WATER SUPPLY AND DEMAND STATUS AND WATER ENVIRONMENT PROTECTION IN CHINA

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Contents

Summary

Firstly, the effect of the water cycle on resources, ecology and environment are discussed in this paper. Secondly, the status of water resources development and the water environment as well as the basic characters are introduced. The writers point out water resources problems in the process of development in the twenty-first century: zonal water shortage in north china, gradual intensification of urban water shortage, point-source water pollution, and ecological deterioration. Thirdly, based on the above analysis, the project for water supply and demand in the twenty-first century is desribed and the general layout of water resources allocation in the whole country is presented. Finally, in the writers' view, it is essential to sustainable development in the twenty-first century that China should carry out water demand management and develop the water saving industry

1. Water Resources Problems in the Process of Development

Surface water flow is just a part of the global water cycle which operates under the comprehensive actions of various kinds of natural forces. Water resources are created by the water cycle process and are endowed with reproducibility as a fundamental character. In general, water resources refer to fresh water, which has a close relationship with human society and the ecological environment. Fresh water comes from precipitation and exists in surface water, groundwater and soil water. The water environment consists of water bodies and their surroundings, and is one of the sub-systems having the strongest influence upon the ecological system.

During the process of development, large-scale human actions impact on the water cycle and cause certain changes in those parts of the ecological system which are dependent on the water cycle. A series of problems therefore arise, such as the trend of increasing drought, reduction of water quality, ecological environment deterioration, and increased flood risk.

Until at least the middle of the twenty-first century, total water demand in China will increase gradually, effected by population increase, national economic growth, urbanization and industrialization. The increase of water demand will deepen the development and utilization degree for water resources. Therefore the pressure on the water cycle will be intensified, and more pressure will be added to the ecological environment. At the end of the twentieth century, the development and utilization degree for water resources has approached or exceeded the water resources carrying capacity in most territories of northern China, and the degree of water pollution has approached or exceeded the bearing capacities of the water cycle in parts of southern China. Sustainable utilization of water resources faces great challenges.

In view of the serious status of water resource shortage and water pollution, rational disposal, efficient utilization and strict protection must be promoted to achieve sustainable development in line with natural and economic rules. Using a systems approach, one can seek to balance the demands of economic development and the carrying capacities of resources and environment, but there will be heavy financial and social costs before achievement of efficient and sustainable utilization of water resources.

1.1. Evolution of the Water Cycle and its Effects on Resources, Ecology and Environment

The total mean annual average precipitation in China is 6188.9 billion m^3, of which 45% contributes to water resources; the remaining 55% is lost in evaporation. Mean annual renewable water resources total 2812.4 billion m^3 of which surface water constitutes 2711.5 billion m^3 and groundwater 828.8 billion m^3 with a deduction of 727.9 billion m^3 for interchange and mutual makeup of surface and groundwater.

1.1.1. Changes in the Water Cycle Induced by Large Scale Human Action

During the twentieth century, on the one hand mankind realized more and more clearly that water resources are of great importance for his survival and development, but on the other hand, the process of economic development has fundamentally changed the natural water cycle. Under the influence of large-scale human action, changes have occurred at different levels, including precipitation, overland runoff and confluence, interchange between surface water and groundwater, flooding, and sedimentation.

Before the middle of the 1960s, in Hebei Province, the water in most of the rivers along the Jing-Guang Railway was very clear, and the depth of groundwater was about 2-3 m. Fountains in this area such as Bai, Dahuo, Yimu, Baichigan, etc. flowed freely. Several hundred tons of goods could be shipped directly to Tianjin Port through the Ziya, Zhangwei, Nanyun and Daqing rivers. To a large extent this situation reflected the water resource situation of Hebei Province under natural conditions.

