



Exploitation of groundwater and environmental issues

Fang Sheng, Chen Xiuling, China

THE EXPLOITATION AND utilization of groundwater has been carried out on a large scale in the northern part of China. The disasters of drought, waterlogging and soil salinity have been controlled effectively, thus ensuring the sustainable development of agriculture, and the domestic and industrial water supply in most cities in the region. This has made great contributions to the development of national economy and society. However, in the regions where groundwater overdraft occurred the following water environmental issues: have appeared continuous drawdown of groundwater table, ground subsidence, sea (saline) waters intrusion and pollution of groundwater. In the canal irrigation districts where groundwater has been rarely utilized, exists the problem of secondary salinization of soil.

Key words: Drawdown of Groundwater, Ground Subsidence, Sea Water Intrusion, Pollution of Groundwater, Secondary Salinization.

Exploitation and utilization of groundwater

The northern part of China belongs to arid, semi-arid and semi-humid climate regions. This area involves 17 provinces, cities and municipalities with a total cultivated land area of about 66.7 million hm^2 . Without irrigation there will be no agriculture in arid region. In semi-arid and semi-humid regions 70% of the precipitation concentrates in July and August; the period from September to the coming June is the dry season. Due to its uneven distribution by time and space the natural precipitation can not meet the water demand for normal growth of crops. It is necessary to develop irrigation to supplement the deficient natural precipitation. However, the surface water resources in this area are very limited, the water demand for the development of industrial and agricultural production and for the livelihood of local people still can not be met. Since the beginning of 1970s, the exploitation and utilization of groundwater has been carried out extensively in the northern part of China. In 1998, the groundwater supply amounted to 90.8 billion m^3 in the five large basins in the region. The total area irrigated by groundwater reached 0.14 billion hm^2 . The ratios of utilization of groundwater are as follows: about 90% in Haihe River plain; 49% in Yellow River basin; 30% in Liaohe River basin. Hebei province, Beijing and Tianjin Municipalities are the regions with exploitation of groundwater to the highest degree. The groundwater supply accounts for 45% of the water supply amount in 16 cities in the northern part of China. In the regions where Large-scale exploitation and utilization

of groundwater has been carried out, the actual average annual groundwater exploitation amount generally surpassed the exploitable water resources—the amount of water resources which can be balanced by replenishment after exploitation. In Hebei Plain where the groundwater exploitation amount ranked first in the northern part of China. The exploitation amount of groundwater in 1980-1997 was 7.761 billion m^3 , the average annual exploitation amount of shallow groundwater was 10.579 billion m^3 , the average annual overdraft was 2.878 billion m^3 , and the total overdraft was 51.8 billion m^3 . In Shandong province, the exploitable amount of shallow groundwater was 12.593 billion m^3 , the average annual overdraft was 0.464 billion m^3 from 1984-1993, the total overdraft was 6.437 billion m^3 . During 1980-1995, the total overdraft of groundwater was 2.27 billion m^3 in Beijing. During 1990-1998, the average annual exploitation amounted to 10.906 billion m^3 in Henan province, the groundwater was overdrawn by a big amount in the eastern and northern parts of Henan province.

Continuous drawdown of groundwater level

The protracted exploitation of groundwater exceeding its replenishment has caused continuous drawdown of groundwater table. Up to now, 0.16 million km^2 of drawdown cone areas have formed in the 0.658 million km^2 of total area of groundwater exploited in the northern part of China. The most serious cases could be seen in Hebei Province and Tianjin Municipality. The total area of shallow groundwater drawdown cones was 8598 km^2 (1997) in Hebei province, and 1963 km^2 (1995) in Beijing Municipality. In Shijiazhuang urban area, Hebei Province, in 1998, the depth of the center of groundwater drawdown cone was 37.8 m with a cone area of 325 km^2 . The average annual drawdown was 1 m. In the piedmont plain of Taihangshan mountain, 1700 km^2 of the first aquifer group have been drained off. In Henan province the area with groundwater depth over 8 m has reached 10360 km^2 . Due to difficult natural replenishment after exploitation, the deep confined groundwater table has dropped rapidly. Till 1989, deep groundwater drawdown cones have formed in Baimiao and Beizhan Districts in Tianjin Municipality, Ji-Zao-heng and Cangzhou region in Hebei province, Dezhou in Shandong province and east suburb of Beijing, the total cone area reached 20000 km^2 . In Cangzhou City the water table depth of deep groundwater reached 93.97 m in 1998.

