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Hydrochemical characteristics of salt marsh wetlands in western Songnen Plain

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Abstract: In western Songnen Plain of China, the saline-alkaline degree of water bodies is high in salt marsh wetlands. Generally, pH is above 8.0, and the hydrochemical types belong to HCO32--Na+. Through analysis on the basic saline variables such as CO32-, HCO32-, Cl-, Ca2+, Mg2+, SO42-, Na+, and the derivative variables such as SAR, SDR, RSC, SSP, the relationships between different variables are found, and the discriminant equations are established to identify different saline-alkaline water bodies by using principal component analysis.

Hydrochemical characteristics of salt marsh wetlands in western Songnen Plain DENG Wei1, HE Yan2, SONG Xin-shan1, YAN Bai-xing1 (1. Changchun Institute of Geography, CAS, Changchun 130021, China; 2. Chinese Academy of Sciences, Beijing 100864, China) According to classification system of wetland in Ramsar Convention, salt marsh belongs to inland salt lake formed by regional hydrogeologic and climatic conditions[1]. In western Songnen Plain, the most distinct characteristic of water environment in salt marsh wetlands is that many water bodies have high salt contents and pH values, so salt marsh wetlands are categorized as a special natural synthesis[2]. 1 Natural environment in western Songnen Plain The Songnen Plain lies to the east of Da Hinggan Mountains with its east adjacent to the Second Songhua River, its south bordering watershed between Songhua River and Liaohe River, and its north adjacent to Qiqihar district. It covers a total area of 5?04km2. Songnen Plain is a low-lying alluvial plain. It is located in the Songliao depression, which began to subside chronically since the Mesozoic, and its bedrock is deeply embedded[3]. Its top is covered with Quaternary fluviolacustrine facies sediment, which has high salt saturation in the rock, and its water solution is alkali, the pH value is about 8.5. Among its salt components, the cations are mainly Na+, and the anions are mainly HCO3-[4]. Due to wind erosion, many free hillocks and closed shallow dish lowlands are distributed alternately in its middle part. Climate type of Songnen Plain belongs to continental monsoon climate, summer monsoon alternates apparently with winter monsoon, and temperature difference is quite obvious. Generally, spring is dry, windy and lack of rainfall, summer has abundant rainfall, autumn is relatively mild with moderate rainfall and abundant sunshine and winter is cold and long. The annual average precipitation is 429.8mm. Due to less rainfall, water system is not fully developed. There are 54 rivers with a length of over 10 km each and corresponding basin area exceeding 20 km2 in the region. Of them Tao?r and Huolin rivers exert great influence on water quantity balance of the limnic wetlands. The low-lying terrain makes the Songhua River, Nenjiang River and their tributaries form centripetal water systems in the Songnen Plain. Drainage of surface water is not free, and Huolin River valley is mainly an inland drainage area. According to statistics, there are more than 700 lakes in this area, of which over 200 lake basins cover an area of over 1 km2 each, and salt concentration is high in many lakes with alkali water[5]. As a result of river course evolution, many lakes in this region are evidences of ancient channels, and some yoke lakes and the erosive depressions are formed by wind erosion during Neotectonic Movement accompanied by the formation of Songliao basin[4]. Most of the salt marshes are closely related to surface runoff, only few have direct and close relation with groundwater. Furthermore, movement and enrichment of elements have consanguineous relationships with surface runoff, and surface geochemical actions are special. 2 Data collection In order to make sure that analyzed data can represent regional salt marsh water environmental characteristics, some salt marsh water chemical data are obtained from the references besides the analytical data from the Limnic Foundation of the Chinese Academy of Sciences. Of the total 103 samples collected, after eliminating certain samples obtained under special conditions, 95 samples are available for analysis. 3 Selectio

