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Wastewater outlet in Baiyang town, Wanzhou County, Chongqing City, China, 2008

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Abstract

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China's water pollution control efforts are currently focusing on urban areas and industrial sectors, the main approach for wastewater treatment is by centralized facilities which usually have a treatment capacity of more then 100 thousand tons per day. This practice does have positive effect on protection of urban water environment and prevention of industrial pollutants. However, centralized wastewater treatment facilities are very expensive because of large demand on pipeline construction, and will face serious financial barrier if promoted to all urban areas of China. When comes to wastewater treatment in small towns and villages, which almost have been ignored so far in the overall national water pollution control planning of China, it is believed that the current approach is not feasible considering the current economic level of these areas.

Decentralized wastewater treatment (DWWT) is proposed as a possible solution to solve this problem considering its advantages including low construction cost and flexible technology options. This thesis discusses the feasibility and potential of DWWT to be applied in China, especially in small towns and villages, and analyzes the solutions for its promotion regarding financial barrier and managerial constraints.

The results prove the necessity to address water pollution in small towns and villages of China from the beginning of "twelfth five-year planning" (2011), as well as the feasibility of DWWT as the major approach. By combine the foreign experiences and current situation of China, the roles of different available financial channels are identified. It is recommended that local governments are the main investors on DWWT facilities, with private investment and central government support as important supplementary financial sources. Finally, the managerial aspects are discussed, to provide suggestions on the establishment of a appropriate governmental management system during the planning and promotion of DWWT systems, and to propose feasible management modes as approaches on management of DWWT from a project level.

Key words: China, Small towns, Village, Decentralized Wastewater Treatment, Financial barrier, Management

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Finally, I would like to say thanks to everyone that helped and supported me during this one year. If someday you see this but can not find your name, come to me to get my apology, I miss you all.

Abbreviation for relevant departments and organizations

MOEP	Ministry of Environmental Protection, China
MOHURD	Ministry of Housing and Urban-Rural Development, China
NDRC	National Development and Reform Commission, China
NBS	National Bureau of Statistics, China
JECES	Japan Education Center on Environment Sanitation
CCICED	China Council for International Cooperation on Environment and Development
MOWR	Ministry of Water Resource, China
JEPB	Jinhua Environmental Protection Bureau, Zhejiang Province, China
BOO	Build-Own-Operate
BOT	Build-Operate-Transfer
BOOT	Build-Own-Operate-Transfer
DBO	Design-Build-Transfer

Content

1. Introduction

The current situation in the water sector of China is similar to the developed countries in the middle of last century: Fast urbanization and economic growth led to rapid and continuous increase of wastewater discharged by both residents and industrial sectors. The installed capacity of the wastewater treatment facilities, on the other hand, was not growing fast enough.

The Chinese government has been putting efforts on water pollution control in urban areas and industrial sectors since the 1970s (Zhang, 2006); however, wastewater treatment in rural areas of China, including small towns and villages, has been paid very limited attention to so far.

Centralized wastewater treatment systems, which conventionally include complex sewage pipeline system and centralized treatment plants, are widely used in China to treat wastewater from urban residents and industrial sectors. However, this approach will face a lot of difficulties if it is promoted to rural areas of China because of e.g. lack of financial support and weakness in management.

Decentralized wastewater treatment (here after referred to as DWWT) is considered a feasible solution for domestic wastewater treatment in small towns and villages of China (Tang 2008). DWWT is a relative definition compared to centralized wastewater treatment. Smaller treatment facilities will help to reduce the demand for sewage pipeline construction, which usually takes a great part in total investment of centralized wastewater treatment projects.

There are many research programs underway to study different aspects regarding to DWWT in China, e.g. technological barriers, financial constraints and managerial aspects. This study mainly focuses on the financial and managerial aspects.

1.1. Purpose and scope

Two major issues will be faced during the development of DWWT in China. The first is financial barriers; and second is the difficulties in management of these large numbers of DWWT facilities that will be distributed in remote rural areas of China. This study aims to further study the feasibility of DWWT application in China, and provide advice to solve the above two key problems. The purposes of the study are listed below.

1 Estimate the quantity of domestic wastewater discharge in small towns and villages to indicate the significance of this part of water pollution, and define the application areas of DWWT in China.

2 Analysis on financial and major environmental issues: How to solve the financial problems in both the construction and operation of DWWT, keeping environmental

impact in mind. This analysis could be decision making support for the government, and also provide information to investors in the wastewater sector.

3 Analysis on managerial issues with regard to environmental, social and economic aspects; introduce feasible management modes (government dominant, BOT, DBO) and governmental management system.

The geographical study boundary is the nine major basin areas of China, as chosen in chapter 3. Timeline of the study is from year 2005 to 2015, the data and information of the early years are used as input to analyze and estimate the possible scenarios of the later years. It should be notice that DWWT is just one kind of approach to deal with domestic wastewater treatment in rural areas of China.

1.2. Background

An overall introduction to the current status of wastewater treatment in China is useful as a background to the study. Classified by sources, wastewater in China includes industrial wastewater, urban domestic wastewater and rural domestic wastewater. The features of each are introduced below.

1.2.1. Industrial wastewater pollution

I. High consumption of water in the industrial sector

Excessive water consumption is a serious problem in China's industrial sectors. The major reasons for this problem are inappropriate industrial structure and rough production technology. In 2005, water consumption per thousand Yuan[*] of GDP was 16.9 m^3, which was 7~8 times of the average water consumption of the developed countries. From 2000 to 2005, the total amount of annual industrial wastewater discharge increased from 19.42 billion tons to 24.31 billion tons, only dropping slightly in 2006 (MOEP China, 2006). Large amounts of industrial wastewater unsustainably increases the pressure on wastewater treatment facilities, leaving a considerable part of wastewater discharged without treatment. (MOWR China, 2006).

II. High COD (Chemical Oxygen Demand) discharge intensity

Besides high water consumptions, high output of pollutants is another problem. In China, output of water pollutants in industrial sector is measured by COD discharge intensity, which is defined as the ratio of COD discharge to GDP (COD discharge/GDP). In 2006, China's COD discharge from industrial wastewater totaled 5.42 million tons (MOEP China 2006), total industrial GDP was 10.3 trillion Yuan (NBS China, 2007), from which we know the discharge intensity on China's industrial sectors in 2006 was 0.526g/Yuan, which is much smaller than the level of 2000 (1.779g/Yuan). This improvement indicates that there was an obvious progress in China's industrial pollution reduction. However, it should be noted that 0.526g/Yuan is not a favorable number

[*] 1 USD=6.823 Yuan (2008 5 24)

compared with the level of developed countries in Europe and North America, and there is still great potential for further reduction.

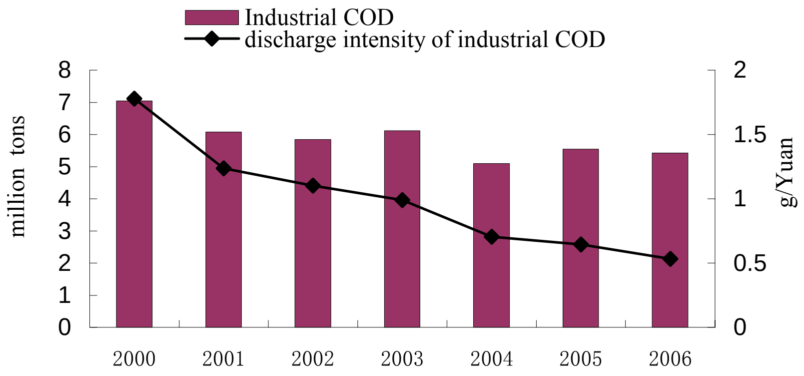

Figure 1.1. COD quantity and discharge intensity of industrial wastewater, 2006 (MOWR 2007)

The most polluting industries are paper, food, tobacco, beverage, chemical and textile, which accounted for 63.7% of total industrial COD, but only contributed 2% of total GDP (MOEP China 2005).

1.2.2. Urban domestic wastewater pollution

I. Water consumed by urban residents is constantly increasing

As a result of the increase in both urban population and individual water consumption, the quantity of domestic wastewater discharge from urban areas of China is growing rapidly. In year 2006, the total urban domestic wastewater discharge reached 29.7 billion tons, which is 34.3% higher than the year of 2000 (MOWR China, 2006).

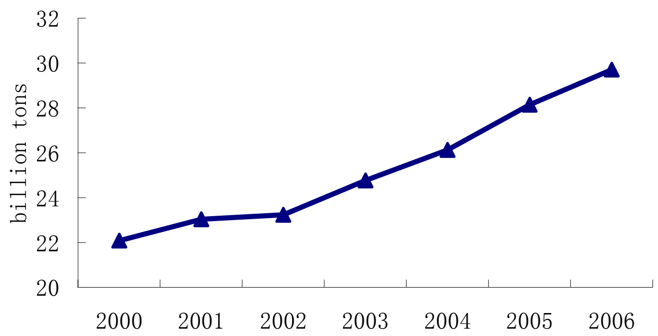

Figure 1.2. Total urban domestic wastewater discharge of China (MOWR 2007)

II. Low rate of wastewater treatment

Compared to the rapid increase of urban domestic wastewater, the treatment capacity, on the other hand, is not growing fast enough. From year 2001 to 2006, the total amount of urban domestic wastewater that received treatment increased from 4.2 billion tons to 13 billion tons, which represents an increase of 300% (MOEP China, 2006). However, based upon the low initial treatment rate, the growth in treatment capacity did not significantly reduce the quantity of domestic wastewater that is currently discharged without treatment.

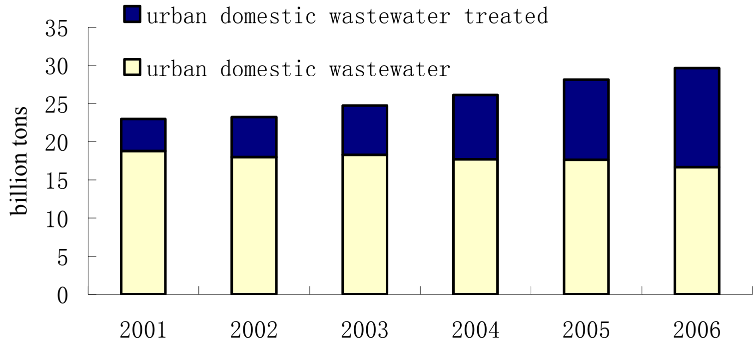

Figure 1.3. Treated and untreated urban domestic wastewater, China

Songhuajiang river basin (located in northeast China) is the most seriously affected area by low urban domestic wastewater treatment. With slow development of wastewater treatment facilities and unsatisfactory operation performance of existing facilities, even major cities in this area had a treatment rate on domestic wastewater of less than 40% in 2005 (MOEP China 2008a).

1.2.3. Wastewater pollution of rural areas.

Wastewater treatment in rural areas of China is at a very beginning stage. Based on a survey conducted by the Ministry of Housing and Urban-Rural Development (MOHURD), out of 74 villages from 43 counties and 9 provinces, 96% did not have drainage and wastewater treatment systems; and the remaining 4% just treated the wastewater by simple technologies such as septic tank. In less developed western areas of China, wastewater treatment rate in rural areas is nearly zero (MOHURD China, 2005).

Currently, national statistics regarding to wastewater treatment rate in China includes only urban areas and industrial sectors. If the contribution of rural areas, which takes more than 50% of total population in China, is taken into account, the reported wastewater treatment rate will drop dramatically.

1.2.4. Governmental attitudes towards environmental protection

There is a nation-wide consent that China should take proactive approaches before serious damages and nonreversible consequences are made by environmental pollutions. The central government is now promoting the “Scientific Concept of Development”. This slogan from the government may not mean a lot in western countries, where cabinet in the central government changes every four or five years. However, it will definitely influence the development trend of China for the next decade. Since the end of last century, China has invested a huge amount of money on environmental protection, including water pollution control.

However, the environmental protection efforts in China are currently constrained by financial barriers, and most current measures are still focusing on “End of Pipe” (EOP) approach. This implies that China is still developing its economy at the expense of the environment. When it comes to the wastewater sector, the current measure is typical “EOP” approach: Wastewater was increased by urbanization and industrialization, hence only these two parts of wastewater are included in the national water pollution statistics, and almost all wastewater treatment facilities were built in urban and industrial areas. Domestic wastewater from small towns and villages was left untreated in almost all parts of China.

2. Method

The main research contents and their relationship are illustrated in figure 2.1.