Today, human activity has greatly changed the natural situation of water resources and the ecological environment in Hebei Province. At the beginning of the 1950s, the total annual water consumption was around 5 billion m^3. In the early 1970s, the amount had grown to 10 billion m^3, and by the 1990s', the amount has extended to 20 billion m^3. Water consumption had been growing, but the total amount of annual inflow had been falling because water consumption had increased in Shanxi Province in the headwaters of the Hai River. The total inflows were 10 billion m^3 in the 1950s, dropping to 7.1 billion m^3 in the 1960s, 5.2 billion m^3 in the 1970s and 2.6 billion m^3 in the 1980s respectively (see Table 1)

	1950s	**1960s**	**1970s**	**1980s**	**1990s**
Total water consumption	5.0	7.0	9.8	15.0	21.1
Water inflow	10.0	7.1	5.2	2.6	
Local runoff	23.3	16.3	14.5	9.4	
Development degree	21%	30%	41%	63%	89%
Total drainage amount	2.0	3.5	5.9	10.5	16.5

Table 1. Trends in Water Resource Conditions in Hebei province (km^3)

Not only did the volume of water needed for development and domestic use increase, while the inflow was being reduced, but the relationship of runoff, confluence and interchange between surface and groundwater also changed dramatically. Annual surface runoff in the 1950s was 23.3 billion m^3, but it had reduced to 16.3 billion m^3 in the 1960s, 14.5 billion m^3 and only 9.4 billion m^3 in the 1980s.

In less than fifty years, water consumption had increased by 300%, but inflow and runoff had reduced by 74% and 60% respectively. People in Hebei Province therefore had to make extensive use of groundwater. Today, the annual average amount of groundwater overdrawing is 3 billion m^3, which is equivalent to 30% of total annual groundwater recharge.

Development and utilization for water resources has exceeded the carrying capacity of local water resources, leading to many problems such as the following phenomena: channel drying up, disruption of navigation, estuary sedimentation, flood retention, drying up of lakes and pools, increased water pollution, falling groundwater table, subsidence of the ground surface by over one meter, groundwater leavy area of over 2000 km^2, with the height of 90 m of drying up areas of groundwater appearance.

These changes in Hebei Province are very striking, but Hebei Province is fairly typical character of northern China, and the situation just described will follow to a certain degree in other areas of northern China. The drying up of the Yellow River underlines the gravity of the situation.

1.1.2. Lateral Water Cycle Resulting from Water Development and Utilization

Development and water utilization diverts water into an artificial 'lateral water cycle' which operates concurrently with the natural cycle. With the development of society and economy, the influence of the artificial lateral cycle has been greatly increased. From the global perspective, total water use was 579 billion m^3 in 1900; it had increased to

1360 billion m^3 by 1950, and grew to 3220 billion m^3 in 1980. In 80 years, therefore, total water use had increased 5.7 times. Of this, urban domestic use increased 12.4 times, industry 19.6 times, and agriculture nearly 3.4 times. The ratio of water consumption to natural runoff increased from 1.2% in 1900 to 7.1% of 1980.

In China, the changes were even greater. From 1949 to 1997, total water use increased from 103.1 billion m^3 to 556.6 billion m^3, i.e. by 5.4 times. The ratio of consumption to natural runoff increased from 3.8% in 1949 to 20.5% in 1997. Compared to the world average, the extent of water development and use in China is higher, and the influence of the lateral water cycle to the natural water cycle is stronger (see Table 2).

		1949	**1980**	**1993**	**1997**
Total water consumption	1000 km^3 $year^{-1}$	103.1	443.7	519.8	556.6
Total population	million persons	455.0	981.0	1173.0	1240
Per capita water consumption	m^3 $person^{-1}$ $year^{-1}$	227	452	443	449
Annual water consumption growth rate	%		4.82	1.23	1.72
Agriculture water consumption proportion	%	90	83	75	70
Domestic quota	Liter $person^{-1}$ day^{-1}	51	78	98	116
Development and utilization degree	%	3.67	15.78	18.48	19.79

Notes:
Data for 1949 from "Water Issues Strategies of China in 21st century" by Liu Changmin He Xiwu
Data for 1980 from "Water Supply and Demand in China" by Liu Shanjian
Data for 1993 from "Summarized Report on Mid-Long Term Water Supply and Demand Plan for Whole Country"
Data for 1997 from "Water Resources Bulletin of China"

Table 2. Growth in Water Consumption in China

1.1.3. Resources, Ecological System and Environment Effects of the Water Cycle Evolution

The appearance of the artificial lateral water cycle means the original principal of the water cycle has been disrupted to different extents; the temporal and spatial distribution changes impact on resources and ecology, and cause environment effects on river basin criteria, all of which are unfavorable for regional sustainable development.

The resource impacts resulting from high intensity development of water resources, include the following: drop of water yield in some areas, reduction of runoff or drying up in the middle and lower reaches of the river, shrinking or disappearance of the tail lake area for inland rivers, and loss of groundwater resources in the lower parts of the catchment.

