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The factor analysis of environment changes on groundwater

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Environmental variations and the influences on water resources are complicated. According to a great number of the statistical data of Hebei province in Northern China since the 1950s, the analyzing indicated that the water resources volume in Hebei province trended towards decreasing during the recent 50 years as the variations of natural environment and human activities increasing. Precipitation reducing and air temperature rising are the basic cause of leading to the water resources decreasing. The continual lowering of groundwater level, which was created by the excess development of groundwater, not only caused surface runoff decreasing but also made groundwater recharge lessening. The level increase of crop output directly consumed a great lot of water resources, simultaneously had farmland evapotranspiration strengthened, and also brought about surface runoff and groundwater recharge decrease.

Keywords: Water resources; Climate change; Surface runoff; Groundwater recharge; Crop water requiremen

INTRODUCTION

Hebei is one of the provinces of the most serious shortage of water in China. Water resource occupancy per person only accounts one sixth in the country per person level. The contradictions of water resource supplying and demanding highlight seriously. The shortage of water resource has become a bottle-neck which limits to the high speed economical development and improve people life level. In recent 50 years, the impact on the water resource quantity and water environment quality is larger and larger because of the change of the global climate changing and the large extent of human economical activity. The article primarily discusses the impact of the environment change on the term of water resource quantity in Hebei province.

Impact Of Climate Change On Resource

Impact of temperature change on water resource

Climate change is one of the main reasons that created the shortage of water resources in Hebei province. According to a great number of statistical and survey from 42 observatories of the province in the 20th century[1]: the rising of year average temperature was 0.1-0.6℃ at the most of observatories in 50-60s'; 0.1-0.7℃ in 60-70s'; 0.1-0.6℃ in 70-80s'; 0.2-1.2℃ in 80-90s',and the biggest one. During recent 50 years, in 1950-90s', the year average temperature in Hebei province increased by 0.2-2.1, and the average ascended by 1.0℃.

If not thinking the other climate change factors, the impact of the temperature change on the water resources mainly embodies that evaporation and intensity enlarges with temperature up. The elevating of temperature can bring about increasing the consumed water and lessening water resources which can be used by the public whether it is water surface evaporation, leaf evaporation, soil evaporation or groundwater evaporation. Since 1950s', the temperature of Hebei elevated gradually by age. The rate of elevation was quickest during 1980s'. Generally, high temperature and drought turned up at the same time. High temperature picked drought up and made the farmland water requirement rise, high temperature also caused the consumed water of town increasing. So, the water resource contradictions of demanding and supplying highlight.

Impact of precipitation change on water resource

According to the statistical data from 112 hydrological stations in Hebei[1], the average precipitation gradually lessened in 1950-80s', the range of decreasing was 79.7mm, the average decreased 26.6mm every 10 years. The range of decreasing in mountains was bigger than in plain; after 1990s' it turned to rise again but still be less 62.1mm than in 1950s'. The statistical data showed that during 1950-90s', the average precipitation decreased by decade in most of stations (table 1).

Generally, water resources of an area are the reparable and newborn surface water resource and groundwater resource. Surface water re-

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source is multi-year average runoff of river and is computed by drainage area. Groundwater resource is multi-year average fresh water recharged and evaluated by groundwater aquifer system. The river runoff comes from the air precipitation, groundwater in mountainous area. Groundwater recharge comes from the air precipitation, surface water and over stream from other aquifer. Whether surface water or groundwater. Therefore, the decreasing of the air precipitation is the basic cause of leading to the shortage of water resource in Hebei.

Table 1. Changes of average precipitation in Hebei (mm).

Age	1950s'	1960s'	1970s'	1980s'	1990s'
Mountain area	590.8	541.9	530.0	497.6	532.5
Plain area	569.3	579.2	550.3	510.8	501.2
Average	582.4	556.5	538.1	502.7	520.3

Impact Of Development Of Groundwater On Water Resource

The Condition of Groundwater Development

Hebei province mainly develops and uses groundwater. During recent years, groundwater development was over 160×10^8 m^3/a, the practical usage of groundwater accounted the usage of water resource in the province for 75%-80%. 85% of the total groundwater put use into the farmland irrigation. There are over 70×10^4 exploitation wells.