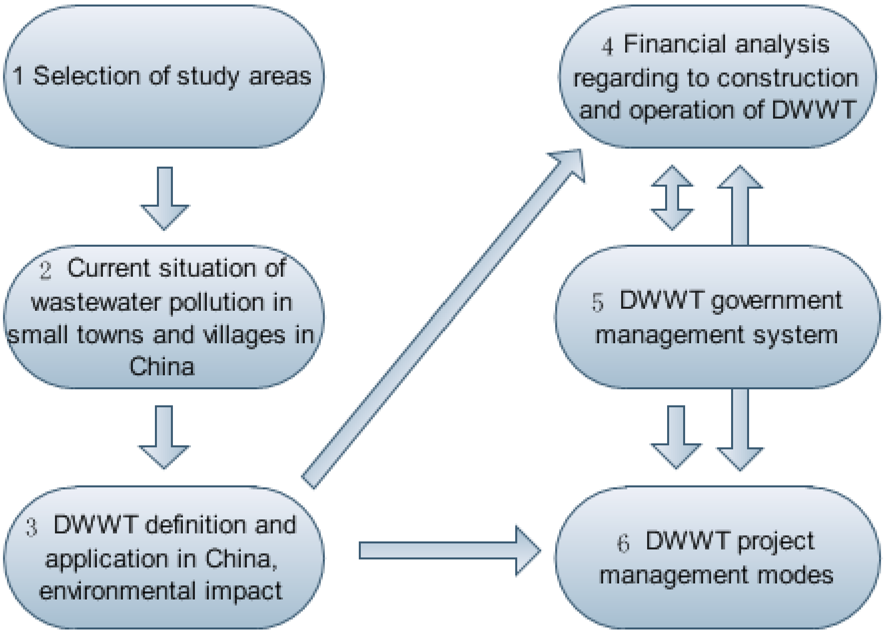

Figure 2.1. Structure of study contents

The whole study contains six parts:

1 Geographical study areas are chosen based on distribution of river and lake basin areas, as well as their importance for overall water environment of China.

2 The amount of domestic wastewater from small towns and villages in each basin area is estimated by formulas. The results are compared with national statistics for industrial sectors and urban residents, to indicate the significance of wastewater pollution in small towns and villages.

3 DWWT is introduced as a feasible option to address this problem. Since it is a relative concept ("decentralized" is defined as compared to "centralized"), the definition of DWWT in China is discussed with regard to its potential application areas in China. By combining the outputs of the previous steps, the effects on environmental improvement by implementing DWWT are estimated by the indicators of COD and NH_4-N emission.

4 Financial demands for construction of DWWT facilities in each basin area are estimated. The construction cost for unit treatment capacity is summarized from literature review of existing small scale wastewater treatment projects in China. Financial pressure is analyzed by dividing the construction cost by the total GDP during the next planning phase (2010-2015) in each basin area. Recommendations on choice of

financial channels are provided. Finally, the local residents' capacity to pay for sewage charge is discussed.

5 Beside financial issue, managerial aspect is another barrier for development of DWWT in China. Two levels of managerial issues are discussed in this study. The first is about governmental management system, that is, how to facilitate and supervise the development of DWWT in China from the perspective of the government. Several factors should be included in the discussion, including the overall planning, potential financial channels and available project modes, etc.

6 The second managerial issue is about choice of appropriate project mode, that is, how to define the roles, rights and obligations of different participators in a DWWT project. Project modes are related to the governmental management system and the potential financial channels discussed above.

The following sources of reference are cited in this research.

- Literature review

Literatures from governments and research institutes are important basis for background description, problems identification, assumptions and ratiocination of this research

- Interview of experts

Experts both inside and outside China were interviewed for their perspectives on construction and operation of DWWT.

- Conference

A conference was held in Beijing by Tsinghua University, with attendance of wastewater treatment experts, local officials and industrial representatives, to discuss the potential and obstacles for DWWT development in China.

3. Selection of study areas and basic information

During the early phase, DWWT is recommended to be developed in some selected areas rather than all parts of China, for the following reasons:

1. As explained in the background section, China is still facing serious financial barriers for construction of wastewater treatment facilities. The budget for DWWT development during the short term will be limited. This makes it difficult and unfeasible to start building DWWT facilities in all parts of China in the short term.
2. Some parts of China are still lacking wastewater treatment facilities even for urban areas and industrial sector, this part of wastewater is more centralized and more harmful to water environment and human health. Under this circumstance, construction of DWWT facilities for small towns and villages is not the first priority in the short term.
3. Large territory area and complex distribution of river and lake basins of China implies that the priorities for pollution reduction in different areas are different with regard to environmental sensitivities. Areas near major water bodies are more sensitive to pollution, and therefore have a more urgent demand for development of DWWT.
4. DWWT is a relatively new approach for water pollution control in China. Its feasibility has only been discussed by foreign experience and theoretical study. It is necessary to apply this technology in certain areas as experimental projects, to further prove its feasibility and also to provide examples and experiences for further promotion.

Selection of study areas is based on the background of China's overall water control planning. China's "eleventh five-year planning (2005-2010)" focused water pollution control on eleven major basin areas. Those are *Huaihe river, Haihe river, Liaohe river, Songhuajiang river, Sanxia reservoir and upper reaches, Huanghe river and middle&upper reaches, Zhujiang river, East line of South-to-North water diversion*[1], *Taihu lake, Dianchi lake* and *Chaohu lake*. These basin areas account for only 39% of China's territory, but 63% of population, 66% of GDP, 48% of water resource distribution and 76% of wastewater discharge of the whole country (Qi, 2007). If water pollution in these major basin areas is controlled properly, the overall quality of China's water environment will be noticeably improved. Therefore, the study area should be chosen among these major basins.

1 a special area defined by the government, to ensure water quality of the South-to-North water diversion project

The planning of Zhujiang river basin had not been released by the end of this study, hence basic information for this area is not available; The East line of South-to-North water diversion is not an independent area, but contained in other basins. For these reasons, these two areas are not included.

Based on the information above, nine of the areas mentioned will be included in this study. The geographical distribution of the chosen basin areas and their basic information are shown in figure 3.1 below.

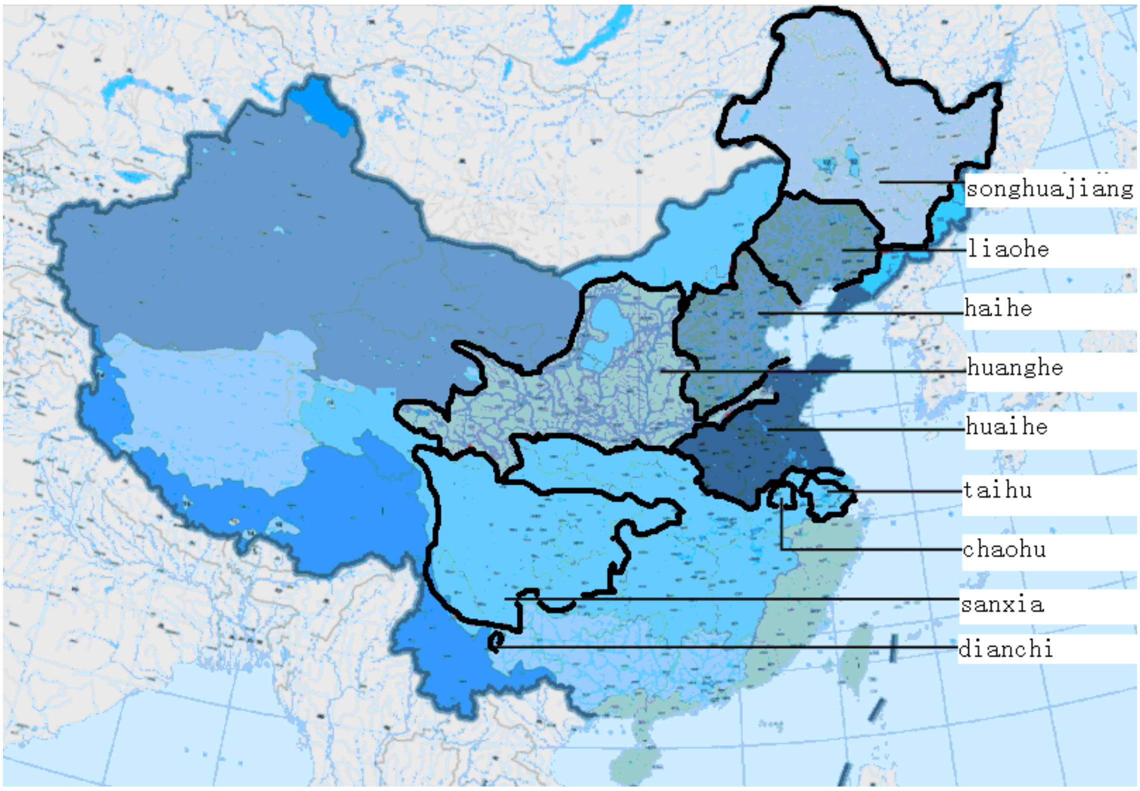

Figure 3.1. Distribution of the chosen basin areas

Table 3.1. Basic information of the chosen basin areas 2006

Name of Basin area	*Population (million)*	*Area (thousand km^2)*	*GDP Billion Yuan*	*GDP per capita (Yuan)*
Haihe	130	320	2300	17692.3
Huaihe	170	270	1600	9411.8
Liaohe	35	219.6	600	17142.9
Taihu lake	45	36.9	2122.1	46814.5
Dianchi lake	3.32	2.92	84.4	25439.8
Chaohu lake	8.64	13.5	109.3	12650.5
Huanghe	110	734	1500	13636.4
Songhuajiang	62	556.8	700	11290.3
Sanxia reservior	159	793	781.2	4913.2

4. Current situation of domestic wastewater in small towns and villages

Formulas are used to estimate the quantity of domestic wastewater. Input data to the models are mainly from statistics published by ministerial level departments and National Bureau of Statistics of China.

4.1. Introduction of the models for wastewater estimation

Theoretically, there are two ways to estimate the domestic wastewater in small towns and villages.

1. To estimate from governmental statistics of water supply,

2. To estimate based on population and individual water consumption.

The first method is not feasible due to complexity and difficulties on access of data: There is no official statistics for water supply in small towns and villages; and the charge policy on water supply is not well established. For these reasons, it is very difficult to estimate the amount of domestic wastewater based on water supply. What makes this more complicated is that there are many rural residents getting water from self-constructed wells, and there are no available data on construction and operation of these wells.

Compared to the first method, the second is more feasible due to easy access of data. Moreover, it is a widely used method in research related to pollutant estimation in rural areas of China. Therefore, the second method is chosen for this study.

Formulas are established as below.

The first model aims to estimate the total amount of water pollutants discharge based on population, daily water consumption of residents and quality of wastewater in small towns and villages of the nine basin areas. The results are used to indicate the significance of this part of wastewater in the overall water pollution of China.

After that, the total amount of domestic wastewater discharge from small towns and villages at year 2011 is estimated by considering population growth and improvement on water supply condition, to provide basis for further research on DWWT application.

$$N_k = \sum_{i=1}^{2}[TP_i \times R_i \times WU_i + TP_i \times (1 - R_i) \times WUN_i] \times 365 \times C_k \times \alpha \div 10^9 \quad (1)$$

$$TW = \sum_{i=1}^{2} TPF_i \times WU_i \times \alpha / 1000 \quad (2)$$

In which

Nk——total emission of pollutant k, kilo tons (k_1: COD k_2: NH_4-N)

TW—— total domestic wastewater emission from small towns and villages in the year

2011, kilo tons/day

TP_i—— population of area i, thousand persons (i_1:small towns i_2:villages)

R_i—— proportion of population served by officially built water supply facility in area i, %

WU_i—— individual water consumption of residents with officially built water supply facility in area i, L/d

WUN_i—— individual water consumption of residents without officially built water supply facility in area i, L/d

C_k—— concentration of pollutant k in domestic wastewater, mg/L

α—— ratio between amount of wastewater discharge and water consumption

TPF_i—— population of area i in 2011, thousand persons

$$TPF_i = TP_i \times (1+IR)^6 \qquad (3)$$

in which

IR—— average population growth rate, %

4.2. Input to the models

Two sets of population are considered in each basin area. First is small town, and second is village.

Population of each basin area can be found in "*Eleventh Five-year Planning for Water Pollution Control*". The village population (TP_2) can be estimated by multiply the total population with the percentage of village population of each basin area (MOEP China, 2008).

The population of small towns (TP_1) is difficult to estimate: Official statistics on small town population is only available on provincial level rather than basin area. It will be a quite time consuming process to get information of all towns (about 20000 towns) for every basin area. Therefore, a compromised method is used for this study: The population ratio between small towns and villages in each basin area is calculated based on the data from *Statistic Yearbook for City and Countryside Development of China* (MOHURD China, 2006), multiplied by the population of villages which is estimated above, the output is the population in small towns of each basin area.

The annual population growth rate from 2005 to 2011 (IR) is valued as 0.06% (NBS China 2007).

The proportion of the population that is served by officially built water supply facilities is 83.89% in small towns (R_1) and 42.16% in villages (R_2) (MOHURD China, 2006). For the year 2011, R is estimated as 100% for both small towns and villages according to the development planning of China on water supply.

For individual water consumption in areas with water supply facility (WUi), the situation is similar to the estimation of township population: Only statistics on provincial level are available. Therefore, weighted average values are calculated based on the data of provinces which each basin area belongs to.

