Urban Water Resources Quota Management: The Core Strategy for Water Demand Management in China

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Received: 19 November 2008 / Revised: 19 June 2010 / Accepted: 30 June 2010 / Published online: 28 July 2010

Abstract Since China has the largest population in the world, the available water resources per capita in China are very limited. With the rapid economic development that is currently occurring, the shortage of water resources at the national level has become extremely critical. How to solve the problems due to water scarcity and water pollution has received increasing attention from the Chinese government and various communities. In order to provide a sustainable development environment for 1.6 billion people in the future, the whole country has started to reform urban water resources management systems in terms of related policies, regulations, methodologies, and technologies focusing on improving the efficiency and effectiveness in water use. Urban water quota management has now become a core strategy in developing a water resources governance model for water demand management aiming at establishing a water-saving society. This paper introduces the main stages and the processes of implementing water quota management in China, analyzes the basic principles, and expounds the elements, information foundation, core module and operational model of the urban water quota management system. It has been demonstrated that urban water quota management has made some remarkable contribution not only in transforming the pattern of water mode and strengthening water management enforcement but also in integrating various management methods in saving water and preventing pollution.

Keywords Water demand management · Urbanization · Water quota management · China

INTRODUCTION

The per-capita share of water resources in China is relatively low, only 27% of the world average, and the

geographical distribution of water is extremely uneven across the country (Chen et al. 2002). Since the reform and the opening of China, the rapid economic growth and urbanization that is occurring has caused increased water demand in China's urban areas (Fu et al. 2006). Poor water supply management, low water use efficiency, and inadequate sewage treatment and discharge have further exacerbated water shortage in urban areas. The average water deficit per year in China is as high as 6 billion m³ and the discharge of raw sewage has caused more than 90% of urban water being polluted. More than 400 out of 660 cities in China are facing water shortages, 100 of which have reached a critical state. This reality has increased the pressure on water conservation institutions and water resource planners to take appropriate measures. The society as a whole is now paying more attention to water resources, and how the limited water resources in urban areas could be better managed has become a hot topic recently in China (Hong 1997).

The water shortage crisis frequently happening throughout the country has attracted the attention of the central Chinese government as well. As a basic national policy of "Building a resource preservative and environmental friendly society", resource conservation has become more important than ever before. The government has clearly stated that "The sustainable use of water resources is of strategic importance for the economic and social development of China, the essence of which is to improve the efficiency of water use, and to give prime importance to water-saving activities." Under the guidance of national policies and the influence of the latest international concept of "water governance" (United Nations/World Water Assessment Programme 2003), the Department of Water Administration of China has begun implementing urban water quota management on a nationwide

scale (water-use sectors) in an attempt to change the ineffective and traditional water-management techniques, and to help extend and enrich the theories and practice of urban water demand management (Haddad and Lindner 2001; Schachtschneider 2002; Dirksen 2002; Bernhardt et al. 2000; Maksimovic and Tejada-Guibert 2001; Baumann et al. 1997).

Facing the common problems of urban water resources, research of water demand management in the world has mainly focused on water-saving techniques, price systems, forecasting and planning, and the trading of water rights, etc. Although the concept of sustainable integrated water resources management has been widely accepted, based on the specific circumstances, different countries have different technology programs and management regulations to carry out. In the industrialized countries of Europe and America, water resources are relatively rich. Combined with a high level of development and utilization of water resources and the economic system, optimal allocation of water resources is on the basis of water rights management and the market economy. Having an extreme water shortage problem, Israel developed water quotas for local residents decades ago. In addition, several countries such as Russia, Iran, and South Africa, have the specific management instruments, which shows the prototype of water quota management. Besides this, few countries have designed a system of overall water quota management practices.

