DEVELOPMENT OF SUSTAINABLE WATER MANAGEMENT
IN BEIJING, CHINA

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ABSTRACT

This is a review paper of sustainable water management of Beijing, the capital of China. Its critical, water-related crisis is described, including both of water scarcity and the risk of flooding. Under the guide of the general principle to consider the population, resources, environment and development as an unity for sustainable development, a number of strategies and measures are taken or being implemented. Authors, in this paper, focus on those measures water-related, ranging from long distance water supply compensation measure, further developing and protecting local surface and ground water resources, promoting re-use of water resources and executing water saving measures and the measures to make use of storm water. Meanwhile, the flood mitigation measures are taken, too. In addition, some of the non-structural measures as strengthening water legislation, increasing the accuracy of monitoring and improving information and communication system as well as educating people are addressed and discussed.

KEYWORDS

Drought and flood mitigation; structural and managerial measures; sustainable development; water resources application and protection.

INTRODUCTION

Water is the source of life. The slogan of the International Decade for Natural Disaster Reduction (1990-2000) "Water: Too Much...Too Little...Leading Cause of Natural Disasters" has been warning us for ten years. However, the cruel fact is that people in different regions over the world are suffering from water-related disasters, either droughts or floods, or both of them, and the consequences are famine, diseases, death, and large economic losses (Blaikie & Cannon etc. 1994) as well as the inconvenience caused for daily life. Particularly in developing countries, urban areas are expanding at a too fast speed with which natural resources in cities cannot sustain them. City centers become more densely populated and highly developed. Moreover, urbanization not only changes the way people live and the infrastructure they use, but also affects the eco- and hydro-environments to a large extent. The deteriorated environment is amplifying the challenges of future generations to cope with these problems. The most two obvious negative effects of fast urbanization are more severe crises due to water scarcity and increased risk of flooding.

Beijing is the capital of China. Economic reform has promoted a significant change in this major city. Population has grown from 2 million in 1949 up to 12.5 million in 1998. The area of the city center will soon reach 1040 km$^2$, while it was less than 100 km$^2$ in 1949, and the gross national product value increased by 1762% during the last twenty years. The available total water resources, however, are limited to about 4 billion m$^3$, which means that the available water resources per capita today are merely some 300 m$^3$. The availability of water mainly relies on precipitation and ground water in this
area. Unfortunately the weather is dry and annual rainfall has been lower than the mean value in recent years, the level of ground water is declining because of the unlimited consumption. (PWDUAB, 1999; BMSB, 1999).

On the other hand, urbanization has great influence on the rainfall-runoff process. The runoff coefficient is becoming larger due to the increase of impervious areas. Consequently flood peaks become larger and occur quicker, and the total flood volumes increase as flood occurs. Regarding its current rate of urbanization and development, it is inevitable that the risk of flooding is increasing in Beijing.

Based on above water related problems, the authors, in this paper, emphasize on following solutions: how can the limited water resources be used properly; where and how can qualified water be made available for domestic, municipal, agricultural and industrial consumption; and how flood risk could be reduced and flood damage mitigated.

GENERAL SITUATION OF WATER RESOURCES AND ITS CURRENT STATUS OF BEIJING

Beijing is located in the Haihe river basin, which consists of five main rivers: Jiyunhe river, Chaobaihe river, Beiyunhe river, Yongdinghe river and Daqinghe river. Among them, Beiyunhe river originates in Beijing territory, while the others have their origins in Hebei province, Shanxi province and in the Inner Mongolia Autonomous region, respectively (Fig.1).

![Fig.1 Demonstration Map of Water Systems of Beijing](image)

Within the border of Beijing Municipality, the annual average precipitation is 595 mm and the total annual average precipitation volume is 9.996 billion m³. Due to the impacts of atmospheric, geographic and topographic characteristics, the precipitation is not homogeneously distributed with time and space. The lowest annual precipitation is 242 mm, and the highest is 1406 mm according to the historical records. The continuously dry and wet periods have an average of 2-3 years. The longest observed wet and dry periods are 6 years and 9 years respectively. 80% of the annual precipitation occurs in the wet season from June to September, consequently floods can be easily triggered during these periods; whereas in the dry season, water shortage occurs frequently and seriously due to limited rainfall and large water consumption (Hao & Liu, 2000; PSAWR, 1999). In short, the hydrological and climatic characteristics of Beijing are 90% drought in spring and rainy in summer, possibly accompanied by storm floods and mud-rock due to its hilly topography.

The available water resources consist of surface water and groundwater, which are 1.5 and 2.633 billion m³ respectively and together up to 4.133 billion m³. However, as precipitation has been lower
than the annual mean in recent years and the big needs in upstream regions for their economic development, therefore the inflows to the two main reservoirs, Guanting and Miyun, are reducing. Meanwhile, in order to meet the needs of municipal, industrial and agricultural water consumption, groundwater is over-used, and its water level is rapidly decreasing and its quality deteriorating due to pollution. As a result, the balance of available water resources, environment and economic development is broken.

