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Temporal and Spatial Distribution of Arsenic Speciation in Sediments of Plateau Lakeside Wetland and Their Relations to Environmental Factors

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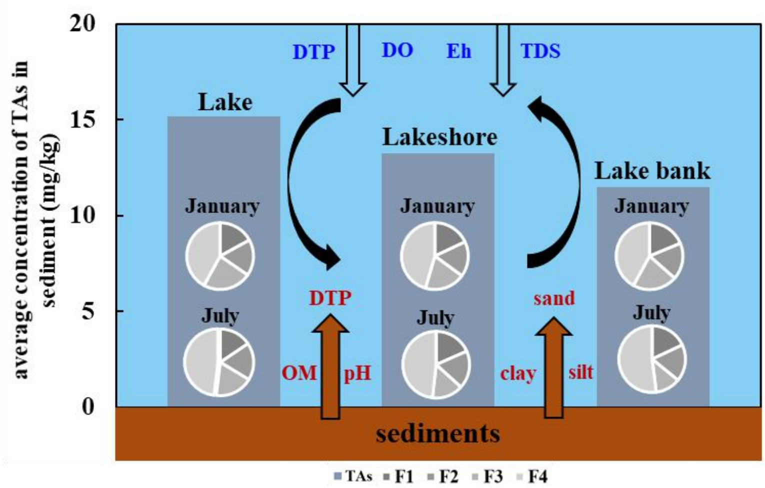
Keywords: lakeside wetland, sediments, arsenic speciation and environmental factors

Graphical Abstract



Abstract: This paper chose the surface sediments of lakeside wetland from southern Yangzonghai as the research object, studied the sediment contents of total arsenic (TAs) and arsenic fractions (acid soluble arsenic-F1, reducible arsenic-F2, oxidable arsenic-F3 and residual arsenic-F4) of different seasons and environmental parameters (Water soluble total phosphorus -WDTP, Sediment Available Phosphorus-SDTP, Organic matter-OM, Sediment pH, Dissolved oxygen-DO, Oxidation-reduction potential-Eh, Conductivity-Ec, Sediment particle size-clay, silt and sand), and analysis spatial and seasonal distribution characteristics of arsenic in relation to environmental parameters by using statistics. The results are shown as follows. (1) There is little variation in the TAs content of the lakeside wetland deposits, but the second belt transect was as high as 89.82 mg/kg in July, and the sediments in some areas are still facing environmental risk. Relatively levels of TAs were observed during winter compared to summer, and the seasonal difference of TAs distribution was not pronounced. In a word, the content of TAs is steady. (2) The most arsenic fractions in sediments is residue and the sum of the valid states is higher than the residue state. Meanwhile F1, F3 present differences in different seasons, and environmental parameters have a

certain influence on its. Lakeside wetland's environment could face a secondary pollution in the future; (3) The correlation analysis, redundancy analysis and factor analysis illustrate that environmental factors which affect arsenic forms are different in the shore area, lake area and central area, S-DTP, OM, pH, these three are the key factor of the lakeside wetland arsenic changes.

INTRODUCTION

Compared to plain areas, lakes on plateaus are characteristics of unique terrain, small drainage area, limited replenishment and high ecological vulnerability, so its eutrophication may attract extensive concern [1-2]. Mineral extraction has caused severe arsenic contamination in many rivers, lakes and other waterways in China, especially in southwest China which is represented by Yunnan province [3]. Arsenic pollution of lake water is serious in Yunnan, and that is the reason why the arsenic pollution becomes a new challenge for the protection of water environment [4]. The lakeside wetland is a water and land intersections of lakes, which is a natural protection barrier for plateau lakes, and its effect on foreign source pollution is significant and has been widely verified [5-6].

Sediment pollution is one of the most serious environmental problems in the aquatic environment, and it is not only an important part of the water body, but also the growth medium of plant and microorganism [7]. What's more, it is an important carrier for the accumulation of pollutants which plays a critical role in intercepting pollutants[8]. Under certain conditions, 99% water pollutants can be stored in various forms in sediments [9]. When physical and chemical conditions (pH, Eh, etc.) in sediment - water boundary surface change, the pollutants in sediments may be released back into the surface sediment interstitial water, and released to the overlying water through the biological or physical chemical process [10]. This may lead to continuous migration of pollutants in water, interstitial water and sediment systems, eventually leading to ecological risk [11]. The harm of arsenic in sediment is not only related to its total content, but also has close contact with its geometrical shape. If the depositing forms change, the migration and toxicity of arsenic in sediment and water are different too [12]. Although the distribution characteristics of As fractions and the influence of environment on it has been discussed extensively, it is difficult to illustrate the influence of environmental factors on As fractions in lakeside wetland [13]. Therefore, the effect of environmental factors on TAs and As fractions in lakeside wetland is still an issue deserving further study [14]. This paper chose the surface sediments of lakeside wetland in Yangzonghai as the research object, explore each belt transects distribution of content of total arsenic (TAs) and arsenic fractions (acid soluble arsenic-F1, reducible arsenic-F2, oxidable arsenic-F3 and residual arsenic-F4) and environmental parameters (water soluble total phosphorus-WDTP, sediment available phosphorus-SDTP, organic matter-OM, sediment pH, dissolved oxygen-DO, oxidation-reduction potential-Eh, conductivity-Ec, sediment particle size-clay, silt and sand) about from sediments in different seasons and the distribution of TAs and arsenic formations in the lakeside wetlands in different seasons, and then reveals the controlling factors, to provide theoretical basis for the protection and treatment about Yangzonghai lakeside wetlands.