Individual water consumption in areas without water supply facility (WUNi) could not be quantified directly. To simplify this study, WUNi is valued as 70% of WUi.

Concentrations of pollutants in domestic wastewater (Ck) in the nine basin areas are different due to natural conditions and living habits of the residents. In this study, pollutant concentrations are estimated based on official statistics on COD and NH_4-N emission and the total amount of domestic wastewater discharge from urban domestic wastewater in each basin area (MOEP 2006).

According to *Design Standard for Water Supply and Drainage of Buildings (GB50015-2003)* (MOHURD 2003), ratio between the amount of wastewater discharge and water consumption (α) ranges between 85% and 95%. Considering the living habit and drainage infrastructure conditions in rural areas of China, the floor level (85%) is chosen.

The most influential parameter values are shown in table 4.1 and 4.2.

Table 4.1. Input of the parameters

Name of Basin area	*Small town population (thousand persons)*	*WUi of towns (L/d)*	*Village population (thousand persons)*	*WUi of villages (L/d)*
Huaihe	20240	82.1	119000	68.7
Haihe	11680	66.4	83200	59.3
Liaohe	4460	70.3	24500	56.1
Chaohu	1020	100.9	6134	78.3
Dianchi	51	90.6	647	80.2
Huanghe	9220	60.3	77000	54.2
Songhuajiang	5180	62.6	31000	46.1
Sanxia	16660	90.9	120460	84.6
Taihu	3750	119.3	12230	105.6

Table 4.2. COD and NH_4-N concentration (2005)

Name of Basin area	*Huaihe*	*Haihe*	*Liaohe*	*Chaohu*	*Dianchi*	*Huanghe*	*Songhuajiang*	*Sanxia*	*Taihu*
COD（mg/L）	306.3	256.4	350.5	251.9	111.8	344.4	474.0	374.3	158.7
NH_4-N（mg/L）	38.1	30.0	49.5	29.6	11.8	44.9	59.5	34.4	19.6

4.3. Results from the models

4.3.1. Results for estimation of water pollutants

Estimation of water pollutants from small towns and villages (from formula 1) is shown in table 4.3.

Table 4.3. COD and NH_4-N from domestic wastewater of small towns and villages in each basin area (2005)

Name of Basin area	*Huaihe*	*Haihe*	*Liaohe*	*Chaohu*	*Dianchi*	*Huanghe*	*Songhuajiang*	*Sanxia*	*Taihu*
COD (kilo tons)	792.4	383.1	156.0	38.7	1.641	425.1	219.1	1145.5	73.5
NH_4-N (kilo tons)	98.6	45.1	22.1	4.6	0.17	55.3	27.2	105.4	9.4

The values of water pollutant emissions from rural areas (estimated by the models), urban areas and industrial sectors (publish by official statistics) are compared in the figure below.

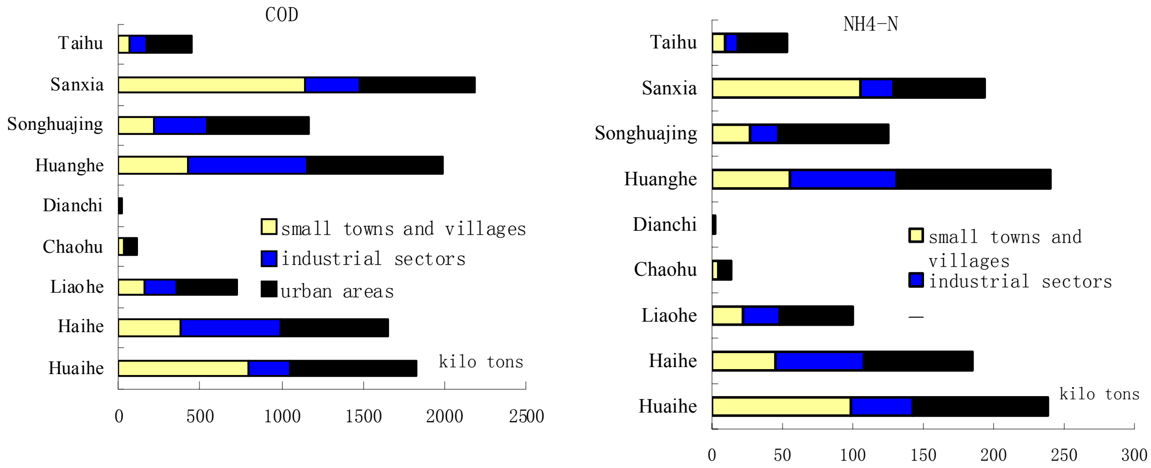

Figure 4.1a. COD and NH_4-N emission of rural areas, industrial sectors and urban areas (2005)

In figure 4.1a, the information of Dianchi and Chaohu could not be shown in detail. Amplified figures are shown below.

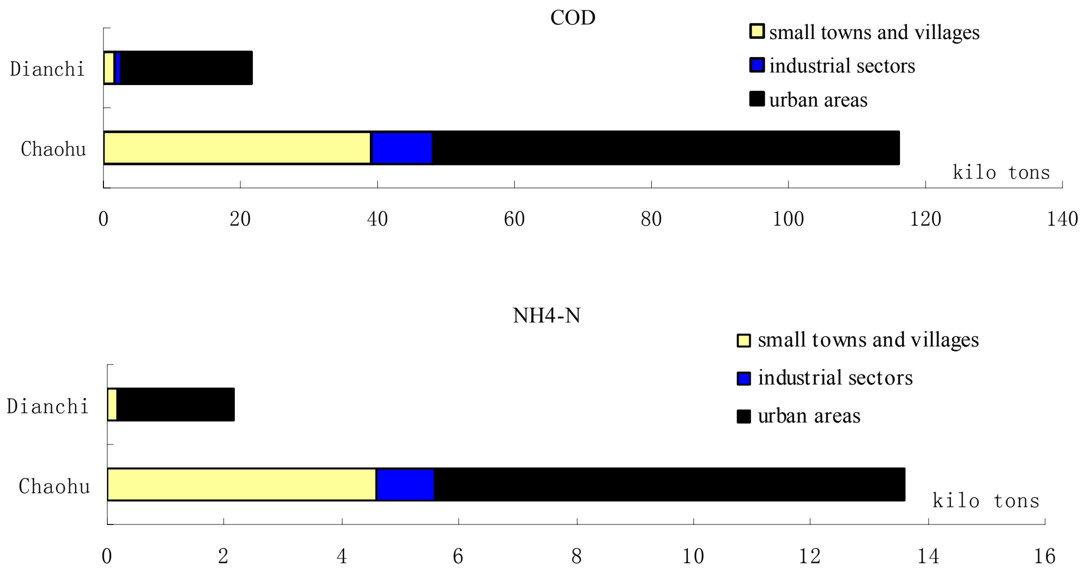

Figure 4.1b. Amplified for Dianchi and Chaohu areas

These figures indicate that COD and NH_4-N emissions from small towns and villages take a considerable part in overall water pollution of China compared with urban areas and industrial sectors. However, since sewage pipes in small towns and villages are not well constructed, this part of wastewater does not flow into natural water bodies directly, some part is just poured around houses of the residents. Although this practice does not cause direct pollution to the main water bodies, it has potential influence on the quality of underground water and the inhabited environment of nearby residents considering bacteria and other harmful contaminants. Therefore, from a long-term environmental protection perspective, this part of wastewater should not be ignored.

4.3.2. Result for estimation of domestic wastewater in year 2011

Results from formula 2 are shown in table 4.4

Table 4.4. Predicted domestic wastewater discharge from small towns and villages in year 2011

Basin area	*Huaihe*	*Haihe*	*Liaohe*	*Chaohu*	*Dianchi*	*Huanghe*	*Songhuajiang*	*Sanxia*	*Taihu*
Wastewater from towns (kilo tons/d)	1456.9	680.0	274.6	90.1	4.0	487.1	283.9	1326.0	392.7
Wastewater from villages (kilo tons/d)	7164.7	4320.6	1204.5	420.8	45.5	3658.4	1252.1	8923.3	1132.2
Total (kilo tons/d)	8621.6	5000.6	1479	510.9	49.5	4145.5	1536.0	10249.3	1524.9

The values in table 4.4 will be used as basis for chapter 5&6.

4.3.3. Limitations of the models

Due to difficulties on access of data, limitations still exist in these models. The population growth rate and the coverage of water supply facility in 2011 are estimated numbers. Pollutant concentrations of wastewater are estimated based on wastewater quality from urban areas. The limitation of the resident on access of water supply is assumed to be eliminated by 2011. However, the key parameters are quantified with reliable sources; and the estimated values could represent the development trends of China according to official references. Therefore, the results of the models are considered appropriate and can be used as basis for further study.

4.4. Conclusions and Discussion

The significance of domestic wastewater pollutant from rural areas was identified by model estimation in this chapter. The insufficient performance on water environment improvement of China also implies the deficiency of the current water pollution control approach, as described below.

According to the official statistics, non of the basin areas included in this study met the targets on water environment improvement at the end of the "Tenth Five-Year Planning" (2005). The targets and real status are listed in table 4.5.

Table 4.5. Surface water quality, 2006

Name of basin area	*Wastewater treatment rate in urban areas*	*Proportion of monitoring sections with **inferior V*** surface water*	*Targets on major monitor sections quality* of "tenth five-year planning"(2000-2005)*	*Main unqualified indicators*
Haihe	36%	57%	V	BOD_5 COD NH_4
Huaihe	<50%	30%	III	BOD_5 COD NH_4
Liaohe		43%	IV~V	BOD5 petroleum NH_4
Taihu		86%	V	NH_4-N TP
Dianchi		55.6%	IV~V	TP NH_4-N
Chaohu	<50%	39%	COD reaches III	NH_4-N TP
Huanghe	<30%	35%	III	COD BOD_5 NH_4
Songhuajiang	<15%	34%~45%	III	COD NH_4 TP
Sanxia		7%	II	Petroleum NH_4 BOD_5

Data source: Communiqué for environmental conditions of China, 2006 MOEP

* See box with supplementary information on next page

Supplemental information: Classification of surface water quality (MEOP 2002)

The *Environmental Quality Standards for Surface Water* (GB 3838-2002) defines functional classification of surface water as:

I: Source water, national natural reserves.

II: Centralized drinking water sources, habitats of rare aquatic animals, spawning and nursery grounds of juvenile fish.

III: Centralized drinking water sources, overwintering grounds and migration routes for aquatic animals, culture zones of fish and shrimp, swimming areas.

IV: Water source for industrial consumption, recreational water of non-direct contact.

V: Water source for agricultural consumption, landscape water.

Inferior V: Not defined in this standard, usually refers to surface water that could not be used by any purpose.

It is a reasonable argument to say that the unfavorable performance in table 4.5 is the result of inadequate effort on centralized wastewater treatment in urban areas and industrial sector, and better water environment will be achieved by further development of centralized wastewater treatment in these areas. However, considering the results of the estimation in section 4.3, it should be noticed that the rural areas should not be ignored in the overall water pollution control of the country.

From the context of the development planning in these major basin areas, it is reflected that the governments has realized the problems in urban domestic and industrial wastewater treatment. It is expected that by the end of year of 2010, centralized wastewater treatment rate in urban areas of China will reach 80% (NDRC China, 2007); and the situation of industrial wastewater pollution will also be improved. If these targets could be fully achieved, it is a reasonable timepoint to start solving the problem of water pollution at small towns and villages from year 2011——the beginning of the "twelfth five-year planning".

5. DWWT definition in China

In chapter 4, the result from formulas has demonstrated the significance of water pollution from rural areas of China, which is the problem to be faced in this study. In this chapter, solutions to this problem will be discussed.

As mentioned before, decentralized wastewater treatment (DWWT) is considered as a feasible approach to solve this problem. In section 5.1, the definition of DWWT is discussed based on the circumstances of China. Then, in section 5.2, effect on water environment improvement by applying DWWT is estimated during the next planning period (2011-2015).

5.1. DWWT definition

DWWT is now widely applied in foreign countries. However, its concept and application areas should be defined according to the features of each country. The major differences between decentralized and centralized wastewater lie in two aspects: one is the application area; the other is the standard of the effluent water after treatment.

To define DWWT in China, the first step is to know how it was defined in other countries. Then, DWWT will be defined in term of application areas and principals for effluent water standard, by combining the foreign experiences and the circumstances of China.

5.1.1. DWWT in US and Japan

Experiences of US and Japan are used as reference here. US is chosen mainly because of sufficient information provided by US EPA, specifically for application of DWWT; and Japan for its analogy with China of high population density, which is a key factor in choice of wastewater treatment approach.

US amended the *Clean Water Act* in the year of 1987, adding a program for non-point pollution control. This amended act brought the pollution of domestic wastewater in small residential communities into public attention. However, local residents can not afford to build centralized wastewater treatment facilities like big cities due to the huge cost on pipeline construction. Under the assistance of EPA, local governments started to build various types of decentralized wastewater treatment facilities according to local environmental and economical conditions (Chen 2004).

