 2 there are some glass beads whose purpose is to keep the water leach evenly. Above the soil column 2, there is a spray to simulate the rainfall. The sampling points are settled every 15cm vertically. Before the start of experiment , sampling points 1-3# are above the water table and in the unsaturated state, sampling point 4# is close to the water table and sampling points 5-6# are below the water table and in saturated state.

Materials

The two kinds of the soil used in the test are both taken from Changping District of Beijing and the depth is 10-15m from land surface. Medium sand and silt are filled in layer by layer. The properties of the two kinds of soil are shown in Table 1.

Table 1 Physicochemical property of the soils

	Density (g/cm^3)	Porosity (%)	NO_3^--N content(mg/kg)	NO_2^--N content (mg/kg)	NH_4^+-N content (mg/kg)	Organic matter (%)	pH	Non-uniformity coefficient
Medium sand	1.116	42.69	2.449	0.127	2.571	0.672	8.36	2.714
silt	1.303	36.39	4.742	0.142	1.857	2.288	8.6	7.69

Experimental method

Soil column experiment

First, keep the water table 40cm away from bottom by distilled water until capillary phenomenon was steady for 7 hours. Then pour 8L potassium nitrate solution with a concentration of 220mg/L into the sand column from the top rapidly. After 48 hours when solution infiltration was steady, start water spraying. And the spray intensity was 20ml/min. The water table in soil column 1 was always steady in the entire test. Time was calculated when the water spraying started in soil column 2. The experiment test lasted 50.3 hours. Some simples were taken and the concentration change of NO_3^--N, NO_2^--N and NH_4^+-N were tested.

Data analysis

Result of the experiment is the average result of there tests. The data from the test were fitted by Origin8.0. The representation method of the concentration changing range of NO_3^--N, NO_2^--N and NH_4^+-N is: $\frac{a-b}{a} \times 100\%$, a means the initial concentration of NO_3^--N, NO_2^--N and NH_4^+-N in soil column 2 at the beginning; b means the concentration of NO_3^--N, NO_2^--N and NH_4^+-N in soil column 2 at the last.

Results and Discussions

After water spraying, the water table in soil column 2 rose from 40cm to 65cm. The results indicated that the NO_2^--N concentration at each sampling point in two soil columns were always at low level and had no law, so it was omitted. We just discussed the change law of NO_3^--N concentration and NH_4^+-N concentration. It took 50.3 hours for the entire test, and timing began when water spraying started. The most significant effect on nitrate concentration was the dilution caused by rainfall and the dispersion caused by soil solution in soil column 2.

In the two soil columns, both sampling points 1# and 2# were in unsaturated zone. The concentrations of NO3--N and NH4+-N in soil column 1 were stable and had a slight change. And the concentrations of NO3--N and NH4+-N in soil column 2 were decreasing rapidly in the early stage, and the changing rate was diminishing until steady. After the experiment, the decreasing

range of NO3--N concentrations at sampling points 1# and 2# in soil column 2 were 95.9%, 86.7%, respectively. And the decreasing range of NH4+-N concentrations were 83.3%, 90%, respectively. The concentrations of NO3--N and NH4+-N in soil column 2 were smaller than those in soil column 1. Because of the test time were short, the leaching occupied a leading role. There was no leaching in soil column 1, the concentrations of NO3--N and NH4+-N were stable in the test period.

The sampling point 3# in the two soil columns changed from saturated state to unsaturated state. In soil column 1, the NO3--N concentrations at sampling point 3# had a trend of decrease and the NH4+-N concentrations did not change significantly. In soil column 2, the NO3--N concentrations at sampling points 3# had a trend of increase in the first 5 hours, and then had a trend of rapid decline, And a stable level in the late stage; the NH4+-N concentrations were diminishing in the early stage, stable in medium stage and increasing in late stage. After the experiment, the decreasing range of NO3--N concentration at sampling points 3# in soil column 2 is 82.9%, and the decreasing range of NH4+-N concentration is 61.5%. Both of the NO3--N concentration and NH4+-N concentration were smaller than those in soil column 1. Due to the short time of the experiment without other effect in soil column 1, the concentrations of NO3--N and NH4+-N have no remarkable trend. However in the soil column 2, the NO3--N and NH4+-N at sampling points 1# and 2# were leached into the bottom of the column, and effected the concentration at sampling point 3#. The process would lead to the increase of NO3--N concentration at sampling point 3# in the early stage. The NH4+-N concentrations were in a low level.

