

Isotopic composition ($\delta^{18}\text{O}$ and δD) of the shallow groundwater in the Poyang Lake basin

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Abstract. The article is focused on the identification of evaporation and other natural processes which affect the isotopic composition of shallow groundwater in the Poyang Lake basin, such as water–rock interaction and mixing of the shallow groundwater and surface water. For this purpose the dual isotope approach (δD – H_2O and $\delta^{18}\text{O}$ – H_2O) was used. The samples were collected from domestic wells around the Poyang Lake. The value of δD obtained for the shallow groundwater ranges from -21.5 to -42.6‰ . The $\delta^{18}\text{O}$ value varies from -3.5 to -7.1‰ . It was found that the shallow groundwater of the Poyang Lake catchment is of meteoric origin. The influence of evaporation on the isotopic composition of shallow groundwater is negligible and observed mainly during the dry season. The deviation from the local meteoric water line, especially during the rainy season, may be explained by the processes in the water–rock system, but this issue is required further research.

1. Introduction

The Poyang Lake basin is a unique ecosystem, which is affected by both natural and anthropogenic factors: water–rock interaction, evaporation, agricultural activity, dense population, etc. With such variety of factors, it is often difficult to identify the main processes which have an effect on groundwater origin. One of the modern techniques to identify these processes is the use of stable isotope tracers, such as ^2H and ^{18}O , which allows tracing various natural processes occurred in groundwater [1].

It is worth to note that the shallow groundwater of the study area is used by people in rural areas for drinking and other domestic purposes. Meanwhile, there is often lack of centralized water supply. In this case, special attention should be paid to identification the processes affecting the origin of groundwater chemical composition. However, these issues are not sufficiently studied in the region. Besides ecological implication, these studies are crucial for fundamental research of groundwater origin, because the dual isotope approach (δD – H_2O and $\delta^{18}\text{O}$ – H_2O) enables to track processes in the water–rock system [2].

The article is focused on the identification of evaporation and other natural processes which affect the isotopic composition of shallow groundwater in the Poyang Lake basin. The potential interaction between the shallow groundwater and surface water is also considered.



2. Materials and Methods

2.1. Study area

The Poyang Lake basin is located in Jiangxi Province, the southeast of China (figure 1). The study area belongs to subtropical humid climate with the average annual temperature 17.5 °C [3]. The annual precipitation ranges from 1400 to 2400 mm [4]. Rainfall distribution during the year is irregular because it is controlled by the East Asian monsoon. The rainy season lasts from March to June, and then rainfall decreases from July to September with evaporation reaching its maximum point [5]. The dry season begins after September and lasts till February. The topography of the Poyang Lake basin varies from mountain (maximum elevation of about 2200 m above sea-level) to alluvial plains [3]. However, in the study area the relief is predominantly flat with alluvial plains and hills.

