Frontiers in Environmental Research
ISSN: 2960-026X
DOI: 10.61784/fer3003

EFFECTS OF GROUNDWATER LEVEL CHANGES ON VERTICAL TRANSPORT OF NITROGEN AND PHOSPHORUS

XinRui Gao*, GuiPing Yan
College of Environmental Science and Engineering, Guilin University of Technology, Guilin 541006, Guangxi, China.
Corresponding Author: Xinrui Gao, Email:845854427@qq.com

Abstract: With the intensification of global climate change and human activities, the fluctuation of groundwater level is becoming more and more significant, which has an important impact on the transport and distribution of nitrogen and phosphorus in soil. In this paper, the effects of water table rise and fall on the vertical transport of nitrogen and phosphorus were investigated, and the joint mechanism of hydrogeological conditions, soil type, vegetation cover and human activities on the migration pattern of nitrogen and phosphorus was analysed. Through a combination of field investigation and indoor simulation experiments, this study monitored the changes of nitrogen and phosphorus concentrations in soil profiles under different water table conditions. The results showed that the rise and fall of the water table directly affected the distribution of dissolved oxygen in the soil pore water, which in turn affected the nitrification and denitrification of nitrogen, as well as the adsorption and release process of phosphorus. The research in this paper not only reveals the control mechanism of groundwater level change on nitrogen and phosphorus transport, but also provides a scientific basis for the rational use and management of land resources.
Keywords: Water table; Nitrogen and phosphorus transport; Vertical distribution; Hydrogeological conditions; Soil environment

1 INTRODUCTION

Nitrogen and phosphorus are two key nutrient elements in ecosystems, and their cycling and transport are directly related to eutrophication of water bodies and changes in soil fertility [1]. The cyclic change of groundwater level is an important hydrological phenomenon in the natural environment, especially under the dual influence of climate change and human intervention, the trend of its change and its impact on the environment are more and more unnoticeable. In recent years, scientists have shown great interest in how changes in the water table affect the vertical transport and transformation of nitrogen and phosphorus by influencing soil physicochemical properties. This study focuses on the effect of water table change on the vertical transport of nitrogen and phosphorus, aiming to understand its inner mechanism and its environmental effect through empirical research.

2 THE CONCEPT OF GROUNDWATER LEVEL CHANGE AND ITS ENVIRONMENTAL EFFECTS

Groundwater level refers to the position of the water surface in the lower part of the groundwater surface where the water pressure at any point is equal to the atmospheric pressure [2]. It is a crucial concept in the groundwater system, which directly affects groundwater recharge, discharge and the direction and rate of groundwater flow. The change of groundwater level is a complex process, which is affected by a combination of factors.

Firstly, rainfall is one of the important drivers of groundwater level changes. Climate change leads to unstable rainfall patterns and changes in the spatial and temporal distribution of rainfall, which directly affects the groundwater recharge process. The amount, intensity and distribution of precipitation affects the amount and quality of groundwater recharge, which in turn affects the rise and fall of groundwater levels. Secondly, surface water bodies also play a key role in changes in groundwater levels. There is a hydrological connection between groundwater and surface water, and changes in surface water can directly affect the level of groundwater through seepage or recharge. For example, changes in the water level of rivers, lakes, wetlands and other water bodies can directly affect the trend of groundwater level changes. Besides, groundwater exploitation is one of the important factors of groundwater level change. With the acceleration of urbanisation and the increase of industrial water use, over-exploitation of groundwater has become a common problem. Large-scale groundwater exploitation will lead to the continuous decline of groundwater level, and even form a situation of groundwater resource depletion, which will have a serious impact on the groundwater system. In addition, the hardening of the ground surface during urbanisation can exacerbate changes in groundwater levels. The increase in the horizontal area of the urban surface and the decrease in soil cover result in rainwater not being able to penetrate the soil but flowing directly into the drainage system, reducing groundwater recharge [3]. This surface hardening also increases surface runoff and groundwater loss, negatively affecting the balance of the groundwater system.