In the two soil columns, the sampling point 4# was in the silt layer and changed from unsaturated state to saturated state. In the layer, there were a large amounts of fine particles and organic matter. At the beginning of the experiment, the NH4+-N concentrations had been in a higher level and an unobvious changing trend at the sampling point 4# in soil column 1, while the NO3--N concentrations had a trend of increase there; In soil column 2, the concentrations of NO3--N and NH4+-N were stable, and in the low level. After the experiment, the concentration decreasing range of NO3--N and NH4+-N in soil column 2 were 45.7% and 55%, which were obviously smaller than those in soil column 1. In the process of the experiment, the concentration changing trend of NO3--N and NH4+-N was slight. In soil column 2, the concentrations of NH4+-N at sampling point 4# were stable at the beginning without the influence of leaching. When the leaching influenced the sampling point 4#, the NO3--N concentrations increased because of the solution exchange.

The sampling points 5# and 6# were always in saturated zone. The concentrations of NO3--N and NH4+-N at sampling points 5# and 6# were relatively stable and change slightly in the test process. In soil column 2, the NO3--N concentrations at sampling points 5# and 6# were stable and then slightly increased in early stage, in a steady trend and then slightly increased in late stage; the NH4+-N concentrations had a decreasing trend. After the experiment, the NO3--N concentrations at sampling points 5# and 6# in soil column 2 were larger than those in soil column 2, and the NH4+-N concentrations were smaller than those in soil column 2. The concentration change of NO3--N and NH4+-N at sampling points 5# and 6# in soil column1 without the effect of leaching was unremarkable. The concentrations of NO3--N and NH4+-N at sampling points 5# and 6# in soil column 2 were also stable in the early stage. It is because the effect of leaching did not reach to these sites. Later, the NO3--N concentrations at sampling points 5# and 6# increased and then decreased to stable stage which indicated the leaching did not influence the two points. The transient increase of NO3--N concentrations resulted from the dispersion. And the decreasing and stable trend indicated the balance between dilution and dispersion. The decreasing trend of NO3--N concentrations resulted from the dilution. The NO3--N concentrations at sampling points 5# and 6# in soil column 2 had a big peak which duo to the little distance from the water table. After the

experiment, the increasing range of NO3--N concentrations at sampling points 5# and 6# in soil column 2 is 21.4%, 675%, respectively. And the decreasing range of NH4+-N concentration is 36.4%, 39.4%, respectively.