China's urban water quota management is an integrated management system, which is led by the central and local governments with participation of the public and industrial sectors. Under the premise of limited water resources, an urban water quota management system basically takes control of the water demand side by using a water quota index system that provides the necessary legal, administrative, economic, and technological framework for carrying out rational allocation and effective control of water resources. Focusing on industrial sectors, which are the most important water use sectors in urban system, this paper systematically introduces the history of the evolving water quota management system in China, and the basic

principles and framework of a water quota management system within the context of implementing a comprehensive management program. The paper provides an in-depth analysis of the importance of comprehensive water quota management and some preliminary impacts of the water quota management system in China.

THE HISTORY AND PHASES OF IMPLEMENTATION OF WATER QUOTA MANAGEMENT IN CHINA

In the course of developing the national economy, China began to set up and formulate quotas and standards on material consumption when the Central Technical Authority of China established the Standards and Specification Department in 1949. However, since at the time there was sufficient water resources available compared to material demand (such as oil and food), water was not considered for inclusion in the index system of materials consumption.

In the 1970s, some cities in northern China began to experience water shortages, and in order to address the problem, engineering measures were adopted to increase the water supply (Liang et al. 2003). In the meantime, the state introduced water-conservation measures, but these were only carried out as the auxiliary measures. When the shortage of fresh water became more critical, the government began to attach more importance on water conservation (Qian et al. 2002). The Water Law of the People's Republic of China, which was issued in 1998, explicitly stipulates that "the state shall exercise planned allocation and practice strict water conservation." This indicates that the major focus of the state's water management approach averted to the demand side (Butler and Memon 2006). Figure 1 shows water supply–demand management countermeasures implemented in China from 1950 to 2000.

The establishment and implementation of this system aims at achieving a positive effect for reducing water use and improving water-use efficiency. However, since water planning targets are based on the water use in the previous

Fig. 1 Water supply–demand management countermeasures in China from 1950 to 2000

year, and are regulated on the actual water quantity, a lack of rationality and fairness has gradually become obvious (Jiang and Chen 2007). According to the reality of serious water shortage, the old-model of management needs to make change. The revolution makes the water planning and saving measures adopt the normalized and scientific administrative means. As a substitute for making up the deficiency, water quota management has become a major approach in developing a successful water supply plan.

Water quota management was first introduced in the early 1980s in northern China. Although the standardized management for water started later compared to other resources, quota management methods for other materials (budgets, logistics, and business and administration systems) provided a solid foundation for the application of quota management to water resources. In addition, the central and local governmental organization systems developed previously for hydrologic management, and the effectively working-relationships among the different levels of government organizations for planning, consulting, and supervising, have created a conducive environment for the integrated policies of supply-and-demand control in the entire nation.

Phase 1: Background of the Water Quota System

In 1984, the State Economic Commission and Ministry of Construction of China developed water quotas for 14 industries, such as metallurgy, coal mining, petroleum, etc. From 1986 to 1998, industrial water use grew rapidly, and the water use in five key industries (thermal power, textiles, petrochemicals, metallurgy, and paper) reached 50 billion m³, about 50% of the total water use in all industries (Department for Environment and Comprehensive Utilization of Resources of State Development and Reform Commission 2003). The water quotas for industry that were established in 1984 have helped industries tremendously to get a clear picture of water use and water conservation. With improvements in technology, and the introduction of new water-saving equipment for high-water-consumption industries, the quantity of water use per unit product is now significantly lower than the original quota standards. Much experience has been gained from water quota system development in key industries. In the same period, improvement in living standards caused the proportion of the domestic water use to increase each year (Department for Environment and Comprehensive Utilization of Resources of State Development and Reform Commission 2003). The Ministry of Water Resources extended water quotas from key industries to most other industries when it issued the notice titled “Pertaining to the strengthened preparation and management of water quotas”, which requested that all provinces, autonomous regions, and

municipalities complete and prepare water quotas for the main industries and other sectors regarding water use before 2001 in their respective regions (Ministry of Water Resources 1999). From this point on, water quota system development began to shift to general industries, commercial enterprises, as well as public services. Establishing a scientific and justified system of water quotas is the first step towards implementing water demand management (Mohamed and Savenije 2000). Based on this system, methods and procedures were then summarized from the implementing process. During the process of amending, supplementing, and applying to other industries, rich experiences have been accumulated, which also provided a broader space for further research and exploration.

