

## Pilot Project of Groundwater Over-exploitation Control in the North China

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**Abstract:** Groundwater is an important source of water supply in China. In some areas, groundwater has been overexploited for a long time in order to meet the demand of water use in economy and society. Hebei is a province with the most serious groundwater over-exploitation problem in China. In 2014, the Chinese government initiated the pilot project of groundwater over-exploitation control in Hebei Province. Comprehensive measures have been adopted, including replacement of groundwater supply with surface water, development of highly efficient water-saving agricultural irrigation system, adjustment of agricultural planting mode and improvement of water use right and water pricing systems. Through more than 2 years of implementation, preliminary results have been achieved. In this paper, the various measures were summarized and analyzed.

**Key words:** the North China, groundwater over-exploitation, comprehensive control

## 1. Introduction

Groundwater is an important water source to support China's economy and society development. Since 1970s, China, especially the north region, started to intensively pump groundwater for agricultural irrigation, industrial development and city expansion. To meet water demand for rapid development of economy and society, groundwater has been continuously and disorderly exploited to great extent for long time in some regions in China, plus faulty operation and management, as well as insufficient emphasis on protection, all these have led to severe problems of groundwater over-exploitation and contamination.

Hebei is one of China's provinces with the most serious groundwater over-exploitation problem, and is relying on groundwater to a great extent. More than 90% of the province's plain areas are classified as groundwater overdraft area. The annual over-exploited groundwater reaches 6 billion m<sup>3</sup>, accounting for more than 40% of the province's total water supply(Su. et al., 2015). Groundwater overdraft has caused the problems of depletion of aquifers, land subsidence, ground fissures and seawater intrusion, etc.

In 2014, four ministries of China, including Ministry of Finance, Ministry of Water Resources, Ministry of Land and Resources and the Ministry of Agriculture, jointly launched a pilot project of groundwater over-exploitation control in Hebei Province. By 2016, the Chinese government has invested more than 3.5 billion USD on this project and initial results have been achieved. Annual reduction of groundwater overdraft in the pilot region caused by agricultural irrigation has reached 500 million m<sup>3</sup>, and groundwater level of some regions has begun to rise.

## 2. Water Resources in Hebei Province

Hebei Province is a serious resource-oriented water shortage region, with the average annual rainfall of 532 mm, and the total amount of water resources of 20.5 billion m<sup>3</sup>/a, per capita water resources of 307 m<sup>3</sup>, which is far below the internationally recognized 500 m<sup>3</sup> of "extreme water shortage standard". The total annual water supply of Hebei Province is about 19 billion m<sup>3</sup>, of which 75% is from groundwater supply. More than 70% of the total water supply is used for agriculture. Hebei Province is one of the major grain-producing provinces in China, with a total irrigation area of about 4.47 million hectares, of which 63% are only irrigated by groundwater, 18% are irrigated by the conjunctive supply of surface and groundwater, and the rest 19% are only irrigated by surface water. Groundwater plays a very important role in the economic development of Hebei Province, especially agriculture.

In the 1950s, the average annual extraction amount of groundwater of Hebei Province was only about 2.8 billion m<sup>3</sup>/a, which had been increased to more than 16 billion m<sup>3</sup> in the first 10 years of this century, and then began to show a gradually

declining trend (see Figure1 and Figure 2). From the change of the number of groundwater pumping wells, it also can be seen that in recent decades, a sharp increase occurs in groundwater exploitation in Hebei Province. In the 1960s, the number of wells in the whole province is only about 1,800, and now the electromechanical wells above designated size are more than 900 thousand.

