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Research on the Hydrochemical Characteristics of Groundwater at the Southern Edge of Taklimakan Desert and along the Southern Desert Highway, China

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Abstract

In this paper, the characteristics of chemical components of groundwater were analyzed by means of investigating and collecting groundwater samples and hydrochemical analyses in the lower reaches of Niya river, Yatonggusi river and Andier river, the south edge of Taklimakan desert and along the southern desert highway in Tarim basin. It indicates that the total dissolved solids (TDS) in shallow groundwater are respectively 2.14-4.97g•L-1, 5.79-7.71g•L-1 and 1.21-38.85g•L-1 in Niya river, Yatonggusi river and Andier river. The partial correlationships of groundwater TDS with HCO3-, SO42-, Cl-, and Na+ ions are extremely obvious, the relative coefficients ranging from 0.9598 to 0.9874, and quite obvious to Mg2+、Ca2+ ions with the coefficients of 0.8508 and 0.7771 in the lower reaches of Andier river. For the groundwater TDS along the southern desert highway, its partial correlationships to SO42-, HCO3- and Cl- ions are extremely obvious, with the relative coefficients ranging from 0.9171 to 0.9686, and quite obvious to Na+ and Ca2+ ions with the coefficients of 0.7873 and 0.6322. In the lower reaches of Andier river, there are some spatial correlations on the aspects of K+ and HCO3- contents in groundwater, and the spatial correlation distances in latitude and longitude are 0.03° and 0.21°. Based on the established semivariogram models, isograms of the distribution of ion contents in groundwater were plotted by using Kriging and IDW methods. The results show that the spatial distribution characteristics of chemical components in groundwater are consistent with that of ions contents changing along the latitude from south to north.

Keywords: Taklimakan desert; desert highway; chemical components of groundwater; spatial correlation

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1. Introduction

In the south of Tarim basin, northwestern China’s arid regions, all of the rivers which were collected by glacier melting and precipitation originated from the Kunlun Mountains. The runoff and groundwater were delivered to piedmont sloping flat, then flowing into deserts in parallel [1].

There is a well closed and low plain topography in the Tarim basin, which results to sealing, detention hydrodynamic conditions and hydrogeochemical environments. Because of the impacts of the extreme drought climate, riching in soluble salts and widespread desert, the regional hydrochemical types of groundwater present diversity. As the main recharge source, the surface runoff has intense effect on the chemical characteristics of unconfined groundwater in the riverbed and its surround. The prevailing anions in the groundwater change successively from the mountain areas to the hinterland of desert. The anion components transfer from HCO3- to SO42- and Cl-, with the increasing TDS. The hydrochemical types of groundwater accordingly transfer from bicarbonate with low TDS (＜0.10g•L-1) and sulfate (1.00-5.00g•L-1) to chloride (＞10.00g•L-1) [1,2].

The storage of oil and natural gas resources is abundant in Tarim basin. Shortages of surface water resources in Taklimakan desert located in the basin negatively affect the exploration and development of oil and gas resources. It is very important to study the distribution and hydrochemical characteristics of groundwater in oil and gas fields in desert, and especially to explore the available groundwater resources. In this paper, the geostatistical methods were used to analysis the distribution characteristics and spatial correlationships of main chemical components in groundwater at the south edge of Taklimakan desert and along the southern desert highway. All these works are done to provide the scientific bases for exploring fresh groundwater and offering groundwater resources available to the industrial and living usage in oil fields.

2. General Situation of Study Area

Taklimakan desert is located in the Tarim basin among the Tianshan, Kunlun and Aerking mountains, and presents ellipse type. It is about 1100km long from east to west, 375km wide from south to north. Its total area is 33.76×104km2, which occupied 64% of Tarim basin and 47.2% of deserts in China. It is the largest desert in China and the second one in the world [1,3].

The first desert highway for exploration and development of oil was built in 1990s’, started in northern Lunnan county, ended in southern Minfeng county (Fig. 1). It crosses Taklimakan desert and the total length is 518km [4].