Phase 2: Establishment of a Nationwide Water Quota Management System

Article 47 of the “Water Law of the People’s Republic of China”, amended in 2002, stipulates that: the state shall exercise systems of unified total amount control and water quota management. The law requires that the relevant departments of all provinces, autonomous regions, and municipalities directly under the central government are directly responsible for preparing of industrial water quotas within their respective administrative areas. Water quota plans have been submitted by various administrative regions in the entire country to the Water Administrative Departments and Quality Inspection Administrative Departments at the corresponding level for approval, and then recorded by the State Council Water Conservation Administrative Department. Since then, water quota management has been established legally, and a water demand management system involving the whole country and various administrative regions, from river basins to regions, has been unveiled.

In order to resolve the technical problems of water quota preparation in terms and definitions, indices and procedures, in 2002 the state issued a series of national standards of water quotas for industrial products. At present, most regions have prepared a water quota management system in accordance with their local natural and socio-economic conditions. In the course of quota preparation, behaviors and structures of water use have been analyzed, water quantities have been measured, and these supplement and improve the quota system, and finally lead to the establishment of water quotas for the various industries and sectors. On the basis of quotas, water users were evaluated and assessed, spurring enterprises to carry out rational utilization and water-saving management. According to the national statistics, 26 provinces/regions and nine municipalities have prepared industrial water quotas concerning more than 2,000 products in over 400 categories. Among

them, eight provinces and regions (Jiangxi, Inner Mongolian Autonomous region, Liaoning, etc.) have issued local standards of water quotas.

Phase 3: Developing the Standardized Process of Water Quota Preparation for Water Quota Management

The local industrial water quotas have been prepared gradually all over the country and the problem of having no water quotas has been basically solved. As a result, local administrative offices have achieved a thorough knowledge of the local water structure and consumption levels. During this period, the reform and practice of water quota management have only just begun; the objectives were focused mostly on quota preparations, while corresponding laws, regulations, and institutional organization are still weak. Still, in most parts of the country, water quotas only serve as a recommendation or guidance, rather than as a compulsory enforcement, because of the lack of concrete schemes and strict measures.

In the beginning, there was little experience and knowledge on designing and standardizing scientifically and concretely, and it was difficult to implement a standardized quota system. The administrative departments had to continue to adopt old accounting schemes to exercise water allocation planning. Scholars and water executives suggest three areas of need for research and analysis related to water quota management: (a) provide specification and standards on key points of quotas such as form preparations,

the scope of water intake, statistics, accounting factors, and managerial practices; (b) establish the classification system of industrial quota and multi-object-oriented hierarchical management system through considering regional harmony and uniformity, and also giving due consideration to the specific condition in each area and the wide variety of products and services; and (c) set up a water quota management system, promulgate related matching policies, design a legal and administrative system, a marketing mechanism, and coordinate them on aspects of policy, economy, and society. These three areas are the premise and basis for revising and perfecting water quotas and a management system, and to proceed from recommendation and guidance to the implementation of restrictive practices and maximization of the control function of water quotas at all levels of administrative departments and all water users. There is the need for water administrative departments, water experts, and specialists to further research so as to identify a feasible management mechanism and modes of water quota.

THE SYSTEM AND PROCEDURE OF WATER QUOTA MANAGEMENT

Basic Principles

The core for implementing water quota management systems consists of a water quota index system, quantified quota indicators, definition of user's reasonable scale of

Fig. 2 The basic principles of water resources quota management

water corresponding to the accounting factors, and the quantity of demand of water based on the above quota and scale. The system will integrate regional water allocation at a macro scale with an assessment of water users at a micro scale. It also includes institutions of water-use compensation and water-withdrawal permit. As shown in Fig. 2, water quota management consists of three dimensions from macro, meso, and micro scales (Jiang et al. 2008). The targets and tasks of the different dimensions are the corresponding managerial solutions and measures to be matched.