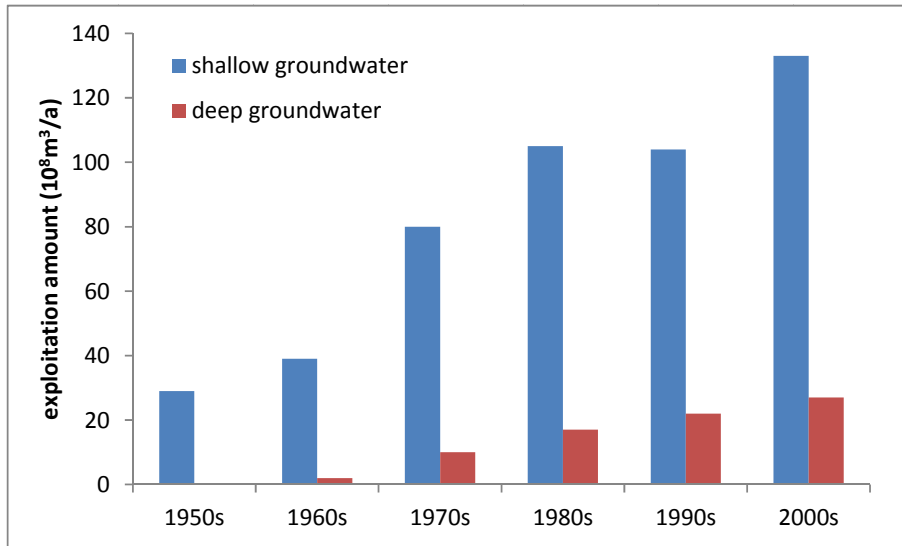


Figure 1. Change of groundwater exploitation amount of Hebei from 1950s to 2000s

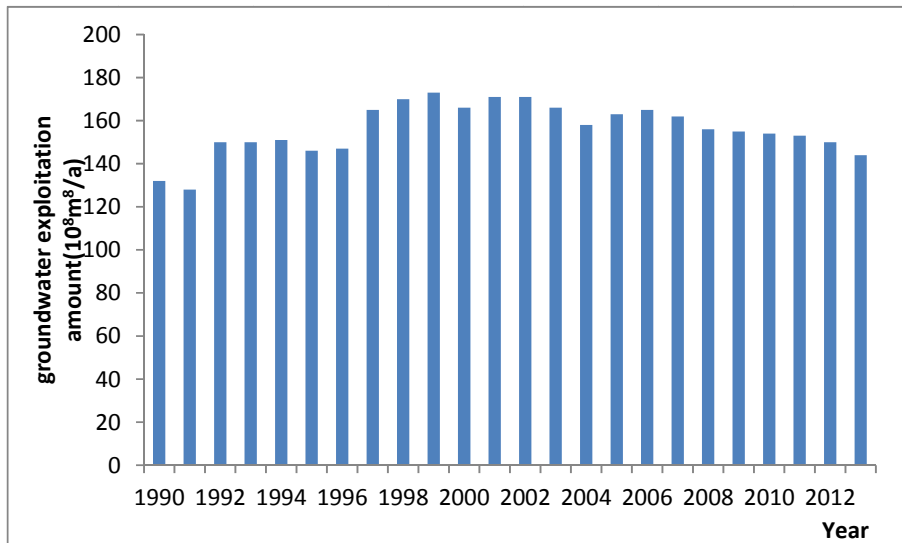


Figure 2. Yearly groundwater exploitation amount of Hebei from 1990 to 2013

According to national evaluation of groundwater over-exploitation areas carried out by China's Ministry of Water Resources, groundwater over-exploitation plain area of Hebei Province is 67000  $\text{km}^2$ , accounting for 90% of the plain area of Hebei. Before the implementation of groundwater overdraft control pilot project, the annual average groundwater over-extraction of Hebei Province is about 6 billion  $\text{m}^3$ , of which 3 billion  $\text{m}^3$  is deep confined groundwater that is difficult to recharge.

The groundwater over-exploitation in Hebei Province has caused a series of ecological and geological problems, including aquifer depletion, ground subsidence, surface cracks and sea (salty) water intrusion. In the early 1960s, groundwater regime of Hebei Province was in the natural state, and the groundwater depth in the plain area was about 3-5m. Because of long-term and large-amount groundwater overdraft, the groundwater level has sustained to decline. The groundwater level in the piedmont plain area has been dropped to about 30m and locally has exceeded 40m, which is lower than the depth of the bottom of the first aquifer in this area, and the aquifer has almost dried out. Then, the groundwater in deeper aquifers has to be extracted, which also caused a large number of scrapped pumping wells, and increasing costs of agricultural irrigation.

### **3. Integrated Measures to control Groundwater Over-exploitation**

To control groundwater over-exploitation and reduce the amount of groundwater use, the countermeasures taken generally focus on two aspects. On the one hand is looking for more water sources other than groundwater, replacing the currently drafted groundwater with alternative ones; on the other hand is taking measures to reduce water demand of all sectors, especially the biggest water consumer, agriculture.

#### **3.1 Replacing groundwater supply with surface water**

Seven out of eleven cities in Hebei Province are in the water-taken area of mid-line of South-North Water Transfer Project and the annual average water transfer capacity is about 3.0 billion m<sup>3</sup>/a, which is mainly planned for water supply in urban region. Replacing extracted groundwater with water from South-North Water Transfer Project is the main measure to treat urban groundwater over-exploitation problem in Hebei Province. In addition, due to the expansion of urban development, some of the water sources previously used for water supply for rural areas had been diverted to provide water for the urban area. These water sources for urban area can be substituted by South-to-North water transfer project and again back to the rural area water supply, as one of the means of groundwater over-exploitation control in rural areas. At present, the construction of supporting water plants and pipeline network of the South-North Water Transfer Project have not been all completed yet, thus the substitution of urban groundwater supply by South-North project transferred water has not yet achieved the desired results.

