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WATER RESOURCES TRANSFORMATION AND WATER QUALITY VARIATION IN THE URUMQI RIVER BASIN

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ABSTRACT: Like other inland basins in arid regions, the natural vertical zones create special conditions for water resources transformation in the Urumqi River Basin. In the course of water resources transformation and utilization, the chemical composition and degree of mineralization are influenced by both geographic conditions and human activities. Although the Urumqi River is rather small in runoff and rather short in flow distance, the water quality changes substantially along the river. However, ion concentrations of surface and ground water in the whole basin are relatively low, generally less than 1 g/L. Therefore, the basin is good at providing low-mineralized water. The pollution is not so serious and the water impurity does not surpass the national standard for drinking. As long as people are conscious with protecting water quality and reducing the further water pollution, it is possible for harm of the slight pollution to be eliminated.
KEY WORDS: water resources transformation, water quality variation, ion concentration

I. WATER RESOURCES TRANSFORMATION

The Urumqi River, with 200km overall length, originates from the northern slope of Tianshan Mountains and flows to the Dongdaohaizi Lake in the centre of Gurbantunggut Desert. Same as the other interior rivers in arid regions, with the characteristics of going through two different nature runoff areas and some different zones of landform-lithofacies, the ground water becomes shallow from piedmont to the centre of basin, this makes a favorable condition for transformation between the surface and ground water[1]. The Urumqi River flows though five hydrogeological units which are both self-independent and connected with each other from south to north (Fig. 1). In the hydrogeological basins of the river basin, the movement and circulation processes of the ground water of the major aquifer systems are closely related to the surface water, and most of the ground water (the part which can be regained and refreshed) are transformed from the surface water resources of the basin.

1. Transformation of the Mountain Water Resources

The Nanshan Mountains, with the lowest altitude from 1550 to 1800m, cover the middle and high mountain areas of the Urumqi River Basin. Alpine relief, developed and abundant precipitation contribute to the formation of glaciers, surface runoff and ground water. The precipitation, except the part consumed by evaporation, are transformed to the surface runoff and ground water. The ground water is mainly the bedrock crevice water. The water-bearing beds which are supplied by the snowmelt water and precipitation all the year, are the bedrock weathering crevice, weathering tectonic crevice and zones of fracture and crush, and they are hydaulically connected with each other. In mountainous area, the incision valleys and developed hydrologic networks are the drainage way of bedrock crevice ground water. Before out of the mountains, most of the mountainous ground water has already become the surface water flowing along the valleys to the river bed; and the other gets into the water-bearing bed of the piedmont directly by the form of the subflow and lateral ground runoff. In the upper reaches of the Urumqi River, the bedrock crevice water resources are $1.202\times10^{3}m^{3}$, of which, $1.0365\times10^{8}m^{3}$ can be transferred to surface water, accounting for 86.27% of the ground water resources. The mountainous ground water draining to the ground water-bearing bed of the plains, out passing through the river course, is $1.684\times10^{7}m^{3}$, accounting for 13.8%.

2. Water Resources Transformation in the Mountainous Basin of Chaiwopu

The mountainous basin of Chaiwopu, which is a seg of Mesozoic-Cenozoic Era and covered with the deposit of gravel, fine gravel and fine soil of Quaternary with thickness from several ten metres to hundreds metres, is a region with rich ground water, pressure water and artesian flow in some small areas. In this region, the ground water, mainly supplied by the rivers, streams and irrigation canals in Nanshan Mountains and the seepage of fields, amounts to $1.948\times10^{8}m^{3}$, 86% of the total resources of ground water, the remaining

14% is supplied by the lateral runoff and seepage of precipitation. Resisted by the bedrock mountains, flowing to the north, the Wulapo Region, the ground water appears in the form of spring. Before the large scale development and exploitation of the irrigation agriculture, the spring water in the Wulapo Region was $1.059\times10^8m^3$; and then, because of enlarging irrigation area, and increasing diversion, the spring water dropped to $6.25\times10^7m^3$ in the beginning of the 1980s.