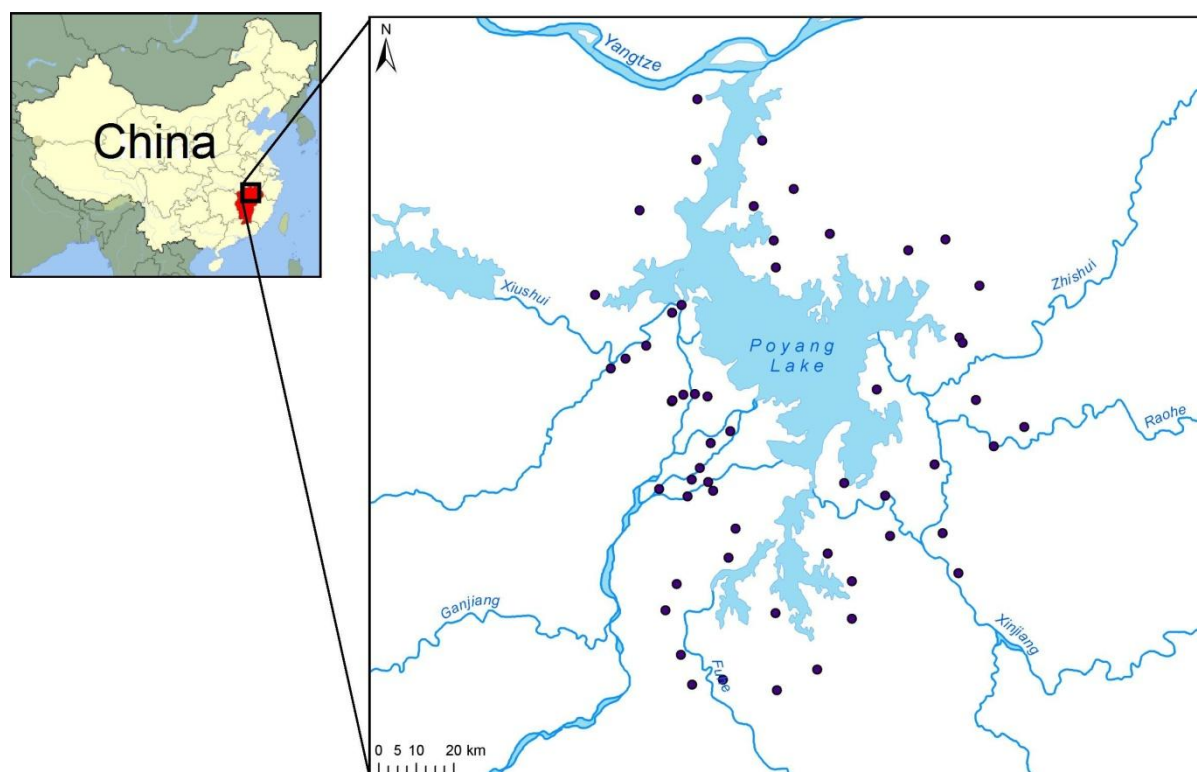


Figure 1. Map of the study area with location of sampling points.

The shallow groundwater of the study area is fresh with TDS primarily up to 500 mg/L. The pH values vary from 4.5 to 7.7, basically geochemical conditions change from slightly acidic to neutral. The groundwater is $\text{HCO}_3\text{--Ca}$ and $\text{HCO}_3\text{--Ca--Na}$ according to the chemical composition. Locally, due to impact of anthropogenic factors, the significant role of chloride and nitrate, less often sodium, potassium, sulphate and other pollutants was observed in the shallow groundwater [6, 7].

2.2. Sampling and analytical procedures

Hydrogeochemical sampling was carried out in October 2013 and March 2014. The shallow groundwater from wells used by local people for drinking and domestic purposes was sampled in sterile 100 ml opaque polyethylene vials. Isotopic composition (δD , $\delta^{18}\text{O}$) was studied in the laboratory of the East China University of Technology (Nanchang, China) using isotope ratio mass spectrometer with element analyzer TC/EA-IRMS (Finnigan MAT 253). The isotopic ratio of H/D was determined by the sample combustion at the temperature of 1350 °C. The determination of the isotope ratios of $^{18}\text{O}/^{16}\text{O}$ was carried out at the temperature of 25 °C after addition of 0.1% CO_2 solution and keeping within 20 hours until an equilibrium state. The method error is $\leq 2\%$ for δD and

$\leq 0.2\text{‰}$ for $\delta^{18}\text{O}$, respectively. Data on isotopic composition are given in accordance with the V-SMOW.

3. Results and Discussions

The value of δD ranges from -21.5 to -42.6‰ (Table). The $\delta^{18}\text{O}$ value in the shallow groundwater varies from -3.5 to -7.1‰ . It slightly differs from the value of $\delta^{18}\text{O}$ in a marine atmosphere in the tropical and subtropical regions ($0 - -5\text{‰}$) presented by G. Craig and L. Gordon [8].

The study of δD and $\delta^{18}\text{O}$ enable to determine genesis of natural water and track the contribution of various factors to origin of its chemical composition. The ratio of the δD to $\delta^{18}\text{O}$ values in atmospheric precipitation was described for the first time by G. Craig (Global meteoric water line) [9]:

$$\delta\text{D} = 8\delta^{18}\text{O} + 10\text{‰}, (1)$$

where 10‰ – excess parameter d , defining the deuterium excess in precipitation compared with its quantity in the equilibrium process, where $d=0$ [1]. However, the slope of meteoric water line and excess parameter d vary depending on the distance between the places of water vapour formation and atmospheric precipitation, temperature, and other factors. Since equation (1) is correct only for the world averaged annual data on the isotopic composition (δD , $\delta^{18}\text{O}$) of precipitation, it is often necessary to introduce regional coefficients [1].

Table. Isotopic composition (δD , $\delta^{18}\text{O}$) of the shallow groundwater in the Poyang Lake basin, ‰ .