Diverting and utilizing water of the Yellow River and Weihe River as agricultural irrigation water is one of the measures to reduce groundwater exploitation for irrigation. However, due to continuous drought, reduction of water resources amount from the upstream, coupled with the land use tension, many previous rural ponds were too dry, and have been abandoned or backfilled, and even have become the sites of the construction of houses and factories, which made the using of surface

water more difficult. This groundwater over-exploitation control project considered the treatment of blocked water system, water area shrinkage and water eco-system degradation in rural area as focal points, also put forward the measures to restore the construction of rural ponds, river canals, reservoirs and water network with connected ponds to better store and allocate surface water. Meanwhile, rainwater and surface runoff water are being collected to increase the surface water available for agricultural irrigation and to reduce the exploitation of groundwater.

In 2015, due to the drought of the water source area, the amount of water from Yellow River and Weihe River was less diverted, which did not meet the expected targets. In 2016, some areas had relatively large rainfall, and a lot of rural ponds were filled up with water, which played an important role in agricultural irrigation.

### **3.2 Adjustment of Agricultural Planting patterns and habits**

The planting pattern of North China is double cropping a year, with one season of wheat, and the other of corn. It is known that the growth of wheat needs a lot of irrigation water. The groundwater over-exploitation control pilot project proposed that in the region with severe problem of deep groundwater over-exploitation and without surface water available for replacement, the planting area of winter wheat irrigated by groundwater should be reduced, which means that the former double cropping system of winter wheat and summer corn should be changed to single cropping system of corn, or cotton, or peanut, or oil sunflower, or miscellaneous grains, or other crops, to realize “one season of fallow while the other one of rain support”. In this way, 180 m<sup>3</sup> of irrigation water can be saved per mu (1 mu = 1/15 hm<sup>2</sup>) of arable land per year. In order to make the farmers be supportive to change planting structure, the cultivated land used to planting winter wheat will be given a certain subsidy, about 500 yuan per mu per year for stopping planting wheat.

So far, in Hebei Province, a total area of about 1 million mu of the originally wheat-planted arable land stops cultivating wheat, and the water-saving effect is obvious. However, this approach is more dependent on the subsidies given by the government, once the subsidies stop, farmers are very likely to return to plant wheat, which in turn will again increase irrigation water use. In addition, some farmers said that even if with subsidies, they may be willing to plant wheat, because the selling price of corn is too low to make profits these years, while planting a season of wheat at least can make stable money because of the government’s agricultural policies. In addition, because of the decreasing income caused by planting corns, some farmers are requiring to increase the subsidy standards to 650 yuan per mu.

In addition, in order to reduce groundwater exploitation, the agricultural department in Hebei Province has largely promoted agricultural water-saving technology(Cheng. & B., 2016). First suggestion is to encourage farmers to cultivate water-saving varieties of wheat. in this way, 50 m<sup>3</sup> of irrigation water can be saved per mu; the second is to

promote wheat conservation tillage water saving technology, that is, the implementation of less tillage policy and crop stalks and stubbles crushed to cover the land to reduce wind erosion, water erosion of soil, and improve soil fertility and crop drought resistance, and then achieve the effect of water-saving and yield increasing, this approach can also bring about 50 m<sup>3</sup> of water-saving per mu. Thirdly, to promote the water and fertilizer integration technology, with water-saving of about 140m<sup>3</sup> per mu. But promotion of this technology may make the farmers be intentionally to switch cultivating crops to high-value-added vegetables and other commercial crops, which needs more irrigation water. At present, more than 10 million mu of crop-planting area has been implemented the agronomic water-saving methods, and the water-saving effect is obvious. Farmers should receive respective training to better utilize these methods.

### **3.3 Development of Efficient Water-Saving Irrigation**

Influenced by the impact of small-scale family management of arable land, local farmers lack understanding of water saving technologies, meanwhile due to the insufficient investment funds, the level of development of efficient water-saving irrigation in Hebei Province is not advanced. Before the implementation of groundwater over-exploitation control pilot project, the province's irrigation area with water-saving irrigation technology used was less than 30% of the total irrigated area, and most farmers still take the measure of flood irrigation. It can be said that the agricultural water waste is one of the important factors which cause the contradiction between supply and demand of water resources in Hebei Province. The groundwater over-exploitation project takes the efficient water-saving irrigation technology as one of the important measures to improve irrigation water efficiency, and reduce water use, mainly by using low-pressure pipes, sprinkler irrigation, micro-irrigation and other measures, to replace the traditional flood irrigation way.