n of saline-alkaline variables in salt marsh water According to the contribution of principal salt components to regional alkalization, the main hydrochemical variables can be classified into two groups, i.e., fundamental variables, such as pH, CO32-, HCO3-, CL-, Ca2+, Mg2+, SO42-, Na+, and deprivative variables, such as Mineralization Degree (MD), Sodium Adsorption Ratio (SAR=SAR=[Na+]/(([Ca2+]+[Mg2+]), Solution Sodium Percent (SSP=[Na+]/ ([Ca2+]+[Mg2+]+[Na+]+[K+])), Remained Sodium Carbonate (RSC=[HCO32-]+[CO32-]-[Ca2+]+[Mg2+]), Sodium Divided Ratio (SDR=[Na+] /([Ca2+] + [Mg2+])), Bicarbonate Anion Ratio (BAR=[HCO3-/([Cl-]+ [SO42-]), Magnesium Calcic Ratio (MCR= [Mg2+]/[Ca2+]), Sulfate Chloride Ratio (SCR=[SO42-]/[Cl-]), which indicate combination situation of hydrochemical factors in salt marsh water body[6] ([ ] represent milligrame equivalent concentration per litre of corresponding ions (meq/L)). 4 Hydrochemical characteristics of salt marsh wetlands 4.1 Description of hydrochemical basic characteristics of salt marsh water Due to long-term and large area subsidence, sediments contained in river water are deposited constantly, and river bed is silted and up-lifted to lead to riverway swing, which restrains free running water and forms some inland basins. Moreover, because of dry climate, intense evaporation and mankind disturbances, in many limnic wetlands, water input amount is less than that output, which causes salt contents increase in limnic wetlands gradually to form salt marsh. Due to difference between supply and drainage modes and natural environment, the salt contents of salt marshes are quite different. Generally, salt content is higher in the interior drainage basins than that in the exterior ones. And the salt content of salt marshes supplied by groundwater is lower than that supplied by surface stream; that of salt marshes that have supply relationship with river is lower than that has no such relationship. Table 1 lists chemical characteristics of river water, and Table 2 lists those of some typical salt marsh wetlands. From Table 2, we can see that the pH values of salt marshes are generally higher than those of rivers, and water is alkaline, the hydrochemical type is soda-Na. Comparatively, and the contents of Na+, F- and Cl- are higher than those of the Second Songhua River, Nenjiang River, Tao?r River and Huolin River (Table 1). In the western Songnen Plain, alkalization of many salt marshes is serious, only in few large limnic wetlands that have supply relationship with rivers, such as Yueliang Lake, Lianhuan Lake and Qagan Lake, this situation is slight. Moreover, alkalization of a few lakes is more serious, and their functions of irrigation and drinking have disappeared. Commonly, in the western Songnen Plain, some natural limnic wetlands are affected by human activities, climate and surface geo-chemical factors, and alkalization is serious. Specially, it is obvious in Huolin River valley, the midstream valleys of Tao?r River and Nenjiang River. In some slightly saline-alkalized areas, the periodical water supplied from rivers dilutes the salt contents of limnic wetlands, and reeds and other swamps vegetations grow well. Table 1 The hydrochemical characteristics of main rivers in the western Songnen Plain (mg/L,*:unit:meq/L) Table 2 The hydrochemical characteristics of salt marshes in the western Songnen Plain (mg/L,*:units:meq/L) 4.2 Correlation analysis of saline-alkaline variables Correlation analysis can discover similarity and difference of character and source of different saline-alkaline variables. Because correlation between mineralization and some saline-alkaline variables, this paper calculates partial correlation coefficients (Table 3) by SPSS statistical softwares. Firstly, from Table 3, it is clear that the correlation is different among different components, and the relativity of some components reaches notable correlation (?=0.01). Specially, in the western Songnen Plain, the lithofacies (soil) are mainly, weathering materials of basalt and granite. They are accumulated by the way of running water transportation, and the NaAlO2, Na2SiO3 and NaHSiO3 in them can react with water and carbonate to form soda, which indicate the correlation coefficients between Na+ and CO32-, HCO32-, Cl-, SO42-, and between Na+ and Na+/(Ca2++Mg2+) are higher. Moreover, because of high evaporation, salt in the groundwater moves upward and accumulates on the surface soil. Dissoluble salts (Cl-, SO42-) entering lakes can be attributed to the high correlation between Cl- and SO42-. Secondly, the variables correlated to pH values are markedly SSP, SAR and [Na++K+]. This indicates that the above variables control the balance between [H+] and [OH-]. For these variables are related to content of [Na+], it shows that [Na++K+] are key variables which control pH of water bodies in the salt mashes in the western Songnen Plain. In addition, pH is related to the [Ca2+] negatively (P=0.00) with the correlation analysis. In the study, the liner correlation between mineralization (M) and [HCO3-] is distinctive in lower mineralized water while that between MD and [Na++K+] is distinctive in most water bodies, especially in highly mineralized water body. The linear relation was fitted by linear equation (Table 4). Table 4 Equation fitted in water bodies with different mineralizations To obtain correlation between variables of salt marsh water, the distance clustering method has been used to get clustering pedigree based on correlation between variables (Figure 1). The variables of saline-alkaline water in western Songnen Plain can be divided into 4 groups: (1) [Na++K+], MD, [Cl-] and [SO42-], mainly reflecting dissolved salt, are saline variables; (2) SAR, SDR, pH, SSP, RSC, [HCO3-] and [CO32-], reflecting alkalization of water bodies, are alkaline variables; (3) [Mg2+], MCR and [Ca2+], reflecting content and combination of minimum cation, are cation variables; and (4) SCR and BAR, reflecting combination of anions, are called as anion variables. Figure 1 Dendrog

