Characteristics of Diffuse Source N Pollution in Lean River Catchment

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Abstract

This paper analyzes the spatiotemporal characteristics of diffuse source N pollution in Lean River catchment. The water sampling points were set up on the main stream and tributary on Lean River, and water samples were taken in wet season, dry season, normal season and in the agricultural busy season; the chemical analysis has been carried out in the laboratory. The results indicate that the peak concentration of total nitrogen (TN), dissolved nitrogen (DTN), nitrate nitrogen (NO3--N) appear in December, and the lowest concentration in September, while the concentration of ammonia nitrogen (NH4+-N) follows converse trend, it is highest in wet season, and lowest in dry season. Furthermore, the concentration of diffuse N is generally higher in downstream area compared to upstream area, and it increased dramatically after rainstorm and intensive agriculture activities. The main finding of this work is that rainfall and runoff are the primary driving factors to cause non-point source N exported from the catchment. Meanwhile fertilizer application causes a great quantity of N into environment, and agricultural activities accelerate the N transformation to water bodies.

Introduction

Poyang Lake is located at the south bank of the mid-low reaches of the Yangze River, it is the drainage center of five rivers (Gan, Fu, Xiu, Rao, Xin) in Jiangxi Province, As the critical buffer area for the Yangtse River, Poyang Lake carries multiple ecology functions with regards to biodiversity conservation and flood mitigation. It is not only an important winter habitat for migrant birds in the world, but also has significant meaning for national and international ecological security.

In recent years, the water quality of Poyang Lake has deteriorated gradually. With strict controlling measures for point source pollution, diffuse pollution from the catchment is becoming an increasingly serious contributor. Nitrogen pollution exported mainly from forestland and arable land, for its high
solubility, it is a key factor for eutrophication. In contrast to point sources, diffuse sources are much more difficult to identify, they originate from a number of different areas within the catchment and they are transported by a number of different hydrological pathways and arrive at different times depending on rainfall patterns. Precise identification of N sources in the catchment is critical for the development of sustainable measures to combat agriculturally-driven eutrophication.

**Materials and Methods**

**Study Catchment.** The Lean River catchment is located in north-east part of Poyang Lake catchment, this region is controlled by subtropical monsoon climate and is abundant in light, heat and water resource. The length of Lean River main stream is 279 km, with a catchment area of 9616km². It is an important incoming branch at the upstream of Poyang Lake. The annual average precipitation is 1820-1770mm, but there are strong spatiotemporal variations, the storm season (April-June) accounts for 48% of the total annual precipitation [1].

According to the interpretation of RS images, the main land use type in the study area is forest land, it accounts for 71% of the whole area and most of it is located at upstream of the catchment, the downstream area is occupied by arable land, it accounts for 20%, and pasture accounts for 5%.

Rainfall is the main driving factor for soil erosion and nutrients loss, also the solvent and carrier of soil solute [2]. Land use pattern, fertilizer application and agricultural activities are the most critical factors for nutrients loss [3,4]. The combination of these factors leads to huge spatiotemporal variations of diffuse N [5].

**Experiment and Chemical Analysis.** 17 regular monitoring points on water quality were selected in both, the main stream and the tributaries of Lean River based reflecting the difference of landscape, land use types, vegetation and anthropogenic influence. The research area is divided into two districts according to the physiognomy and the terrain: the northeast low mountains and the southwest hilly area. 10 monitoring points were arranged at upstream area with more than 70% forest (LG508, LZ509, LZ5092, LZ510, LG511, LZ5121, LG513, LG514, LZ515, LZ516), and the other 7 monitoring point at downstream area with more than 60% arable land (LG501, LZ502, LZ504, LZ5041, LZ505, LG506, LZ507). Water-quality samples were collected at different seasons for all sites. The water course in Lean River catchment and water-quality monitoring points can be seen in figure 1.