3 DYNAMICS OF NITROGEN AND PHOSPHORUS IN THE SOIL-WATER-PLANT SYSTEM

In the soil-water-plant system, nitrogen and phosphorus are critical nutrient elements in the ecosystem, and their form and availability are regulated by a variety of biogeochemical processes [4]. Soil is an important reservoir and exchange site for these elements, while changes in the water table directly affect their distribution and transport in the soil.

Nitrogen exists in various forms in soil, including organic nitrogen, ammonium nitrogen (NH_4^+) and nitrate nitrogen (NO_3-). Organic nitrogen is mainly derived from organic matter in the soil, whereas ammonium nitrogen and nitrate nitrogen are caused by microbial activity. Ammonium nitrogen is converted from the organic form mainly through microbial mineralisation, whereas nitrate nitrogen is produced through nitrification. The distribution and transport of these two forms of nitrogen in the soil are affected by changes in the water table.

Shifts in the water table affect the transport and transformation processes of nitrogen in the soil. Nitrate nitrogen, in particular, because it is more soluble in water, is more likely to migrate with groundwater flow. When the water table rises, the amount of soil pore water increases, resulting in nitrate nitrogen being more easily dissolved and transported with groundwater flow. And when the water table decreases, the oxygen content in the soil increases, which is favourable to nitrification and increases the generation of nitrate nitrogen, thus affecting the content and distribution of nitrate nitrogen in the soil.

Compared with nitrogen, phosphorus exists mainly in the adsorbed state in soil particles. Minerals such as iron, aluminium and calcium in the soil play an important role, and they form complexes with phosphorus, making the migration and cycling of phosphorus in the soil restricted. Changes in the water table affect the water content in the soil and the movement of soil particles, which in turn affects the process of phosphorus adsorption and release [5]. When the water table rises, the water content in the soil increases, which may dilute the phosphorus concentration in the soil and reduce the adsorption of phosphorus to soil particles, making it easier for phosphorus to be released into the pore water. On the contrary, when the water table decreases, the water content in the soil decreases, which may increase the opportunity for phosphorus to come into contact with soil particles and increase the adsorption of phosphorus, thus decreasing the dissolution and transport of phosphorus in the soil.

4 EXPLORATION OF THE MECHANISM OF THE EFFECT OF GROUNDWATER LEVEL ON THE MIGRATION OF NITROGEN AND PHOSPHORUS

The mechanism of groundwater level rise and fall on nitrogen and phosphorus transport is a systematic problem involving complex biogeochemical processes. Firstly, the rise and fall of the water table will cause changes in the chemical properties of soil pore water and affect the concentration and activity of dissolved substances in the soil. When the water table rises, the amount of pore water in the soil increases. This increased water leads to a decrease in the oxygen content of the soil, especially when the soil pore space is filled with water, which may result in a low-oxygen or even anaerobic environment [6]. Under these conditions, denitrification takes place and nitrate nitrogen is reduced to nitrogen gas, thus reducing the amount of nitrate nitrogen in the soil. The reduction of nitrate nitrogen, which is a form that readily permeates downward, reduces the migration of nitrate nitrogen to groundwater bodies.

Also, a rising water table leads to dilution of phosphorus concentrations in the soil. The relative decrease in the concentration of phosphorus in the soil with increased moisture reduces the adsorption of phosphorus to soil particles and therefore reduces the amount of phosphorus fixed. This makes it easier for phosphorus to dissolve in soil water and migrate downward with water movement, increasing the potential for phosphorus to migrate to groundwater bodies.

Conversely, when the water table falls, the amount of air in the soil pores increases and the amount of oxygen in the soil increases. This provides favourable conditions for nitrification and promotes the production of nitrate nitrogen. Nitrification is the process of oxidising ammonia nitrogen or organic nitrogen to nitrate, so the nitrate nitrogen content in the soil increases. This increases the amount of nitrate nitrogen migrating downward, increasing the likelihood of nitrate nitrogen entering groundwater bodies.