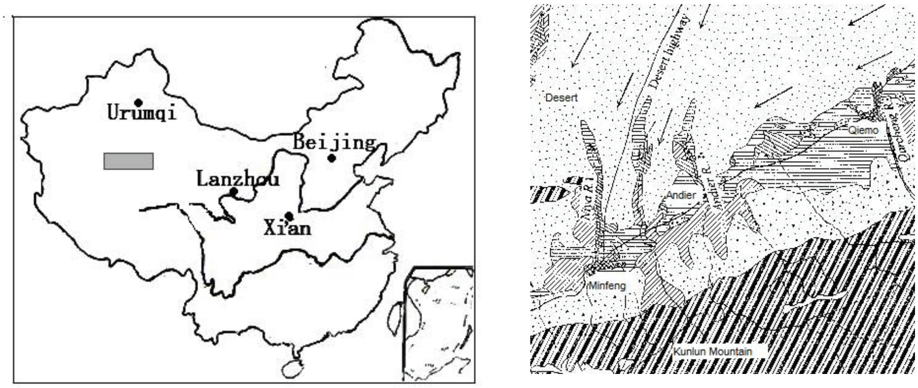


Fig. 1 Location map of the study area

3. Characteristics of Groundwater Distribution in Desert

According to the data of hydrogeological exploration holes in the middle of Taklimakan Desert, the thickness of unconsolidated sediments in Quaternary is 400-600m [1,5]. The sand layer in desert presents good storage and permeability of moisture and becomes the medium for groundwater storage and movement. Shallow groundwater appears in the form of unconfined groundwater with a unit water table depth below 100m in loose stuff pores. The aquifers are mainly made of water deposits, water-wind-drift interlace and single wind-drift sediments without consolidation [6].

The rivers including Yeerqiang river, Hetian river, Keliya river, Niya river and Cheercheng river originated from the north of Kunlun mountain recharged the groundwater in desert, just limited to the both sides and terminate of river contiguous to desert, while it needs a longer period to affect the groundwater in hinterland of desert[7,8]. Along the southern desert highway from roadmark L518 to L498, the groundwater with table depth about 2.0m is recharged by the leakage of surface water in Niya river and spring water. The roadmark from L498 to L293 lies in running desert, shallow groundwater is distributed widespreadly. All of aquifers are desert water-bearing zones, except for the former stream channel aquifer at the joint of Yatonggusi river and desert highway. Groundwater flow is very slow, and recharge is feeble [2,7,8].

4. Hydrochemical Characteristics of Groundwater at the Southern Edge of Taklimakan Desert

1.1. Water Samples Collection

The shallow groundwater samples were obtained by artificial digging and well investigation at the vertical direction of river flow in both riversides in the lower reaches of Niya river, Yatonggusi river and rt highway (Fig. 2, Fig. 3). Hydrochemical

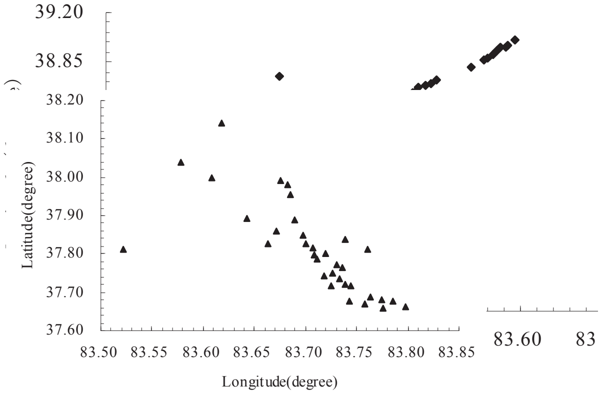


Fig. 2 Main groundwater sampling points in the lower reaches of Andier river

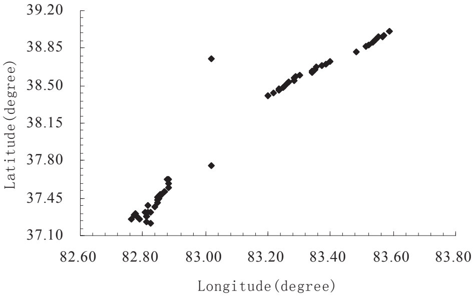


Fig. 3 Main groundwater sampling points along the southern desert highway

1.2. Analysis of Hydrochemical Characteristics of Groundwater in River Basin

The groundwater quality varies in difference from east to west at the southern edge of Taklimakan desert controlled by the topography and geomorphology. In the eastern region, the groundwater is overflow in piece-link swamp between Yatonggusilangan and Andierlangan. Under the condition of strong evaporation, TDS increases from original values of less than 1.00g•L-1 to 10.00-100.00g•L-1. Correspondingly, the hydrochemical types transfer from bicarbonate-chloride to chloride exiting in saline or semi-saline water. In the western Minfeng area, the groundwater overflows as spring and its TDS is less than 1.00g•L-1, which belongs to bicarbonate-chloride type [2].