Table 5.1. DWWT application areas in US (US EPA, 2003)

Type of system	Description
Individual onsite systems	Systems that serve an individual residence and can range from conventional septic tank/drainfield systems to systems composed of complex mechanical treatment trains.
Cluster systems	Wastewater collection and treatment systems that serve two or more dwellings or buildings, but less than an entire community, on a suitable site near the served structure.
Commercial, residential, institutional, and recreational facilities	Systems designed to treat larger and sometimes more complex wastewater sources from commercial buildings (e.g., restaurants), apartment, or institutional or recreational facilities.

By the classification in table 5.1, US defined DWWT mainly based on type and number of users. The first two groups are typical DWWT applications; in the third group (Commercial, residential, institutional, and recreational facilities), the application fields are broader, showing the characteristics of centralized wastewater treatment. However, compared to existing facilities with larger treatment capacity in the US, this group is still defined as decentralized.

DWWT in US aims mainly to address non-point water pollution in small residential communities. Now there are about 25% of total population and one third of newly built communities using these facilities.

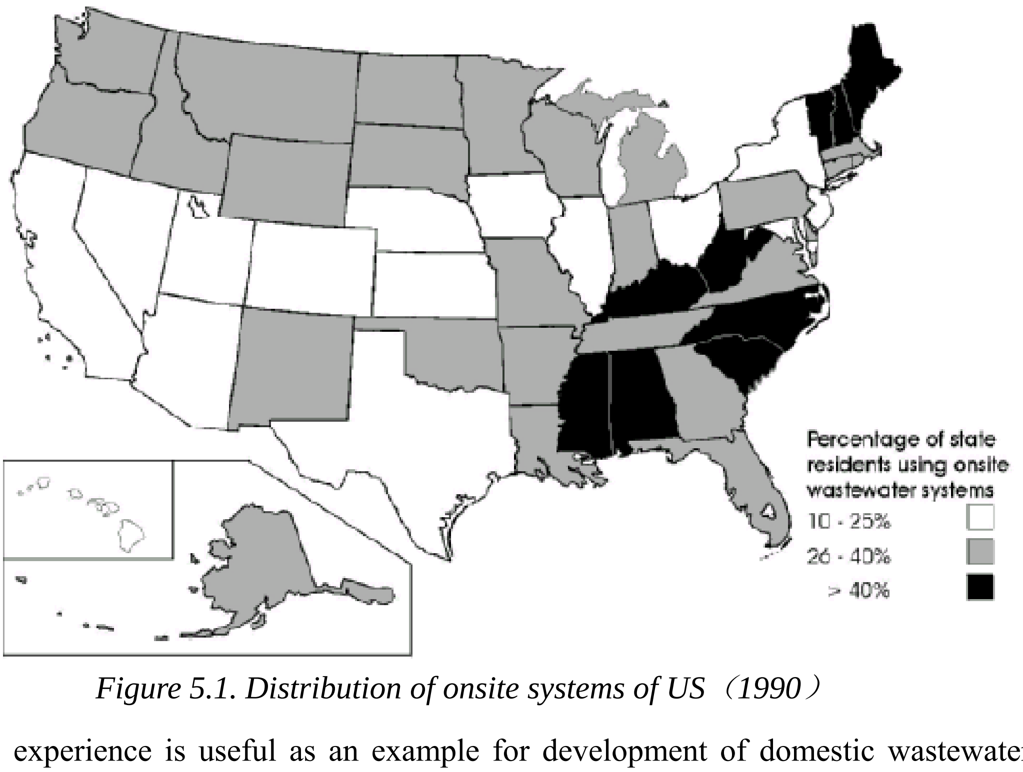

Figure 5.1. Distribution of onsite systems of US（1990）

The US experience is useful as an example for development of domestic wastewater treatment in China in which more than half population are living in small towns and villages.

In Japan, the most important feature of DWWT is the choice of technology. Johkasou system, which was first introduced to help building water flush toilets in areas without sewage pipelines, represents the current DWWT technology in Japan. Johkasou system was also the main technological approach by which the Japanese government developed the *single household and small scale wastewater treatment program* started at the end of 20th century. Subsidies provided by the government greatly relieved financial burden of local governments and residents for construction and operation of the treatment facilities. This subsidy policy became the most important factor for the promotion of this technology (JECES Japan, 2005).

From the year 2001, Japanese government started to reform the cabinet. The Office of Johkasou Affairs was shifted from The Ministry of Health Labor and Welfare to The Ministry of Environment. This shift indicated that the Johkasou system will serve not just as a technology of wastewater treatment, but also an important management approach to improve the nation-wide water environment.

The Japanese method, in which the role and function of the central government was emphasized, has the potential to be applied in China considering its current top-down management system. However, this single technology approach does not fit the situation of China. The first reason is the diversity on natural conditions of China: Wastewater treatment technologies are very sensitive to climate and geographical factors, so a single or small number of technological options could not meet the demand for areas with different features. The other reason is the constraint on economical levels: The construction and operation cost of Johkasou system is relatively higher than other technologies, therefore it is not feasible to promote this technology across China, whose economical level is still much lower compared with Japan.

5.1.2. DWWT definition in China

"Decentralized" is defined in relation to "centralized". For this reason, the features of centralized wastewater treatment in China should be introduced first.

In China, centralized wastewater treatment projects were usually built with treatment capacity of more than 100 thousand tons/d. Inflow water of centralized wastewater treatment facilities includes mainly two parts: urban domestic wastewater and industrial wastewater. In areas where domestic wastewater and storm water are not separated, storm water is also included. The inflow water is stable in velocity and has complex components of pollutants, including heavy mental and other hazardous substances from industrial wastewater.

DWWT facilities serve a small number of users. The velocity of inflow water is usually not continuous and may show seasonal changes in e.g. large hotels, restaurants and travel resorts. The components of pollutant are relatively simple (Wang, 2007). Due to these features, DWWT in China requires higher capacity to resist variations in inflow of water.

5.1.2.1. Application area of DWWT in China

In recent years, the number of small towns in China grows very fast. Now there are about 20 thousand administratively designated towns (Na, 2008). However, the construction and operation of wastewater treatment facilities in towns is still at the beginning stage. In villages, there are nearly no wastewater treatment facilities except for septic tanks used in a small number of areas.

Based on the discussions above, this study defines application of DWWT in China in the following four areas.

I. DWWT used in small towns

Small towns are among the most important target areas of DWWT development in China. In this study, small town refers to administratively area which is below county and above village level. It is recommended that the treatment facility should be built to cover the whole town, to relieve the management burden of the township government.

II. DWWT used in villages

In parts of the US and Japan, each household in rural area built an individual wastewater treatment facility (US EPA, 2003; Ohmori & Yahashi, 2004). This approach requires tremendous cost on construction and operation, and is therefore not feasible in China's villages where the income and the environmental protection awareness of the residents are still far behind the developed countries. A feasible solution is to build treatment facilities in unit of each village, or connect to treatment facilities of higher administrative area (usually township).

III. DWWT used in natural reserves and travel resorts

In natural reserves and travel resorts where there are regular and numerous visitors, demands for wastewater treatment are more urgent because of high sensitivity of water environment and high discharge of wastewater. However, these areas are usually far away from cities and there are no centralized wastewater treatment facilities around to share. Decentralized wastewater treatment can be considered to avoid potential or ongoing water environment pollution in these areas.

IV. DWWT used in urban areas

Small scale "centralized" treatment plants: It should be noticed that the word "centralized" here means the treatment capacity is larger than the three applications above. However, it is still smaller than conventional wastewater treatment facilities in urban areas of China. Currently, most cities in China without wastewater treatment facilities have already built basic systems of sewage pipelines. However, there is still huge financial demand to finish the pipeline construction to ensure the operation of a centralized wastewater treatment facility. In these cases, the proposed centralized wastewater treatment plants can be separated into a number of smaller facilities. Although these "smaller facilities" may be larger than "centralized treatment" in some foreign countries, they should still be defined as “decentralized” in China comparing to the originally proposed large treatment facilities.

Residential communities and public buildings in urban areas: If there is no short term plan to build wastewater treatment facilities in the local areas, communities and public buildings in urban areas can choose to construct their own small scale treatment facilities. This kind of decentralized facilities can meet the demand of pollution reduction, and also provide possibilities for reuse of reclaimed water. China has been promoting reuse of reclaimed water from centralized wastewater treatment since mid 1990s. However, this practice was not very effective due to problems on reuse pipeline construction and charging mechanism on reclaimed water. If wastewater treatment facilities are built in unit of residential communities, these problems will be greatly relieved: The cost on reuse pipeline construction is reduced; and the charging mechanism will be more flexible, because the users of reclaimed water are also the producers of the original wastewater.

5.1.2.2. Standard of the effluent water

Now there are nation-wide standard for effluent water of urban domestic wastewater treatment in China (MOEP, 2003), shown in table 5.2.

Table 5.2. Standard for effluent water from domestic wastewater treatment

(GB 18918-2002)

	Items		Level 1		Level 2	Level 3
			A	B		
1	COD (mg/L)		50	60	100	120
2	BOD_5 (mg/L)		10	20	30	60
3	SS (mg/L)		10	20	30	50
4	Animal or vegetable oils (mg/L)		1	3	5	20
5	Petroleum (mg/L)		1	3	5	15
6	anion active agent (mg/L)		0.5	1	2	5
7	NH_4-N (mg/L)		15	20	-	-
8	NH_4-N (mg/L)		5	8	25	-
9	TP	Built before 12/31/2005	1	1.5	3	5
		Built after 1/1/2005	0.5	1	3	5
10	Chroma (dilution factor)		30	30	40	50
11	pH		6-9			
12	colon bacillus (p per liter)		1000	10000	10000	-

The quality and quantity of inflow water in DWWT is usually highly unstable. Therefore, a uniform nation-wide standard for the effluent water will not be feasible. The effluent standard for DWWT should be established by the local governments based on local economic level, quality and sensitivity of water environment and characteristics of inflow water. Generally, the following principles should be considered.

I. The ultimate objective of DWWT is to achieve pollution reduction, rather than generate effluent water under a single and fixed standard. To maximize the overall pollution reduction, different areas should establish their own standards based on local conditions.

II. Classify the whole study area regarding to water environment sensitivity. For the areas which are more seriously polluted and have more urgent demands for pollution reduction, stricter standards should be applied.

III. Classify the whole study area regarding to economic condition. For the areas which have lower economic levels, lower standards are suggested to be applied in order to achieve maximize pollution reduction in the short term. Moreover, potential for expansibility should be considered to meet stricter standards in the future.

5.2. Effect on environmental impact from application of DWWT

To indicate the significance of DWWT development, estimation is conducted for the amount of pollutant reduction, if DWWT is promoted, at the end of the next planning phase (2015), by formula 4.

$$TR_k = TW_{15} \times C_k \times 365 \times r / 1000000 \qquad (4)$$

In which

TR_k—— total reduction of pollutant k, kilo tons/year

TW_{15}—— amount of domestic wastewater at the end of 2015, kilo tons

r —— treatment coverage rate, %

C_k —— concentration of pollutant k, mg/L

First, the total amount of domestic wastewater from small towns and villages in year 2015 should be predicted, using a method similar to formula 2 in chapter 4.

The next step is to estimate the planning target on DWWT coverage rate in small counties and villages in year of 2015 (r). Up to now, data and information available are not completed and reliable enough to make accurate prediction of the target treatment rate. This study tries to proceed with the estimation based on two hypothetical target treatment rates, which are the ceiling level and the floor level respectively.

According to *Planning for Constructions of Wastewater treatment and Reclaimed water reuse Facilities in Urban areas from 2005 to 2010* (NDRC China, 2007), wastewater treatment rate in county areas (A county includes several towns, one of which is the central town. Here the “county area” refers to the central town of the county) will reach 30% in the end of 2010, and this value in 2004 was 11.2%. The current wastewater treatment rate in small towns and villages is nearly zero. For this reason, even if

DWWT is developed at the growth rate of the county areas (which is considered very fast), the predicted treatment rate for DWWT in 2015 will still be lower than 30%.

Based on *Summary of National Environment Condition Statistics* (MOEP, 2007), in 2010, the wastewater treatment rate in urban areas will be 18% higher than in 2005. In county areas, the 2010 target (30%) value is 18.8% higher than the 2004 level. If the nation-wide development of DWWT in small towns and villages could start at the end of 2010, a growth of 15% by the year 2015 can be considered a conservative prediction.

Based on the discussion above, the ceiling and floor level for DWWT coverage rate in small towns and villages are set to 30% and 15% respectively.

The values of pollutant concentrations of the wastewater are cited from table 4.2 in chapter 4.

The estimated results are shown in table 5.3.