MATERIALS AND METHODS

The general situation in the study area

Yangzonghai is located at the border of Chenggong, Yiliang and Chengjiang in Kunming city of Yunnan province, which is a natural fault-forming freshwater lake formed by the karst formation of the plateau. The lake is a spindle-shaped lake with a surface area of 31.9 km2 and a total of

6.04×108 m3. The maximum depth of it is 30 m and the average depth is 20 m. The Yangzonghai basin belongs to the subtropical climate, with a rainfall of 824.6 mm. During the rainy season in May and October, the precipitation accounted for 85% of the whole year, while the dry season accounted for 15%. In 2008, severe arsenic contamination occurred in the Yangzonghai, the concentration of arsenic in lake water body up to 0.19 mg/L , which is more than the Chinese surface water environmental quality standards Ⅴ class limit [15]. Then, the pollution of arsenic in water is governed by the spraying of flocculating agent (iron salt) in 2009-2011, and this caused the concentration of arsenic in the lake to drop dramatically even below the level III standard. However, the concentration of arsenic in the sediments increased significantly, reaching 54.86 ~ 193.29 mg/kg which exceeded the Chinese soil environmental quality standard III limit of 30 mg/kg [16]. The arsenic content of the lake and lakeside wetland is still higher, arsenic contamination in the Yangzonghai faces the risk of being turned into mud and coastal wetlands.

Field investigation data shows that Yangzonghai lakeside wetlands are located in the east, south, west, and north. The main vegetation is water plant and heavy water plan. In addition to the lakeside wetlands in the south bank, other coastal wetlands are degraded seriously because of lake structure and surrounding human activities, and the southern shore lake wetland has typical research value.

Sample layout and sample collection

This paper chose the surface sediments of lakeside wetland from southern Yangzonghai as the research object, deployed 4 belts of sample by using the method of typical sample. For each sample, set up three parallel samples and set 3-5 sample points along the shore to the direction of the lake (Fig 1). Samples are sampled in July and October 2015. By using the stratification of the columnar sediment sampler and the water quality layered sampler sediment samples collected sediment samples (10 cm) and surface water (50 cm). Each sample was collected in three parallel samples and loaded into a clean polyethylene sealing bag and bottle. Finally, the samples were tagged back to the laboratory.

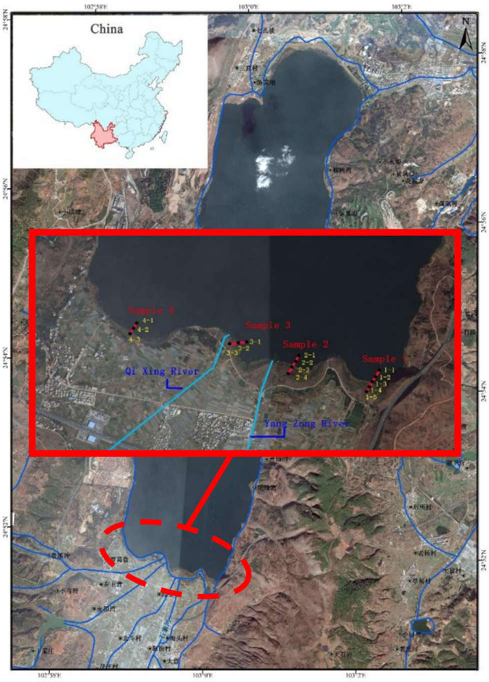


Fig. 1 Schematic map of sampling points in Yangzonghai lakeside wetland

Sample analysis and data processing

Sample analysis

The sediment samples were dried by natural air, and the samples were sieved and then sieved. The water samples were stored in the cold storage room and measured in 48 hours. The arsenic speciation in sediments was determined by the improved BCR sequential extraction method and inductively coupled plasma spectroscopy (ICP-OES, 700) [17]. TAs in sediments was determined by HCl-HNO_3-$HClO_4$ digestion and inductively coupled plasma atomic emission spectrometry (ICP-OES,700) [18]. S-pH values of sediments were determined by potentiometric method [19]. The S-DTP in sediments was determined by $NaHCO_3$ extraction and molybdenum antimony colorimetric method [20]. The particle size of sediment was measured by Malvin Laser Particle Sizer (MAZ3000). Sediment organic matter (OM) was determined by potassium dichromate method [21]. The pH value of sediment was determined by potentiometric method. The water dissolved total phosphorus (W-DTP) were measured after filtration using potassium persulfate UV spectrophotometry. Each sample of each index do 3 parallel. The DO, Eh and Ec of physical indicators were measured by HACH water quality analysis portable instrument (HQ40d).

Statistical analysis

Using the July 2015, January 2016 data after the inspection, excluding outliers and other pretreatment. The variance analysis (ANOVA) with multiple comparisons (Duncan's test) was performed using SPSS 19.0 software to compare the differences between morphological and environmental parameters between different zones and between different seasons. Pearson correlation analysis was used to reveal the relationship between As species and various environmental parameters. Using the redundancy analysis (RDA) in Canoco for Windows 4.5 software, the 2-month lake-lakeshore-lake bank center distribution was associated with the distribution of various environmental factors. Finally, all statistical analyzes were performed at a significant level of $P < 0.05$ by factor analysis in SPSS 19.0.

RESULTS

Physical and chemical characteristics of the water and sediment in lakeside wetland

Temporal and spatial distribution of environmental factors in different seasons of Yangzonghai lakeside wetland is shown in Table 1. From the spatial distribution to the concentration of W-DTP, S-DTP, OM, Eh and pH in the lakeside wetland is higher, may be related to the upstream activities, storm disturbance and so on. The sediment size of lakeside wetland is dominated by sand. The results of single factor analysis of variance showed that there were no differences in the spatial distribution of 10 environmental factors in lakeside wetlands ($P > 0.05$).