Sample	$\delta\text{D}_{\text{V-SMOW}}$	$\delta^{18}\text{O}_{\text{V-SMOW}}$	Sample	$\delta\text{D}_{\text{V-SMOW}}$	$\delta^{18}\text{O}_{\text{V-SMOW}}$
P2	-29.1	-3.5	P37	-42.1	-6.3
P7	-37.2	-6.1	P38	-41.2	-5.3
P8	-37.4	-6.1	P39	-34.4	-6.6
P9	-29.1	-5.1	P42	-39.4	-6.7
P10	-38.2	-6.2	P43	-39.0	-6.8
P11	-37.5	-6.2	P44	-32.8	-5.2
P12	-29.6	-5.8	P45	-26.8	-4.5
P13	-38.0	-6.5	P46	-28.7	-5.0
P14	-25.5	-4.6	P47	-40.0	-6.9
P15	-21.5	-3.7	P48	-35.3	-6.3
P16	-29.5	-4.6	P49	-37.1	-6.4
P17	-30.4	-4.3	P50	-37.2	-6.5
P18	-34.6	-5.5	P51	-42.6	-7.1
P19	-32.4	-5.3	P52	-39.7	-6.8
P20	-29.6	-4.9	P53	-38.9	-6.7
P24	-39.2	-6.4	P54	-30.4	-5.1
P25	-30.2	-5.8	P56	-35.4	-6.3
P27	-32.2	-5.9	P57	-25.0	-4.7
P28	-28.9	-5.8	P59	-35.3	-6.2
P29	-34.9	-6.8	P60	-34.0	-6.0
P30	-31.3	-5.6	P61	-31.4	-6.3
P32	-32.2	-6.2	P63	-28.2	-5.6
P33	-30.3	-5.9	P64	-31.8	-5.3
P34	-32.3	-6.0	P65	-29.6	-4.6
P35	-36.4	-6.3	P66	-30.3	-5.4
P36	-35.0	-6.2	P67	-32.7	-5.7

The ratio of δD to $\delta^{18}\text{O}$ in the studied groundwater has been estimated using the global meteoric water line modified for region with average annual temperature less than 20°C . The distance between the study area and the ocean as the main source of water vapor formation has also been took into account, based on data, given in [1]. Equation of the modified meteoric water line is the following:

$$\delta\text{D} = 8\delta^{18}\text{O} + 9.83\text{‰}, (2)$$

The local meteoric water line obtained by Zhou and Sun et al. for Lushan hot springs area [10–12], which situated the northwest of the Poyang Lake, has also been considered. This line is described by the following equation:

$$\delta D = 7.16\delta^{18}O + 8.88\text{‰}, (R^2=0.98), (3)$$

The points corresponding to the values of δD and $\delta^{18}O$ in the studied shallow groundwater are located close to the modified meteoric water line, but the local meteoric water line slightly better approximate them (figure 2). In addition, they are close to the average values calculated by G. Craig and L. Gordon [8] for continental precipitation but they are depleted in heavy isotopes.

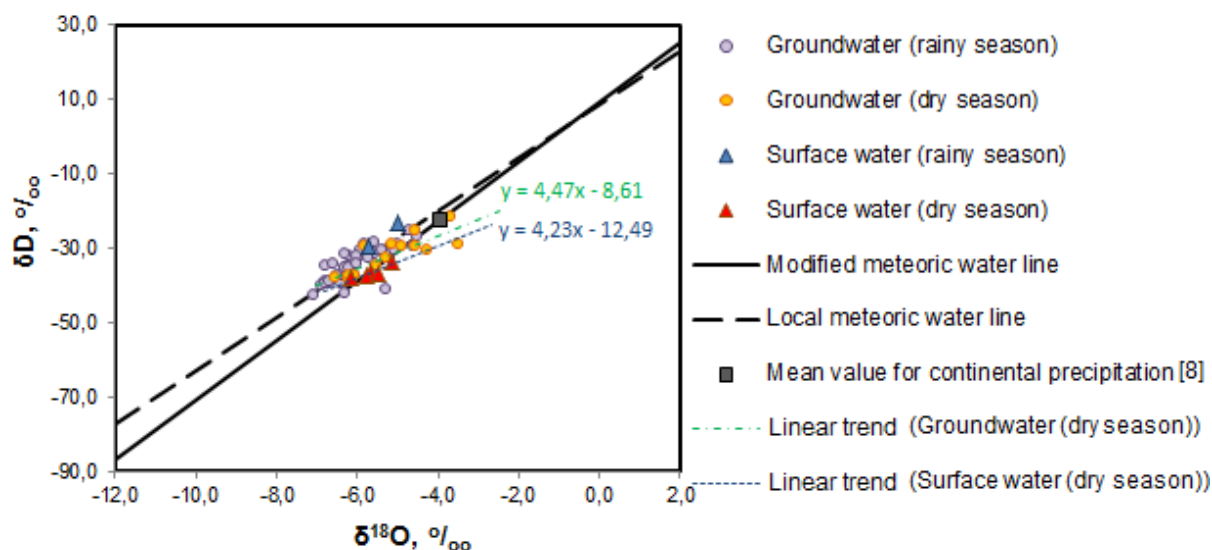


Figure 2. Values of $\delta^{18}O$ vs. δD in natural water of the Poyang Lake basin.