At present, in order to treat the groundwater over-exploitation, the pilot area has newly developed more than 6 million mu efficient water-saving irrigation area, and achieved certain results. However, the cultivated land management mode in the North China is still operated on small scales by each farmer's family. When farmers use sprinkler irrigation and other irrigation methods to water their own arable lands, it is inevitable not to affect the neighbor farmlands, so some farmers who only have relatively small area of farmland are not willing to adopt this approach. Besides, some irrigation equipment, such as traveling irrigation machines, which is not convenient to use, are rarely accepted by the farmers in Hebei Province.

## **4. Improvement of water use right and pricing system**

Groundwater as water resource almost everywhere, is used to utilized "without any restrictions", resulting in the phenomenon of serious groundwater disordered development, which also made groundwater management very difficult to handle.

Therefore, Hebei Province is trying to clarify the water use rights and carry out water pricing reform.

#### **4.1 Clarifying water use rights**

In order to more effectively manage the use of water resources, Hebei Province has carried out the work of water resources use rights clarification, and is trying to assign water use right to each water user. Take the following Anping County in Hebei as an example to illustrate the method of water use rights clarification in Hebei Province: the first step is to determine the amount of available water resources which can be allocated, including the allowable withdrawal of shallow groundwater, the local surface water, as well as the South-North project transferred water and other transferred water, the total amount of water can be distributed is about 50.4 million m<sup>3</sup>; the second step is to determine the water allocation to each sector according to the current status of water use. In the past three years, the urban and rural domestic water use was 8.59 million m<sup>3</sup> and the water use of non-agricultural sector (including water use of industrial enterprises, construction industry and mining industry) was 8.56 million m<sup>3</sup>, and the ecological water consumption was 0.5 million m<sup>3</sup>, the reserved water amount is determined to be 147,600 m<sup>3</sup>. Then, agricultural water allocated is calculated by deducting the amount of water used for domestic, non-agricultural sector, ecological environmental and reserved water from the total distributed water, and which is about 33.1 million m<sup>3</sup>; the third step is to issue water right certificates. Domestic water use, non-agricultural sector water use and the ecological environmental water use should be issued water use permits, and agricultural water users should be issued water use right certificates. The amount of water use rights of each farmer's family is equal to the amount of agricultural water allocated per mu multiples area of arable land operated by the farmer's family. The cultivated land area of Anping County is 475 thousand mu, and the agricultural water allocated to per mu land is 70 m<sup>3</sup>/mu.

So far, water use rights have been clarified in most pilot regions. The problem is that even the amount of water use right has been determined to each individual users, it did not clarify the type of water resource that the users should take, i.e. surface water or groundwater.

#### **4.2. Water pricing reform**

Low water price is an important cause of waste of water resources. Hebei water prices are generally low, which do not reflect the scarcity of water resources, the endogenous motivation for whole society to save water is insufficient (Ma. & L., 2016). Thus, Hebei Province carried out a series of reform measures relevant to the water price and the fees to be collected.

First, implementing strategy of water resources tax rather than water resources fee.

By increasing the groundwater tax standards, the enterprises can be urged to adjust water use structure, mitigate the use of scarce groundwater, and use surface water more often. It is estimated that with the water tax reformation, the average tax for per cubic meter surface water is about 0.3 yuan; the groundwater tax is distinguished for non-overdraft area, overdraft area and serious overdraft area. The average water taxes of groundwater resources are 1.42 yuan , 2.01 yuan and 3.54 yuan, respectively for non-overdraft area, overdraft area and serious overdraft area. Then, on average, the tax of groundwater resources is 4.1 times of surface water; the tax of groundwater in serious over-exploitation area is 2.5 times of non-over-exploitation area, and 11.8 times of surface water. The big difference of water tax between groundwater resources and surface water is conducive to guiding enterprises to adjust the water use structure timely, and also to improve water efficiency.

Second, implementing the “three-level ladder water pricing system” for domestic water use. Normally, the first, second, and third levels of water price differences should follow the ratio of 1: 1.5: 3. The amount of water use with the first level domestic water price should guarantee the basic domestic water needs for residents, in principle, is not more than 10 m<sup>3</sup> of each household per month. The second ladder of water use amount with the second level domestic water price should reflect the reasonable water use demand of improvement of residential living quality, is not more than 15 m<sup>3</sup> of each household per month. The amount of water use beyond the second ladder should be charged with the third level domestic water price.