According to some data statistic,in 1950s'[2], the groundwater exploited of the whole province was focused around pore phreatic water, the well depth was 10-15m and the exploitation quantity was over 30×10^8 m^3/a, and well irrigation area was 67×10^4 hm^2, so groundwater was in the balance situation. In 1960 ', groundwater was exploited still as pore phreatic water, the well depth was 20-40m, and the exploitation quantity was over 50×10^8 m^3/a, and well irrigation area was 133×10^4 hm^2, so groundwater was still in the balance state. In 1970s', groundwater was exploited as the mixed of phreatic water and confined water in the plain before mountains, the depth reached 60-80m.In the plain, people started to exploit a lot of deeper confined water, the depth was 200-250m. Groundwater development was about 110×10^8 m^3/a in this period, and the exploitation in Hebei plain was about 100×10^8 m^3/a, and the well irrigation area was 233×10^4 hm^2. In the period, groundwater level began to go down territorially and developed several groundwater decreasing funnels. In 1980s', the exploitation in the whole province was 130×10^8 m^3/a, the exploitation in Hebei plain reached 120×10^8 m^3/a, the number of well was 60×10^4 and the irrigation area reached 287×10^4 hm^2, the well depth was 170-350m. In 1990s', groundwater exploitation in the whole province reached 160×10^8 m^3/a, the exploitation in Hebei plain was about 135×10^8 m^3/a. The exploited well reached 70×10^4, and the irrigation area was 280×10^4 hm^2 and the depth was 250-380 m (table 2).

Impact of Excess Development of Groundwater on Water Resource

Since 1980s', groundwater exploitation has been about $140\text{-}150\times10^8$ m^3/a. The Hebei plain exploitation has been about 120×10^8-130×10^8 m^3/a. Generally the excess development has reached 15×10^8 -23×10^8 m^3/a each year and the highest has been about 30×10^8-40×10^8 m^3/a. According to the groundwater exploitation data from 1985 to 1995, the excess development of the low groundwater was 15.6×10^8 m^3/a; and the deep groundwater was 8.9×10^8 m^3/a. The total excess development was 24.5 m^3/a. The groundwater level has gone down in a large range, and the low groundwater level in Hebei plain generally has gone down 5-15m, the deeper is 20-30m; the deep groundwater level generally has gone down 20-40m, the deeper is 40-50m.

Table 2. Decade changes of groundwater exploitation in Hebei

Age	**1950s'**	**1960s'**	**1970s'**	**1980s'**	**1990s'**
Development of groundwater /$\times10^8$ m^3/a	3	5	11	13	16
Well irrigation area /$\times10^4$ hm^2	67	133	233	287	280

It resulted in that groundwater level continued to go down in a large range and there was some groundwater level decreasing funnels in

some cities that exploited a lot of water and consumed much water. The Hebei plain has appeared groundwater level decreasing funnels since the beginning of 1970s' and they gradually turned to perennial funnels. Over 20 years untill the end of 1995, there was over 20 funnels of groundwater level decreasing. The low funnels located mainly in the Hebei plain before mountain and nearby some cities that connected to the middle of the plain. At the end of 1995 there was 10 perennial funnels; the deep groundwater decreasing funnels located mainly in the middle of Hebei plain and coastal area and there was 12 perennial funnels. According to data, the bigger funnels were Shijiazhuang, Jizaoheng and Cangzhou[3] (table 3).

The recharge of groundwater in Hebei plain is mainly atmospheric precipitation. The supplying of the atmospheric precipitation nearly accounts for 70% of the total ground water supplying quantity. Since 1970s', as a result of ground water massive exploitation, in the Hebei plain great scope, the groundwater level has continued to drop, the water level depth large scale increased. Unsaturated zone largely changes thick. According to the pertinent data, above 70% of total precipitation in Hebei plain approximately all transforms as soil water, another small part turns to the deep aquifer, and transforms as the ground water. Atmospheric precipitation military supplies ground water quantity except with the air precipitation, unsaturated zone, the vegetation cover situation, the preliminary soil water content related outside, but also concerns with the thickness of the unsaturated zone. Under the same condition, the bigger thickness of the unsaturated zone is, then the more the atmospheric precipitation which the unsaturated zone absorbs and detains are, the less the quantity of the atmospheric precipitation which supplies ground water is. Therefore, the dropping of the region groundwater level and the increasing of the unsaturated zone thickness are one of the main reasons that create the groundwater recharge reducing. On the other hand, the increasing of the unsaturated zone thickness, can cause the more atmospheric precipitation to be absorbed by the zone, causes surface water volume reducing, then, and causes the reduction of the surface water resource.

Table 3. Changes of groundwater depression cones in Hebei Plain

Year	Shijiazhuang funnel		Jizaoheng funnel		Cangzhou funnel
	Area/km^2	Depth/m	Area /km^2	Depth /m	Depth /m
1965	58	7.57			0.00
1970	154	10.37		12.06	
1975	187	15.29	3476	32.68	50.28
1980	189	20.39	3588	50.31	69.99
1985	259	31.32	4698	56.10	75.65
1990	338	37.22	4023	56.84	82.08

Impact of The Change of Surface Runoff on Water Resource

Change of Surface Runoff

In Shijiazhuang Plain, the agricultural irrigation water occupies about 80% of total exploited groundwater quantity. The figure. 1 shows that, the buried depth of groundwater (h) is closely related with exploited agricultural groundwater quantity (Q) and will be increased with ever growing exploitation. Generally, the two elements show a positive correlation which can be summarized as

$h = 1.4558e^{0.0929Q}$, $R^2 = 0.7455$.