Ecological effects resulting from excessive development are as follows: wetland disappearance and loss of ecological diversity, surface subsidence and seawater intrusion due to over-abstraction of groundwater, vegetation degradation, desertification, water and soil losses, and river and lake settlement resulting from the falling groundwater level.

Unreasonable development and utilization methods for water resources also result in serious environmental effects such as secondary salinization induced by moisture and salt imbalance, eutrophication of rivers and lakes by water-ammonia phosphorus imbalance, and water pollution from discharge of industrial wastewater and sewage because of the shortage of treatment capacity for urban wastewater.

Human actions not only have long-term effects on the environment and water resources but they also have short-term effects on the water cycle. Loss of vegetation in the upper part of a catchment area accelerates surface runoff and confluence of flows, leading to increase in peak volume. Enclosing parts of lakes for land reclamation and settlement along riversides reduces the natural regulation capacity of the river. Sedimentation in river channels reduces flow capacity and reduces infiltration, heightening in-stream flood. These influences change the flooding behavior and increase flood risk. The consequences were painfully evident in the 1998 flood disaster.

1.2. Basic Features of China’s Water Resources

The basic characteristics of China’s water resources can be summarized as follows. The total volume is very large, but per capita availability is clearly below the world average. Rain coinciding with hot weather is a favorable condition for agricultural production, but distribution of rainfall varies both within and between years, so that floods and droughts are not uncommon. Overall the terrain being higher in the west and lower in the east is favorable for agricultural production, but overall there is a mismatch between water resources, population and cultivated land. Backgroundwater quality is good in most of the rivers and lakes, but grave pollution takes place in densely populated areas and the downstream stretches of rivers. Development and utilization of water resources in northern China is very high, but it does not meet the demands of socio-economic development and environmental protection. Distinct disturbance of water cycle norms have been induced by large-scale human activities, with seriously harmful consequences for sustainable utilization of water resources.

1.2.1. Total Water Resources and *Per Capita* Availability

Water resources availability per mu of cultivated land of China is 1391 m^3 which is only equivalent to 69% of the world average. The population in China now exceeds 1.24 billion, and per capita availability of water resources is 2186 m^3. Using the 1995 value, it is equivalent to 31% of the world average, ranking China in 121st position in the world. It is also equivalent to 19% of the figure for USA, 8% of Russia, 5% of Brazil and 2% of Canada. The total water resources of Japan are merely 1/5 of that of China, but their per capita availability is twice that of China (see Table 3).

Country, Region	**Total runoff**	**Population**	**Runoff per capita**	**Hierarchy of runoff per capita**	**GDP per capita**	**Cultivated Area**	**Runoff per mu**
	km^3	million	m^3		U.S.$	10^4mu	m^3
Canada	2901.0	29.46	98 462	8	19 233	68 130.0	4258
Russia	4270.0	147.81	29 048	31	2377	196 455.0	2174
Burma	1052.0	46.53	23 255	37	1623	14 310.0	7352
Bangladesh	2357.0	120.43	19 571	44	238	12 684.0	18,582

Australia	343.0	17.86	18 963	45	19 653	70 222.0	475
Indonesia	2986.0	197.59	15 254	49	992	25 695.0	11 620
USA	3056.0	263.25	11 609	56	27 555	278 613.0	1097
Czech	58.2	10.30	5653	77	4621	4714.5	1234
Philippines	323.0	67.58	4779	86	1077	8280.0	3901
Japan	547.0	125.20	4373	90	37 337	5955.0	9186
Mexico	357.4	93.67	3815	93	2149	38 550.0	927
France	198.0	57.98	3415	97	27 037	27 465.0	721
Pakistan	468.0	140.50	3331	99	388	31 575.0	1482
Thailand	179.0	58.79	3045	105	2810	25 627.5	698
China	2711.5	1211.21	2239	121	578	208 900.0	1298
India	2085.0	927.04	2228	122	337	249 150.0	837
Germany	171.0	81.59	2096	123	29 652	17 752.5	963
S-Korea	66.1	45.00	1469	132	10 078	2680.5	2466
Poland	56.2	38.59	1464	133	3001	21 315.0	264
U.K	71.0	58.82	1219	136	18 324	8892.0	798
Egypt	58.1	62.93	923	141	961	4225.5	1375
Singapore	0.6	2.85	211	151	30 000	1.5	40,000

Table 3. Statistics on social, economic and water resources for selected countries of the world (year 1995)

It is clear from the Table that China's water resources are seriously deficient as regards per capita and per cultivated land availability. Water resources have become one of the rarest natural resources for sustainable development in twenty-first century China. See Table 4 for data concerning the nine level one river basins in China.