The area of isopiestic line of -50m was 1195 km². The rate of annual water table drop was 2.68m/a. Calculating according to this rate, the third aquifer group (roof block 150m) will be drained off in less than 15 years. The area of Ji-Zao-heng deep groundwater cone in Hengshui City reached 5668 km² with a depth of cone center of 76.18 m. It dropped 19.34 m as compared with 1990, indicating an average annual drop of 3.87 m/a. The groundwater table drawdown by a big margin has caused the discharge of spring water attenuated or even dried up. In Jinan, Shandong province, the "Spring City" of China, the spring water attenuated and nearly dried up. Xintai "Hundred Spring", Hebei province, the discharge of spring was 7—9 m³/s in 1960, its irrigated area was 20 thousand hm², however, in 1986 the spring dried up. Due to the great drop of groundwater table the water pumpage cost has doubled and redoubled. The replacement and renewal of water lifting implements has speeded up. In 1986-1992, in Hebei Province, on the average, 8580 motor-pumped wells ran dry every year, accounting for 21.9% of the total amount of scrapped wells. In Shijiazhuang region the water pumpage cost rose to 30 yuan from 8 yuan per mu per year in 1970's and the power consumption doubled. The scrappage rate of motor-pumped wells came to 3—10% each year. The submersible power-operated pumps were used to replace the centrifugal pumps.

Ground subsidence

The groundwater overdraft will lead to the formation of groundwater drawdown cone in vast area. The transformation of groundwater heads and the stress state in the exploited aquifers and in the perched water strata above and under the aquifers, the occurrence of water release from cohesive soil and the generation of compression effect in the aquifers and perched water strata, thus resulting in ground subsidence. Ground subsidence has been found in 36 cities and towns in China. The maximum ground subsidence amounted to 2.46 m in Tianjin. In the plain region covering the middle and eastern parts of Hebei Province, the total land area with subsidence over 100 mm reached 33900 km². In Cangzhou City, the accumulated ground subsidence was 1523 mm in 1970-1994. The average annual ground subsidence was 60.92 mm. In the City's urban area, the crest of the South Canal Dyke has subsided by 1300mm. More than 2000 horizontal and vertical crevices have appeared on the Qianlidi Dyke of Baiyangdian Lake from Renqiu to Wenan. The horizontal crevices have appeared through the Beidadi Dyke of Hutuohe River as well. The karst area covering Taian, Zaozhuang, Laiwu, Yiyuan and other places in the middle and southern parts of Shandong Province occurred surface depression with 3—10m in depth and several meters to hundreds meters in length. On the dam of irrigation district of Xiaohe River uneven subsidence has occurred. With ground subsidence, the flood and Waterlogging disasters became more serious. The ground subsidence there caused the subsid-

ence of foundations of railways and buildings, the cracking of highways and bridges, the emergence of cracks on underground pipes, the scrappage of motor-pumped wells and the decrease of flood-discharging capacities of rivers.

Sea (saline) water intrusion

Owing to the groundwater overdraft the groundwater table has dropped by a big margin, resulting in sea (saline) water intrusion, which caused the water quality to be salty in the area with hydrogeological condition of seawater intrusion access to the fresh groundwater aquifer in the coast land. In the regions of sandy coast and bed rock coast which face Huanghai Sea and Bohai Sea in the northern part of China, sea (saline) water intrusion has occurred in 112 townships of 29 counties in Yantai, Weihai, Qingdao in Shandong Province, Qinhuangdao City in Hebei Province, Dalian, Jinzhou, Jinxi and Yingkou in Liaoning Province. The sea water intrusion with a total area of 1433.6 km², of which the heavy sea water intrusion area with the content of C Cl⁻ over 1000mg/l in groundwater was 224.3 km². The most serious cases of seawater intrusion were seen in Yantai and Dalian with an area of 495.2 km² and 433.8 km² respectively. The distance of seawater intrusion into inland generally was 5—8km. The underground saline water developed in the mud coast area covering the lower reach of Liaohe River in Liaoning Province, the eastern part of Hebei Province, the region to the east of South Canal and the north coast plain in Shandong Province. Seawater intrusion was not seen in that area, but in the area having saline water, the phenomenon of saline water intrusion to the fresh water aquifer has been discovered. In Cangxian County, the area of aquifer of saline groundwater the bottom depth of which dropped by over 10 m was 1260 km² in 1992 as against with 1974. The inland border of saline water aquifer with bottom depth of 80 m has extended by about 10 km to the fresh water area. In 1967, in Hejian City the area of fresh groundwater with mineralization of less than 0.5 g/L was 307.2 km², which disappeared in 1992. In the Tangshan-Qinhuangdao coast area in Hebei Province, the groundwater drawdown cone area formed due to overdraft of groundwater, has caused the intrusion of the ancient sealed up saline water into the fresh water aquifer and the formation of a saline water intrusion area of 24 km² with the maximum Cl⁻ content of 1250 mg/L. In Liaoning, Hebei and Shandong, 8000 motor-pump wells have been abandoned due to sea water intrusion, the volume of groundwater exploitation has reduced by 130 million m³ per year, nearly 0.133 million hm² of cultivated land has been covered in the sea water intrusion area. A large area of cultivated land has salinized, the irrigation area has reduced by 40000 hm². One million of population and 0.4 million of livestock had difficulties in getting drinking water. The industrial production value decreased by over 360 million yuan per year. People drunk groundwater polluted by sea (saline) water, and their health were affected.