5 INFLUENCE OF HYDROGEOLOGICAL CONDITIONS AND SOIL TYPE ON NITROGEN AND PHOSPHORUS TRANSPORT

Hydrogeological conditions and soil type are important factors affecting nitrogen and phosphorus transport, and they have a significant effect on the vertical migration of nitrogen and phosphorus in soil. Firstly, different hydrogeological conditions can directly affect the transport and distribution of water in the soil, which in turn affects the transport of nitrogen and phosphorus [7]. For example, sandy soils have larger porosity and lower adsorption capacity, which makes it easier for water and the dissolved nitrogen and phosphorus therein to penetrate downward and migrate vertically. The loose structure of sandy soils allows water and the dissolved N and P therein to move rapidly through the soil, and thus sandy areas are usually more prone to N and P leaching, leading to nutrient loss and environmental pollution.

On the contrary, in clayey soils, the high adsorption of clay particles makes the soil more capable of adsorbing nitrogen and phosphorus, and the migration rate is slower. This leads to the phenomenon of nitrogen and phosphorus accumulation in the soil profile. Due to the dense structure and smaller porosity of clayey soils, water and the dissolved nitrogen and phosphorus therein move slower through the soil and are more readily adsorbed and immobilised by the soil particles, which slows down the rate of vertical migration of nitrogen and phosphorus. As a result, clayey soil areas typically exhibit a lower risk of nitrogen and phosphorus loss, but may also result in the accumulation of nutrients in the soil, with consequences for soil fertility and ecosystem health.

In addition to hydrogeological conditions, the amount of organic matter in the soil is an important factor influencing nitrogen and phosphorus transport. Organic matter-rich soils can reduce the loss of nitrogen and phosphorus through their good adsorption and fixation effects. Organic matter has a high surface area and negative electronegativity, which can form complexes with nitrogen and phosphorus plasma nutrients and fix them in soil aggregates, preventing their downward infiltration and loss [8]. Therefore, organic matter-rich soils usually exhibit a higher nitrogen and phosphorus retention capacity, which helps to reduce nutrient loss and environmental pollution.

6 CONCLUSION

Through the study of the effect of groundwater level changes on the vertical transport of nitrogen and phosphorus, we can conclude that the dynamic change of groundwater level is an important factor affecting the cycling and transport of nitrogen and phosphorus in the groundwater environment. This effect is realised by altering the physical and chemical properties of the soil, microbial activity and the level of dissolved oxygen in the soil solution. In order to effectively manage and protect water resources, an understanding of these mechanisms is essential for the development of scientific groundwater protection policies and the implementation of soil management practices.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Hu Cong, Hu Gang, Zhang Zhonghua, et al. Characteristics of carbon, nitrogen and phosphorus stoichiometry of submerged plants in Chengjiang Karst wetland, Guangxi. Journal of Ecology, 2021(13).
[2] Yu Yanghua, Zhong Xinping, Zheng Wei, et al. Species diversity, functional traits, stoichiometry and their associations of plant communities in different successional stages of karst forests. Journal of Ecology, 2021(06).
[3] Zhang Yujian, Wang Keqin, Song Yali, et al. Ecological stoichiometry of leaf-apophyseal-soil in a subalpine forest plant in Yunnan. Journal of Ecology, 2020(21).
[4] Song Yifan, Lu Yajing, Liu Tijun, et al. Soil-plant-microbial C, N, P and their stoichiometric characteristics in different rainfall zones of desert grassland. Journal of Ecology, 2020(12).
[5] He Maosong, Luo Yan, Peng Qingwen, et al. Characteristics of carbon, nitrogen and phosphorus stoichiometry of crude roots of 45 species of desert plants in Xinjiang and their relationship with the environment. Journal of Ecology, 2019(09).
[6] Gulimige Hanati, Wang Guangyan, Zhang Yin, et al. Study on the mechanism of the effect of intermittent ecological water transfer on groundwater level and vegetation in arid zones. Arid Zone Geography, 2018(04).
[7] Huang Juying, Yu Hailong, Liu Jili, et al. Effects of rain control on plants, microorganisms and soil C, N and P stoichiometric characteristics in desert grassland. Journal of Ecology, 2018(15).
[8] Li Ting, Zhang Wei, Connie Liu Guang, et al. Progress of research on the structural characteristics of desert soil microbial communities. Desert China, 2018(02).