Scientific Research

The Characteristics of Groundwater in Yarkant Basin

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Abstract: As a main tributary river of Tarim River, Yarkant River no longer discharge to the biggest arid inland river in China (Tarim River) from the end of the last century, although it's discharge is $75.71\times10^8 m^3/a$ and the groundwater resources is $42.72\times10^8 m^3/a$. The groundwater in the Yarkant Basin has an obvious characteristic that depend on the conversion of surface water, and the natural recharge is limited. Based on systematic evaluation, the quantity of surface water transform into groundwater including the stream leakage, reservoir influent, canal influent, irrigation seepage is $41.94\times10^4 m^3/a$, almost 98.2% of annual total groundwater recharge.

Keywords: characteristic of groundwater, sustainable utilization, Yarkant Basin

1. Introduction

Yarkant drainage basin is the largest oasis irrigated by Yarkant water system in Sinkiang Uigur municipality Region. The east and west irrigation area located in the middle of Takelamagan desert and Bujila-Tuolake desert, the longitude is between 74°28′~ 80°54′ and latitude 34°50′~ 40°31′ and the total area is 10.81×10^4 km^2, including 6.08×10^4 km^2 mountainous area and 4.73×10^4 km^2 plain area(Fig 1).

The population of Yarkant Basin is 1.75 million. In 2000, the agriculture and industry production value has reached to RMB 4.281 billion, almost 86.21% is from agriculture. But located in the dry inland of northwestern China, the water resource is an important factor affected local economic development.

2 General condition

2.1 Topography and landform

The natural landform of Yarkant Basin come into being from neotectonic period, changing ancient climate and geography environment from Quaternary Period along Kunlun Mountain with strong eroded and weathering effect creating large amount of crumbs which has been transported to the lower area and deposit there. Topography inclined from southwest to northeast can be divided into 6 units: middle-high mountain area with erosion landform that ascend strongly(Ⅰ); low mountain area with denudation landform that ascend promptly(Ⅱ); hilly area with denudation landform that ascend c(Ⅲ); inclined plain with descended erosion pile(Ⅳ); alluvial plain descend relatively (Ⅴ); and desert landform made by wind(Ⅵ).

Fig 1 The map of Yarkant basin

Human activities are mainly on the plain area , so the discussion focused on the characteristics of landform in plain area.

(1) alluvial and diluvial fan

Mainly composed of coarse deposite formed during Epipleistocene and Holocene Series period with the altitude between 1218~1380 meters above sea level, mostly located north of Yecheng county and south of Shache county. The water systems were developed in branch shape with well developed valleys.

(2) spillage belt at proluvial fan

Swamps and wetlands of different extension along slight soil salinization have been found in the north of Jianggelesi and both sides of eastern bank in Zepu county trench, the Yiganqi reservoir in Shache county. The belt is 10~15km wide and buried deeper than 1 meters because

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of the agricultural irrigation system, others buried at the deep of 1~3 meters.

(3)alluvial plain

Yarkant river alluvial plain: located in the north of Yiganqi reservoir to Shache county and Kuqi village, reached the Selibuya village of Bachu county, distributed at most of the Yarkant and Tihe basin. The landform inclines from south to north, with the altitude of 1375m~1120m and the slope is 1~3‰ on the ground. River nets and water system are well developed, lots of billabong and abandoned riverway were remained and the first and second terraces formed at that period.

(4) alluvial and lake sediments plain

Located in the north of Selibuya in Bachu county and the south of Xiaohaizi reservoir. Yarkant river flows through this section, the erosion datum plane is nearly at the height of river bed which seems too shallow that make the riverway unsteady and overflow in flood season. The alluvial and lake sediments plain came into being after the mud and fine sediment transferred by river. The landform is plain, on the microcosmic view, the surface water and shallow ground water merged in some small billabong formed wetland and swamp.

(5) desert

The desert distributed at large-scale on the two sides of alluvial and lake sediments plain, west of which is the Takelamagan desert and east of which is Bujila and Tuokelake desert.

2.2 Surface water system

There are four rivers and one channel in this drainage area of Yarkant water system. The average discharge of these four rivers is $75.708\times10^8 m^3/a$, of which Yarkant river takes 86.2% .

Yarkant river is one of the most important headstream of Tarimu River, it is 1179km long, the upstream is 629km in the mountain area and the downstream is 550km in the plain area. The river is the branch river of Yarkant river that long 315km. These two rivers are perennial and flow through several different landform and hydrogeology units. The leakage developed in the upstream from surface water and the discharge to the surface water exists in the downstream, the rivers are well transformed with ground water.