3. Water Resources Transformation of the Valley in Urumqi Proper

The valley of the Urumqi River in Urumqi Proper, from the dam of Wulapo Reservoir at the south to Liyu Mountain at the north, is the way to the north for the surface and ground water in the basin. Both sides of the valley are hill-mountains, most of which are the layers of sandstone and gravel-rock of the Triassic and Jurassic and a small amount of which are sandstone and mud—like fine sandstone of the Permian, so that both the primary environment and the quality of bedrock crevice water are worse. In this valley, there are deposit layers of gravel and fine gravel of Quaternary, 20—30m or even a hundred metres thick. The ground water, which is distributed in these layers with shallow burial, is the main sources of the living and industrial water supply. In the Chaiwopu basin, the ground water is mainly fed by the ground runoff ($5.016\times10^7m^3$) and the seepage of rivers, canals, fields and reservoirs, totally amounting to $7.77\times10^7m^3$, 79.9% of the resources of ground water. Since the exploitation of ground water is more than the feeding, the ground water level decreases rapidly. In some areas, especially the northern part, because of invasion of the crevice water of both—side mountains and hills, the water quality becomes worse and worse.

4. Water Resources Transformation of the Piedmont Region of the Urumqi River

The piedmont of the Urumqi River, with 100—500m or more deposit of loess silt gravel layer of Quaternary and 150—200m deep ground water level, lies between the piedmont fracture of the Liyu Mountains and Xishan Mountains and the rise of northern ancient pasture. The surface water in this region, which is mainly utilized for irrigation, is supplied by the Toutun River and Dongshan water system besides the Urumqi River from the Heping Canal. At present, in the transformation relationships between the surface and ground water, most river, canal and field water can be transformed into ground water. while only less ground water can be transformed into surface water. But in the primeval natural condition, abundant spring water overflowed from the edges of northern fan delta, can reach to $2.4729\times10^8m^3$. After this, due to enlarging the planted area, building the water resource stations and irrigation systems of ground water and drawing the ground water excessively, the ground water level declined and the spring water decreased by a big margin. Up to the beginning of the 1980s, the spring water was only $3.72\times10^7m^3$. So far, the ground water resources are $1.3702\times10^8m^3$, mainly from the seepage of surface water (86.2%). The exploitation quantity of ground water can reach to $2.7368\times10^8m^3$. This makes the ground water level decrease regionally and form a cone of pressure relief, forming a 30—40m deep and 60—70m^2 descending funnel centred at the scurce of Qigeda Lake.

5. Water Resources Transformation of the Northern Fine Soil Plain

This region is located at the north of the ancient pasture. The east of Mengjin Reservoir is an alluvial plain of the rivers of Dongshan water system and the west is sedimentary bands crisscrossed by Toutun River and Laolong River. The water-bearing bed of ground water mainly consists of fine sand. The average thickness of Quaternary is 50m and the pressure water-bearing bed is 150m or so. In the multilayered structure of this region, the main feeding sources of ground, pressure and deep flowing water are the ground runoff flowing from the piedmont to the north; and those of shallow ground water are the seepage of canal systems and fields. In this region, the feeding sources from ground water are $7.749\times10^7m^3$, among which the seepage of reservoirs, canal systems and fields takes for 77.0%.

II. WATER QUALITY VARIATION

In order to study and understand the development of river and ground water quality and its change with time and space in the Urumqi River Basin, 15 sampling sites are set up from mountainous area to plain along the river from 1987 to 1988, so the samples can be collected to analyse the routine ion, pH values, total hardness and pollution (Fig. 1).

