ANALYSIS ON FEATURES OF SOIL-RIVER-GROUND-PLANTS WATER BASED ON STABLE OXYGEN ISOTOPE IN POYANG LAKE WETLAND

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ABSTRACT

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Poyang Lake is the largest freshwater lake in China, and the largest single area of habitat for migratory birds. The water level of Poyang Lake was declined continuous, and extreme droughts have frequently occurred in recent years, the structure and function of the wetland ecosystem were destroyed. In this paper, Stable oxygen isotopes was used as a tracer to identify composition of soil water, river water, ground water, and plants water. The focus was on characterize the variation with depth of the stable oxygen isotope composition and identifying the main sources of oxygen in soil water, ground water, river water and plants water, understanding the mechanisms of water movement among them. Soil water sampled at 10 cm intervals over the top 100 cm at two sections in the Poyang Lake wetland, and water samples collected from the plants, river water and ground water, were analysed for stable oxygen isotope composition, exploring the recharge and discharge of relationship between them. The results shown that the values of $\delta^{18}O$ at depth of 0~30cm at section I were declined with increasing soil depth, the value of $\delta^{18}O$ at depth of 0~40cm at section II had rare variation with increasing soil depth. The groundwater supply at section I was mainly influenced by precipitation, at section II was by precipitation and river water. The average value of $\delta^{18}O$ in the domain species plants leaves of *phalaris arundinacea*, *carex cinerascens*, and *phragmites communis* was -0.9‰, -4.23‰, -5.25‰ respectively.

1. INTRODUCTION

Poyang Lake is the largest shallow freshwater lake in China, as well as an important international wetland. In recent years, high water level in Poyang Lake is gradually decreasing, while the time of low water level duration is increasing [1], and annual minimum water level has been on a decrease trend [2]. Extreme drought events have occurred frequently in Poyang Lake [3-6], changing of water level had significant influences on soil water content of bottomland. The low water level has represented more important reason for degradation of the wetland plants [7]. Therefore, study on the moisture source, migration and dynamic rules in circulation of soil-river-ground-plants by features of stable oxygen isotopes, had great significances on protection and recovery of wetland plants and sustainable development of wetlands ecosystem.

Analyzation of water stable isotope played an increasingly important role in studying moisture source, migration, dynamic rules and water resource utilization of plants in circulation of soil-river-ground-plants by analysed oxygen isotope ratio. Dawson and Ehleringer [8] shown that the water demand of plants growing along the river were rarely from the river water. By using the mix model of oxygen isotopes, Shen et al [9] applied the direct inference method and iso-source model to evaluate ponded water, soil water and ground water's contributions to rice crop by using stable isotopes of hydrogen and oxygen. Zhan et al used [10] the stable isotopes and hydrological data to analyse the interactions between precipitation, river water, lake water and shallow ground water in Poyang Lake. Zhang [11] analysed water supply sources of soil in Poyang Lake wetland by using stable hydrogen and oxygen isotopes. In this paper, we taken the Poyang Lake as study area, based on field acquisition of soil, river water, ground water and plants water, by useing stable isotope to analyse features of oxygen isotope and moisture sources in soil of wetland, and features of oxygen isotope with plants.

2. Research area and data

2.1 Research area

The Poyang Lake located in 115° 49' ~116° 46' E and 28° 21' ~29° 52' N, in administrative level it belong to Jiangxi Province, and downstream of Yangtze river. National Nature Reserve of Poyang Lake in Jiangxi have jurisdiction over 9 lakes, including Dahu Pool, Sha Lake, Beng Lake, Zhushi Lake, Meixi Lake, Zhonghu Pool, Dacha Lake, Xiang Lake and Changhu Pool, was an important international wetland with abundant biological diversity. The annual average temperature is 16.5~17.8℃. The annual precipitation is 1,368.7~1,633.8mm, from April to June accounts for 46%. The annual evaporation is 800~1,200mm, from July to September accounts for 50%. Featured as the flood in summer and drought in autumn. Major flood period of Poyang Lake lasted from April to July, and the high water level were kept from August to September due to the flow jacking and backward with Yangtze River. The development soil type of wetland in Poyang Lake included red soil, paddy soil, yellow-cinnamon soil, alluvial soil and moisture soil. The moisture soil were the typical wetland soil mainly distributed in the embankment and the ecotone of the lake basin. Wetland phytocoenosium in Poyang Lake distributed in annuluses along moisture gradient, due to lakeshore terrain slope, soil structure and water depth. Based on dominant community radio, *carex cinerascens* were the most widely distributed plants and covered the biggest area