Table 1 Distribution of the main water and sediment quality parameters in the lakeside wetland of Yangzonghai

Parameters	Space			Seasonal	
	Lake	Lakeshore	Lake Bank	Summer	Winter
W-DTP (mg/L)	0.025~0.054	0.025~0.104	0.028~0.121	0.025~0.121	0.039~0.103
S-DTP (mg/kg)	2.388~11.618	2.783~19.931	2.663~10.863	2.388~9.623	2.663~19.931
OM (g/kg)	4.168~64.289	8.951~76.267	11.345~53.819	8.129~64.289	4.168~76.267
Clay (%)	0.008~0.024	0.001~0.024	0.002~0.029	0.001~0.022	0.008~0.029
Silt (%)	0.081~0.194	0.045~0.167	0.053~0.209	0.045~0.157	0.076~0.209
Sand (%)	0.782~0.911	0.809~0.949	0.761~0.945	0.821~0.949	0.761~0.915
DO (mg/L)	6.44~8.81	6.36~8.84	6.36~8.49	6.36~8.84	6.36~8.89
Eh (mV)	41.2~167.4	91.4~152.6	94.5~167.4	41.2~167.4	41.2~167.4
pH	7.34~8.47	7.09~8.31	8.11~8.47	8.11~8.47	7.09~7.78
EC (us/cm)	411~438	411~473	415~473	411~473	411~473

From the seasonal distribution, the water quality parameter W-DTP concentration is slightly higher in summer than in winter, indicating that summer is the time of water bloom. While S-DTP and OM levels are higher in winter than in summer, indicating that winter sediments are more likely to accumulate nutrients. The results of T test showed that the pH value was significantly different in summer and winter (P <0.05).

Total arsenic and arsenic fractions in sediments from lakeside wetland

As seen from Fig. 2, the average content of TAs in the surface sediments of lakeside wetland was not significant. The average concentration of TAs in sediments from the lakeside wetland in January followed the order: 13.95~17.48 mg/kg (lake) > 11.89~17.49 mg/kg (lakeshore) > 11.04~12.62 mg/kg (lake bank). However, the total arsenic content in July ranged from 10.97 to 89.83 mg/kg (lake), 10.45~41.93 mg/kg (lakeshore), 6.06~15.42 mg/kg (lake bank). Notably, the content of TAs in sediments was 89.82 mg/kg in July, which indicated that the distribution of TAs in sediments of lakeside wetland was not uniform and there was a certain ecological risk.

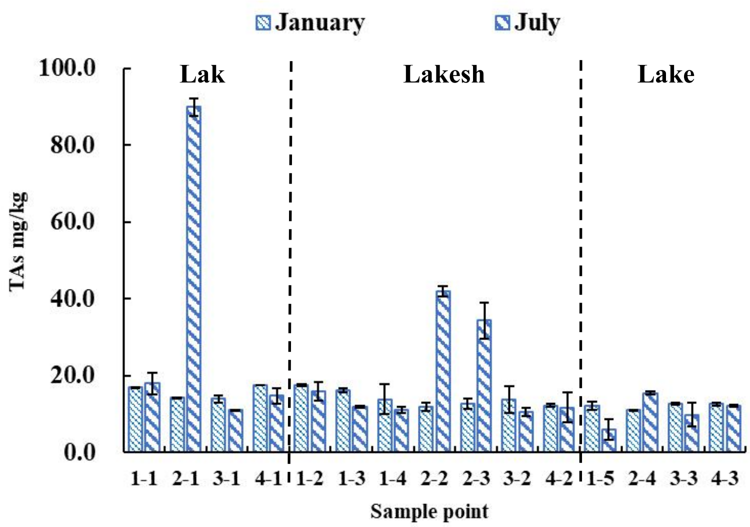


Fig. 2. Concentrations of total arsenic in surface sediment collected from different samples during summer and winter. Mean and standard deviation of three sampling sites in each region are shown.

From the seasonal changes, most of total arsenic content in the winter (11.03~17.48 mg/kg) is slightly higher than the summer (6.06~17.99 mg/kg), indicating that the total arsenic in the summer when more easily released. In the summer and winter, the total arsenic content of sediment along the lake to the direction of the lake bank was roughly decreasing trend, indicating that the lakeside wetland has its intercept effect.

The total arsenic in sediments of lakeside wetland is not as comprehensive as the standard, and the stability of different forms of arsenic in sediments is different. Arsenic release from the sediments was also closely associated with as fractionation in sediments. According to Fig. 3, factor analysis of variance showed that there was no significant difference in the distribution of arsenic fractions in lakeside wetland. In January, the arsenic content in the range of 14.98~20.48% (F1)、13.96~18.52% (F2), 13.09~22.31% (F3), 44.10~52.78% (F4). And the content of arsenic in July ranges from 4.69~23.54% (F1), 7.73~19.33% (F2), 8.04~26.70% (F3), 35.44~78.80% (F4). The arsenic morphology is mainly in the residual state, but the sum of in front three arsenic forms is larger than that of the residual state, which indicates that the potential release risk is large.