1. Development of Surface Water Quality

1.1 *The ion variation of the Urumqi River with elevation and river length*

In the Urumqi River basin, both the natural vertical zones from mountain

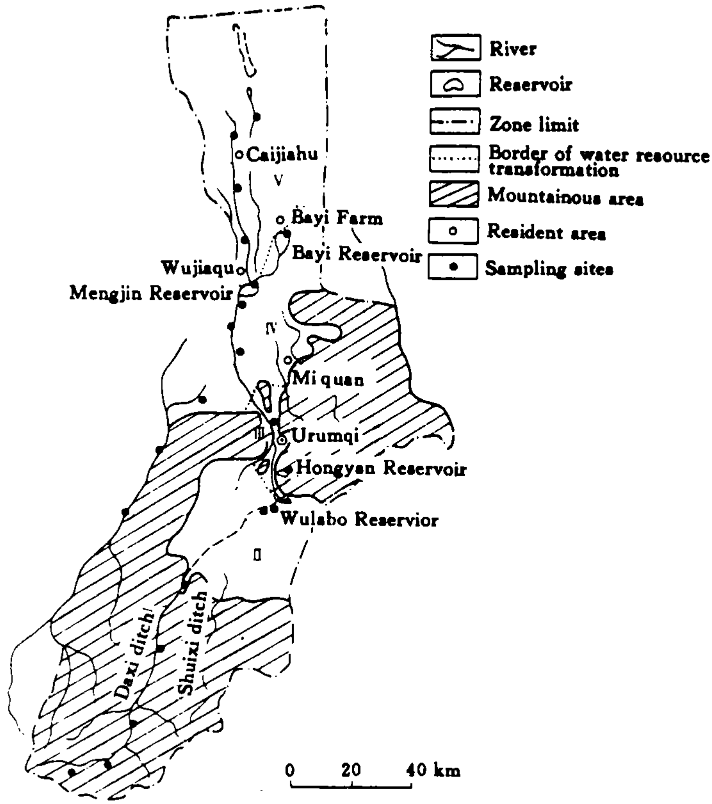

Fig. 1 Zonation of water resources transformation and sampling sites of water chemistry in Urumqi River basin

to plain and the change in degree of mineralization of rivers are obvious. Following the elevation decrease and length increase from source to end, the ion concentration goes up gradually from 0.07g/L to 0.60g/L, and the variation of chemical types changes from simple to complicated. Because the rivers are in high-mountain areas, with rather more precipitation, high and precipitous topography and torrential flow, the flow is too rapid to dissolve and filtrate fully the contents of aqueous solute in the rocks, most of which are carboniferous layer and middle-deep pyrolith, with hard and close structure, the ion concentration is minimum, below 0.01g/L and the HCO_3-Ca is the main ion component. Along with lengthening of the river, the degree of mineralization goes up gradually from 0.16g/L in the beginning of Younger Canal to 0.21g/L at the exit of Wulabo Reservoir, the chemical type of water is still bicarbonate water and the content of Na^+ is more than that of Mg^{2+}. After the river flows along the downtown district of Urumqi City to the Third Mill of Tractor Fittings at Anjing Canal, due to the pollution by human activities, the increase to

0.376g/L, the SO_4^{2-} and Cl^- are doubled that of before. From the Mengjin Reservoir to the irrigation area of lower reaches degree of mineralization, as a result of exploiting large amount of ground water with low degree of mineralization, even though the ion concentrations of surface water only slightly go up from 0.45g/L to 0.50g/L, the dominant cation has already been Na^+ (Fig. 2, Table 1). The correlation relationship between the and elevation can be expressed as the following:

$$G = 0.01 + 251/E \quad (1)$$

where: G—degree of mineralization (g/L); E—elevation (m a.s.l.) and the relation between the ion concentration and river length as the following:

$$G = 0.075 \times 1.09^{0.1L} \quad (2)$$

where: G—degree of mineralization (g/L); L—river length (km).

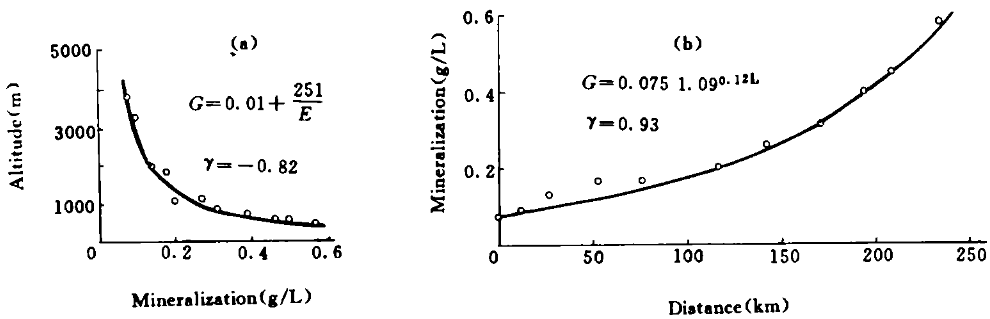

Fig. 2 The relation between the rate of mineralization and altitude (m) and distance (km)