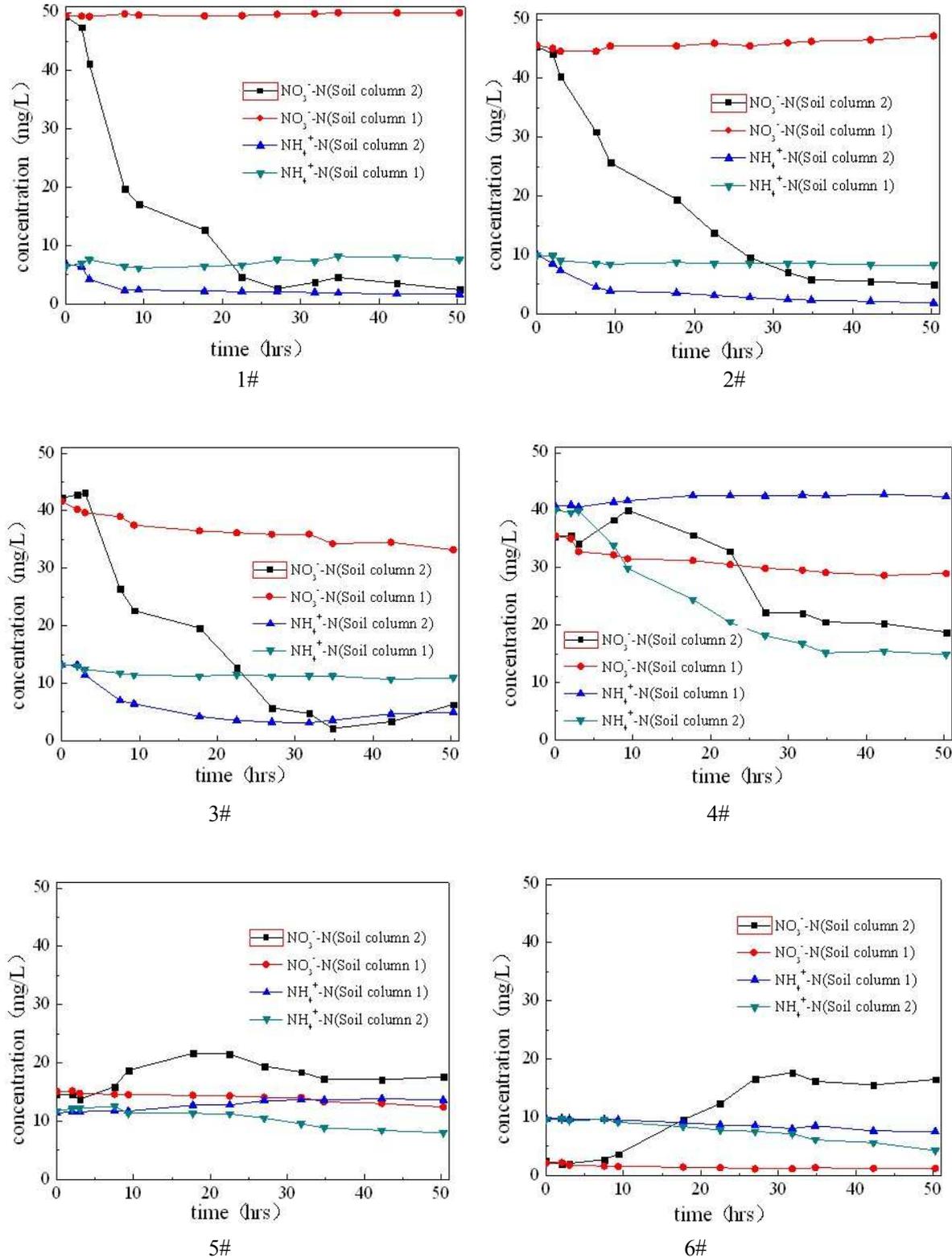Figure 2 shown the concentrations contrast of NO3--N and NH4+-N in the two soil columns.

Fig.2 Concentrations contrast of NO_3^--N and NH_4^+-N in the stable water table and rising water table in soil layer.

Conclusions

(1) The concentrations of NO_3^--N and NH_4^+-N in unsaturated zone have a decreasing trend from the effect of leaching under the condition of rainfall, and it can lead to the groundwater contamination; the concentrations of NO_3^--N in saturated zone are influenced by the dispersion under the condition of rainfall, and with the increase of the rainfall it achieves balance between the dilution and dispersion. The NH_4^+-N concentrations have a slightly decreasing trend.

(2) Under the condition of rainfall, the NO_3^--N concentrations increases in saturated zone, and the NO_3^--N concentrations decreases finally in the path of the water table rise and the unsaturated zone, and NH_4^+-N concentrations have a trend of decrease in saturated-unsaturated zone.

(3) The NH_4^+-N concentrations in medium sand is more easily influenced by leaching than those in silt under the condition of rainfall.

Acknowledgment

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