Table 5.3. Predicted pollutant reduction by DWWT in the end of 2015 (kilo tons/year)

	Towns				*villages*			
target rate	15%		30%		15%		30%	
pullutants	COD	NH_4-N	COD	NH_4-N	COD	NH_4-N	COD	NH_4-N
Huaihe	25.2	3.1	50.3	6.3	123.8	15.4	247.6	30.8
Haihe	9.8	1.2	19.7	2.3	62.5	7.3	125.0	14.6
Liaohe	5.4	0.77	10.9	1.5	23.8	3.4	47.6	6.7
Chaohu	1.3	0.15	2.6	0.30	6.0	0.70	12.0	1.4
Dianchi	0.025	0.003	0.05	0.005	0.29	0.03	0.57	0.06
Huanghe	9.5	1.2	18.9	2.5	71.1	9.3	142.2	18.5
Songhuajiang	7.6	0.96	15.2	1.9	33.5	4.2	67.0	8.4
Sanxia	28.0	2.6	56.0	5.1	188.4	17.3	376.8	34.6
Taihu	3.5	0.43	7.0	0.87	10.1	1.3	20.3	2.5
Total	90.3	10.4	180.6	20.8	519.5	58.9	1039.0	117.0

The financial pressure for DWWT construction and operation under each target treatment rate will be analyzed in chapter 6.

5.3. Conclusions and Discussions

Four potential application areas of DWWT in China were mentioned in section 5.1. Due to the purpose of this study, only small towns and villages were emphasized in this report. Future researches can be conducted to study the function of DWWT in urban areas and natural reserves of China. The predicted pollutant reduction by DWWT in the end of 2015 is estimated, the result shows that there will be great positive environmental effect for the development of DWWT.

6. Financial analysis for DWWT construction and operation

In this chapter, financial issues about DWWT development are discussed. Financial demand and pressure* for DWWT construction in each basin area is estimated in section 6.1. In section 6.2 recommendations on financial structure are provided. At last, operation cost of DWWT facility and the local residents' payment capacity is analyzed in section 6.3.

6.1. Analysis on financial demand and pressure for DWWT construction

6.1.1. Construction cost of DWWT facilities

The cost demand of DWWT construction in each basin area is calculated by the following formula.

$$M = TW \times p \times r / 1000 \qquad (5)$$

In which

M——cost for construction of DWWT, million Yuan

TW——amount of domestic wastewater from small towns and villages in 2011, kilo tons/d

p—— construction cost of unit treatment capacity, Yuan/(ton/d)

r——target of treatment rate in 2015, %

The amount of domestic wastewater from small towns and villages in 2011 is cited from table 4.4.

Since DWWT is not nation-widely applied in China, there are no official instructions and standards for construction cost of DWWT facilities published by governmental departments or research institutes. Therefore, case studies and literature reviews are used as source of information.

62 projects with treatment capacities below 10000 tons/d built between 1996 and 2007 were investigated. Unit construction cost for different technologies and capacities are shown in table 6.1 (Chang, 2003; SDRC, 2005; Qian, 2004; Chen, 2007).

* Financial pressure is evaluated in this study as the proportion taken by the above estimated construction cost in the total GDP in each basin area from 2011 to 2015.

Table 6.1. Construction cost of unit treatment capacity (Yuan)

Treatment Capacity Tons/d	*Constructed wetlands*	*Rapid Infiltration*	*Catalytic oxidation*	*Biological aerated filters*	*Oxidation ditch*	*SBR*	*traditional activated sludge process*	*Aerated lagoon*
<500			1850	927				1040
500-1000	1200		1603				3000	
1000-1500		714						
1500-2000	1100							
2000-3000			987					
3000-5000				1098				
5000-10000	1760	865	1425	1012	2701	2829	8667	

Based on literature reviews, the unit construction cost ranges from 1200 to 2200 Yuan. Considering the possible demand of pipeline expansion, the unit construction cost of DWWT (p) is set at 2000 Yuan.

As described in section 5.2, the ceiling and floor values of treatment rate targets are 30% and 15% respectively.

The estimated results are shown in table 6.2.

Table 6.2. DWWT construction and financial demand from 2011 to 2015

	Treatment rate	*Huaihe*	*Haihe*	*Liaohe*	*Chaohu*	*Dianchi*	*Huanghe*	*Songhuajiang*	*Sanxia*	*Taihu*	*Total*
Treatment capacities （kilo tons/d）	15%	1521.45	882.45	261	90.15	8.73	731.55	271.05	1808.7	269.1	5844.18
	30%	3042.9	1764.9	522	180.3	17.46	1463.1	542.1	3617.4	538.2	11688.4
Construction cost (million Yuan)	15%	3042.9	1764.9	522	180.3	17.46	1463.1	542.1	3617.4	538.2	11688.4
	30%	6085.8	3529.8	1044	360.6	34.92	2926.2	1084.2	7234.8	1076.4	23376.7

6.1.2. Financial pressure of local governments

Financial pressure is evaluated in this study as the proportion taken by the above estimated construction cost in the total GDP in each basin area from 2011 to 2015.

Official statistics of GDP by basin area was updated more slowly than by province. Here the data of 2005 are chosen as basis.

From year 2005 to 2009, the growth rate of national GDP of China was higher than 9% (NBS China, 2008). However, Chinese government always keeps 8% as target on economic growth in both optimistic and dim years (Weng, 2009). Therefore, growth rate of 8% is chosen here.

After total GDP from 2011 to 2015 is predicted, the proportions taken by construction cost of DWWT are illustrated in figure 6.1 below.

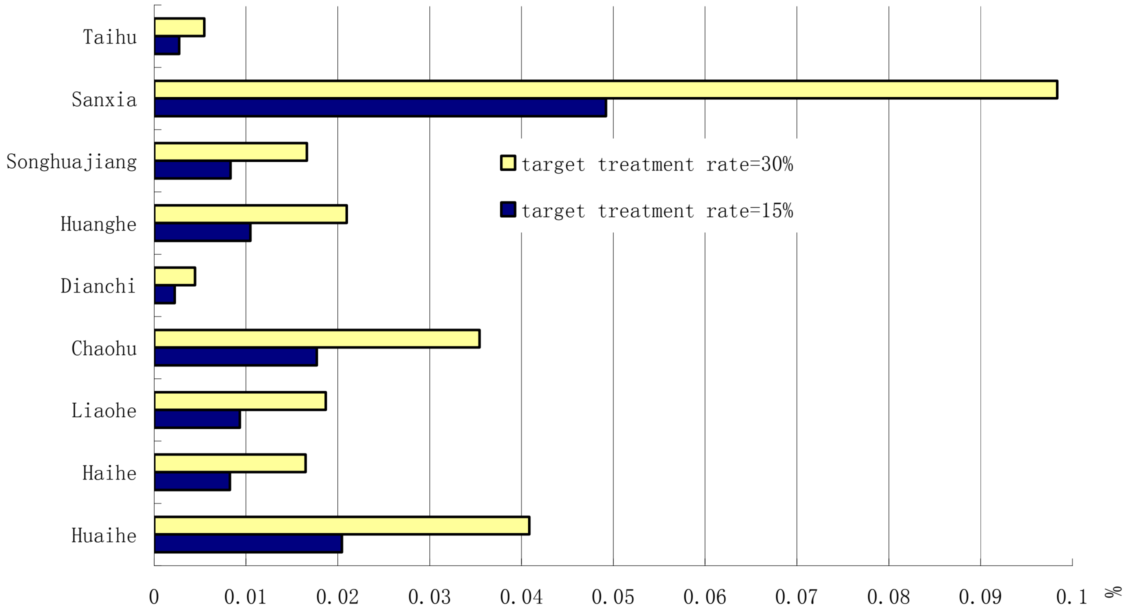

Figure 6.1. Proportions taken by construction cost of DWWT in total GDP

From figure 6.1, it can be concluded that Taihu and Dianchi basin areas have the smallest financial pressure. The construction cost takes less than 0.01% of local GDP even under the higher treatment rate target (30%).

On the other hand, Huaihe, Chaohu and Sanxia basin areas will face higher financial pressure. In Sanxia, it takes nearly 0.05% of local GDP to meet the lower target rate (15%). If this part of GDP is allocated to DWWT, all the other basin areas will meet the higher target of 30%.

However, it should be noticed that the predicted financial pressures in figure 6.1 are not just dependent on local economical conditions, it is also influenced by population and the living habits of local residents.

In two most optimistic basin areas, Taihu shows a good result mainly because of its strong economical condition: Its GDP per capita in 2005 was about 3.4 times of the national average. Compared to Taihu, however, Dianchi has a very small area (just 2920 km^2), and covers mainly the urban districts and nearby counties of Kunming city——the capital of Yunnan province (MOEP, 2008). High urbanization ratio in this small basin area greatly decreases the demand for DWWT. For these reasons, the economical condition of Dianchi area is not representative for the common level of the south-west part of China.

In the three basin areas which face higher financial pressure, local GDP per capita in

2005 were all below the national average. However, the poor result for Sanxia is the outcome of several factors: First, Sanxia basin area has the lowest GDP per capita among all the nine areas in 2005; second, its individual water consumption of rural residents is between 80-90 L/d, ranks the second highest; and last, Sanxia basin area has a much higher proportion of rural residents (about 80%), which greatly increased the demand of DWWT construction (MOEP, 2008; MOHURD, 2007).

6.2. Financial channels for DWWT construction

In this section, the issue of financial channels for construction of DWWT facilities is discussed, by combining the foreign experiences and the current financial channels for centralized wastewater treatment of China.

6.2.1. Foreign experiences

In US, there are many forms of financial channels for DWWT construction, including the state government, local governments, companies, residential communities and users. The most widely used source is the Clean Water State Revolving Fund (CWSRF).

CWSRF is a governmental fund created during the amendment of the *Clean Water Act* in 1987. It aimed to provide long term financial source for water environment protection of the whole country. The initial fund in CWSRF was provided by federal and state governments. It is provided as low or non interest loan to support wastewater treatment projects which aim to control point or non-point water pollution. Non-point water pollution controlling projects include construction, maintenance and expansion of DWWT facilities in small towns, villages, and urban surrounding areas (USEPA, 1992). The maturity length of the fund is 20 years. Recollected principal and interest will flow back to this fund and support new projects.

Since the year 1988, CWSRF has provided loans of 39 billion USD to more than ten thousand wastewater treatment projects, in which two thirds are small scale residential community projects serving less than ten thousand people.

State governments established local programs to assist construction and operation of DWWT plants under CWSFR. In Aug 1997, the Ohio EPA and Mahoning County jointly created a supporting program to develop on-site wastewater treatment systems. Residents apply for loans to build on-site treatment facilities according to their own needs. A bank will evaluate the application and forward its decision to the local EPA, who will then transfer the loan to the applicants from CWSRF if the application is approved. More than one million USD was provided to Mahoning county through this program from 1998 to 2002 (USEPA, 2003).

The CWSRF is still well operated. Each year, about 1 billion USD of principal and interest could be recollected, and the US congress makes appropriation of another 1.1 billion USD to this fund (CCICED, 2004). The total asset value of CWSRF had exceeded 42 billion USD in 2007.

Governmental funds like CWSFR have many advantages: They are designed to support a specific sector, operated under governmental policies, and have stable fund resources and low financing cost. Establishment and operation of governmental funds require adequate initial funding and assured further financial sources from the central government, as well as eligible governmental organizations and appropriate market.

The US experience has demonstrated the advantages of this fund, which is urgently needed for appropriate distribution of resources considering the huge regional differences of China. China already has the fundamental experience to create a fund like CWSFR, for instance, financial and policy support from central government, improving financial environment, and similar governmental funds in areas of education and medical care. Therefore, it is feasible to create a governmental fund for wastewater treatment in China in the next few years.

In Japan, the main investors of the Johkasou system are local governments and individual users. Meanwhile, to promote the application of Johkasou system, the Ministry of Health Labor and Welfare published *The Johkasou Law* in 1985 and established the Office of Johkasou Affairs two years later. The central government launched subsidy programs to support individual users and local governments. From the year 1987 to 2004, subsidy provided by the central government to develop Johkasou system increased from 100 million yen to 25.7 billion yen, and there were 200-300 thousand new Johkasou systems built in Japan every year. (Min, 2003; JECES, 2005).

6.2.2. Financial channels for wastewater treatment in China and application potential for DWWT

In the 1990s, construction of wastewater treatment facilities in China relied mainly on governmental investment and aid from foreign governments.

On December 2002, the Chinese government published *The Decision about Accelerating Marketization of Municipal Utilities*, which claimed to "encourage social capital, foreign capital, joint venture and other corporate capitals to invest in municipal utilities and create diversified financial structure." From that time, wastewater treatment industry in China turned into the era of multiple investors, including central and local governments, companies, international financial groups, government development and aid organizations, etc. (MOHURD, 2002).

Table 6.3. Investors and financial channels for construction of wastewater treatment plants in China

Investors	*Financial channels*
Central government	fiscal appropriation, national debt
Local government	local fiscal revenue
International financial group	direct foreign investment, preferential loan, bilateral aid
Companies	corporate debt equity financing, direct project investment, loan from commercial bank, donation

DWWT is part of the wastewater treatment industry in China. Therefore its financial channels will be structured based on the current available options above. Application potential in DWWT and possible problems of these financial channels are discussed below.