Water quota is the standard of quantity of water intake per capita, or per area, or per product in unit time (Gu 2002). It is also a comprehensive reflection of the users' water demand and levels of water-saving and water management. The scientific and rational quota is formed through the course of investigation, analysis, calculation, and discussion with users, verification, and experts' review. Water quota has become an important indication of the rational water use in every industry, and a vital basis for administrative departments' water-planning targets, and the premise for water-savings' administration and for decision-making on economic control. Therefore, the water quotas should be flexible and adaptable to local situations (Jin et al. 2004).

Total amount control at macroscopic level and water use at microcosmic level have been combined in the system on the basis of quota. Consequently, water allocation can be optimized among different hierarchies and sectors, behaviors and actions of which in water use will be improved, improving the efficiency of water use at the microscopic level ultimately. Meanwhile, microcosmic effective use of water reacts on water resources planning and dispatching, and demand-side management will be reinforced. By doing so, it is expected that the whole country will ultimately achieve the purpose of constructing the virtuous cycle of an urban water system, taking effective control of water environment pollution and decreasing investment on building more water-conservancy projects.

In addition, it has been identified that a perfect water quota system is composed of six essential elements: (a) a multi-tiered system; (b) the category; (c) grades; (d) type of water sources; (e) accounting factors; and (f) accounting units. The selection and setting of these elements will affect the quota management's fair progression in each managerial dimension.

The Information Foundation

Water quota management is a system that was created using water data and information from various business and professional sectors. After processing, treatment, arrangement, and combination according to certain programs, the water-use data can be categorized into three basic information sources that support water quota management. These information sources include: statistical data of water-use measures; attribution data of productive operations; and statistical data of urban and industrial water use. The detailed categorization of the collected water-use data is shown in Table 1.

System Framework and Corresponding Management Methods

Architecture of Management System

As shown in Fig. 3, the water quota management system is developed on the foundation of the state's water administrative bureaucracy. Under the backdrop of water resources arresting the development of the urban economy, the supervisors of urban areas, industries, and other water users, use water quotas to carry out the longitudinal management among each hierarchy. Management tasks are assigned station by station, and available water resources are allocated through a channel by which relative information is transmitted and feedback can be received. The integrated functions of water quota management can be performed depending on coordination and connection of each administrative department so that water information can be captured and analyzed timely and accurately, and transferring the information effectively and orderly into the whole system.

Primary Contents and Methods of Management

Water quota management needs to be implemented through an institution that mainly depends on the government. In order to play a more effective role in sustainable development and utilization of water resources, and to achieve the goals in each managerial dimension; other than administrative means, law, economy, technology, and education are all major means that will assist the

Table 1 The components of the water quotas' informational foundation

Measured data	Statistical data	Attribution data
Measure of water apparatuses;	Statistics of enterprises;	Attributions of industries and sectors;
Measure of water units;	Statistics of industries;	Attributions of classes and grades in one industry;
Measure of water users	Statistics of region	Attributions of water-saving facilities;
		Other information affecting water intake

Fig. 3 The system of water quota management

Fig. 4 The content of water quota management

implementation of water quota management. In practice, government administration integrated with market and technology will enforce the implementation of water quota management. Figure 4 shows the main contents and fundamental process of the water quota management.

In the water quota management system, national and local water laws and regulations are the premise and basis for water administrative departments at various levels that exercise functions and powers representing the state and the local governments. They not only indicate the legal status of the water quota management but also provide a base for adopting administrative means. Nevertheless, it is also necessary to implement economic means. Economic leverage, like price, levies, and fines, are used to adjust the

relations between these various types of interests for regulating behaviors in water use and allocation of water resources. Enhancing the water-use efficiency and forming water-saving patterns of economic growth and consumption are the key objectives of the water quota management. As a vital component of the system, water quotas can establish incentive water saving instructions for different regions, industries and sectors, and water users, and the target of water-saving will finally be put into effect (Cao et al. 2003). In addition, the use of electronic information technology provides a reliable technical guarantee for collecting large amounts of data, analyzing water-use data, preparing rational quotas, and assessing the implementation of quotas.