![Figure 1](image1.png)

**Figure 1** The water-quality monitoring points in Lean River catchment

Water-quality samples were collected in April and September 2009 as well as in June, August, October, and December 2010, corresponding to wet season, normal season, dry season and agricultural seasonality. All sampling points were apart from the places like village and livestock farms, which are liable to point source pollution, and the location of the points were orientated by GPS to secure the
repeatability of sampling. After the samples were taken, they were refrigerated to analyze nitrogen by five measurements: Total nitrogen (TN), Total dissolved nitrogen (TDN), Nitrate (NO$_3^{-}$-N), Nitrite (NO$_2^{-}$-N), and Ammonium-N (NH$_4^{+}$-N). The theory and methodology of the sample analysis had been applied according to the instruction of “Investigation standard of lake eutrophication” [6] and “Analytical methods of water and wastewater” [7]. The results were examined in terms of the spatial and temporal patterns of N concentrations, the dynamics in N mass loads and concentrations were used to assess the seasonal distribution in load delivery to the rivers. All this will be helpful to improve the understanding of nutrient cycling and mobility within catchments and to develop the most appropriate measures to tackle diffuse pollution most effectively and sustainably.

**Results and Discussion**

Diffuse pollution occurs when rainfall or irrigation water run over land or through the ground, pick up pollutants[8], and deposit them into rivers, lakes or introduce them into ground water[9]. With the point sources of water pollution have been generally reduced due to their relative ease of identification and control, attention is now being directed towards the contribution of diffuse sources to water quality impairment[10].

The forms of N in the river include N in phytoplankton, particulate N (PN), DON (dissolved organic nitrogen), DIN (dissolved inorganic nitrogen which is the sum of NO$_3^{-}$-N, NO$_2^{-}$-N and NH$_4^{+}$-N concentrations). DON is liable to decomposed into DIN by microorganism or aerobic condition.

The water quality data were obtained according to the methods of sampling and analysis above, using average value of all data in one area at the same time as the water quality of this area.

**Seasonal distribution in TN, DTN, NO$_3^{-}$--N concentrations**. TN (total nitrogen) is the sum of DIN and DON concentration, it is an important indicator for eutrophication of surface water.

![Figure 2](image-url)

*Figure 2* Characterization of TN loading in Lean River Catchment

DTN (dissolved total nitrogen) is the main form of N in water bodies, and it is dominantly delivered from soil nutrients and agricultural cultivation, it is the critical factor for eutrophication [11].

![Figure 3](image-url)

*Figure 3* Characterization of DTN loading in Lean River Catchment
NO$_3^-$-N is an important form of DIN, it provides energy for plants by photosynthesis, and also can change into NH$_4^+$-N by deoxidation.

Figure 4 Characterization of NO$_3^-$-N loading in Lean River Catchment

The figures above show TN, DTN and NO$_3^-$-N concentrations in different seasons at two districts. The trends were quite similar. The concentration of TN, DTN and NO$_3^-$-N had an pronounced increase from April to June, then declined constantly during summer, until the lowest value in September, after that, they recovered dramatically to highest value in December. This seasonal distribution of N concentration may reflect a combination of several factors. There are few agricultural activities at winter time in Lean River catchment, which leads to a relative low concentration of N in April. However, as soon as agricultural activities and flood season began, fertilizer application caused abundant diffuse source N pollutant, meanwhile rainfall and inappropriate irrigation formed surface or ground runoff which has great potential for N leaching, so the concentration of N increased to middle level of the whole year at June. The water volume in Lean River reaches its annual peak in July, and kept its highest water level in August and September due to the backwater in the storm-water system related to the Yangtse River. At the same time, the agricultural high season requires a lot of nutrients, so the concentration of N has been diluted. In September, the agricultural activities were suspended, so the value reached the lowest level in this period. From October, the rainfall in Lean River catchment declined dramatically, the surface runoff decreased accordingly. However, the agricultural activities remained intensive during this month, so the concentration of N recovered. Then all the activities ceased in November before the winter starts, and the water volume shrinks to the least of the whole year. Meanwhile, the low temperature minimizes the effectiveness of biodegradation, so the concentration of N reached the highest value.

Seasonal distribution in NH$_4^+$-N concentrations. The cationic nature of NH$_4^+$-N allows it to bind loosely with cation exchange sites within the soil column, thus decreasing its likelihood of being washed away.

Figure 5 Characterization of NH$_4^+$-N loading in Lean River Catchment

The seasonal distribution of NH$_4^+$-N in two districts can be seen in figure 5. The concentration of NH$_4^+$-N is a product of nitrification, while the nitrification is determined by oxygen. NH$_4^+$-N is also the N
source for phytoplankton, and it can be released to water via microorganism. So its concentration is labile and the change trend was different with the other forms of N.