Fig. 1 Study area and the location of sections

2.2 Data collecting and processing

Since the fluctuation of water level of Banghu affected a little by low water level period of Poyang Lake [12], two sections were arranged, section I was arranged at upstream of Xiu River along the Beng Lake, section II was arranged at downstream of Gan River along the Beng Lake, and each section was laid out four sampling points every 150m. In April 2014, 99 samples are taken from the river water, ground water, soil and plant, shown as Table 1, including 77 soil samples. Soil samples are taken by cylindrical auger boring with the depth of 100 cm, sampling is taken every 10 cm deep, however, at the sampling point 4 (the deepest layer, about 90~100cm deep underground) at Section II, soil sample cannot be taken due to soil texture and soil water content. Meanwhile, soil volumetric moisture content of each layer was measured by TDR instrument. 8 dominant species plants samples were gathered around soil sample points, dominant species at section I was phragmites, and at Section II was carex cinerascens. 8 ground water samples were gathered at soil sample points. 7 river water samples were gathered at the upper, middle and lower position of the sections, shown as Figure 1.

All water samples were filled in 60ml with polyethylene plastic bottles, the bottle covers were sealed by seal membrane or plastic wrap to avoid bubble in the bottles and prevent evaporation of water sample, then the bottles were kept in incubator with ice bag before cold storage in the laboratory. Soil samples were placed in 8ml glass bottles, and the bottlenecks were sealed by plastic wrap before storage in the incubator. Plants samples were wrapped by freezer bags, and bag mouths were sealed by plastic wrap before storage in the incubator. Soil samples and plants samples were frozen in the refrigerator after back to the laboratory. Soil moisture and plants moisture were extracted by vacuum extraction device in Isotopic Laboratory of Chinese Academy of Forestry [13]. Stable oxygen isotope contained in water samples were measured in Stable Isotope Laboratory of State Key Laboratory of Water Resource and Hydropower Engineering Science in Wuhan University, $\delta^{18}\text{O}$ content in water samples were measured by MAT253 isotope ratio mass spectrograph connected with Flash EA/HT, and the analytical precision of $\delta^{18}\text{O}$ instrument was 0.3‰. Measure results of all water samples presented by micrometer on the basis of V-SMOW standard.

3.1 $\delta^{18}\text{O}$ features of soil water

The composition features of the oxygen isotope of soil water at section I shown as Figure 2(a). The values of oxygen isotope in the soil water were in a range of $-10.48\text{‰} \sim -5.23\text{‰}$, and the mean value was -8.36‰ . The values of oxygen isotope in soil water were decreased with increasing depth. The values of $\delta^{18}\text{O}$ in soil water were concentrated at the surface of soil in the depth of 0~30cm, and were decreased with the increasing depth, due to the isotope fractionation caused by strongly evaporation of the moisture in surface soil. Oxygen isotope values of the deep soil below the depth in 70cm had rarely variation. While the value of oxygen isotope were little at oil surface in the depth of 0~40cm at sampling point 2, and values were increased with the increasing depth, this trend was in keeping with results by Tian Richang [14], caused by the different plants covered. The composition features of the oxygen isotope of soil water at section II shown as Figure 2(b). The values of oxygen isotope in the soil water were in a range of $-12.39\text{‰} \sim -6.55\text{‰}$, and the mean value was -8.63‰ . The value of $\delta^{18}\text{O}$ at the depth of 0~40cm in surface soil water changed on the small side at each sampling point, standard deviation were 0.39, 0.50, 0.77 and 0.24 respectively. Clark's [15] research shown that the composition of oxygen isotope almost had no change when the standard deviation of the $\delta^{18}\text{O}$ value in the soil water was less than twice of analytical error. In this experiment, measurement accuracy of $\delta^{18}\text{O}$ was 0.3‰, the composition of $\delta^{18}\text{O}$ in the surface soil water were relatively stable, the reason might be that the dominant species of plants at sampling points in section II were carex cinerascens, which had large coverage [16, 17] and had small surface evaporation. Bristow and Horton's [18] research shown that mulch of soil had great influenced on physical environment of surface soil, especially at the depth of above 40cm of soil. With the increased depth of soil, $\delta^{18}\text{O}$ value changed in disorder. At the depth of 0~40cm, at sampling point 1, the mean value of $\delta^{18}\text{O}$ of soil water was -9.71‰ , at sampling points 2~4, the values of $\delta^{18}\text{O}$ were similar, the mean value was -7.67‰ . It's shown that soil permeability at sampling point 1 was better than other three sampling points, which may related to plants coverage. The oxygen isotope value at the depth of 60cm of sampling point 1 and at depth of 80cm of sampling point 3 were -11.29‰ and -12.39‰ respectively. The reason for small oxygen isotope value at the depth of 60cm of sampling point 1 needs to be verified further, but effected from precipitation could be excluded. Figure 3 shown that the soil water content at the depth of 60cm was lowest, it's impossible that precipitation flows to this area through the preferential flow form. At sampling point 3, the precipitation infiltrates into soil deeply through the preferential flow form due to soil pores.