Wu River and Ke River are both short rivers in Yecheng country with perennial water. Not far from the mountain exit, they will lose in Gobi gravel belt due to leakage. Finally, at the proper conformation and physiognomy position, underground will drainage and rivers by springs come into being. Although the river is perennial, but it has been strongly influenced by seasonal change which may cause little water in winter or even none.

The four rivers referred above are all origin from the north of Kunlun Mountain, supplied by melting snow and rainfall as well as cranny water in the bedrock. Because the recharge are mostly from melting snow, so the runoff are influenced by climate quite a lot that the surface runoff distributed lopsided and allotted unstable. As in summer it will be flood while from autumn the runoff reduced rapidly.

The average discharge of Yarkant river is $65.25\times10^8 m^3/a$, the flood season is from July to August and dry season from February to April.

With the increasing human activities in recent several decades, the demand of water resource increased rapidly. And also thanks to the improvement of irrigation works, only in flood season, the Yarkan River may overflow to Talimu River.

2.3 Climate conditions

Yarkant drainage basin located at the hinterland of the European-Asian continent, surrounded by high mountain which barricaded the warm and humid current from the Indian Ocean. Takelamagan large desert in the east, the rainfall amount are lacked with strong vaporization.

According to the rainfall records of the five weather stations from 1953 to 2002, the average rainfall amount is rare but it varied obviously in different year. The total rainfall was less than 7.8mm during dry years, while it could reach to 100mm in humid years. Based on the rainfall data from 1993 to 2002, the graphs showed that adequate rain happened from May to August and November and December sometime had no rainfall.

The evaporation was very strong because of the desert dry and hot weather. As show in the records of evaporation from 1980 to 2002, the average evaporation per year reached to 2196mm, focus on April to September, which the changing trend was almost the same.

3 Characteristics of groundwater

The Yarkant alluvial and lake sediments plain is a whole hydrogeology unit based on the geological landform of Yarkant drainage basin. Considering the low control level of the plain, it can be evaluated as a whole equilibria part.

RS, geophysical prospecting of 3-D structure water bearing formation together with plentiful hydrogeology mapping and also other developed measures have been adopted to analyse the water resource in the whole research area.

3.1 Natural recharge of groundwater

The natural recharge of groundwater including two parts: front-mountain recharge and the infiltration.

(1) Infiltration

The infiltration can be calculated as:

infiltration=available rainfall per year×acreage of calculation area×coefficient of infiltration

The amount of available rainfall per year is based on the average rainfall amount from 1980 to 2003 and the coefficient of infiltration is figured out by the data from each weather station. The acreage of rainfall leakage is calculated by unit varies with buried depth 0~1~2~3~5m. Except the fine earth plain with gravel and desert, if the buried depth is more than 5m, it can be regarded as no rainfall leakage. Above all the results of rainfall leakage are $2250\times10^4 m^3/a$ which is 0.53% of the total recharge.

(2) Recharge from mountain area

According to the distribution of Pleistocene Series gravels in Yarkant drainage Basin and the surface rivers, the recharge from mountain area is the composed from underground runoff in Xiyu region and surface water.

The runoff in Xiyu gravel rock

Xiyu gravel rock is widely distributed at the mountain front due to the undulation of tertiary mudstone, deep than 100m. The gravel rock is cemented, its permeability very low.

The width of Xiyu gravel rock is 139.9km from Kaqun cannel to Baola gulley. Considering the depth influenced by runoff, Darcy formula can be adopted to do calculation which the thickness of aquifer is 180m and the hydraulic slope(I) can be got from the graph of phreatic water contour.

Discharge from river:

The section near the exit of mountain of Yarkant is Quaternary unwound stratum averagely 50m; as for Ti River, the discharge can be ignored due to very thin unwound stratum. The thickness of unwound stratum in east river is only 10 to 40m. Therefore, the submerged discharage of each river bed is not too much, the calculation results of five rivers shows as below (Table 2):

The discharge from the mountain is:

$4417.392\times10^4 m^3/a + 1170.270\times10^4 m^3/a=5587.662\times10^4 m^3/a$。

The discharge from the mountain is 1.31% in the total recharge.