The TDS of shallow groundwater is respectively 2.14-4.97g•L-1, 5.79-7.71g•L-1 in the lower reaches of Niya river and Yatonggusi river, 2.54-4.97g•L-1, 5.79～7.63g•L-1 in the fine soil plain[9]. In the lower reaches of Andier river, the TDS is 1.21-38.85g•L-1, in this region, 2.44-10.89g•L-1 in the fine soil plain, 7.14-24.63g•L-1 in desert, 9.62-31.50g•L-1 in reedy salina, and 1.22-2.22g•L-1 in older river channel. As a whole, the TDS decreases along the latitude. The values of TDS is alternately distributed along 37.65 -37.85 N, less than 3.50g•L-1 along 37.85 -37.95 N, while little decrease to 2.00-3.00g•L-1 to the northern 38 N. The ion contents in groundwater have a reducing tendency from south to north, alternatively distributed along 37.65 -37.85 N, the variation ranges of Na+, K+, Ca2+, Cl- and F- contents are relatively larger, SO42- medially, Mg2+ and HCO3- smaller. To the north direction, the content of each ion presents plain decline tendency (Fig. 4). According to the partial correlationships analysis of chemical components in groundwater, partial correlationships of groundwater TDS with HCO3-, SO42-, Cl-, and Na+ ions are extremely obvious, the relative coefficients ranging from 0.9598 to 0.9874, and quite obvious to Mg2+、Ca2+ ions with the coefficients of 0.8508 and 0.7771[10], in the lower reaches of Andier river.

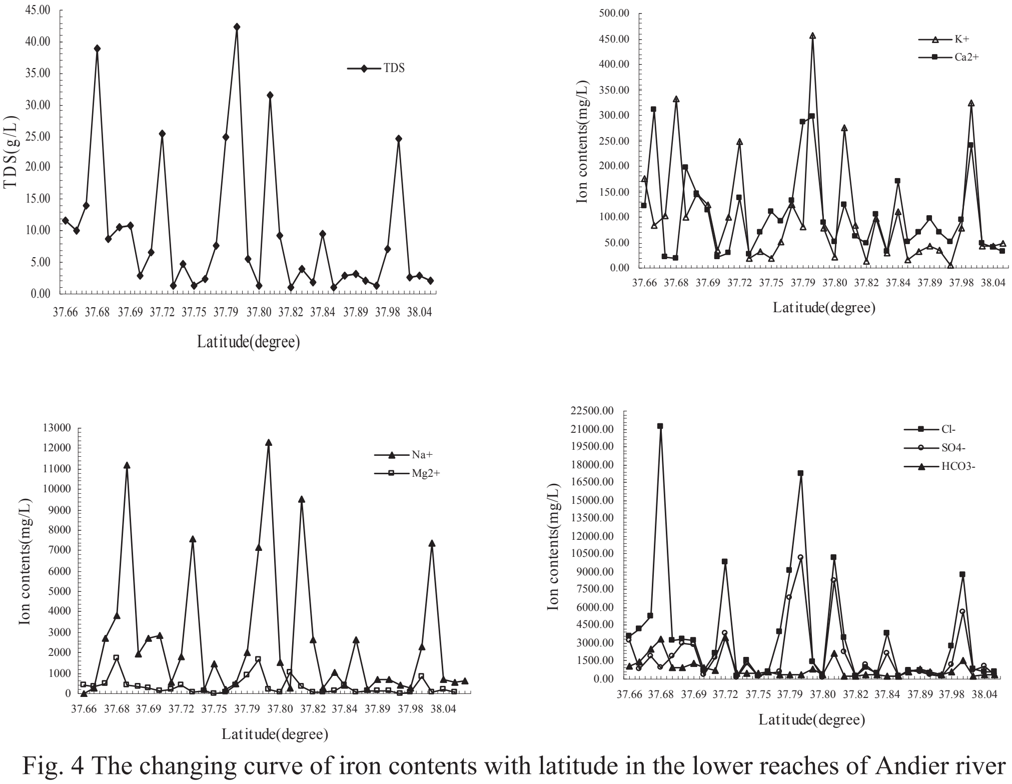


Fig. 4 The changing curve of iron contents with latitude in the lower reaches of Andier river