6.2.2.1. Fiscal investment

I. Current status of fiscal investment in wastewater treatment of China

Fiscal investment includes two parts: One is fiscal appropriation with zero interest rate from central and local governments; the other is low interest national debt.

Wastewater treatment projects are mainly built by appropriation from local governments. Support from central government (central appropriation and national debt) are important supplementary sources. From the year 1998 to 2005, the central government spent 61.63 billion Yuan on 1987 wastewater treatment projects, which spurred local investment of 104.5 billion Yuan (Chang & Zhu, 2006). During 2006-2010, another 691 water pollution control projects in major basin areas will be supported by the central government (Weng, 2008). In recent years, central government supports for wastewater treatment are shifting to small towns and western areas of China. During the case study in Chongqing City (which lies in the west China), it is proved by the local government that the national debt is playing an increasingly important role in the construction of wastewater treatment facilities in township areas.

II. Application potential of fiscal investment in DWWT

Water environment is considered as public property, and has more direct influence on local areas. Therefore, local governments should take more responsibility for the construction and operation of wastewater treatment facilities. Fiscal appropriation and national debt from central government are mainly used to support local governments which have high financial pressure and urgent needs on water pollution reduction, e.g. Sanxia basin area.

III. Problems about fiscal investment used in DWWT

Fiscal appropriation from local governments is considered as the most direct financial channel for DWWT development. However, during the early planning phase (2010-1015), it will be a big financial burden for the local governments to afford this alone.

Regarding fiscal appropriation and national debt from central government, the approval procedures are very complex. This shortcoming will be amplified when applied in DWWT projects which have smaller treatment capacity and broad distributions. Another problem is the immaturity on approval mechanism of central government investment: Some local governments got approved with ineligible projects which are not properly proposed. In some extreme cases, the projects had already been finished, but repacked as new projects to get money from central government. These problems will influence the resource coordinating function of the central government.

Finally, government invested wastewater treatment projects in China had the pervasive problems of low efficiency and unclear distribution of responsibilities. The quality of construction and operation performance could not be guaranteed. More details about project management will be discussed in chapter 7.

6.2.2.2. Loans from international financial group (hereafter referred as international loans)

I. Current status of international loans in wastewater treatment of China

International financial groups which support wastewater treatment in China include the World Bank, Asian Development Bank (ADB), Japan Bank for International Cooperation (JBIC) and others. By the year of 2005, 67.46% of the loans from the World Bank supporting wastewater treatment in China was given into big coastal cities in the east of the country. However, since the year 2007, the World Bank started shifting its focus areas to the inland cities and township areas. ADB and JBIC are also changing their strategies in the same way. With the fast development of China's economy, this kind of international loans is expected to decrease in the future.

II. Application potential of international loans in DWWT

The international financial groups have very strict requirements on the quality of the proposed projects. The purpose of the loans is to support the development of less developed countries and areas, therefore it is expected that during the year 2011 to 2015, international loans will support DWWT projects mainly in middle and western areas of China, where the economical level is lower than the national average and the water environment is more sensitive to pollution.

6.2.2.3 Corporate investments

I. Current status of corporate investments in wastewater treatment of China

As a result of the marketization reform on municipal utilities industries from 2002, a huge amount of domestic social capital and foreign capital flowed into the market of wastewater treatment. These corporate investments greatly facilitated the diversity of wastewater treatment industry in China, and at the same time, relieved the financial pressure of local governments.

BOT (Build-Operate-Transfer) is the most widely used management mode for corporate capital invested in wastewater treatment projects. Therefore, in wastewater treatment industry of China, BOT can be considered as the synonym of corporate investment projects.

By the year 2006, 311 BOT wastewater treatment projects (hereafter referred to as BOT projects) have been built in China with a total investment of more than 16 billion Yuan. BOT projects usually include construction of the treatment plants and a small part of pipelines; the local governments are still the investors of the major pipeline systems. Existing BOT projects showed an obvious distribution in geography and treatment capacity: 61.67% projects were built in eastern coastal areas in China; one third in small towns; and more than 50% have treatment capacities between 10000-30000 tons/d (Chang & Lin, 2006).

Corporate capital is considered as an important supplementary financial channel for DWWT development apart from fiscal investment. However, the initial purpose of corporate investments is to make profit. Therefore, there are higher requirements on local investment environment and capacities of local residents to pay for sewage discharge. That is also the main reason why most BOT projects were built in the richer eastern part of China.

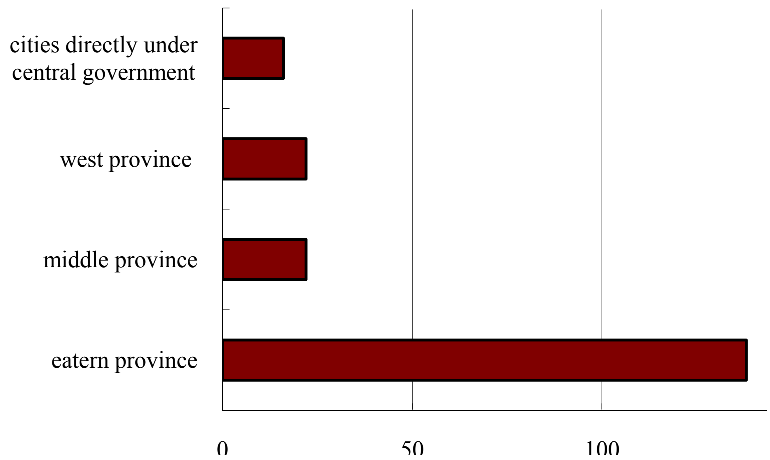

Figure 6.2. BOT projects distribution in China, 2001-2005

II. Application potential of corporate investments in DWWT

As mentioned in the first chapter, there are two major obstacles during the development of DWWT in rural areas of China. One is the shortage of finance, and the other is how to manage these DWWT plants. As a form of corporate investment, BOT mode will play a positive role in solving these problems: First, it will relieve the local government of the financial pressure; second, during the operation phase, the investors have the incentive to keep the treatment facilities operating properly in order to recover initial investment and make profit. Therefore, the local governments need not pay excessive management resources on operation details of the treatment facilities.

Based on the current distribution of BOT projects in urban areas of China, it is expected that during the early phase of DWWT development, BOT mode will be applied mainly in eastern China. After more experiences has been collected from existing BOT projects and the marketization of wastewater treatment industry in China is further developed, BOT mode in DWWT will be extended to middle and western areas.

III. Problems about corporate investments used in DWWT

Considering the small individual treatment capacity of DWWT, it can be predicted that there will be a large number of treatment plants broadly distributed in the remote areas of China. However, the current legislation system regarding BOT projects in China is still immature. It will therefore be an uncertainty whether the rights and responsibilities of each part can be fully performed by merely the restriction of BOT contracts.

Another problem is the high cost during the process of negotiation and planning before the BOT contract is signed. In projects with small treatment capacity, this part of cost will take an even higher proportion in the total investment, which means the construction cost for unit treatment capacity will be further increased. The high early phase cost will be a negative factor which reduces the interest of investors. More details about advantages and disadvantages of BOT mode in DWWT will be discussed in chapter 7.

6.2.3. Financial channel structure for DWWT construction of China

The financial structure should be consistent with the local economic situation and the payment capacity of local residents. In light of this principle, the studied areas are classified with regard to income of the local county governments and income of residents (ADBC, 2006). The government income is considered as an indicator for the local economical strength to build DWWT facilities; and the individual income represents the capacity of residents to pay for sewage charge, which is very important for marketization of wastewater treatment industry.

The income of residents is reflected by individual income per year. The World Bank has defined the poverty line as a living cost under the equivalent of 1.25 dollars a day (The World Bank, 2006). Considering the exchange rate (about 6.8), the annual income of 3000 Yuan can be set as poverty line in this study. The high income line for China’s rural areas is not clearly defined in available studies. Here annual income of 10000 Yuan per year is chosen.

Statistics here is by unit of county, which is the upper level administrative unit of the studied areas, including both small towns and villages.

Table 6.4. Individual income of village residents in nine major basin areas, 2005

income level	*Resident income (Yuan/p)*	*Number of counties*	*Proportion (%)*
Total		1003	100
Low	0~3000	546	54
Middle	3000~10000	457	46
High	>10000	0	0

Table 6.5. Individual income of township residents in nine major basin areas, 2005

income level	*Resident income (Yuan/p)*	*Number of counties*	*Proportion (%)*
Total		1003	100
Low	0~3000	8	0.8
Middle	3000~10000	218	21.7
High	>10000	777	77.5

This classification is not complete due to lack of data on some parts of the Taihu basin area, which is the richest among the nine areas studied.

The study areas are small towns and villages, and therefore the income of the township level governments is the most relevant indicator to evaluate governmental capacity of DWWT construction. However, the fiscal income of township level was not reported in the national statistics. Here it is assumed that towns in the same county have similar economical level (which is basically true). Therefore, the data on county government is used.

Fiscal income below 200 Yuan per capita is defined as a low level, and above 1000 Yuan as a high level.

Table 6.6. Fiscal income of county governments in nine major basin areas

income level	*Government income（Yuan/p）*	*Number of counties*	*Proportion (%)*
Total		1003	100
Low	0~200	493	49
Middle	200~1000	439	44
High	>1000	71	7

Table 6.7. below provides suggestions about financial structures for DWWT during the next planning phase (2011-2015) according to the classifications above.

Table 6.7. Recommended financial channels for DWWT during 2010 and 2015

Government income	*Resident income*	*Major financial channels*
High	High	Local government, corporation
	Middle	Local government, corporation Middle and western China：local government investment in early period, corporation capital as supplement
	Low	Local government, national debt
Middle	High	Local government, corporation
	Middle	Local government, national debt
	Low	Local government, central government, national debt
Low	High	N/A
	Middle	Central government, national debt
	Low	Central government, national debt

It should be noticed that the table above is only a simple recommendation that reflects the basic principles on establishment of the financial structures. Each basin area should conduct further research to make more detailed and accurate decisions.

6.3. Operation cost

In this section, the operation cost of DWWT facility is estimated according to existing small wastewater treatment projects. Combined with the sewage charge level of urban wastewater treatment and payment capacity of rural residents, the sewage charge policy of DWWT is discussed.

6.3.1. Analysis of full operation cost of DWWT in China.

Case studies are cited to estimate the operation cost of DWWT (Li, 2006; CAEPI, 2007), which includes energy cost (E1), medical cost (E2), labor cost (E3), depreciation cost (E4), heavy repair cost (E5), maintenance cost (E6), management cost (E7) and interest cost (E8).

According to relevant design standards (Zhou XG, 2005; Zhou L, 2003; An, 2003):

$$E_1 = e \times d \times 365 \tag{6}$$

in which，e——daily electricity consumption, Kwh/d，

d——electricity price, Yuan/Kwh;

$$E_2 = \frac{365Qab}{10^6} \tag{7}$$

in which, Q——treatment capacity, ton/d,

a——medical consumption, mg/L,

b——medical price, Yuan/ton;

E_3= labor salary×number of labors (8)

E_4= original value of fixed assets× compositive depreciation rate (9)

E_5= original value of fixed assets×heavy repair rate (10)

E_6= original value of fixed assets×maintenance rate (11)

E_7=（E_1+E_2+E_3+E_4+E_5+E_6）×15% (12)

E_8= total debt×annual interest rate (13)

Total cost $YC= E_1+E_2+ E_3+ E_4+ E_5+ E_6+ E_7+ E_8$ (14)

Unit treatment cost $$AC = \frac{YC}{\sum Q}$$ (15)

In which， $\sum Q$ is the total amount of treated wastewater.