$$\delta^{18}\text{O} = \left[\frac{(^{18}\text{O}/^{16}\text{O})_{\text{sample}}}{(^{18}\text{O}/^{16}\text{O})_{\text{V-SMOW}}} - 1 \right] \times 1000 \quad (1)$$

Tab.1 The types and number of samples

sample types	river water	ground water	soil water		plants water	
			section I	section II	section I	section II
numbers	7	8	39	38	4	4

(a) section I

(b) section II

Fig. 2 $\delta^{18}\text{O}$ value of soil water at different sections

3. Results and Discussions

Fig. 3 The volumetric water content of soil at point 1 and point 3 in section II

3.2 $\delta^{18}\text{O}$ features of ground water and river water

The composition features of the oxygen isotope of ground water at section I and II shown as Figure 4. The values of oxygen isotope in the ground water were respectively in a range of -8.15‰ ~ -6.64‰ and -5.33‰ ~ -3.14‰ , and the mean value were -7.13‰ and -4.14‰ respectively. Oxygen isotope value of the ground water of section I was less than section II, four sampling points at each section, the oxygen isotope values of the ground water presented the same trends that at middle sampling points were greater than two sides, which might related to their respectively supply source and buried depth. Table 2 Shown that the buried depth of the ground water at section I was greater than that at section II, so the ground water at Section I influenced by evaporation was weaker and the isotope value was small than that at section II. Figure 5 shown that the oxygen isotope values in the Xiu River that flows through section I were in a range of -7.24‰ ~ -3.43‰ . Gan River flows through section II, at two sampling points in section II the oxygen isotope values were -3.35‰ and -4.64‰ respectively, expected "Up Xiu River" and "down Xiu River" these two points, the oxygen isotope value from river water were lower, others sampling points were basically similar. In general, the oxygen isotope value from river water in Gan River was greater than that in Xiu River, which is consistent with the results from Liang Yue [19]. Figure 4 and 5 shown that the oxygen isotope value of ground water from sampling points at section I were less than that from river water in Xiu River, while the oxygen isotope value of ground water from sampling points at section II were almost similar with that from river water in Gan River. According to the isotope value of local atmospheric precipitation [20], ground water at section I was mainly from precipitation, and at section II was from precipitation and the water of river and lake [11].

The depth of ground water shown as Table 2, combined with oxygen isotope values of soil water and ground water, we known that oxygen isotope value of the ground water at sampling point 1 of section I was similar to that in soil water of corresponding underground depth, while others sampling points' oxygen isotope values of the ground water were greater than that in soil water of corresponding underground depth, and all oxygen isotope values of ground water were greater than that in surface soil water (except that the values of oxygen isotope in ground water at sampling point 3 and 4 of section I were similar with that in the depth of 20cm for surface soil water). These conclusions might be related to the borehole bored at field, plants types and its coverage, shallowed water lever of ground water and exposed heel without sealing, caused the strongly evaporation and $\delta^{18}\text{O}$ enrichment.