ram of saline-alkaline variables 4.3 Numerical classification of water bodies Based on clustering of variables, the s aline variables ([Na++K+], M, [Cl-], [SO42-]), alkaline variables (SAR, SDR, pH, SS, RSC), cation variable (MCR) and anion variables (SCR) were selected to make numerical classification of water bodies. 4.3.1 Principal component analy sis on water body of salt march in the western Songnen Plain In this paper, the statistical value of KMO (Kaiser-Meye r-Olkin Measure) is 0.893, and probability of Bartlett´s Test of Sphericity equals to 0.00, both satisfy the conditio ns for PCA. The cumulative contribution of the first two variables is 79.98% (Table 5), which can be chosen as the pr incipal component. The community factor points out that each variable indicates percentage of original variable squar e deviation. Except MCR and SCR, community factors of other variables exceed 70%, especially [Na++K+], M and SAR, the ir community factors surpass 90%. In conclusion, [Na++K+], M and SAR entering the principal component can reflect th e saline-alkaline situation of salt march water. Secondly, in Table 5 it can be found that [Na++K+], M, Cl- and SO42- in the first principal components have the higher factor loads. In salt marsh water bodies in the western Songnen Pla in, the main cations are Na+ and K+ while the main anions are Cl- and SO42- especially in high mineralized water. So the first principal components mainly reflect the mineralization of water bodies which can be called as saline equati on. Factor loads of the second principal components can be formed as following: SAR>SSP>SDR> RSC>pH>[Na++K+]>M. Amon g the higher load variables, the first five variables are relative to alkalization of water bodies, so the second pri ncipal components can be called as the alkaline equation. The above analysis accords with the reality because hydolyz e of Na and K leads to the alkalization of water bodies in most of the water bodies in the western Songnen Plain, so SAR which includes the influence of bivalent Ca2+ and Mg2+ on Na+ and K+ has the highest loads. RSC is alkaline inde x, so it contributes to the second principal components. Table 5 The results of PCA EIG=Eigenvalue; CR=Contribution r atio; CCR=Cumulation contribution ratio. The measured value of all the samples were computed by factor score equatio n. Scattering plot of PC1 and PC2 is obtained (Figure 2). In this figure, there are four distinctive glomerate region s which represent the saline-alkaline situation of all the water samples. According to the glomerating degree and com prehensive analysis of all the samples, we classify all the 95 water samples into 4 main categories, of which 43 belo ng to class I, 21 to class II, 13 to class III and 18 to class IV. The scores of PC1 and PC2 of class I, i.e., facto r scores of saline and alkaline equation are all low, so we call this type of samples low degree saline-alkaline wate rs. According to the principles, we call the second type of samples with low saline equation score and high alkaline equation score alkaline waters, and third type of water samples with the controversial contributing values to the sec ond type of the saline waters, while the fourth type of samples with both high salinity and alkalinity, the principa l component contributing values are called the saline-alkaline waters. Figure 2 Scatter plot first and second princip le component 4.3.2 Stepwise discriminant analysis On the basis of the four water types, Fisher? Stepwise Discriminan t Analysis is used to pick out the 5 variables which are M (g/L), pH, SAR, SSP and RSC, among which M represents the saline degree of water bodies and the other four represent the alkaline situation of water bodies. So the combinatio n of all the variables can be used to represent the saline-alkaline characters of water bodies in the concerned regio n. Based on the analysis of the 95 samples, we can establish a four-class discriminant for the evaluation of water bo dies in the western Songnen Plain (Table 6). The value of the discriminants can be calculated by using the measured v alues of the samples. And the rank corresponding to the maximum value of L is the rank to which the analysed water sa mple belongs. In order to inspect the validity of these discriminants, we apply all the index values of samples to th e discriminants and get the ranks for all the samples, then we can compare this result with that from clustering anal ysis. The result shows that the precision of the four discriminants are all above 85%, and discriminant for low salin e-alkaline water bodies has the highest precision of 90.2%. Table 6 Discriminant modes for water bodies of salt marsh es in the western Songnen Plain x1, x2, x3, x4 and x5 represent pH, M (g/L), SAR, SSP and RSC respertively 5 Conclusi on In the western Songnen Plain, the salt marsh wetlands are significant natural landscapes that are formed under spe cial geological and geographical environment and terrestrial hydrologic conditions. Hydrochemical characteristics of limnic wetlands have intimate relationship with its causes of formation and element character. This analysis is an ef fective way to explain the differences of element source, movement and accumulation under special conditions. This pa per clarifies the movement laws of saline-alkaline components in the region, and establishes a set of a four-class di scriminant for the analysis of salt marsh water bodies. And the goal is to develop and utilize the water resources i n this region reasonably by means of controlling and preventing regional salinization. The first class of water bodie s has favorable water quality and thus can be used for multi-goal developments such as irrigation for farming, fish c ulture, development of paddy field. The second class of water bodies has great potential disadvantages, that is, thou gh the mineralization of this kind of water bodies is not too high, the relatively high concentration of exchangeabl e univalent cations in the salinity can generally result in secondary salinization, which has been proved during the

irrigation practices in the western Songnen Plain. Due to the relatively high concentration of salinity, the third class of water bodies is inappropriate for irrigation, but can be used for development of bulrush field and fish culture and so on. The fourth class of water bodies is normally natural salt marsh or the influx area for drainage during the amendment of salinized land, so its usability is limited and can be used for the production of natural bulrush or as the influx area of the salinity in the region, which is important to the balance of total saline amount in the region, and is helpful to maintain the stability of ecosystem. References

关键词： salt marsh wetland; hydrochemical types; correlation analysis; principal component analysis; discriminant analysis; Songnen Plain