As described above, surface water resources are declining due to extended drought and increasing consumption. At the same time, the ground water is being over-used. According to the water consumption and the available water resources, it is estimated that the water shortage will be 0.794 billion m$^3$ in normal year, and 1.28 billion m$^3$ in a dry year until 2005. If the current trend continues these figures will be 1.182 and 1.641 billion m$^3$ respectively in 2010 (Hao, C.Y., 1999; PSAWR, 1999). Therefore, it is a rigorous challenge to settle down the shortage of water resources of Beijing in early 21st century.

MEASURES OF SOLVING THE SHORTAGE OF WATER RESOURCES

In order to meet the requirements of water consumption and to guarantee sustainable economic development in Beijing, a master plan for sustainable application of water resources in the early 21st century has been adopted. In this plan, three main types of measures are embraced: structural, managerial and emergency measures. Structural measures include development and protection of water resources, water re-use and water saving. Management measures consist of targets and schemes of reforming the current management system, amending laws and regulations and corresponding water related policies. Emergency measures are the strategies and actions of distributing water properly during extremely dry years. At the same time, the measures to improve water quality are implemented, too.

In following part, the structural measures are focused.

**Water Supply Compensation Measures**

The South-to-North Water Transfer Project is regarded as the primary and long-term measure to relief the shortage of water in Northern China. According to the plan of the middle route project, 0.705 billion m$^3$ will be provided in a dry year and 1.2 billion m$^3$ in an average year (IPSNWT, 1995). However, this project with huge investment and a long construction term is still in discussion. Consequently, other short-term and local compensative measures must be taken into account and executed before the water transfer project will put into operation.

**Further Developing and Protecting Local Surface and Ground Water Resources**

According to the measurement records from 1961 to 1997, there were 1.16 billion m$^3$ of water per year flowing out of the Beijing territory. In addition, the 70% catchment is controlled by reservoirs, while the remaining 30% still out of control. Moreover, the Jumahe River, one of the five main rivers, is not controlled at all. Ground water might be over-used cautiously in emergency situations. These resources can be developed for further use. The corresponding measures are:

- Intercepting runoff in hilly areas;
- Controlling flow in rivers for irrigation;
- Building auxiliary water resources for emergency conditions, i.e. applying ground water properly in extremely drought conditions;
- Removing sediments and improving the water quality in reservoirs.

Regarding to above strategies, 220 intercepting works are planned; 11 rubber dams will be built along the rivers and 42 wells be drilled as emergency water resources. After the implementing of these
structural measures, an extra 135.5 mio. m$^3$ of storage volume will be available. Additional 30 mio m$^3$ in the Guanting reservoir will be available after removing the sediments. This volume can be used to regulate the local runoff and the flows from upstream.

Besides, the rules of prohibiting sailing and trip around the reservoir areas had been mandated some years ago.

**Promoting Re-Use of Water Resources**

With above planned river controlling-irrigating works, a target of 142 mio m$^3$ re-use water for agricultural irrigation will be available. If this target can be achieved, the water discharge from the two main reservoirs, Guanting and Miyun, for agricultural irrigation can be reduced by 1750 mio m$^3$. At the same time, the consumption of ground water can be decreased by 40 mio m$^3$ and the operation of 1000 groundwater wells be stopped.

The drainage from urban areas can be collected up to 2.45 million m$^3$ per day. It is estimated that 0.9 billion m$^3$ of clean water can be saved per year, if the part of drainage can be used after being treated properly.

**Executing Water Saving Measures**

Four types of water saving measures are taken account of, the domestic, industrial, agricultural and municipal ones.

Domestic water saving measurements are carried out by restricting water consumption in combination with increasing the price of water, promoting the installation of water saving facilities, such as water saving toilets and showers. Industrial water saving is executed by reforming the industrial structures, reducing the excessive use of water, applying techniques of water saving and promoting using water saving facilities. Meanwhile agricultural water consumption can be controlled by applying water saving irrigating techniques and developing agricultural plants of water saving etc. In addition, municipal water consumption will be reduced by 2.3 mio m$^3$ per year via re-using water to irrigate gardens and green lands, wash city streets and other municipal utilities.

**Storm Water Application**

Rainfall is one of the two main water resources in Beijing. In order to make full use of the available resources, extensive measures of water collection are planned and are being implemented in urban, plain and mountainous areas. A pond with a capacity of 5 mio m$^3$ will be built in a western suburb of Beijing. In addition, pervious roads, parking places and squares, infiltration wells for roofs and surfaces will be constructed. Green lands will be increased to detain rainfall and to compensate ground water. Moreover, enlarging river channels, maintaining water gates and rubber dams as well as improving lakes and tanks in plain areas in combination with constructing, expanding and strengthening reservoirs in mountain areas are being carried out simultaneously.