1.2 *The seasonal change of degree of mineralization*

The degree of mineralization of Urumqi River, which is maximum in May and minimum from June to August, has a negative correlation relationship with the discharge. The Urumqi River is one of the mixture feeding by the snowmelt water and precipitation, the seasonal distribution of discharge mainly depends on both precipitation and temperature in mountains. In the high-flow period from June to August in Summer, the very fresh snowmelt water makes the degree of mineralization minimum; and in the low-flow period, the ground water feeding makes it maximum.

1.3 *The relationship between ion content and degree of mineralization*

The bicarbonic acid, Ca^{2+} and Mg^{2+} of the Urumqi River come mainly from dissolving the limestone and metamorphic rock in the high-mountain region. The sulphate comes from the gypsum in low-mountain region and the kinds of Glauber's salt in the soil of piedmont gobi belt Cl^- and Na^+ come from corroding or eroding the salt layer by rainstorm and flood and dissolving the salt in secondary saline soil. Therefore, the ion contents of the river change

Table 1 The degree of mineralization and ion constituents of water in the Urumqi River

Zone	Altitude (m)	Degree of mineralization (g/L)	Hydrochemical type
Terminal of Glacier No. 1	3580	0.074	$HCO_3-SO_4-Cl-Ca-Mg$
Hydrological station in Yingxiongqiao	1890	0.165	$HCO_3-SO_4-Cl-Ca-Mg(Na)$
Qingnianqu—Wulabo reservoir	1100	0.261	$HCO_3-SO_4-Cl-Ca-Na-Mg$
Wulabo—Third tract factory	760	0.376	$HCO_3-SO_4-Cl-Ca-Na$
Menjin reservoir—Caijiahu	550	0.500	$SO_4-HCO_3-Cl-Na-Ca-Mg$ or $HCO_3-SO_4-Cl-Na-Ca-Mg$

continuously with the increase of both river leghth and degree of mineralization. When the degree of mineralization is less than 0.5g/L, most of the dominant anion is HCO_3^- and cation is Ca_{2+}, increase. When the degree of mineralization goes up to above 1 g/L, then, in anions, Cl^- is dominant in the first place, and in cations, Na^+ increases rapidly. In the condition of low degree of mineralization (Fig. 3).

The correlation relationship between the total hardness and degree of mineralization can be regarded as an exponential function as the following:

$$H = 17.8 \times G^{3/5} \quad (3)$$

where: H—total hardness (German hard water); G—degree of mineralization.

2. Development of Ground Water Quality

The quality of ground water, along with the Urumqi River, is rather better and the degree of mineralization is not more than 1 g/L. Especially in the Shaliangzi region, the water quality is the best with less than 0.3 g/L (Table 2).

But affected by the environmental hydrogeology, there is a trend from the salt at higher altitude to the fresh at lower altitude on the vertical direction (Table 3).

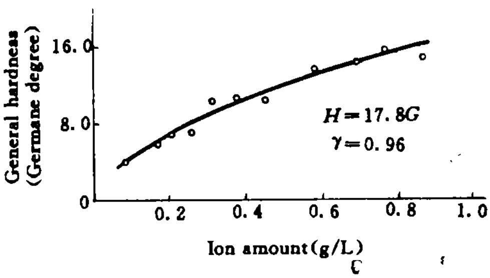

Fig. 3 The relationship between the general hardness and ion amount in the Urumqi River