Fig.4 $\delta^{18}\text{O}$ value of ground water

Fig.5 $\delta^{18}\text{O}$ value of river water²

Tab. 2 the depth of groundwater of sampling points

sampling points	1	2	3	4
depth of section I	0.65	0.7	0.97	0.85
ground water(m) section II	uncanned	0.7	0.44	0.28

3.3 $\delta^{18}\text{O}$ values of plants leaf water

Oxygen isotope value in leaf water of surface dominant species plants at section I and section II shown as Figure 6. The research shown that the dominant species plants at section I and Section II were phalaris arundinacea, phragmites and carex cinerascens respectively, the oxygen isotope values in leaves water were in a range of -6.52‰ ~ -0.9‰ and -5.04‰ ~ -3.58‰ respectively, the mean values were -4.16‰ and -4.23‰ respectively. Oxygen isotope value in the leaves water of phalaris arundinacea was the largest, the mean value was -0.9‰ ; and that of phragmites was the smallest, the mean value was -5.25‰ ; and that of Carex cinerascens was located in middle, the mean value was -4.23‰ . There was a little difference in oxygen isotope values in plants leaf water of same dominant species plants, and at the same section with the different sampling points, the reason might be that the influence on plant transpiration varies from migration features of main element (Ca, Mg, etc.) in different landform sections (sloping land, depression, etc.) [21].

Distribution and depth of plants root system were important factors to determine the moisture source used by plants [22]. Hair root of xeromorphic phragmites communis mostly distributed in the depth of 0~30cm underground [23], root system of carex cinerascens generally distributed in the depth of 0~20cm underground [24], and root system of phalaris arundinacea distributed in the depth of 0~30cm underground. The oxygen isotope value of surface soil water corresponding to plants root system depth at different sampling points of two sections shown as Table 3. Only at sampling point 3 of section I the oxygen isotope value of soil water was similar with corresponding oxygen isotope value of plants leaf water, at others sampling points the oxygen isotope values of soil water were less than corresponding oxygen isotope values of plants leaf water, the reasons shown as: (1) the isotope fractionation was not occurred when water absorbed by plants root system and conveyed to leaves [25, 26], but when the leaf water directly contacted with the air, heavy isotope in leaf water will enriched with plant transpiration [27]. (2) the distribution depth of plants root systems and the isotope value of absorbed water from soil were different, means the moisture source of plants were different.

Fig.6 $\delta^{18}\text{O}$ value of plants water

Tab.3 The average $\delta^{18}\text{O}$ value of surface soil at two sections

	sampling points	1	2	3	4
section I	soil depth(cm)	0~30	0~30	0~30	0~30
	$\delta^{18}\text{O}(\text{‰})$	-7.02	-8.98	-6.39	-7.14
	sampling points	1	2	3	4
section II	soil depth(cm)	0~20	0~20	0~20	0~20
	$\delta^{18}\text{O}(\text{‰})$	-9.37	-7.82	-7.47	-7.54

Conclusion

Based on the field acquisition, the data included river water, ground water, soil water and plants water at two sections, by using stable isotopic technique, analysed the features of stable isotope in soil water, plants water, river water, and ground water, explored the moisture source relation between them, the following conclusions were drawn:

- (1) The oxygen isotope in the soil water of section I was in a range of -10.48‰~-5.23‰, the mean value was -8.36‰. Oxygen isotope in soil water at the depth of 0~30cm of section I were enriched, and were decreased with the increasing depth. At sampling point 2, due to the plants coverage, the oxygen heavy isotope in soil water at the depth of 0~40cm were increased with the increasing depth. The oxygen isotope in the soil water of section II was in a range of -12.39‰~-6.55‰, the mean value was -8.63‰, which was similar with the mean value of oxygen isotope in soil water of section I. $\delta^{18}\text{O}$ composition in surface soil water at depth of 0~40cm of section II were relatively stabled, due to the carex cinerascens large coverage of plant dominant species in the section and little influences on surface by evaporation.
- (2) The oxygen isotope in ground water at section I and section II were in a range of -8.15‰~-6.64‰ and -5.33‰~-3.14‰ respectively, the mean value were -7.13‰ and -4.14‰ respectively. Based on oxygen stable isotope value in ground water, river water and lake water at two sections, and with buried depth of ground water, shown that the ground water in section I was mainly from precipitation, and in section II was mainly from precipitation, the river water and lake water.
- (3) In the average value of oxygen isotope in the dominant species plants water of the Poyang Lake, phalaris arundinacea was the largest, the mean value was -0.9‰; the second was carex cinerascens, the mean value was -4.23‰; and phragmites communis was the smallest, the mean value was -5.25‰.

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