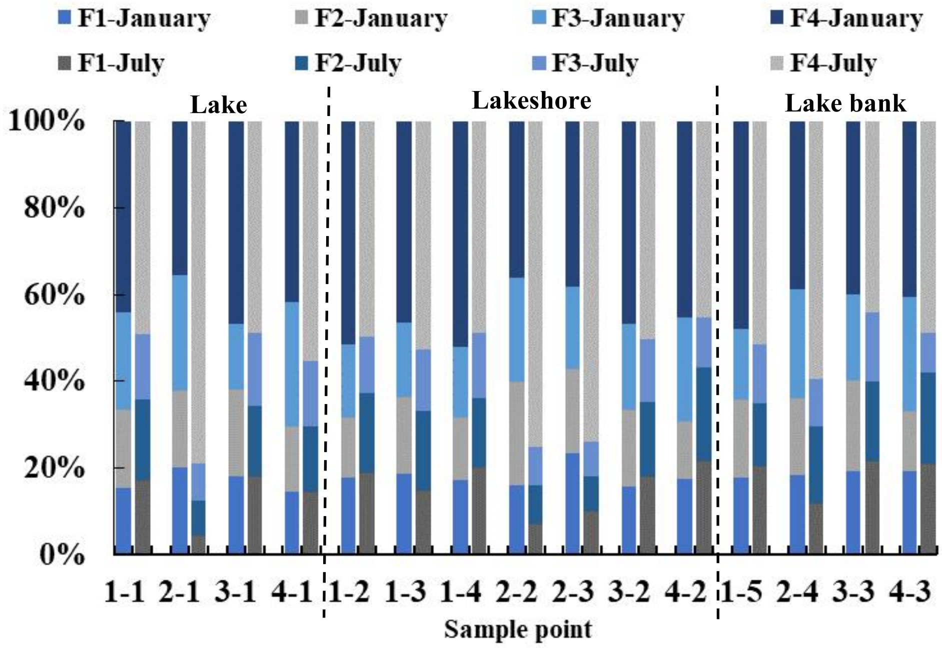


Fig. 3. Proportions of As fractions in surface sediments collected from lakeside wetland in summer and winter.

From the seasonal variation, the arsenic content in summer was 14.67~23.54% (F1), 13.24~23.96% (F2), 15.01~28.48% (F3), 35.44~52.06% (F4), and in winter it was 4.69~21.63% (F1), 8.11~21.58% (F2), 8.04~16.78% (F3), 44.20~78.08% (F4). The results of T test showed that there were significant seasonal differences in the contents of F1 and F3 ($P < 0.05$), which may be related to their nature and environmental factors.

The relationship between As distribution and the main environmental quality factors in lakeside wetland

The change of different environmental parameters may affect the migration and transformation of arsenic in sediments. In order to analyze the influence of environmental factors on the arsenic distribution and variation of sediments in lakeside wetlands. In this study, the Pearson correlation coefficient was used to calculate the correlation between environmental factors and arsenic speciation content in different seasons.

Table 2 The correlation coefficients and significances between speciation of arsenic and environmental factors in the sediments of lakeside wetland.

		W-DTP	S-DTP	OM	pH	clay	sand	DO	EC
January									
Lake	**F3**					0.966*			
Lakeshore	**F2**	0.755*			-0.775*				
	F3				-0.756*				
	F4		-0.810*			0.775*	-0.757*	-0.771*	
	TAs								0.879**
Lake bank	**F1**	-0.997**						-0.991**	
	TAs							-0.974*	
July									
Lake	**F1**		0.959*						
	F3				-985*				
	F4				-0.984*				
	TAs				-0.973*				
Lakeshore	**F3**	0.936**	0.898**	0.846*					
	F4	0.954**	0.894**	0.769*				0.804*	0.804*
	TAs	0.899**	0.864*					0.868*	0.868*
Lake bank	**F1**			-0.997**					
	F3				-0.962*	-0.972*	0.972*		
	F4			0.998**					

* At 0.05 level (double side) significant correlation;

** At 0.01 level (double side) significant correlation;

According to table 2, the correlation between arsenic speciation and environmental factors was different in other months and regions. In January, the lake area of F3 was positively correlated with clay. In July, the lake area of F1 was positively correlated with S-DTP, F3 and F4 was negatively correlated with pH. In lakeshore of January, there was a significant positive correlation between F2 and W-DTP, F2 and F3 were significantly negatively correlated with pH, F4 was negatively correlated with S-DTP, sand and DO, and positively correlated with clay. In lakeshore of July, F3 and F4 were significantly positively correlated with W-DTP and S-DTP, and positively correlated with OM, F4 and DO, EC were significantly positively correlated. In January, the F1 of lake bank area was significantly negatively correlated with W-DTP and DO. In lake bank of July, F1 and OM showed a significant negative correlation, F4 and OM was significantly positive correlation, F3 and pH, clay, sand was significantly negative correlation.

In order to explore the wetland change of environmental factors, and the correlation between arsenic sources, this study focused on the 15 variables (including 10 environmental parameters, TAs and 4 arsenic) factor molecules based on principal component analysis (n=30). The analysis of the elements in SPSS showed that the value of KMO was 0.584> 0.05 and the Bartlett spherical test was P = 0.000, indicating that the data could be factorized. Table 2 shows the characteristic value is larger than the first principal component 1 (T1), the second principal component (T2), the third principal component (T3) and the fourth principal components (T4) of the cumulative variance contribution rate of 74.36%, most of the information can be summarized in the initial amount.