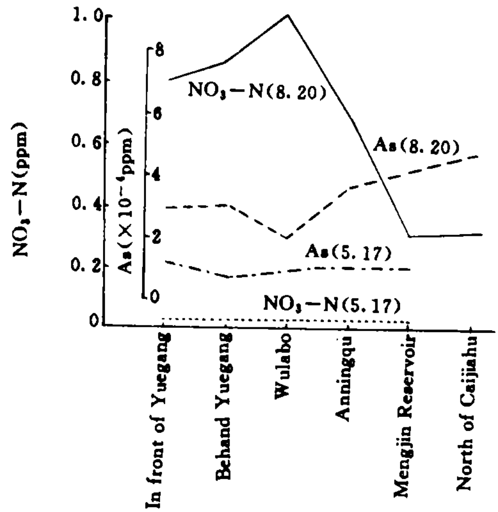

Fig. 4 Variation of NO_3—N content and As content in May and Aug. along the Urumqi River

Table 2 **The variation of the degree of mineralization of well and spring water along the Urumqi River during May and Sept.** 1987

Sampling point	Degree of mineralization (g/L)					pH	Hydrochemical type
	May	June	July	Aug.	Sept.		
Spring of Wulabo reservoir	0.313	0.380	0.254	0.235		7.37—7.69	$HCO_3-SO_4-Cl-Ca-Na$ or $Ca-Mg-Na$
Well water in Wulabo region				0.306		7.61	$HCO_3-SO_4-Cl-Ca-Na-Mg$
Well water in Water station of Anning	0.530		0.603	0.550		7.30—7.65	$HCO_3-SO_4-Cl-Na-Mg-Ca$ or $Na-Ca-Mg$
Well water in bean-curd plant of Anning		0.560	0.232	0.246	0.243	7.53—7.80	$HCO_3-Cl-SO_4-Ca-Na$
Well water in Shaliangzi	0.234				0.253	7.40—7.8	$HCO_3-Cl-Ca-Na$
Well water in Caijiahu	0.325	0.506	0.604	0.401	0.330	7.65—8.1	$HCO_3-SO_4-Cl-Na-Ca$ or $SO_4-HCO_3-Cl-Na-Mg-Ca$

The water-bearing bed is mainly sand in the north plain region and becomes gradually fine sand to the north. The accumulation of chemical composition in the middle-deep pressure water is small because of the movement. In the course of movement of the pressure water, exchanges occur between Ca^{2+} and Na^+, therefore, the constant element is mainly HCO_3-SO_4-Na and the degree of mineralization is not more than 1 g/L. The changes of the ground water composition happen mainly in low phrenetic region. Such as in Nanshan Mountain region in 1966, most of the ground water is the HCO_3-Ca water with low degree of mineralization, but in 1982, the $HCO_3-SO_4-Ca-Mg$ water had appeared in the east of Daxigou. The HCO_3 — Ca water with no more than 0. 30 g/L in the region of Wulabo in 1966, had become the $HCO_3-SO_4-Ca-Na$ water with 0. 24—0. 38 g/L in 1987. In the region from Anning Canal to Wujia Canal, because the mixture between phrenetic and pressure water affected by enlarging the exploitation of ground water, the HCO_3-SO_4-Ca (or Na) water with more than 1 g/L degree of mineralization in 1966 had become the $HCO_3-SO_4-Ca-Na$ (or Na—Ca) water, less than 1 g/L in 1987. As time goes on, the middle—deep pressure water will be affected by human activities (Table 4).

Table 3 Vertical variation of degree of mineralization of the groundwater

Sampling point	Type of groundwater	Top of buried deep(m)	Mineralization (g/L)	Well
Anning canal	Pressure water	60	0. 954	
	Pressure water	100	0. 561	
Caijiahu	Pressure water	52. 71	0. 535	W48—4
	Pressure water	117. 56	0. 23	W48—4
	Artesian water	208. 0	0. 262	W48—4
	Artesian water	402. 58	0. 360	W48—4