The water use amount ladders and water prices for different levels of domestic water use in Baoding city in Hebei Province are: the first ladder is 0-120 m<sup>3</sup> with water price of 3.55 yuan/m<sup>3</sup>; the second ladder is 120-180 m<sup>3</sup> with water price of 4.66 yuan /m<sup>3</sup>; and the third ladder is 180 m<sup>3</sup> or more with water price of 7.99 yuan/m<sup>3</sup>(Qi. & J., 2016).

Third, formulating agricultural water use prices. For a long time the cost of agricultural water use in Hebei Province was only the cost of drilling wells and electricity consumption of pumping , farmers did not need to pay any corresponding water resources fees, which made the farmers pay little attention to water waste of flooding irrigation. The water price reform put forward the agricultural water price collection standards. Agricultural water price collection normally take the approach of "quota management, charge more for excess". The amount of water under the quota of water rights will be charged at parity water price according to the basic operating costs, and generally, the prices of surface water, shallow groundwater, and deep groundwater are 0.12 yuan / m<sup>3</sup>, 0.3 to 0.5 yuan / m<sup>3</sup> and 0.8-1.0 Yuan / m<sup>3</sup>, respectively. For excess water use, an extra 0.1 yuan is added on the basic charge for per cubic meter water use.

Changing water resources fees to water resources taxes has prominent effects on the industrial water saving. High water consumption industries such as iron and steel



industries have always been pillar industries in Hebei Province. Since the implementation of water resource tax reformation, many iron and steel enterprises have actively equipped with advanced sewage treatment equipment and water recycling systems, to reduce withdrawal of fresh water. But on the other hand, the agricultural water price reform is relatively difficult to implement, and the reasons are complex, may include agricultural water use measurement has not been fully covered, farmers have been used to use irrigation water free for a long time, and the interests of farmers should be fully guaranteed.

## **5. Discussion and Conclusion**

Groundwater over-exploitation control and management are very complex, especially in China, the utilization of groundwater is widely dispersed, the over-exploitation has a very long history, and some regions rely on groundwater too much(Wang et al., 2000). Besides, groundwater management in China is relatively weak. Groundwater over-exploitation control should not only focus on taking engineering measures, but also improving management regulations and enhancing management capacity should be emphasized.

Firstly, the issue of groundwater over-exploitation is related to many aspects, including water use, ecological protection, land use, food production, etc., involving functions and responsibilities of several departments. The inter-departmental cooperation and coordination mechanism must be established and enhanced. This pilot project of groundwater over-exploitation control in Hebei Province, is led by the Ministry of Finance at the national level, and involved by the Ministry of Water Resources being responsible for technology lead, Ministry of Land and Resources being responsible for groundwater table monitoring, and Ministry of Agriculture being responsible for agronomic water saving measures. Above departments have all closely participated in the whole process of the project, including planning and design, implementation and development, evaluation and assessment.

Secondly, in China, agricultural sector is the biggest consumer of groundwater, groundwater over-exploitation control and management face numerous farmers, thus getting support from farmers is the key. First, the advocacy of groundwater resources protection should be enhanced to let farmers understand the significance and meaning of groundwater resources protection and be aware of the whole process of the implementation; second, The interests of farmers should be guaranteed. Some approaches of controlling groundwater over-exploitation, such as adjustment of agricultural planting structure, may have certain impact on the income of farmers, then, there must be a corresponding compensation mechanism so that farmers would not suffer much income loss; Third, the technical training of farmers is necessary and should be enhanced to assist farmers to maintain application of water-saving technologies and facilities, and also to understand the corresponding water rights, water prices and other management measures.

Thirdly, groundwater monitoring and metering system are the foundation of groundwater resources management and exploitation control. Although the supply of groundwater resources accounts for more than 70% of the Hebei province's water supply, the groundwater resources monitoring and pumping amount metering system have not be well established. The groundwater over-exploitation control pilot project in Hebei is trying numerous methods to improve dynamic monitoring system of groundwater. Many groundwater table monitoring wells are built and groundwater information management platform is established in the department of water resources at county, city and province levels. All industry and urban water use, as well as the majority of agricultural water use are trying to be metered.

Last but not the least, effective management regulation needs to be formulated. In order to control over-exploitation of groundwater and enhance the protection of groundwater system, Hebei Province promulgated the “Groundwater Management Regulation of Hebei”, which defines the responsible parties and the procedure of groundwater management, and the punishment measures of unreasonable exploitation and destructive behaviors of groundwater. On this basis, the government also put forward the approach and systematic requirements of water use rights and water price reform, making the management legalized and long-term effective.

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