3.2 Recharge of groundwater

Table 1 The pumping test in Yarkant basin

No.	Location	Radius (mm)	Strain (m)	Deep (m)	Dead level (m)	Dynamic level (m)	Drop (m)	Flow (L/S)	Unit emerge (L/S.m)	Hydraulic conductivity (m/d)	Infection radius （m）
SK1	Kaqun station	213	60	100.00	3.26	40.68	37.42	20.80	0.56	0.414	240.84
observation	14.36m				2.56	4.90	2.34			0.446	
YC3	Qiyi channel	213	30	100.00	63.90	93.00	29.10	13.90	0.48	0.81	309.40
J12	Kaqun west			100.43	9.60		20.75	10.30	0.50	1.33	215.80
J13	Kaqun west			67.15	1.93		15.50	11.20	0.72	2.52	201.50
J14	Kaqun east			120.54	20.63		21.09	11.20	0.53	1.51	255.00

Table 2 Recharge from mountain and river

section	Hydraulic	Extent （m）	Ave contain layer deep （m）	Hydraulic conductivity (m/d)	Water grade	Supply （$10^4 m^3/a$）	Sum （$10^4 m^3/a$）
AB	recharge from mountain	19200	180	1.324	0.0043	718.055	4417.392
BC		51400	180	1.324	0.0045	2011.701	
CD		69300	180	1.324	0.0028	1687.637	
Yarkant	river bed	3868	47.48	21.804	0.005	730.796	1170.270
Wu river		2600	39	8.570	0.008	253.747	
Ke river		400	47.37	8.570	0.008	46.415	
Baolagou		3800	14.65	8.570	0.008	139.311	

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(1) Leakage recharge of riverway

As shown before, the average water amount in this drainage basin is $75.708\times10^8 m^3/a$, the coefficient of leakage recharge is (N)0.1169 and the amount of riverway leakage is $8.8528\times10^8\ m^3/a$ by using the method of leakage coefficient of river way. In this way, it is 20.72% of the total recharge.

(2) Recharge of cannel leakage

The cannel has been divided into 6 levels, including trunk and little branches, which in all 27455 cannels cumulated 31369.55km. For many yeas, only 25% of the cannel had been rebuilt with anti-leakage, others are still the traditional cannel which made much loss due to evaporation and leakage.

According to the data provided by management bureau of Yarkant Basin, the total surface water utilization was $65.2\times10^8\ m^3/a$ and the total agriculture irrigation amount was $69.72\times10^8\ m^3/a$. Based on those data, the cannel leakage recharge figured out is 59.05% of the total recharge.

(3)Recharge of farmland leakage

It's difficult to work out the abstraction volume. So it can be calculated by subtracting evaporation and leakage as well as woods abstraction volume. At last it was figured out as $28887.5\times10^4 m^3/a$, 6.76% of the total replenishment.

(4) Recharge of reservoir leakage

There are 40 reservoirs in the drainage basin, which can control runoffs and delayed the early spring to make sure the production of agriculture. On the opposite side, they made great loss due to strong evaporation.

After calculation, the recharge of reservoir leakage is $45385.7\times10^4 m^3/a$,10.62% of the total recharge. The results also showed that the loss rate of whole drainage basin is 33.9%

2.3 Total volume of groundwater

The total volume of groundwater consists of three parts:

a) Rivers runoff: the total runoff including Yarkant River, Ti River, Wu River and Ke River is 75.71×108m3/a.

b) Natural recharge of ground water: is $0.784\times110^8 m^3/a$ including $0.559\times10^8 m^3/a$ from leakage from mountain and $0.225\times10^8 m^3/a$ from leakage.

c) Recharge from surface water: $42.72\times10^8 m^3/a$, mainly the repetition water between surface water and groundwater.

Above all, the total water resource volume consists of rivers runoff and natural recharge, while the total ground water is the summation of natural recharge and transferred recharge.