Table 1 TDS and hydrochemical types of groundwater in river basin at the southern edge of desert

Names of river	TDS[g·L -1]	Main ion components	Hydrochemical types
Niya	2.14-4.97	SO42- 、 Na+ • Mg2+ 、 Na+ • Ca2+→SO42-、Na+	SO4—Na • Mg、SO4—Na • Ca →SO4—Na
Yatonggusi	5.79-7.71	Cl-、SO42-、Na+→Cl-、Na+	Cl • SO4—Na、Cl—Na
Andier	1.21-2.89	Cl-、HCO3-、SO42-、Na+	Cl • HCO3—Na、Cl • SO4—Na
	3.04-38.85	Cl-、Na+	Cl—Na

Along the direction of surface water flow in Niya, Yatonggusi and Andier river, with the increasing TDS, main ion components in groundwater transfer from SO42-, mix of Na+•Mg2+and Na+•Ca2+, or Cl-, HCO3-, SO42-, Na+, or mix of Cl- and SO42-, Na+ or Cl-, Na+, to SO42-, Na+ or Cl-, Na+. The hydrochemical types transfer from SO4—Na•Mg, SO4—Na•Ca, Cl•HCO3—Na, Cl•SO4—Na to SO4—Na, Cl—Na, Cl•SO4—Na[9](Table 1).

1.3. Analysis of Hydrochemical Characteristics of Groundwater along the Southern Desert Highway

There are spring overflowing and low-lying reed swamp areas along the southern desert highway from roadmark L518-L498. The groundwater table depth is quite shallow, groundwater TDS is 0.47 -41.07g•L-1 (Fig. 5). The mix anions of Na+ and Ca2+, or Na+ and Mg2+ exist in the groundwater with TDS less than 1.50g•L-1. With the TDS from 1.50 to 3.00g•L-1, mainly SO42- or mix of SO42- and Cl-, more than 3.00g•L-1, the ion components gradually transfer to the mix of Cl- and SO42-, until to the mainly Cl-. With the TDS increasing, the hydrochemical types transfer from SO4—Na•Ca, SO4—Na•Mg to SO4•Cl—Na•Ca, SO4•Cl—Na•Mg, Cl•SO4—Na•Ca, Cl•SO4—Na•Mg, and ultimately becomes Cl—Na.

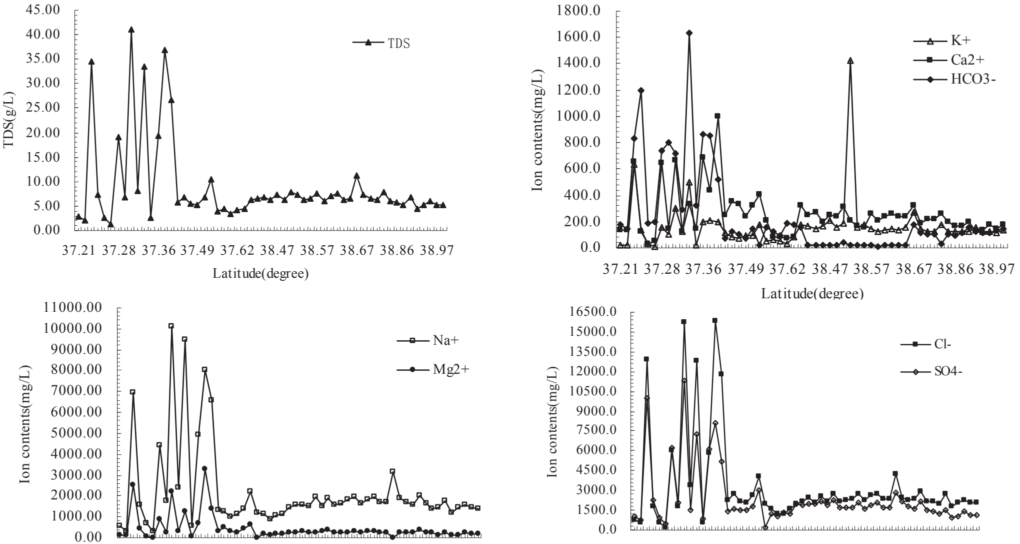


Fig. 5 The changing curve of iron contents with latitude at the south of desert highway