It should be noted that the samples collected during the dry season are slightly enriched in heavy isotopes of oxygen and hydrogen than the water taken during the rainy season (figure 3). The difference between the average values of δD and $\delta^{18}O$ in the rainy and dry seasons is statistically significant. This fact can be explained by the climate patterns. In the course of the dry season evaporation usually exceeds precipitation. As a result of evaporation, water is enriched in heavy isotopes, mainly ^{18}O , during their infiltration through the unsaturated zone. The slope coefficient of the linear trend line is close to 5 for the groundwater samples collected during the dry season (figure 2). It corresponds to evaporation process [1, 2, 13]. In this regard, in the course of the dry season, the deviation from the meteoric water line is likely connected with the influence of evaporation on groundwater. At the same time this linear trend line is very similar to the regression line for the surface water, which was also collected during the dry season. Surface water is normally subjected to more intensive evaporation than shallow groundwater and, as a result, more enriched with heavy isotopes ^{18}O and 2H [13]. Therefore, we can suggest that mixing of the shallow groundwater and surface water may occur where conditions are appropriate (low-lying alluvial plains, flooded fields, etc.). The surface water within the study area may be presented not only by natural water bodies, but also by artificial ponds for farming and water for rice field flooding, which can infiltrate in the shallow aquifer.

In the early rainy season, the amount of precipitation increases sharply, which leads to the depletion of heavy isotopes of hydrogen and oxygen in the shallow groundwater. However, the samples collected during the rainy season also demonstrate the considerable deviations from the local meteoric water line. The most significant deviations are connected with the isotope ^{18}O enrichment. According to some authors [1, 2], such deviation may be explained by the processes in the water–rock system, which can lead to fractionation of oxygen and hydrogen isotopes.

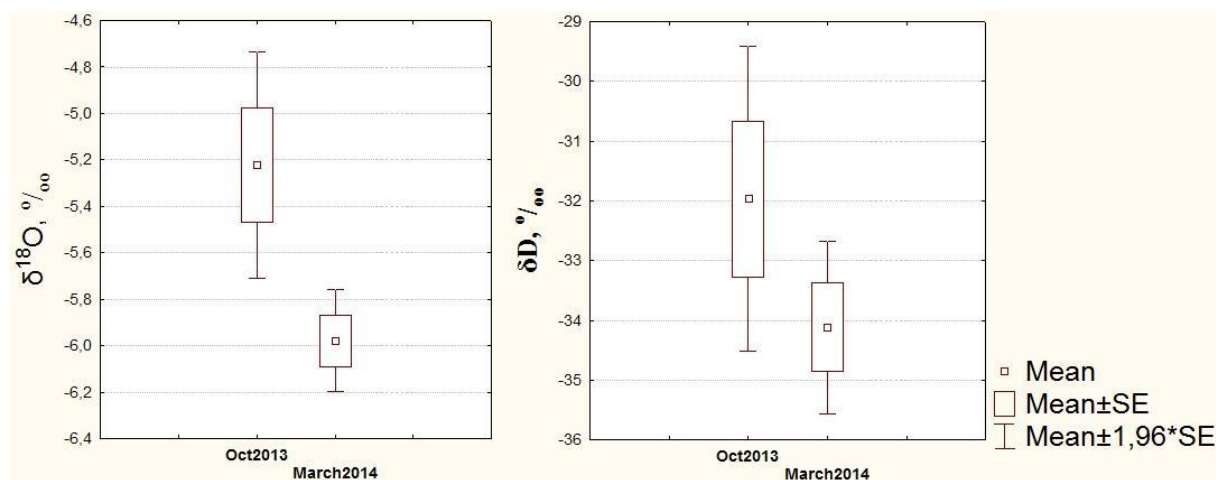


Figure 3. Box-and-whiskers plot for isotopic composition ($\delta^{18}\text{O}$, δD) of the shallow groundwater in different seasons.

4. Conclusion

We found that the shallow groundwater of the Poyang Lake catchment is of meteoric origin according to its isotopic composition. The influence of evaporation on the groundwater chemical composition is negligible and observed mainly during the dry season. This factor may affect the groundwater chemical composition indirectly due to local mixing of the shallow groundwater and surface water, subjected to more intensive evaporation. In addition to the above mentioned fact, the deviations from the local meteoric water line, especially in the rainy season, may be explained by the processes in the water–rock system, but further studies are required.

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