Table 3 Recharge of the groundwater resource in Yarkant basin

Subarea (county)	Recharge of the groundwater resource in Yarkant basin ($10^4 m^3/a$)									Total supplyment
	Natural seepage			Recharge from the surface water transform						
	Precipitation seepage	Seepage from the mountain	Sum	River seepage	Reservoir seepage	Stream seepage	Irrigation seepage	Industry and drink	Sum	
Ⅰ(yecheng)	145.1	2898	3043.1	13333.5	860.0	33345.3	4240.8	857.435	52637.0	55680
Ⅱ(zepu)	123.1	1034	1157.1	3648.1	50.0	17579.7	2649.5	459.375	24386.7	25544
Ⅲ(shache)	583.8	1656	2239.8	38578.6	9964.5	75088.8	8207.4	1246.425	133085.8	135326
Ⅳ(maigaiti)	279.4		279.4	17094.6	9990.3	31658.0	3842.0	489.41	63074.3	63354
Ⅴ(bachu)	735.9		735.9	11043.2	7437.2	40713.5	4746.9	609.605	64550.4	65286
Ⅵ（yuepuhu）	28.4		28.4	0.0	0.0	3994.4	457.4	45.605	4497.5	4526
Ⅶ（qianjin）	132.9		132.9	0.0	5369.2	12669.7	1138.4	120.335	19297.6	19431
Ⅷ（xiaohaizi）	221.1		221.1	4830.0	11714.6	37308.5	3605.0	371.99	57830.1	58051
Sum	2249.6	5588	7837.6	88528	45385.7	252358.0	28887.5	4200.2	419359.4	427197.0
Percentage	0.53	1.31	1.83	20.72	10.62	59.07	6.76	0.98	98.17	100.00

4 Exploration of groundwater

There are 3662 irrigation machines in Yarkant basin that used for agriculture irrigation. According to the statistic data of each county, the groundwater withdrawn rate is $8\times10^8 m^3$ /a.

(1) The using rate of surface water is relatively higher, but is imbalance during spring.

The utilization level is 82.6%, while the effective utilization of irrigation is only 40%. The withdrawn is not even in one year, from March to May are the peak months of agriculture water utilization which is 9.96% of the whole year runoff, but at the same time, the woods and grasses industry need $20\times10^8m^3$ which is 30%~35% of the whole year water demanding.

(2) Land resource is difficult to be utilized due to seriously lacking of water

The total aera of oasis is 14764.1 km^2 which consists of 7.5339 million mu irrigation area and 4.8 million mu agriculture land, 1.24 million mu woods land as well as 0.56 million mu grassland. Until now, although the utilization level of surface water was good that had restricted the utilization and exploration especially during the spring.

(3) Seriously loss of water resource and soil salinization problems

The water table moves up because of irrigation leakage, also result in soil salinization especially in the deeper of irrigation area. Every year 1~1.5 million ton of salt cumulated in the irrigation area considering the evaporation volume, caused ecological problems and seriously influenced the agriculture development.

While on the upper of alluvial plain, the phenomenon has seldom appear due to better drainage condition. In the middle of the plain, soil salinization happened on 95% of plantation, 54.6% of which are seriously. In recently years the salinization area has reduced but hasn't been improved at all. The salinization of lower reach of irrigation area is more than 90% of total plantation due to the drainage fall behind.

(4) Safety of oasis is threathened by desertization, Ecological environment of lower reach become worse rapidly due to the contravention of water demanding and utilization.

Yarkant basin is an corridor oasis among three large desert with several flowing dunes inside, therefore the safety of oasis has been threatened all the time. The total area of desert is $2.38\times10^4km^2$, account for 48.2% of drainage basin. Because of increasing demand of Yarkan basin and the degeneration of lower reach riverbed, the ecological environment become very weak and it is difficult for Yarkant river discharging enough water to Talimu River.

5 Measures to the sustainable utilization of groundwater

(1) Establish regulations on water resource management

Lacking of enough water resource regulations is the most important reasons of the waste.

Recently, more and more environment laws have been established. So it's necessary to establish some native laws to strengthen the management and nail down the responsibility together with abide the correlative laws.

(2) Synthesizing programming to realize the reasonable collocating of water resources

According to the characteristics of Yarkan Basin and Industry development conditions, scientific scheme has to be set up aimed at the harmonizing development among human, resources, environment and economy.

(3) Combine together and care for not only the whole but also units

Water resources of distribution in Yarkant basin may between surface water and groundwater as well as upper, middle and lower reach of it. Also it is possible to make better use of underground reservoir and surface reservoir together. In this way, the balance of supply and consume may be kept, the sustainable utilization of groundwater and well-balanced ecological environment can be sure as well.

(4) Protect water resources from contaminated

Problems of soil salification are the most strategic problems in dry districts for sustainable development and environment improvement. Unreasonable irrigation and drainage cause salification, therefore perfect drainage and irrigation system have to be established and high effective technologies have to been put forward. On the other side, the research of soil salification should base on the formation, distribution and evolvement and emphasize on the improved theory and technologies under the limited water resource. Also, fully develop the better plant species which can bear dry and salty soil is also an expecting measures.

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