	Population	**Surface water resources**	**Ground water resources**	**Total water resources**	**Water resources per capita**	**Water resources per mu**	**GDP per capita**	**Irrigation area per capita**
	million	km^3	km^3	km^3	1000 m^3	m^3	US$	mu
Whole Country	1172.67	2711.5	828.8	2812.4	2398	1442	578	0.64
Liao R. B.	113.17	165.3	62.5	192.9	1704	490	679	0.56
Hailuan R.B.	117.63	28.8	26.5	42.1	358	192	649	0.87
Yellow R.B.	190.46	66.1	40.6	74.4	390	251	489	0.74
Huai R.B.	99.22	74.1	39.3	96.1	969	383	486	0.69
Yangtze R.B.	402.53	951.3	246.4	961.3	2388	2071	550	0.53
Pearl R.B.	141.51	468.5	111.6	470.8	3327	3589	663	0.45
Southeast R.B.	65.07	255.7	61.3	259.2	3983	5327	779	0.46
Southwest R.B.	18.34	585.3	154.4	585.3	31 914	17 114	287	0.50
Inland R.B.	24.74	116.4	86.2	130.4	5270	1178	487	2.27

Note: Data of GDP per capita is 1997, the remaining data is 1993.

Table 4. Statistics of water resources availability per capita and per mu for nine Level One river basins in China

1.2.2. Water Resources Temporal and Spatial Distribution

Water resources in China vary greatly between and within years. The ratio of maximum to minimum flow for the middle-sized rivers in the south of the Yangtze basin is below 5, and it is over 10 in northern China. Various phenomena occur as a result of annual variation in runoff, e.g. the alternating appearance of wet years, normal years and dry years, periods of water abundance and low water periods that might last for several years. More extreme variation results in the frequent appearance of drought and flood disasters, which can have disastrous consequences for people's living and productivity, also intensify the difficulties of water resources regulation and utilization.

The distribution of precipitation is also uneven within a year. Maximum runoff in four consecutive months accounts for 60% of the total runoff in a year, usually appearing from April to July in middle-sized rivers to Yangzte River in the south, over 80% from June to September in the north of China, and 90% in some places,especially in Hai River Plain. In the south-west of China 60-70% of the annual precipitation frequently falls from June to September or from July to October. In spring in the north of China, there is a significant mismatch between the shortage of water, because of the small quantity of river runoff, and the large quantity of water needed for irrigating crops.

It is clear from Table 4, that water resources are comparatively abundant in the south, but much less so in the north, with a great gap between the two. The catchment areas of the Yangtze River and the river systems to its south account for 36.5% of the total areas of China, but the water resources in those areas account for 80.9% of the national total. The catchment areas of the northwest constitute one third of the whole country, but its water resources only make up 4.6% of national total. In terms of area, the water resources of individual river basins in the north are well below the general level of the country. For instance, water resources of the Hailuan River Basin are equivalent to 1/2 of average of whole country, and those of Yellow River are even less than 1/3.

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Biographical Sketches

Professor Hao. WANG, general engineer of Department of Water Resources (DWR) of China Institute of Water Resources and Hydropower Research (CIWHR), graduated from Tsinghua University with a Ph.D.
He has been engaged in research into water resources planning, water energy planning, and macro-economic analysis for many years. He established the theory of rational allocation for water resources, with colleagues. He acted as general director and chief expert in many projects such as 'Water Resources Sustainable Development and Environmental Protection in North-west China (State-key Project in the Ninth Five-year Plan, Ministry of Science and Technology of PRC (MST))', 'Water Resources Evolution Rules and Reproducibility Mechanism for the Yellow River (State-key Project in the Ninth Five-year Plan, MST)', 'Water Management in North China (State-key Project in the eighth Five-year Plan, MST)', 'Strategic Options for Water Resources Sustainable Development of China in the Twenty-first Century'(Ministry of Water Resources (MWR)), 'Expert System for Mixed Utility Generator Scheduling (Ministry of Energy Industry(MEI))', etc.

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