PRELIMINARY EFFECTS OF THE WATER QUOTA MANAGEMENT SYSTEM

The establishment of a water resources control system—which integrates the total quantity control and quota management—is the core for establishing a water conservation society in China. Water quota management gains a full utilization in key links of water resources management, such as judging, approval, appraisal, and checking. At present, each region of China defines water use targets, adjusts industrial structures, and controls the total water withdrawal quantity and integrates the government macro-control and the user microscopic adjustment measures. It carries out the “Regulations on Administration of Water Abstraction Licensing and Collection of Water Resources Charges”, which enables the institutional constraints of water use. It attempts to overcome “the government malfunction” that universally exists in the former water management programs, and simultaneously builds a good foundation for the smooth transition to the new water control method, i.e., shifting to the market allocation of water resources.

As a country with vast territory and multi-administrative levels, China implements zonal water development and management by watershed management institutions and water administrative departments at all levels. On the city level, the administrative department for water of the local government is responsible for implementing water quota management. In this respect, Beijing is a typical and successful case.

As a typical water deficient city in northern China, the water resource problem in Beijing is the primary factor that affects and restricts the economic and social development of the city (Ruan and Wei 2004). Under the crisis of water shortage, Beijing proposed the “Regulation of Urban Water Saving in Beijing City”, which was passed by the Beijing Municipal Government Conference in early 1991 to “implement the quota management gradually in various industries and residents’ living” even before “Water Law” was made available (revision). Beijing first chose some key industries to start the exploratory stage of quota management, and then it gradually expanded quota management to all industries in the city. It coordinated related regulatory policies and gradually formed the water quota management mechanism for urban industries, in which are dependent on water resources. Based on the accumulation of many years of managerial experience, the establishment and application of urban-scale water quota management, and the widespread investigation and study, the Beijing water resources quota management ranking level is in the nationally leading position. In order to increase the power of implementation of water quota management and standardize essential factors of quota management, a series of local standards are being established and published for

various industries. This Beijing approach provides a positive and exemplary role in the application and popularization of water quota management on a national scale.

The implementation of water quota management promotes the sustainable utilization of water resources in Beijing and has resulted in a series advances in the management of water resources, such as the enhancement of water management level, the optimization of water-use structure, the adjustment of industrial structures, the coordination of society and economy water-use activities and the popularization of water-saving appliance. Clearly, this promotes the sustainable utilization of water resources in Beijing. From the water-use management perspective, not only has the quota management system been established and the regulations system improved, but the “Water Saving Method and Implementation for Beijing City” has also been worked out, and both the quota management assessed by stages and the early warning working mechanism have been established. In order to coordinate the implementation of water quota management, a three-level water-use management-supervision-inspection system of city (counties and districts)-industry-water users has been formed. A water-use management information system and a water-use information database for industries and enterprises have been established to share information between different water management departments. Many kinds of water-use education materials and water-saving propaganda materials are being developed. Based on water quotas, the implementation measures of ladder water prices are lying in research.

In terms of water quantity, the total water use of the entire city has been reducing year by year—from 4.0 billion m³ in 1997 to 3.2 billion m³ in 2006, and is now stabilized at about 3.5 billion m³. During this period, Beijing has adjusted its industry structure with tremendous changes to three-industrial structure—the proportion of the third type industry has increased rapidly while the proportion of the primary and the second industries has decreased gradually. The proportion of GDP occupied by the first, second, and third industries changed from 4.7, 40.8, and 54.5 in 1997 to 1.3, 28.7, and 70.0% in 2006, respectively. In line with the principles of developing high-tech, low-pollution, and low water-requirement industries, the three industries as well as the internal structure of industry are being adjusted, such as: publishing industry water-use quota standards, banning the entry into the marketplace of industries that consume large amounts of water, withdrawal of 27 traditional industries including shaft-kiln cement, small-scale paper industry, and so on, removing or closing down 188 high-water-consumption and pollution enterprises, e.g., Beijing Steel Corporation, coking plants, and so on. The adjustment of industrial structures caused immense changes of water use in Beijing: agricultural water use maintained a decreasing trend—