Pollution of groundwater quality

According to the investigation made in 165 cities in 1992, the quality of drinking groundwater in over 25% of the 165 cities has not met the national hygiene standard of drinking water. About 30% of the population though out the country drank the polluted water. About 30 million people in more than 10 provinces to the north of Huaihe river drank water with high NO_3^- content, about 50 million people drank water with high fluorine content and 0.11 billion people drank highly mineralized water. The drainage of industrial wastewater and domestic sewage in a great quantity and the exploitation of groundwater in a big amount for agricultural use have directly or indirectly caused the pollution of groundwater. Especially in the region of groundwater overdraft that has changed the kinetic condition of groundwater, accelerated the pollution of groundwater by polluted river flow, seepage of sewage and irrational sewage irrigation. Since 1980s, the township-run enterprises have developed swiftly, they are small in size but are distributed widely and basically have no sewage treatment facilities. The sewage drained off from them often caused pollution of part of water bodies. In north China region, surface water is used to a great extent, the capacity of self-purification of river is lower, and some rivers even have no self-purification capacity. The water bodies of river, one of the replenishment sources of groundwater has been polluted seriously, and as a result, it has indirectly polluted the groundwater. In 1998, the groundwater resources volume was 27.2 billion m^3 in Haihe River Basin, in which 17.2 billion m^3 were polluted, accounting for 62% of the total. The drainage amount of wastewater and sewage was 3.68 billion m^3 in Haihe river basin in 1980, and only 0.3 billion m^3 of sewage entered the sea in 1983, most sewage was utilized for irrigation. In Beijing, the amount of sewage drained off was 0.98 billion t in 1991, in which 0.828 billion t were not treated before draining into rivers, seepage wells, seepage pits and irrigated farmland. As a result both surface water and groundwater were polluted. The area of groundwater not meeting the standard of drinking water accounts for 46% in plain area. The area of groundwater with its total hardness exceeding the standard increased from 205 km^2 in 1980 to 297 km^2 in 1995. The Cl^- content of groundwater increased from 65.5 mg/L in 1980 to 109 mg/L in 1995 at Wanshousi in Fengtai District. In Shandong province, the length of the river reach with seriously polluted water (exceeded V class water) accounts for 70.8% of the total. The polluted river flow infiltrated into ground and unavoidable be polluted the groundwater. According to the monitoring results of 41 drinking water supply wells along the Xiaoqinhe River, the over limit rates of the pollution factors, such as fluoride, sulfate, volatile matters, COD and petroleum were all over 80%. The groundwater in the area of 800 m from both banks of the Xiaoqinhe River has been polluted with a pollution depth of less than 60m in Zaoping, Boxing counties. The polluted area was 80 km^2 , covering 156 villages with 162000 residents having difficulties in

getting drinking water. The incidence of diseases of liver intestines and stomach was obviously higher than that in the unpolluted area. In organic contaminants, exist 30 kinds of carcinogen, teratogen and mutagen. The contents of 5 kinds detected organic matter including carbon tetrachloride and benzopyrene etc. Seriously exceeded the standard of drinking water.

Secondary salinization of soil in irrigation districts

At the end of 1950's, secondary salinization of soil in large area occurred in the irrigation districts in Huang-Huai-Hai Plain due to irrigation using water diverted from the lower reach of Yellow River, and from reservoirs or using water stored on the low-lying land in the Plain area. The Xinjiang Production and Construction Corps mainly diverted river flow for irrigation. In the past 30 years, the total area of abandoned land due to soil salinization caused by irrigation almost equaled that of the newly reclaimed land. The soil salinization in irrigation districts has worsened the ecological environment and caused serious losses to agriculture. The basic cause of soil salinization in irrigation districts is the excessive irrigation water consumption, when the groundwater recharge volume is larger than the discharge volume, the groundwater level will rise approaching to surface soil resulting in intensified evaporation of phreatic water and salt accumulation in surface soil. Since the beginning of 1970's, the large-scale exploitation and utilization of groundwater has been carried out in the northern part of China. The groundwater level there has drawdowned year by year. The drought, waterlogging and salinity in the well irrigation districts have been controlled. At present in the canal irrigation districts where groundwater is rarely exploited and utilized, such as the Yellow River diversion irrigation districts in Ningxia and inner Mongolia. Most river flow irrigation districts in Xinjiang and other places, the groundwater table keeps perennial on high level, there still exist the problem of secondary salinization. In the Yellow River diversion irrigation districts and coastal plain in the northwest part of Shandong province, where the area with groundwater depth less than 2m reached 27220 km^2 in 1998, the area of the saline-alkali cultivated land still reached 0.144 million hm^2 in whole province.

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