The rivers of Hebei distribute four water systems: Hai river, Luan river, Liao river and Inland river. The total area of the basin is 18.77×10^4 km^2. According to the data from Hebei Bureau of Water Resources, in 1950s', surface runoff of the whole province was 199×10^8 m^3/a and water which goes into the sea was 86.4×10^8 m^3/a; in 1980s', surface runoff of the whole province was 81.3×10^8 m^3/a, and water into the sea was 13.2×10^8 m^3/a. Comparing with 1950s', at present the river runoff of the whole province and water which goes into the sea has decreased at a large range (table 4).

In the hydraulic engineering, after the founding of the nation, Hebei carried out the big scale hydraulic engineering construction. At present, the mountainous area has completed 18 large-scale reservoirs, 38 medium reservoirs and 1086 small reservoirs. The total storage capacity is 112.9×10^8 m^3. These reservoirs control 85% of the mountainous area, and control 90% of water that comes from the moun-

tainous area. These hydraulic projects mostly completed in 1960s'. In 1970s' they tended to the normal operation. The surface water usage rate of the entire provinces reached 70% in 1980- 90s', the partial area reached above 90%. The degree of surface water development and utility is higher, has surpassed the convention, and created the serious ecological environment problem.

Table 4. Changes of surface runoff and runoff into the sea in Hebei

Age	1950s'	1960s'	1970s'	1980s'	1990s'	Average
Surface runoff/$\times 10^8$ m^3/a	19.9	13.7	12.6	8.13	12.8	12.5
Runoff into the sea /10^8 m^3/a	8.64	5.89	6.08	1.32	3.37	4.63

Impact of change of surface runoff on water resource

River runoff stands for surface water resource. As the decreasing of surface runoff since 1970s', it caused the decreasing of surface water resource directly.

Groundwater has to be developed and used as the serious lack of surface water resource. During 1970s', because of the excess development of groundwater, the continual decline of groundwater level and the increasing of the unsaturated zone, they have made surface runoff and groundwater recharge decrease. And the environment problem is more and more serious.

Impace of Change of Grain Output on Water Resource

Hebei is a big agricultural province[4]. At the end of 1998, the area of farmland in Hebei is 648.46×10^4 hm^2. Since 1970s', the total grain output of Hebei has always been the tendency of increasing. The grain output was 1272.5×10^4 t in 1970 and 1522.4×10^4 t in 1980 respectively. And the grain output in 1998 reached 2917.5×10^4 t, which was 2.3 times higher than that in 1970 (figure 1).

Generally the higher the crop output level is, the more the crop water requirement and the more the soil water consumes[5].

Under the same rainy condition, the higher the crop output level is, the less the surface runoff and the recharge of groundwater is. Therefore, the improvement of grain output level is one of the reasons for the decreasing of water resource.

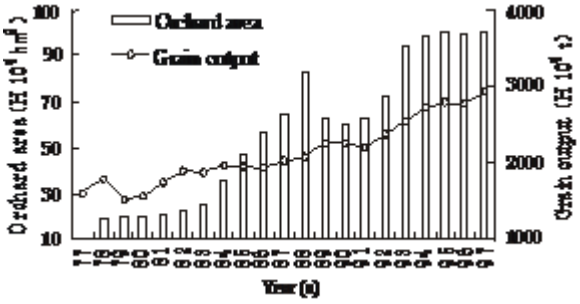

Fig. 1. Grain output and orchard area in Hebei

CONCLUSIONS

(1) The impact of the change of environment on water resource was complex. The climate factors: the precipitation reducing, air temperature rising and so on results in the decreasing of surface runoff and groundwater recharge, the enhancing of farm evaporation. They are the basic cause of leading to the water resources decreasing. The continual lowering of groundwater level which is created by the excess development of groundwater not only causes surface runoff decreasing but also makes groundwater recharge lessening. It is a major man-made factor of decreasing the water resources.

(2) In the use of water resources, agriculture is a big consumer of water[6]. The quantity of farmland irrigation is about 85% of the whole quantity of using groundwater of Hebei province. Especially for the increase of crop output of Hebei plain, it consumed a great lot of water resources and had farm evaporation strengthened, and also brought about surface runoff and groundwater recharge decrease.

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