consumption fell from 1.8 billion m³ in 1997 to 1.3 billion m³ in 2006; industrial water consumption dropped from 1.1 billion m³ in 1997 to 0.62 billion m³ in 2006; and domestic water use maintained a consistent increasing trend (increased from 1.1 billion m³ in 1997 to 1.4 billion m³ in 2006). The variation of annual water use in Beijing (1997–2006) is shown in Fig. 5.

While adjusting industrial structure, the implementation of quota management is not only speeding up the development and application of new techniques of water saving, but also raising the popular rate of water-saving appliances. As shown in Fig. 6 (The variation of main index of water use in Beijing (1997–2006)), both quantity of water use per \$US 10,000 GDP and per ten thousand industrial output show a fast declining trend, while the reusing rate of industrial water use shows an ascendant trend. From 1997 to 2006, Beijing has invested in a total of 2,310 water-saving projects, with the cumulative quantity of water saving reaching 620 million m³. In the year of 2007, 160,000 sets (items) of water-saving appliances were widely applied, among which there were 100 thousand water-saving faucets, and 60 thousand sets of water-saving toilets and water tank parts. At present, the popularity of water-saving appliances in the residential areas of the city and the suburb has successfully achieved 85 and 80% respectively.

Fig. 5 The variation of annual water use in Beijing (1997–2006)

Fig. 6 The variation of main index of water use in Beijing (1997–2006)

Quota management plays a positive role of raising the efficiency of water use, promoting water savings, slowing the growth of total water use in the entire nation, and also realizing the development model in which water resources need to be taken into account. In the years between 1997 and 2006, Chinese cities developed at a frantic pace, and the Chinese economy has grown at a greater rate than any other economy (Cao et al. 2007). GDP grew at a rate over 8%. In contrast, national water use showed a stable tendency, while the quantity of water use per \$US 10,000 GDP has showed a remarkable linear decreasing tendency. That is, the quantity of water use per \$US 10,000 GDP has been reduced from 5,808 in 1997 to 2,160 m³ per \$US 10,000 in 2006 (the exchange rate is approximately 8.0 RMB/USD).

DISCUSSION AND CONCLUSIONS

Bounded by the water quotas index, the water-use efficiency of most industrial and domestic sectors has improved significantly. Affected by Chinese household registration system and differences water resource endowment in different regions, water quota index of domestic sector are quite different in different cities. Dozens of cities have been the pilot cities implementing “ladder water price” in domestic sector, following preparation of the water quotas. In order to guarantee residents’ basic water use, the benchmark of quantity and imposing ultra-scale fee are in the process of exploration. Although relative theories and practices of water quota management need to be further expanded and researched in depth (such as the study of water industry classification, and complexity of water behaviors, etc.), strengthening the governance by the local government, combined with natural and socio-economic conditions, the importance of water quota management in the whole system of water resources management is shown gradually.

As an absolutely necessary (but relatively scarce) resource for human survival and societal development, detailed research and exploration to properly control and scientifically allocate water resources on the demand side have been made across China. It establishes a pioneering management mode on efficient utilization of resources. In this process, we have accumulated a wealth of valuable practical experience, and have developed the theory and methods that provide scientific guidance on how to distribute the limited resources rationally and fairly, and on how to implement effective supervision for the distribution. From industrial sectors to agricultural sectors, urban areas to rural areas, with the development of Chinese society and economy, the mode and connotation of water quota

management will be gradually improved, and the theory of water resource management will also be expanded.