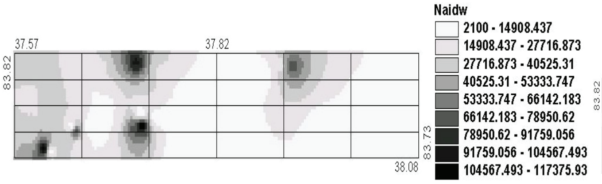
There are continuous running sand dunes with few plants along roadmark L498-L293 in the southern section of desert highway. The shallow groundwater water table depths of exploration sites among dunes range from 0.10 to 13.00m. In the most road sections, the groundwater TDS is more than 3.00g•L-1, the maximum is 26.65g•L-1 and hydrochemical type is Cl—Na. The ion contents in groundwater also have reducing tendency from south to north, alternatively distributed along 37.20 -37.65 N. The variation ranges of contents of Na+, Mg2+, Cl-, SO42- and HCO3- ions are relatively larger, Ca2+ medially, K+ and F- smaller. The contents of Na+, Mg2+, Cl- and F- ions are somewhat increasing along 37.65 - 37.85 N, the content of HCO3- sharply decreased, while the contents of K+, Ca2+ and SO42- present the fluctuant variations with small extents. To the northern areas, the fluctuation extent of HCO3- increases and that of other ions decrease (Fig. 5). For the groundwater TDS along the southern desert highway, its partial correlationships to SO42-, HCO3- and Cl- ions are extremely obvious, with the relative coefficients ranging from 0.9171 to 0.9686, and quite obvious to Na+ and Ca2+ ions with the coefficients of 0.7873 and 0.6322.

1.4. Analysis of Spatial Correlations of Chemical Components in Groundwater

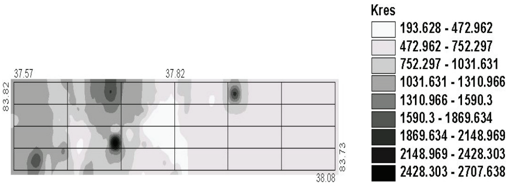
Under the supports of ArcInfo and ArcView on GIS platform, the different kinds of semivariogram models estimating and interpolating the values of spatial random variables were used to fit respectively, the corresponding parameters C0 (nugget variance) and C1 (arch height) of models and sums of square of deviations were available[11,12]. The smallest was selected and model parameters were modified by using cross validation (Table 2).

Table 2 The semivariogram models and parameter values of ions in groundwater in the lower reaches of Andier river

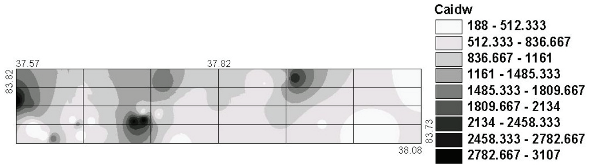
Observation items	K+	HCO3-
model types	exponential	exponential
C0	380290.111	41653157.265
C1	557323.336	36802313.397
range[degree]	0.03	0.21