Table 3 Rotated component matrix

Project	The factor load rate after rotation			
	1	2	3	4
Eigenvalues	5.074	2.667	1.969	1.444
Variance contribution rate	33.826	17.779	13.127	9.624
Cumulative variance contribution rate	33.826	51.604	64.731	74.355
F1				0.813
F2	0.439		0.304	0.496
F3	0.406			0.768
F4	0.913			
TAs	0.881			
W-DTP			0.728	
S-DTP	0.508	0.304	0.537	
pH				0.837
OM	0.783			
clay		-0.940		
silt		-0.962		
sand		0.966		
DO			0.771	
Eh			0.790	
EC			-0.573	

Note: values of load ratio less than 0.3 are not listed

In T1, OM and S-DTP have a larger factor loading in the normal direction, and the correlation between OM and S-DTP has a strong influence on the lakeside wetland. In addition, TAs (factor load 0.881) and F4 (0.913) were also associated with T1, indicating that the content and distribution of TAs and F4 in lakeside wetland were affected by OM, especially the ecological risk of potential release of F4. The composition of sediment particle size in T2 is one of the most important factors affecting the adsorption capacity of heavy metals in sediments, and the factor loadings are -0.940, -0.962 and 0.966, which are closely related to T2. In T3, W-DTP (0.728), S-DTP (0.537), DO (0.771), Eh (0.790) have a larger factor loading in the normal direction, while EC (-0.573) is larger in the negative axis direction. Finally, the pH value in T4 has a large load value, and the soil pH value is an important physical and chemical parameter of soil, which has important influence on the effectiveness of soil trace elements, and F1 and F3 are obviously related to T3. This indicates that the distribution and variation of F1 and F3 in the lakeside wetlands may be affected by pH value. Under weak acid conditions, heavy metal ions are more active and easier to be released and absorbed and enriched by plants.

DISCUSSION

Effects of different seasons on TAs and arsenic speciation in sediments

The distribution of arsenic in the sediments of Yangzonghai lakeside wetland is related to the source of arsenic, the structure of lake, the interception of pollutants and the process of pollution control. In January and July, the arsenic content of sediments decreased significantly along the direction of the lake to the lakeshore, indicating to a certain extent, reflecting the lake wetland has an interception effect on arsenic. It is found that lakeside wetlands can effectively control and reduce the pollutants flowing through the lakeside wetlands through the processes of physical, chemical and biological processes in the water-sediment-plant system and their comprehensive effects [22-23]. It is the purification between the water environment and the terrestrial environment protection belt. Overall, the total arsenic content of sediments in January was slightly higher than that in July, which may be caused by the environmental factors in summer, and the release of some arsenic species. However, the content of arsenic in one of the samples in July exceeded of the Chinese soil environmental quality standard (30 mg/kg), which was as high as 89.83 mg/kg, the cause may be in the process of sampling points which deviate from the result. It shows that the arsenic content of sediments in lakeside wetlands is not uniform and has certain environmental risks. It may be related to the terrain and spring position of the south bank lakeside wetlands. Li F et al., [24] found that the more exposed spring rise and geological structural vulnerability exists in the South underground, it can be through the underground karst route into the water.

Arsenic will exist in sediments in different combinations, and the stability of arsenic in different forms in sediments is also different. Extraction of arsenic in sediments by BCR extraction method, F1 is relatively active form, F2 and F3 are relatively stable form, F4 difficult to use very stable form, the first three forms also known as the effective arsenic [25]. The content of arsenic in sediments of Yangzonghai lakeside wetland showed that F4> F2> F1> F3.

F1 includes exchangeable and carbonate-bound arsenic, which is adsorbed on soil aggregates and other ingredients. It is sensitive to environmental changes and it is easy to release, migrate and be biologically absorbed and cause secondary pollution [26]. The proportion of F1 in Yangzonghai sediments were 14.67% ~ 20.28% (January) and 6.62% ~ 27.29% (July). Wang S et al. [27] (2009) found a high proportion of F1 in Jinzhou Bay sediments, and the proportion of 46.18% to 69.14%. It will be a serious threat to the local environment and ecosystems. In Yangzonghai, the low content of F1 may be treated with flocculant, and there is the result of the presence of adsorbent. It can be argued that the relative risk of environmental and biological hazards is small because of the relatively low proportion of arsenic in Yangzonghai.

F2 is formed by the adsorption or coprecipitation of anions by iron-manganese oxide, which is not readily released, but is also reduced to bio-available iron-manganese oxide bounds when certain conditions in the water are changed. It ranges from 2.25 mg/kg to 4.36 mg/kg (January), 1.74 mg/kg to 4.77 mg/kg (July). And Zhang Y et al., [28] in the 2010 study is slightly different (Yangzonghai sediments 0 ~ 2 cm sediment iron and manganese oxide combined with an average content of 27. 73 mg/kg, and 6 ~ 8 cm down to 1.16 mg/kg). This difference may be caused by the different sampling time. In 2010's sampling, Yangzonghai project management is still in progress, resulting in surface iron and manganese oxide combined with high content, and this paper's sampling time is 5 years after the end of the management project. Further studies have shown that the stability of arsenic in sediments is increasing during the migration process over time [29]. F3 is the organic matter and arsenic active groups or sulfide combination of the form, generally not easy to release. It is slightly higher in the sediment content and proportion than F2.

The residual arsenic in the sediments is very stable and does not participate in the redistribution balance of the sediment-water system [30]. It cannot be released under natural conditions. The migration and bioavailability are very small and safe for the environment and the environment. The arsenic content in the sediments of Yangzonghai is very high, ranging from

6.62% to 27.29% (January), 6.62% to 27.29% (July), indicating that arsenic in sediments is stable. The treatment of Yangzonghai flocculant may also promote the increase in the proportion of arsenic in the sediment. Yuting M I et al., [31] research river sediment, Liu Y et al., [32] research sediment of Bosten Lake in arsenic is also the main form of residual.