The compositive depreciation rate is 5% (equipment 5.33%, sewage pipeline 3.2%, automatic control equipment 9.6%, main structure 3.2%), heavy repair rate is 2%, and maintenance rate 1%. (Zhou XG, 2005; Zhou L, 2003; An, 2003)

Seven cases are cited here:

(1) Muyu wastewater treatment project in Shennongjia forest

Muyu town lies in south part of Shennongjia forest, Hubei province. The project is a catalytic oxidation treatment plant with treatment capacity of 2840 tons/d. It is built to serve the township residents. The total investment is 8.12 million Yuan, including 2.47 million for pipeline and 5.65 million for the treatment plant. In daily operation, the electricity consumption is 665 kWh, electricity price 0.583 Yuan; price of phosphate removal media is 2000 Yuan/ton, usage proportion of 45 ppm; 6 workers are hired, salary 600 Yuan/month. Total operation cost is calculated as:

$$E_1 = 665 \times 0.583 \times 365 = 141508.7\text{Yuan}$$
$$E_2 = \frac{365 \times 2840 \times 2000 \times 45}{10^6} = 93294\text{Yuan}$$
$$E_3 = 600 \times 6 \times 12 = 43200\text{Yuan}$$
$$E_4 = 2470000 \times 3.2\% + 5650000 \times 5\% = 361540\text{Yuan}$$
$$E_5 = 8120000 \times 2\% = 162400\text{Yuan}$$
$$E_6 = 8120000 \times 1\% = 81200\text{Yuan}$$
$$E_7 = (141508.7 + 93294 + 43200 + 361540 + 162400 + 81200) \times 15\% = 132471\text{Yuan}$$
$$YC = 141508.7 + 93294 + 43200 + 361540 + 162400 + 81200 + 132471 = 1015614\text{Yuan}$$
$$AC = \frac{1015614}{2840 \times 365} = 0.98\text{Yuan / ton}$$

(2) Lujiao constructed wetland project in Banan district of Chongqing city

Nanquan town in Banan district of Chongqing city has a population of about 5000. The constructed wetland project was built in 2006, with a treatment capacity of 1000 tons/day. Effluent water meets the national standard of level one B (table 5.2). Total investment is 2.05 million Yuan, including 0.85 million for pipeline and 1.2 million for the treatment plant. In daily operation, the electricity consumption is 282 kWh, electricity price 0.5 Yuan; 6 workers are hired, salary 600 Yuan/month. Total operation cost is calculated as:

$$E_1 = 282 \times 0.5 \times 365 = 51465\text{Yuan}$$
$$E_3 = 600 \times 2 \times 12 = 14400\text{Yuan}$$
$$E_4 = 1200000 \times 5\% = 60000\text{Yuan}$$
$$E_5 = 1200000 \times 2\% = 24000\text{Yuan}$$
$$E_6 = 1200000 \times 1\% = 12000\text{Yuan}$$
$$E_7 = (51465 + 14400 + 60000 + 24000 + 12000) \times 15\% = 24280\text{Yuan}$$
$$YC = 51465 + 14400 + 60000 + 24000 + 12000 + 24280 = 186145\text{Yuan}$$
$$AC = \frac{186145}{1000 \times 365} = 0.51\text{Yuan / ton}$$

(3) Baihua village wastewater treatment plant in Shenzhen city

Baihua village lies in southeast part of Guangimng street, Anbao district of Shenzhen city, Guangdong province. This village has total population of 3500. The sand filter treatment plant was built in the year of 2003, with treatment capacity of 1300 tons/d, effective treatment capacity 1000 tons/d. The effluent water meets the national standard of level one A (table 5.2). Total investment is 0.9278 million Yuan, including civil engineering of 0.3726 million, equipments of 0.4003 million, pipeline of 24 000 and automatic control equipments of 9 000. In daily operation, the electricity cost is 86.36 Yuan, and the labor cost 100 Yuan. Total operation cost is calculated as:

$$E_1 = 86.36 \times 365 = 31521\text{Yuan}$$
$$E_3 = 100 \times 365 = 36500\text{Yuan}$$
$$E_4 = 400300 \times 5.33\% + 24000 \times 3.2\% + 9000 \times 9.6\% + 372600 \times 3.2\% + 154800 \times 5\% = 42631\text{Yuan}$$
$$E_5 = 927800 \times 2\% = 18556\text{Yuan}$$
$$E_6 = 927800 \times 1\% = 9278\text{Yuan}$$
$$E_7 = (31521 + 36500 + 42631 + 18556 + 9278) \times 15\% = 20773\text{Yuan}$$
$$YC = 31521 + 36500 + 42631 + 18556 + 9278 + 20773 = 159259\text{Yuan}$$
$$AC = \frac{159259}{1000 \times 365} = 0.44\text{Yuan / ton}$$

(4) Jincheng wastewater treatment plant in Zibo city of Shandong province

Jincheng treatment plant was built in the year 2004, the inflow water includes domestic wastewater and part of the city's industrial wastewater. The total treatment capacity is 4800 tons/d, with 3000 in effective operation. Technology type is A^2O

(Anaerobic-Anoxic-Oxic). Total investment is 4.12 million Yuan, including civil engineering of 0.86 million, equipments of 1.93 million, pipeline of 0.87 million and automatic control equipments of 0.26 million. In daily operation, the electricity cost is 276 Yuan, medical cost of 21.6 Yuan, labor cost of 200 Yuan. This plant is operated 350 days per year. Total operation cost is calculated as:

$$E_1 = 276 \times 350 = 96600\text{Yuan}$$
$$E_2 = 21.6 \times 350 = 7560\text{Yuan}$$
$$E_3 = 200 \times 350 = 70000\text{Yuan}$$
$$E_4 = 1930000 \times 5.33\% + 870000 \times 3.2\% + 260000 \times 9.6\%$$
$$+860000 \times 3.2\% + 200000 \times 5\% = 193189\text{Yuan}$$
$$E_5 = 4120000 \times 2\% = 82400\text{Yuan}$$
$$E_6 = 4120000 \times 1\% = 41200\text{Yuan}$$
$$E_7 = (96600 + 7560 + 70000 + 193189 + 82400 + 41200) \times 15\% = 73642\text{Yuan}$$
$$YC = 96600 + 7560 + 70000 + 193189 + 82400 + 41200 + 73642 = 564591\text{Yuan}$$
$$AC = \frac{564591}{3000 \times 350} = 0.54\text{Yuan / ton}$$

(5) AquaMats demonstration wastewater treatment project in Huxiangjunbie Villa area of Huhan city

Huxiangjunbie villa area lies near Tazi lake in Jiangan district of Huhan city. The AquaMats treatment plant with treatment capacity of 150 tons/d was built in 2005 to treat wastewater from the villa residents. Total investment is 0.273 million Yuan. In daily operation, the electricity cost is 44.64 Yuan, labor cost 4.5 Yuan. Total operation cost is calculated as:

$$E_1 = 44.64 \times 365 = 16294\text{Yuan}$$
$$E_3 = 4.5 \times 365 = 1642.5\text{Yuan}$$
$$E_4 = 273000 \times 5\% = 13650\text{Yuan}$$
$$E_5 = 273000 \times 2\% = 5460\text{Yuan}$$
$$E_6 = 273000 \times 1\% = 2730\text{Yuan}$$
$$E_7 = (16294 + 1642.5 + 13650 + 5460 + 2730) \times 15\% = 5966.5\text{Yuan}$$
$$YC = 16294 + 1642.5 + 13650 + 5460 + 2730 + 5966.5 = 45743\text{Yuan}$$
$$AC = \frac{45743}{150 \times 365} = 0.835\text{Yuan / ton}$$

(6) Tianyuan wastewater treatment project in Shenzhen city

Tianyuan travel resort lies in Aaobao district of Shenzhen. It is the largest ecological tourism spot of the city. The treatment plant was built in 2001 to treat wastewater from service facilities in the resort, with treatment capacity of 800 tons/d. The technology type is a Rotating Biological Contactor. Effluent waster meets the national standard of level two (table 5.2). Total investment is 1.56 million Yuan, including 0.38 million for civil engineering and 0.862 million for equipment, 46000 for pipeline and 56000 for automatic control equipment. In daily operation, the electricity cost is 152 Yuan, chemical cost 184Yuan, labor cost 33.3 Yuan. Total operation cost is calculated as:

$$E_1 = 152 \times 365 = 55480\text{Yuan}$$
$$E_2 = 184 \times 365 = 67160\text{Yuan}$$
$$E_3 = 33.3 \times 365 = 12154.5\text{Yuan}$$
$$E_4 = 862000 \times 5.33\% + 46000 \times 3.2\% + 56000 \times 9.6\% + 380000 \times 3.2\% + 213400 \times 5\% = 75623\text{Yuan}$$
$$E_5 = 1557400 \times 2\% = 31148\text{Yuan}$$
$$E_6 = 1557400 \times 1\% = 15574\text{Yuan}$$
$$E_7 = (55480 + 67160 + 12154.5 + 75623 + 31148 + 15574) \times 15\% = 38571\text{Yuan}$$
$$YC = 55480 + 67160 + 12154.5 + 75623 + 31148 + 15574 + 38571 = 295711\text{Yuan}$$
$$AC = \frac{295711}{800 \times 365} = 1.0\text{Yuan / ton}$$

(7) Reclaimed water project in Nanjiao hotel of Jinan

Nanjiao hotel is a four star hotel in south of Jinan city, the capital of Shandong province. Nearby are another five star hotel and the living quarter of the provincial department of finance. In 2001, the three parts co-invested in this reclaimed water project which has treatment capacity of 4000 tons/d. The effective treatment capacity is 3600 tons/d in summer and 3000 in winter. Reclaimed water from the biological aerated filter plant is used for landscape, carwash and water flush toilet. Total investment is 4.61 million Yuan, including civil engineering of 1.03 million, equipments of 2.51 million, pipeline of 0.2 million and automatic control equipments of 0.5 million. In daily operation, the electricity cost is 0.34 Yuan/ton, chemical cost 0.1Yuan/ton, labor cost 0.075 Yuan/ton. This plant is operated 340 days per year. Total operation cost is calculated as:

$E_1 = 0.34 \times 3300 \times 340 = 381480\text{Yuan}$
$E_2 = 0.1 \times 3300 \times 340 = 112200\text{Yuan}$
$E_3 = 0.075 \times 3300 \times 340 = 84150\text{Yuan}$
$E_4 = 2514000 \times 5.33\% + 200000 \times 3.2\% + 500000 \times 9.6\% + 1033000 \times 3.2\%$
$+360000 \times 5\% = 238698\text{Yuan}$
$E_5 = 4607000 \times 2\% = 92140\text{Yuan}$
$E_6 = 4607000 \times 1\% = 46070\text{Yuan}$
$E_7 = (381480 + 112200 + 84150 + 238698 + 92140 + 46070) \times 15\% = 143211\text{Yuan}$
$YC = 381480 + 112200 + 84150 + 238698 + 92140 + 46070 + 143211 = 1097949\text{Yuan}$

$$AC = \frac{1097949}{3300 \times 340} = 0.98\text{Yuan / ton}$$

The operation costs of these projects are summarized in the following table.

Table 6.8. Operation cost of wastewater treatment for different technologies and capacities (Yuan/ton)

Treatment capacity (tons/d)	*constructed wetland*	*sand filter*	*catalytic oxidation*	*biological aerated filter*	*others*
<500					0.835
500~1000	0.51		1.0		
1000~1500		0.44			
1500~2000					
2000~3000			0.98		
3000~5000				0.98	0.54

The relationship of operation cost with technology type and treatment capacity can be partly identified from table 6.8. However, lack of existing small treatment plants and limitation on data access lead to great difficulties for a more detailed study. Project types of SBR (Sequencing Batch Reactors), Oxidation Ditch and MBR (Membrane Bioreactor) reactors which are more expensive in operation are not included. Sludge treatment, which should not be ignored in wastewater treatment, is not reflected in these cases. Based on the collected cases and the constraints above, it is estimated that the operation cost of DWWT in China, sludge treatment costs excluded, is around 1 Yuan/ton.

6.3.2. Current sewage charge level and payment capacity of rural residents

China started to collect sewage charge officially from the year 1999 (NDRC China, 1999). According to the report from the Pricing Department of National Development and Reform Committee, the sewage charge collection mechanism was widely promoted during the years from 2003 to 2008. At the end of 2008, 90% of urban areas had established sewage charge mechanisms. After several price adjustments, the latest national average sewage charge is 0.67 Yuan/ton.

Sewage charge level in major cities of China is shown in table 6.9.