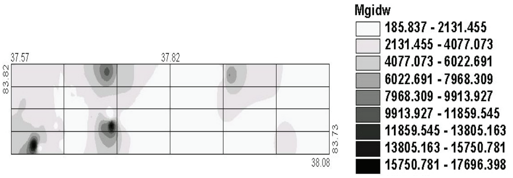
Na+



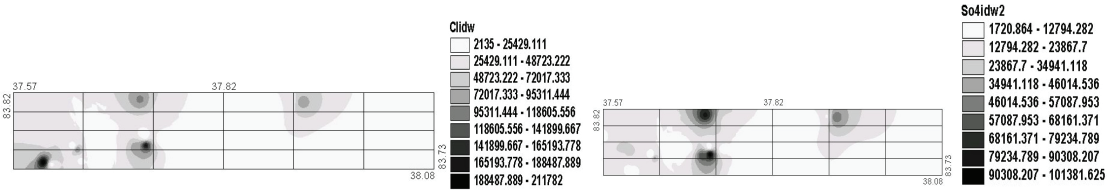
K+



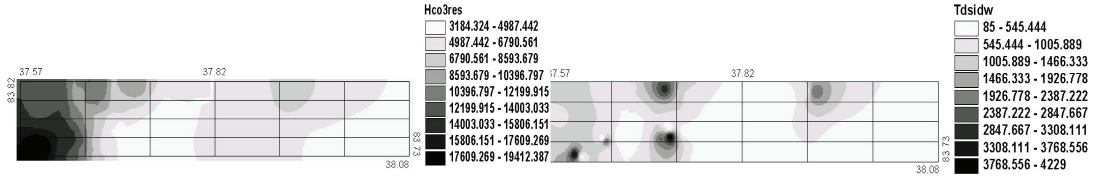
Ca2+



Mg2+



Cl- SO42-



HCO3- TDS

Fig. 6 Isograms of ions and TDS in groundwater

It can be concluded in Table 2 that there are some spatial correlations on the aspects of K+ and HCO3- contents in groundwater in the lower reaches of Andier river, and the spatial correlation ranges in latitude and longitude are 0.03º and 0.21º, resulted by the effects of small-scale factors on the ion contents such as soil properties, rainfall, irrigation, fertilization etc. Based on the established semivariogram models, isograms of the distribution of ion contents in groundwater were plotted by using Kriging and IDW methods (Fig. 6). The results show that the spatial distribution characteristics of chemical components in groundwater are consistent with that of ions contents changing along the latitude from south to north.

5. Conclusions

Based on the analysis of distribution characteristics of chemical components in groundwater in the lower reaches of Niya, Yatonggusi, Andier river, the southern edge of Taklimakan desert and along the southern desert highway, it indicates that groundwater TDS has well corresponding relationship to the ion contents. The spatial distribution status of TDS shows that there exists shallow groundwater with low TDS in the above regions, which could be developed as the water resources for industrial and living usage in oil fields in desert. The decision of location of water sources depends on the correct analysis of hydrogeological conditions and the particular exploration works.

References

[1] Comprehensive Investigation Team about Taklimakan Desert of Chinese Academy of Sciences. Water Resources Assessment and Utilization in Taklimakan Desert. Science Press, Beijing (1993)

[2] Du Hulin, Ma Zhenwu, Xiong Jianguo, et al. Water Resources Study and Its Utilization and Assessment along the Taklimakan Desert and in Desert Oil Fields in Tarim Basin. Ocean Press, Beijing (2005)

[3] Xia Yang. Chemical Composition Characteristics of Dominant Plant Species in the Taklimakan Desert. Journal of Desert Research, Vol. 14, No.2 (1994), p. 30-36

[4] Cheng Guangting, Feng Qi, et al. Formation and Evolution of Sand-wind Environments along the Desert Highway in Tarim Basin. Chinese Environmental Sciences Press, Beijing (1997)

[5] Li Wenpeng, Hao Aibing, Liu Zhenying, et al. Study of the Perspective Regions of Exploiting Groundwater in Tarim Basin. Geology Press, Beijing (2000)

[6] Wang Zhenqing. Sand Prevention and Controlling of Highway in China. Liaoning University Press, Shenyang (2000)

[7] Du Hulin, Xiao Honglang, Zheng Wei, et al. Chemical Characteristics of Surface Water and Groundwater in South of Tarim Desert Oil field. Journal of Desert Research, Vol.28, No.2 (2008), p. 388-394

[8] Li Wenpeng, Zhou Hongchun, Zhou Yangxiao, et al. Groundwater Movement Systems in the Typical Arid Zones in the Northwest of China. Earthquake Press, Beijing (l995)

[9] Du Hulin, Gao Qianzhao, Xiong Jianguo, et al. Distribution of Surface and Undergroundwater
Resources in South Region to Tarim Desert Oil Field. Journal of Desert Research, Vol.27, No.4 (2007), p. 698-703

[10] Qian Ju, Long Xunjian, Du Hulin, et al. Analysis of the Spatial Variability and Statistical Characteristics of Groundwater in the Taklimakan Desert. South-to-North Water Transfers and Water Science and Technology, Vol.5, No.5 (2007), p103-108

[11] Zhang Zheng, Liu Shuchun, Ju Shuohua. GIS and Variance Analysis of the Hydrogeological Spatial Distributed Variables. Site Investigation Science and Technology, No. 3 (1995), p30-34, 29

[12] Hu Kelin, Li Baoguo, Chen Deli. Spatial Variability of the Regional Shallow Groundwater Depth and Water Quality. Advances in Water Science, Vol.11, No.4 (2000), p408-414