Acknowledgments This work was funded by grants from the key projects of China National “Eleventh Five-Year” science and technology supporting plan: “Research on Comprehensive water resources allocation technology of South-to-North Water Diversion” (No. 2006BAB04A16).

REFERENCES

- Baumann, D.D., J.J. Boland, and W.M. Hanemann. 1997. *Urban water demand management and planning*. New York: McGraw-Hill.
- Bernhardi, L., G.E.G. Beroggi, and M.R. Moens. 2000. Sustainable water management through flexible method management. *Water Resources Management* 14: 473–495.
- Butler, D., and F.A. Memon. 2006. *Water demand management*. New York: IWA Publishing.
- Cao, K.T., E.K. Gao, and Z.J. Wang. 2003. *Reading guidance of water law of People's Republic of China*. Beijing: China Legal Publishing House (in Chinese).
- Cao, S.X., L. Chen, and Z. Liu. 2007. Disharmony between society and environmental carrying capacity: A historical review, with an emphasis on China. *AMBIO* 36: 409–415.
- Chen, J.Q., H. Wang, and X.L. Yang. 2002. *Science of water resources*, 250 pp. Beijing: Science Press (in Chinese).
- Dirksen, W. 2002. Water management structures in Europe. *Irrigation and Drainage* 51: 199–211.
- Fu, T., M. Chang, and L.J. Zhong. 2006. *Urban water industry reform of China: Practices and case studies*, 2–7. Beijing: China Building Industry Press, 329 pp (in Chinese).
- Gu, D.F. 2002. Scientific encyclopedia of China's resources. Water Resources Section, China Water Information Website.
- Haddad, M., and K. Lindner. 2001. Sustainable water demand management versus developing new and additional water in the Middle East: A critical review. *Water Policy* 3: 143–163.
- Hong, A.L. 1997. Water resources development and protection and urban development. *Anhui Geology* 4: 44–46. (in Chinese).
- Jiang, Y.L., and Y.S. Chen. 2007. Fixed management of the water exploration of universities in Beijing. *Water and Wastewater Engineering* 6: 68–72 (in Chinese).
- Jiang, Y.L., Y.S. Chen, and J.P. He. 2008. Studies on principle of quota management of water resources. *China Water Resources* 17: 6–8 (in Chinese).
- Jin, M.H., W.J. Tang, and L.L. Qi. 2004. Water quota principle for industrial enterprises products. *China Standardization* 2: 47–49 (in Chinese).
- Liang, Y., S.K. Cheng, and Q.W. Min. 2003. Changes and the comparative study of water management models. *Soil and Water Conservation Research* 10: 35–37 (in Chinese).
- Maksimovic, C., and J.A. Tejada-Guibert. 2001. *Frontiers in urban water management: Deadlock or hope*. New York: IWA Publishing.
- Mohamed, A.S., and H.H.G. Savenije. 2000. Water demand management: Positive incentives, negative incentives or quota regulation? *Physics and Chemistry of the Earth* 25: 251–258.
- Qian, Y., C.M. Liu, and Y.S. Shao. 2002. *The water sustainable exploitation and utilization in cities of China*. Beijing: China Water Power Press (in Chinese).
- Ruan, B.Q., and C.J. Wei. 2004. *The construction of the safety guarantee system of water resources in capital region*. Beijing: Science Press (in Chinese).
- Schachtschneider, K. 2002. Building new WDM regulations for the Namibian tourism sector on factors influencing current water-management practices at the enterprise level. *Physics and Chemistry of the Earth* 27: 859–864.
- The Department for Environment, Comprehensive Utilization of Resources of State Development, Reform Commission. 2003. *The implementation guidelines for water quota national standards of industrial enterprises*. China Standard Press (in Chinese): Beijing.
- The Ministry of Water Resources. 1999. Pertaining to the strengthened preparation and management of water quotas (in Chinese).
- United Nations/World Water Assessment Programme. 2003. 1st UN World Water Development Report: Water for people, water for life. Paris: UNESCO and Berghahn Books. <http://www.unesco.org/water/wwap/wwdr>.

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