In general, the sediments of Yangzonghai are mainly arsenic in the residual state, but the effective arsenic content is higher than that of the residual arsenic, and has higher secondary release potential. The results of T test showed that there were significant seasonal differences ($P < 0.05$) in the contents of F1 and F3, which were related to its nature and environmental factors had different effects on arsenic in different seasons.

Effects of environmental factors on total arsenic and arsenic speciation in sediments of Lake Wetland

Correlation analysis and redundancy analysis of Yangzonghai lake wetland sediment arsenic and the environmental factors that influence environmental parameters of the sediment arsenic occurrence, which is associated with the special wetland environment, due to the impact of different positions in wetland of arsenic species in different environmental parameters [33]. The lake and wetland area close to the terrestrial plants are more, the influence of arsenic and the main clay, silt, sand, OM, pH and W-DTP, the particle size is one of the most important elements on the adsorption capacity of heavy metals in sediment, the sediment particles smaller, larger specific surface area, stronger adsorption for heavy metals, into the heavy metals in the sediment preferentially enriched in the fine particles. Effect of arsenic speciation is mainly affected by pH value, according to the research for heavy metal extraction, sediment metal bioavailable fraction increased with the decrease of pH and the potential biological can be reduced with pH did not show correlation by the state, and the residue state combined with silicon salt increases with decreasing pH. Due to the upstream disturbance influence, exogenous pollutants can enter the lake area with the rain, surface runoff, the phosphorus and arsenic in the periodic table of elements are the main group elements V, their chemical properties are similar to that of PO_4^{3-} and AsO_4^{3-} competitive adsorption sites of sediment, exchange adsorption solution of arsenic extraction [34]. Research shows that the content has a great influence on the texture of the sediments of heavy metals in sediments, organic matter and heavy metal ions to form complex and easy to reduce the bioavailability of heavy metal ions and mobility, thereby greatly reducing the activity of heavy metal ions, resulting in heavy metal content increased.

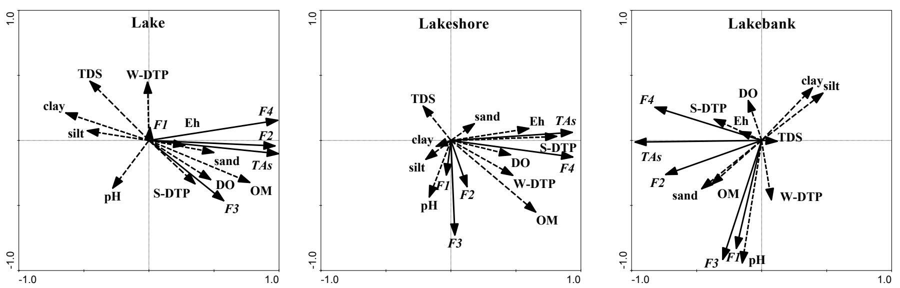


Fig. 4 Correlation plots of the redundancy analysis on the relationship between As species and environmental factors

The lakeshore area is an important area of interception of pollutants, between lake and lake, lush vegetation. The results showed that the arsenic speciation in F1 and F2 is relative to other forms of influence is weak, and the main environmental parameters pH, OM, Eh, W-DTP, S-DTP, and Lake area is not associated with the sediment grain size, heavy metals in soil and showed obvious effect of the particle size, particle size and soil the weak correlation between heavy metals, may be due to the different particle size of sediment in different proportions to adsorption of heavy metals, less sand in soil, but soil texture in a larger proportion of heavy metal content of total contribution is large, leading to higher content of heavy metals in sediments of the study area, and on the heavy metal adsorption capacity of clay soil a large proportion of the total amount of heavy metals with smaller and smaller [35-36]. F1, F2 and weak influence itself belong to the bioavailable environment state and the Lake District, F2 (Fe/Mn oxides and hydroxides) in the presence of oxygen on the heavy metals fixation plays a leading role; in hypoxic conditions, metal sulfide plays a leading role in metal speciation, due to oxidation and reduction the rise in potential, sulfide and organic binding state of the form can be transformed into unstable F1 [37]. The lake bank area and different lake district is in addition to F1, other arsenic influential, and environmental parameters with the shore area is basically the same, mainly S-DTP, OM, pH, clay, silt.

Lake wetland is the most complex in the water environment, the sediment ecosystem contains aquatic plants, aquatic animal and microorganism, effects of the complex system of geochemical changes affected by environmental factors, but also affect the arsenic speciation transformation characteristics of biological utilization and migration [38]. According to factor analysis, the size effects of environmental factors on the arsenic speciation of Lake wetland sediments are classified, results show that the first is the OM effect of F4, TAs, second is the particle size of sediments, followed by W-DTP, S-DTP, DO, Eh, EC, F1, F3 and finally pH effect. According to the analysis of correlation and redundancy also confirmed this point, OM and arsenic have significant correlation, while the particle size due to different wetland environment of different importance, seasonal environmental parameters of water had little difference, but when the various environmental factors and changes will affect the arsenic speciation changes, such as increasing phosphorus will have different effects on the adsorption of arsenic in the sediments, generally think that the increase of phosphorus desorption amount will increase arsenic, increase the content of heavy metals in sediments and in alkaline waters, free arsenic can combine with hydroxyl to form complexes, in acidic waters, due to the hydrogen ion competition reduces the adsorption of arsenic in the acidic conditions, adsorption sites for adsorption of organic compounds on Fe-OOH can produce competitive adsorption of arsenic in sediment, and inhibit the adsorption of arsenic in sediments [39-40].