III. ANALYSIS OF POLLUTION

1. Variation of the Contents of NH_3-N, NO_3-N and NO_2-N

The seasonal variation of the contents of NH_3-N, NO_3-N and NO_2-N have a close relationship with the organic pollution of water body. Generally, the NO_3-N content in August, especially in the Wulabo Reservoir, is 0. 02—1. 00 mg/kg higher than that in May, about 30 times more, but the NH_3-N in August is 4 times less than that in May (Fig. 4). Probably, these conditions are caused by that the runoff brings the waste of livestock in mountainous area with much more precipitation, and the nitrogen-bearing organisms have strong oxidation—resolve capacity due to high temperature. Generally, the NO_3—N content of the well of Anning Canal is more than that of surface water, but the NH_3—N is very less. It may be resulted from that declining of the ground water level, the better air permeability of the covering layer and strengthening of the oxidation capacity make the NH_3—N transform to NO_3—N continuously.

Table 4 The variation of hydrochemical type of phreatic water in Urumqi City

Direction	Section	Location	Degree of mineralization (g/L)	Hydrochemical type
	Wulabo	Wulabo	0.30	SO_4— HCO_3—SO_4—C_a—N_a
		Yanerwuo	0.46	SO_4— HCO_3—SO_4—C_a—N_a
South	Hongshan	Xi Park	0.90	SO_4 HCO_3—C_a—N_a
		Geological Bureau	1.20	SO_4C_a—N_a
to	Liyushan	Slaughtering house	1.50	SO_4—C_l—N_a—C_a
North	Ergong	Railway Bureau	1.20	SO_4— HCO_3—C_a—N_a
		Water factory	1.90	SO_4—C_l—N_a—C_a
	Baijiahu	Railway engineering center	1.20	SO_4—C_l—N_a—C_a

2. **Pollution of F and the Other Metal ions**

The F content in the Urumqi River basin in August is always less than that in May. Nevertheless, from the south to north and from mountain to plain in the same month, the changes of F contents are not very obvious. The F content of the Laolong River in the north is maximum, 0.855 mg/kg, because the river is the drainage way of the irrigation region of the lower reaches, and the ground water is mainly in vertical drainage, these make some elements gathered by evaporation and concentration. All the contents of the other elements, such as As, Zn, Mn, Pb, Cu and Cr^{+6}, do not surpass the national standard for drinking. But like the other arid regions, because of very small scale of pollution diameter, no capability of purification of rivers themselves and no drainage of pollutant of the inner revers, it must be paid attention to that the pollutant matter will accumulate in the lower reaches at last and lead to many disasters[2].

On the other hand, based on the result of analysis, the Zn content of the mountainous rivers is higher than that of the rivers in cities the lower reaches and in plain. It may be caused by that the air pollution and dust granules of storm deposit on ice and snow and are gathered by long-term dissolving and fitration. The Zn element takes mainly the dissolving form in water bodies and is easy to be absorbed by the soil and regetation in the flowing process of rivers, these make Zn content of lower reaches lower than that of the source.

To sum up, the following conclusions can be made:

1) Backing to the Tianshan Mountains and facing to the vast desert, the ecological environment of the Urumqi River is rather fragile. Although the river is rather small in runoff and rather short in flow distance, because of the change of terrain and surface material, the natural water quality varies with altitude obviously.

2) The water of the Urumqi River Basin, of which quality is rather good and most of the degree of mineralization of the surface and ground water are not more than 1 g/L, is a good water supply source for city living, industry and agriculturee.

3) Because the water quality of the basin is affected in a rather large degree by the human activities of concentrated cities, industry, agriculture and so on, it needs some effective measures, such as to set up the protection region of water resources, control the drainage of pollution and stop the action of over exploiting the ground water etc., so as to protect the sources of surface and ground water at present.

4) Analysis of the pollution indicates that, except the part of northern region with high F content, the other impurities do not surpass the national standard for drinking. But from a long-term point of view, it needs to pay attention to protecting water quality and reducing the further water pollution, because the lower reaches is an accumulation region of all kinds of impurities.

REFERENCES

[1] 汤奇成,等. 干旱区水文与水资源利用. 北京:科学出版社,1992,147－151.
[2] 施雅风,曲耀光. 乌鲁木齐河流域水资源承载力及其合理利用. 北京:科学出版社,1992,66－68.