The high temperature of Lean River catchment in June, July, August, and October boosted the volume of algae in the water. Both, the poor oxygen content in the soil (which weakened the nitrification effectiveness) and intensive agricultural activities caused the highest concentration of NH$_4^+$-N during the wet season [12]. The lowest NH$_4^+$-N concentration in winter time corresponds with a strong nitrification in the dry season, which is from October to next April in Lean River catchment. The concentration was at middle level in September for less agricultural activities. So the change trend of NH$_4^+$-N was basically converse with the other forms of DIT.

The concentration of NO$_2^-$-N was generally lower (<0.1mg/L) than that of natural water (0.3mg/l) in all monitoring points during the sampling period, so this study gives no further analysis about it.

From the figures above, the all forms of N concentrations were generally higher in downstream than that in upstream that reflects the forest have a higher potential to reserve N than arable land[13].

**Nitrogen concentration and forms in Lean River.** The three main forms of DIN have interact-transformation among them depends on different circumstances [14].

![Figure 6 The interact-transformation among NO$_3^-$-N, NO$_2^-$-N and NH$_4^+$-N[15]](image)

![Figure 7 The proportion of different N forms](image)

The average proportions of DTN to TN is 73%, this reflects that DTN is the dominate form, the percentage increased from 47.7% in April to 91.5% in October.

The average proportions of NO$_3^-$-N to DTN is 50%, and the value for NH$_4^+$-N is 30%, so NO$_3^-$-N is the main form of DIN; and the sum of NO$_3^-$-N and NH$_4^+$-N account for 80% of DTN, they are the main forms of diffuse N loss.

At the beginning of April, the ratios of NO$_3^-$-N and NH$_4^+$-N were low for the less surface runoff after a long dry period. Then the ratios had a pronounced increase for the rainfall and fertilizer application, the N fertilizer produces NO$_3^-$-N in the soil[15], while the NO$_3^-$-N has positive linear relation with rainfall[16,17,18,19], and the rising temperature boost nitrification and denitrification, so the NO$_3^-$-N had a even more quick increase than NH$_4^+$-N. As a result, percentage of NO$_3^-$-N reached to 62.4%, while NH$_4^+$-N was 29.6% in June, and the sum of them account for 90% of DTN. This value kept going to 98.3% in August, in this period, the percentage of NO$_3^-$-N droped to 58.1% due to the weakened nitrification, while NH$_4^+$-N got 41.8%. This condition lasted up to September, until the percentage of NH$_4^+$-N reached its peak point of
63.3%, much higher than 35.6% for NO₃⁻-N, this was the only period that the amount of NH₄⁺-N was higher than that of NO₃⁻-N. After October, the percentage of NO₃⁻-N recovered by strong nitrification in dry season and fertilizer application, and the percentage of NO₃⁻-N dropped to less than 10% in December.

**Summary and Conclusion**

This study has analyzed the distribution of TN, DTN, NO₃⁻-N, NH₄⁺-N, NO₂⁻-N in two districts in wet season, normal season, dry season and agricultural busy time based on the regular water sample data from Lean River catchment.

The distribution and seasonal changes of TN, DTN, NO₃⁻-N are basically similar. They increase from April by the beginning of rainfall and agricultural season, reach to middle level at June, and then drop dramatically to the lowest value in September for annually maximum water volume at Poyang Lake catchment. After October, the values recover for the dry season and reach the highest point for the annually minimum water value at December. This analysis indicates that agricultural fertilization is the main source of diffuse N in soils, and the rainfall runoff is the main driving factor for N loss.

NO₂⁻-N in Lean River did not reach the pollution limit since its concentration was generally lower than that of natural water in all monitoring points during the sampling period.

NH₄⁺-N concentration was basically converse with NO₃⁻-N in seasonal distribution by decreasing in dry season and increasing in wet season.

N concentrations were generally higher in downstream than that in upstream, that reflects the forest is better than arable land in retention for N, and diffuse source pollution is mainly affected by rainfall, land use, vegetation, and human activities.

The average proportion for DTN to TN is 73%, the highest proportion is 91.5%, so the DTN was the main factor for eutrophication. Furthermore, it is an important measure to reduce the diffuse sources of nutrients that deliver to water by declining the surface or ground runoff caused by rainfall and inappropriate irrigation.

The average proportion for NO₃⁻-N to DTN is 50% and 30% for NH₄⁺-N, so they are the main forms of DTN, and NO₃⁻-N is dominant form of DIN for its better solubility.

**Reference**


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