CONCLUSIONS

(1) The TAs content of lakeside wetland sediments fluctuates little, and there is no obvious seasonal difference. The TAs content is stable, but it shows the trend of lake-lake bank descent, which shows that the lake wetland has an interception effect and arsenic pollution comes from endogenous; The spatial distribution of arsenic in sediments is not obvious, mainly in the residual state, but the proportion of available state is higher than that of residue. From the seasonal distribution, F1 and F3 are different, and the lake wetland is at risk of arsenic release.

(2) The results show that the arsenic morphology of Yangzonghai sediments is controlled by different environmental factors in the lake - lakeshore - lake bank, and the sediment particle size, OM, pH, W - DTP, and the lake area by the pH, OM, Eh, W-DTP, S-DTP, arsenic in the lake and lake area of the influence of large, in the lake area F1, F2 weak, with the lake area environmental parameters pH, Eh, OM. Factor analysis further showed that the arsenic morphology of lake wetland was most affected by OM, pH and phosphorus.

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REFERENCES

[1] Bai, J., Cui, B., Chen, B., Zhang, K., Deng, W., and Gao, H., et al. (2011). Spatial distribution and ecological risk assessment of heavy metals in surface sediments from a typical plateau lake wetland, china. Ecological Modelling, 222(2), 301–306.

[2] Bai, J., Yang, Z., Cui, B., Gao, H., and Ding, Q. (2010). Some heavy metals distribution in wetland soils under different land use types along a typical plateau lake, china. Soil and Tillage Research, 106(2), 344-348.

[3] Nazeer, S., Hashmi, M. Z., and Malik, R. N. (2014). Heavy metals distribution, risk assessment and water quality characterization by water quality index of the river soan, pakistan. Ecological Indicators, 43(43), 262-270.

[4] Zhang, Y., Zhou, J., Gao, F. J., Zhang, B. J., Biao, M. A., and Li-Qing, L. I. (2015). Comprehensive ecological risk assessment for heavy metal pollutions in three phases in rivers. Transactions of Nonferrous Metals Society of China, 25(10), 3436-3441.

[5] Liu, G., Tian, K., Sun, J., Xiao, D., and Yuan, X. (2016). Evaluating the effects of wetland restoration at the watershed scale in northwest yunnan plateau, china. Wetlands, 36(1), 169-183.

[6] Hoffmann, C. C., Heiberg, L., Audet, J., Schønfeldt, B., Fuglsang, A., and Kronvang, B., et al. (2012). Low phosphorus release but high nitrogen removal in two restored riparian wetlands inundated with agricultural drainage water. Ecological Engineering, 46(46), 75-87.

[7] Chen L, Cai Q, Xu S, et al. Distribution Characteristics, Pollution Assessment, and Source Identification of Heavy Metals in Sediments of Wetland Lakes[J]. Polish Journal of Environmental Studies, 2015, 24(4):1525-1533.

[8] Adsorption, B. O., and Coprecipitation, A. (2015). The risk assessment of sediment heavy metal pollution in the east dongting lake wetland. Journal of Chemistry, 2015(15), 1-8.

[9] Deng, J., Wang, Y., Xin, L., Hu, W., Zhu, J., and Lin, Z. (2016). Spatial distribution and risk assessment of heavy metals and as pollution in the sediments of a shallow lake. Environmental Monitoring and Assessment, 188(5), 296.

[10] Jiang, Y., Liu, X., Gao, J. F., Cai, Y. J., and University, N. F. (2015). Pollution characteristics and potential ecological risk assessment of heavy metals in surface sediments of shallow lakes in jiangsu province,china. Resources and Environment in the Yangtze Basin.

[11] Zhang, J. Q., Tian-Peng, H. U., Zhang, Y., Tao, M., Chen, Y. E., and Zhang, J. C., et al. (2014). Pollution characteristics and ecological risk assessment of heavy metals in surface sediments from the cihu lake in huangshi city. Earth and Environment.

[12] Peltekov, A. B., Boyanov, B. S., and Markova, T. S. (2014). Behavior of arsenic in hydrometallurgical zinc production and environmental impact. Polish Journal of Chemical Technology, 16(4), 80-86.

[13] Equeenuddin, S. M., Tripathy, S., Sahoo, P. K., and Panigrahi, M. K. (2013). Metal behavior in sediment associated with acid mine drainage stream: role of ph. Journal of Geochemical Exploration, 124(1), 230–237.

[14] Zhang, Y., Zhou, J., Gao, F. J., Zhang, B. J., Biao, M. A., and Li-Qing, L. I. (2015).