**MEASURES OF FLOODS MITIGATION**

There has been no severe flood occurring in Beijing since 1963. Consequently it is easily off their guards for governments, authorities and the public, especially in continuous drought years. As sudden floods can occur any time, flood mitigation measures have to be taken into account. According to the master plan of water drainage of urban areas of Beijing (PWDUAB, 1999), following structural and non-structural measures are prepared:

- Controlling floods from the Guanting gorge by constructing the Yongding river detention reservoirs;
－ Carrying out the general principles and plans of floods control in the urban areas;
－ Increasing the accuracy of monitoring and the standards of flood control works;
－ Improving the municipal flood control communication and information system;
－ Ensuring the availability of physical and mental resources, the collaboration of the public and other social service systems.

The Yongdinghe River Detention Reservoir with a total storage capacity of 44.8 mio m$^3$ situates in the right flood plain. It will function together with the Lugou Bridge key flood diversion project. While the Yongdinghe River encountered the flood of 1%, a flow of 2500 m$^3$/s can be retained by the Lugou Bridge key flood diversion project and excess water can be impounded in the detention reservoir so that downstream safety can be ensured from the right levee's flood.

"Storing floods in the upstream western areas, intercepting flow from both of northern and southern areas and then draining them away in the downstream eastern areas" is the general principle of dispatching floods in urban areas of Beijing. The pond being built in the western suburb will control floods from the upstream 81 km$^2$ catchment and preventing floods from entering urban areas. Draining flood in downstream eastern channel will be beneficial to the city’s drainage. The concrete measures include increasing the sewer coverage rate from 50% to 90%, and raising the flood control standards of the main drainage channel from 2% to 1%. Intercepting flow in the southern and northern areas will be achieved by expanding the previous floodway and building a new lake flood diversion project. In addition, a series of other measures to reduce the surface runoff and recharge the ground water in the wet season, such as increasing green land areas, constructing pervious surfaces and collecting roof runoff, will be put into action step by step.

CONCLUSION AND DISCUSSIONS

The severe water crisis in Beijing teaches us a lesson. Its experiences and the necessary measures to overcome the crisis can be valuable to the other countries and areas with similar problems. At present, the Central Government, the Ministry of Water Resources, Beijing Municipality and the relevant Departments are paying full attention and making great efforts to settle down the problems by taking internal and external, long term and emergency measures. The general and primary principle for development in the 21$^{st}$ century is to consider population, resources, environment and development as a unity. This is apparently a sustainable development strategy. The whole country is taking actions to regulate their policies and tasks towards this main goal.

Beijing is a large city with developed industry and agriculture. Therefore, water saving and water protection has to rely on these two main users. The goals are achieved by reforming production structures, avoiding repeating production; assembling water saving techniques and facilities; and promoting water re-using. Auxiliary measures are taken by controlling domestic and municipal water consumption.

In addition to the physical measures, it is crucial to carry out the laws of protecting water resources and the water environment, the law of floods control and the law of water and soil conservation. It is also essential to educate the publics not only to be able to cope with emergency situations caused by water scarcity and floods, but also to keep the awareness for saving water and protecting water in their daily life.
REFERENCES


Beijing, the capital of China, is characterized by intense water scarcity during the long dry season as well as heavy flooding during the brief wet season. Beijing is one of the most water-scarce cities in the world. Total water use is 3.6 billion cubic meters, compared to renewable fresh water resources of about 3 billion cubic meters. The difference is made up by the overexploitation of groundwater. Two-thirds of the water supply comes from groundwater, one third from surface water. Average rainfall Since 1998, the Chinese government has, in line with the requirements of sustainable development, summarized experiences in water management and pioneered modern practices in water conservation. In particular, it has crafted a strategy that meets China’s national conditions particularly those in water conservation and the requirements of the times: - Human-centered and promoting harmony between man and nature. A new philosophy for water management in the new era has been put forward to coordinate the development and preservation of water resource, in particular the coordination and reasonable allocation of water resource for residential, industrial and ecological purposes. The idea of. 10. The study proposes that a water demand management strategy, based on demand control and quota management, could be a better option for sustainable water management in China. An example of the Haihe River Basin is provided to show the success of water demand management using total demand control and quota management. It can be expected that through the encouragement of a water conserving society, by water demand management, it is possible to harmonize the relationship among water, the environment, ecosystems, and human beings in China. This is a preview of subscription content, access via your To its credit, China is focusing on sustainable development at a point when its per capita output is barely more than one-third the level in the so-called advanced economies. A relatively poor country has made a conscious choice to shift its focus from the quantity of economic growth to its quality. Consistent with this dramatic structural transformation, China has been aggressive in shifting the mix of its fuel consumption away from carbon-intensive coal to oil, natural gas, hydro, and renewables. The Xiong’an New Area, planned as a subsidiary center south of Beijing, is particularly noteworthy in this regard, as is the existing Sino-Singapore Tianjin Eco-city and Hainan’s recently announced plan to shift to all clean-energy vehicles.