Comprehensive ecological risk assessment for heavy metal pollutions in three phases in rivers. Transactions of Nonferrous Metals Society of China, 25(10), 3436-3441.
[15] Bi, J., Liu, C., and Li, S. (2014). Variation of water quality of Yangzonghai Lake affected by arsenic pollution. Water Resources Protection, 30(1), 84-89. (in Chinese)
[16] Zhang, Y., Sun., J., Xiang, X., Jing, J., Liu, J., and Huang, G., et al. (2012). A Survey of Heavy Metals in Sediments of Yangzonghai Lake in Yunnan Province：Their Source and Distribution. Environmental Science and Technology, 33(12), 177-181. (in Chinese)
[17] Pardo, R., B.A. Helena, Cazurro, C., Guerra, C., Debán, L., and Guerra, C. M., et al. (2004). Application of two- and three-way principal component analysis to the interpretation of chemical fractionation results obtained by the use of the b.c.r. procedure. Analytica Chimica Acta, 523(1), 125-132.
[18] Yan-Qiao, H. U., Cheng, W. C., Zhi, Y. C., Wang, Y. B., Zhao, L. C., and Wei, L., et al. (2016). Simultaneous determination of 11 elements in chromites by inductively coupled plasma-atomic emission spectrometry with hcl-hno_3-hf-hclo_4 digestion method. Chinese Journal of Analysis Laboratory.
[19] Meleshko, D. P., and Pachepskii, I. A. (1981). Evaluation of error in the potentiometric determination of the pH value of the porous solution of moisture-unsaturated soils. Agrokhimiia.
[20] Sinegani, A., and Sharifi, Z. (2007). Changes of available phosphorus and phosphatase activity in the rhizosphere of some field and vegetation crops in the fast growth stage. Journal of Applied Sciences and Environmental Management, 11(3), 113-118.
[21] Han, T., Wu, Z., and Wu, Y. (2010). By graphite electric heating digestion-potassium dichromate method determination of organic matter in sediment. Environmental Science and Management.
[22] Li T, Gao X. Ecosystem Services Valuation of Lakeside Wetland Park beside Chaohu Lake in China[J]. Water, 2016, 8(7):301.
[23] Jie, L. I., Chen, J., and Xia, F. (2012). A pollutant removal rule of constructed wetland on the the dianchi lake lakeshore. Environmental Science and Technology.
[24] Li, F., Li, X., Xu, Q., Yang, S., Fang M. and Huang, J., et al. (2015). Identification of Arsenic Sources and Pollution Control inYangzonghai Lake. Environmental Science Survey, (5), 27-31. (in Chinese)
[25] Yongxia, L. I., Huang, Y., Gao, F., Minmin, X. U., Sun, B., and Wang, N., et al. (2016). Speciation and risk assessment of heavy metals in surface sediments of the loushan river. Environmental Chemistry.
[26] Islam, M. S., Ahmed, M. K., Raknuzzaman, M., Habibullah-Al-Mamun, M., and Islam, M. K. (2015). Heavy metal pollution in surface water and sediment: a preliminary assessment of an urban river in a developing country. Ecological Indicators, 48(48), 282-291.
[27] Wang, S., Jia, Y., Wang, S., Wang, X., Wang, H. and Zhu, H., et al. (2009). Arsenic concentration, distribution, and form sin the water sand sediments of Jinzhou Bay and its adjacent estuaries. Chinese Journal of Ecology, 28(5), 895-900. (in Chinese)
[28] Zhang, Y., Xiang, X., Zhang, Y., Chen, X., and Wang, J., et al. (2012). Distribution and Sources of Arsenic in Yangzonghai Lake, China. Environmental Science, 33(11), 3768-3777. (in Chinese)
[29] Wang, S., Xu, L., Zhao, Z., Wang, S., and Jia, Y. (2012). Arsenic retention and remobilization in muddy sediments with high iron and sulfur contents from a heavily contaminated estuary in china. Chemical Geology, 314-317(4), 57-65.
[30] Li, X., Wang, Y., Li, B., Feng, C., Chen, Y., and Shen, Z. (2013). Distribution and speciation of

heavy metals in surface sediments from the yangtze estuary and coastal areas. Environmental Earth Sciences, 69(5), 1537-1547.
[31] Yuting, M. I., Cai, Y., Jing, Y. U., Zhang, H., and Zhang, X. (2016). Arsenic in river sediments in gold mining areas:chemical speciation and release kinetics. Environmental Science and Technology.
[32] Liu, Y., Mu, S., Bao, A., Zhang, D., and Pan, X. (2015). Effects of salinity and (an)ions on arsenic behavior in sediment of bosten lake, northwest china. Environmental Earth Sciences, 73(8), 4707-4716.
[33] Lipski, W. J., and Marek, W. (2014). Particle size fraction and arsenic partitioning in tailings and sediments in lianhuashan tungsten mine, southern china. Applied Mechanics and Materials, 522-524, 365-369.
[34] Rubinos, D. A., Iglesias, L., Díaz-Fierros, F., and Barral, M. T. (2011). Interacting effect of ph, phosphate and time on the release of arsenic from polluted river sediments (anllóns river, spain). Aquatic Geochemistry, 17(3), 281-306.
[35] Gorny, J., Billon, G., Lesven, L., Dumoulin, D., Madé, B., and Noiriel, C. (2015). Arsenic behavior in river sediments under redox gradient: a review. Science of the Total Environment, 505, 423-434.
[36] Kiurski, J., Vasic´, M. V., Aksentijevic´, S., Luburic´, U. K., and Miloradov, M. V. (2010). Metals distribution and particle size analysis in water and sediment of the djetinja river and dragic´a spring (serbia). Chemical Industry and Chemical Engineering Quarterly, 16(4), 363-372.
[37] Ascar L, Ahumada I, Richter P. Influence of redox potential (Eh) on the availability of arsenic species in soils and soils amended with biosolid[J]. Chemosphere, 2008, 72(10):1548-52.
[38] Johnson, L. R. (1986). The chemical speciation and transformations of arsenic in humans and in the environment. Utilitas Mathematica, 52(6), 1611-1623.
[39] Neubauer, E., Köhler, S. J., Von, d. K. F., Laudon, H., and Hofmann, T. (2013). Effect of pH and stream order on iron and arsenic speciation in boreal catchments. Environmental Science and Technology, 47(13), 7120-8.
[40] Chow S S, Taillefert M. Effect of arsenic concentration on microbial iron reduction and arsenic speciation in an iron-rich freshwater sediment [J]. Geochimica Et Cosmochimica Acta, 2009, 73(20):6008-6021.