Table 6.9. Sewage charge in major cities of China, 2008 (Yuan/ton)

City	Beijing	Tianjin	Shijianzhuang	Tangshan	Qinhuangdao	Xingtai	Hengshui	Taiyuan	Datong	Changye	Jincheng	Yuncheng	Hohhot
Price	0.9	0.8	0.8	0.9	0.51	0.2	0.45	0.25	0.2	0.2	0.2	0.25	0.45
City	Fushun	Jinzhou	Tieling	Changchun	Jilin	Tonghua	Yanbian	Harbin	Daqing	Jiamusi	Mudanjiang	Shanghai	Nanjing
Price	0.5	0.51	0.55	0.4	0.3	0.3	0.4	0.8	0.5	0.3	0.7	0.9	1.1
City	Wenzhou	Jiaxing	Shaoxing	Quzhou	Hefei	Huainan	Tongling	Anqing	Chuzhou	Fuzhou	Xiamen	Sanming	Quanzhou
Price	0.5	0.8	0.5	0.5	0.76	0.6	0.5	0.18	0.3	0.85	1	0.8	0.8
City	Qingdao	Zaozhuang	Yantai	Taian	Heze	Zhengzhou	Luoyang	Xinxiang	Zhoukou	Wuhan	Huangshi	Xiangfan	Jingmen
Price	0.7	0.7	0.7	0.9	0.9	0.65	0.8	0.65	0.65	0.8	0.6	0.5	0.8
City	Shaoguan	Shenzhen	Shantou	Jianghu	Zhanjiang	Nanning	Liuzhou	Zunyi	Yan'an	Anshun	Qiannan	Kunming	Shaotong
Price	0.4	0.9	0.5	0.75	0.55	0.5	0.5	0.3	0.74	0.2	0.2	0.75	0.4
City	Baotou	Wuhai	Hulun Buir	Shenyang	Dalian	Anshan	Leshan	Dazhou	Guiyang	Jiuquan	Hami	Shizuishan	
Price	0.3	0.35	0.3	0.5	0.6	0.6	0.35	0.3	0.7	0.4	0.8	0.65	
City	Xuzhou	Suzhou	Nantong	Yangzhou	Hangzhou	Ningbo	Zigong	Panzhihua	Mianyan g	Xining	Geermu	Pingliang	
Price	0.92	1.17	0.9	1	0.5	0.45	0.45	0.3	0.65	0.52	1.2	0.3	
City	Zhangzhou	Nanchang	Jiujiang	Ganzhou	Yichun	Jinan	Sanya	Chongqing	Chengdu	Yinchuan	Urumqi		
Price	1	0.5	0.2	0.15	0.25	0.7	0.45	0.7	0.8	0.4	0.7		
City	Changsha	Hengzhou	Changed	Binzhou	Huaihua	Guangzhou	Beihai	Guigang	Haikou	Wuzhong	bayingu olent		
Price	0.65	0.4	0.4	0.6	0.4	0.7	0.36	0.3	0.6	0.4	0.68		
City	Qujing	Chuxiong	Xi'an	Baoji	Weinan	Hanzhong	Yulin	Tongren	Lanzhou	Yili			
Price	0.5	0.4	0.65	0.52	0.7	0.4	0.6	0.4	0.3	0.7			

According to the research of Yang Jintian (2005) and the World Bank report *Water price revolution of China* (2007), the highest affordable water price (including both water supply and drainage) in China accounted for 4%-5% of the households' disposable income. *Statistical report on development of domestic economy and society* published by the National Bureau of Statistics of China pointed out that the average disposable income of village households of China was 4140 Yuan in the year of 2007. Therefore, the highest affordable water price should be 207 Yuan per family. In 2007, the total population in rural areas was 0.949 billion, and the number of households was 0.252 billion (NBS China, 2007), which makes the average number of household members 3.76. Assuming a wastewater discharge of each village resident of 60 L/d, the annual wastewater discharge per household would be $60\times3.76\times365=82.3\times10^3$ L.

Based on the information above, the highest affordable water price for a village household of China is estimated to 2.5 Yuan/ton. Deducted by the average supply water price of 1.7 Yuan/ton, it is concluded that the highest affordable sewage charge level for rural residents is 0.8 Yuan/ton.

6.3.3. Feasibility of sewage charge collection on DWWT and governmental subsidy

Theoretically, the sewage charge should recover the full operation cost. However, due to the current situation of China, there will be great difficulties to meet this goal in the early phase of DWWT development, for the following two reasons:

First, the current sewage charge collection mechanism is only applied in urban areas, and there are still many problems for its implementation. In a survey conducted by the author in 2008 on residents in villages of Beijing, it was shown that most of local residents thought they should take no responsibility for environmental pollution, but the government should take them all. Moreover, the income level of the village residents was very low. Therefore, any new charges will face strong resistance.

Second, the current level of sewage charge, even fully paid by the residents, could not cover the operation cost. As shown in table 6.9, sewage charge levels in most cities are below 1 Yuan/ton. In cities with strong economics (Beijing, Shanghai), it is only 0.9 Yuan/ton; in the middle-west areas of China, it is even below 0.3 Yuan/ton. According to the analysis in section 6.3.1, this charge level is not high enough to cover the operation cost

Based on the discussion above, it is recommended that a large part of the operation cost of DWWT, if promoted in small towns and villages of China, should be provided by the local government in the form of subsidy during the early phase.

6.4. Conclusions and Discussions

The financial analysis in section 6.1 indicates that the Taihu area has the highest economical capacity to built DWWT facilities. The Dianchi area, although showing similar results, is an exceptional case due to its small area and high urbanization ratio.

Sanxia area has more than one negative factor which will restrict the development of DWWT. However, this area has more urgent demand on pollution reduction and is therefore a major area for external support.

Each financial channel has its potential role and possible problems when used in DWWT. Therefore, a multiple financial structure is recommended so that various financial channels could be complementary to each other. The suggestion in section 6.2.3 provides basic principles on choice of financial structure with regard to local economical conditions. However, further research based on detailed information of each area is required.

In the short term, local residents in rural areas will not be able to pay for the full operation cost of wastewater treatment. Subsidy from local government is strongly required to maintain satisfied operation of the DWWT facilities.

7. Management of DWWT

This chapter focuses on the managerial aspects during the construction and operation of DWWT facilities. Section 7.1 focuses on the governmental perspective, that is, on how to establish a nation-wide governmental management system for the development of DWWT in small towns and villages of China. Section 7.2 pays more attention to the project level, that is, the management mode for single projects.

7.1. Governmental management system

Management systems of DWWT in US and Japan are introduced at the beginning of this section to provide examples. Then the DWWT governmental management system for China is proposed, including relationships among different parts and key factors in the system.

7.1.1. Foreign experiences

US EPA defined 13 principal factors in DWWT management: Public education, Planning, Performance requirements, Record-keeping, Reporting, Financial assistance, Site evaluation, System design, Construction installation, Operation & maintenance, Residuals management, Training & monitoring, Corrective actions and enforcement. An appropriate governmental management system should guarantee the implementation of these principal factors based upon local conditions. US EPA also put forward five management approaches according to different levels of risks posed on DWWT systems. The risks are environmental sensitivity, public health, wastewater characteristics and treatment complexity (USEPA, 2005). The management approaches are illustrated in figure 7.1.

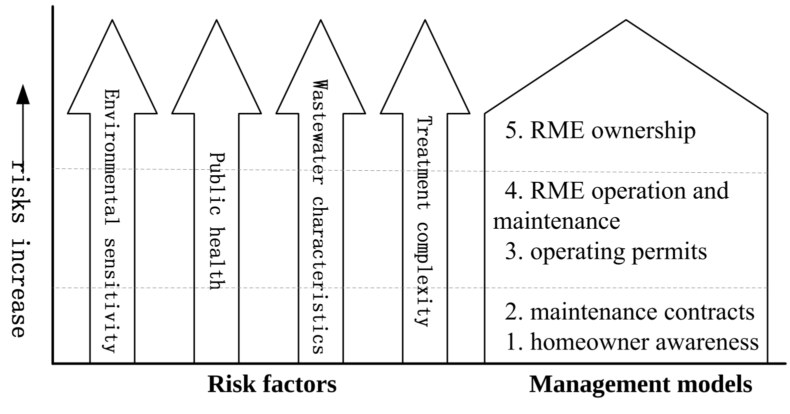

Figure 7.1. Using risk inputs to select a management model[*]

Application areas, benefits and limitations of these management approaches are

[*] In the figure, RME refers to Responsible Management Entity

explained by EPA, as shown in table 7.1.

Table 7.1. Description of five management approaches (USEPA, 2005)

Typical applications	*Program description*	*Benefits*	*Limitations*
1 Homeowner awareness			
-Low environmental sensitivity areas where sites are suitable for conventional onsite systems	-Systems sited and constructed based on prescribed criteria -Maintenance reminders -Inventory of all systems	-Code-compliant system -Easy implementation -Inventory of systems that is useful for tracking and area wide planning	-No compliance ID mechanism -Sites must meet siting requirements -Cost to maintain database
2 maintenance contract			
- Areas of low to moderate environmental sensitivity where sites are marginally suitable for conventional onsite systems due to small lots, shallow soils or low permeability soils -Small cluster systems	-Systems properly sited and constructed -More complex treatment options (mechanical, clusters of homes) -Service contracts must be maintained -Inventory of all systems -Contract tracking system	-Lower risk of treatment system malfunctions -Homeowner's investment protected	-Difficulty tracking and enforcing compliance due to reliance on the owner or contractor to report a lapse in services -No mechanism provided to assess the effectiveness of the maintenance program
3 Operation permit			
-Areas of moderate environmental sensitivity such as wellhead or source water protection zones, shellfish-growing waters, or bathing/water contact recreation areas -Systems treating high strength wastes, or large capacity systems	-Performance and monitoring requirements -Engineered designs allowed but may provide prescriptive designs for specific sites -Regulatory oversight by issuing renewable operating permits that may be revoked for noncompliance -Inventory of all systems -Tracking of operating permit and compliance monitoring -Minimum for large capacity systems	-Systems can be located in more environmentally sensitive areas -Regular compliance monitoring reports -Noncompliant systems identified and corrective actions required -Less need for regulation of large systems	-Higher level of expertise and resources for regulatory authority to implement -Requires permit tracking system -Regulatory authority needs enforcement powers
4 Responsible Management Entity (RME) Operation			
-Areas of moderate to high environmental sensitivity where reliable and sustainable system operation and maintenance is required (sole-source aquifers, wellhead or source water protection zones, critical aquatic habitats, and outstanding value resource waters) -Cluster systems	-System performance and monitoring requirements -Professional O&M services through RME (public or private) -Regulatory oversight by issuing operating or NPDES permits directly to RME (system ownership remains with property owner) -Inventory of all systems -Tracking system for operating permit and compliance monitoring	-O&M responsibility transferred from the system owner to a professional RME that holds the operating permit -Problems identified before malfunctions occur -Onsite treatment in more environmentally sensitive areas or for treatment of high-strength wastes -One permit for a group of systems	-Enabling legislation might be necessary to allow RME to hold the operating permit for an individual system owner -RME must have owner's approval for repairs; might be conflict if performance problems are identified and not corrected -Need for easement/right of entry -Need for oversight of RME by the regulatory authority
5. Responsible Management Entity (RME) Ownership			
-Areas of greatest environmental sensitivity, where reliable management is required. Includes sole source aquifers, wellhead or source water protection zones, critical aquatic habitats, and outstanding value resource waters -Preferred management program for cluster systems serving multiple properties under different ownership	-Establishes system performance and monitoring requirements -Professional management of all aspects of decentralized systems -RMEs own or manage individual systems -Trained and licensed professional owners/operators -Regulatory oversight through NPDES or other permit -Inventory of all systems -Tracking of operating permit and compliance monitoring	-High level of oversight if system problems occur -Model of central sewerage that reduces the risk of noncompliance -Onsite treatment in environmentally sensitive areas -Effective planning and watershed management -Potential conflicts between the user and RME removed -Greatest protection of environmental resources and homeowner investment	-Enabling legislation or formation of special district might be required -Might require significant financial investment by RME for installation or purchase of existing systems or components -Need for oversight of RME by the regulatory authority; might limit competition -Homeowner associations may not have adequate authority

In Japan, DWWT governmental management can be divided into three parts: 1 small scale wastewater treatment in urban areas; 2 wastewater treatment in rural areas; 3 Johkasou treatment.

Small scale wastewater treatment in urban areas is part of the urban water pollution control in Japan, serving 1000 to 10000 residents for each single project. The supervision department is The Ministry of Land, Infrastructure and Transport. Local governments are responsible for project management and maintenance.

Wastewater treatment in rural areas serves less than 1000 residents for each single project. The supervision department is The Ministry of Agriculture, Forestry and Fishery, the responsible department for project management and maintenance is also the local governments.

The Johkasou systems are used mainly in single household or residential communities. During the promotion of Johkasou systems, The Ministry of Environment established *The Johkasou Law*, and provided a subsidy for Johkasou construction. Local governments conducted public education programs and cooperated with The Ministry of Environment on supervision. The householders are responsible for daily maintenance of the Johkasou facilities.

The maintenance procedure of Johkasou systems is illustrated in the following table, including operation maintenance, cleaning and statutory inspection. Householders usually employ designated companies to conduct the daily maintenance. Statutory inspection is undertaken by relevant governmental departments (MOE Japan, 2007).

Table 7.2. Maintenance of Johkasou system

Maintenance item	*Purpose*	*Frequency*	*Contents*
Operation maintenance	Ensure daily operation	One week to half a year, depending on technology and treatment capacity	Sludge adjustment Aeration adjustment Back washing Scum removal Aeration machine check Water quality check
Cleaning	Remove sludge	Usually once a year	Sludge removal Cleaning of internal components
Statutory inspection	Evaluate newly built Johkasou systems	3 to 5 month after construction	Exterior condition check Water quality check Operation report check

7.1.2. DWWT governmental management system of China

7.1.2.1. Structure of China's DWWT governmental management system

The governmental management system for environmental protection in China is constituted by the State Council and environmental protection departments from different levels of government. The leading department is the Environmental Protection Commission, which guides and conducts environmental protection actions through the Ministry of Environmental Protection. During the implementation of policies and management of projects, assistance is required from other departments including Ministry of Water Resources, Ministry of Construction and Ministry of Agriculture, etc. The central government guides and supervises environmental protection measures of the lower level governments. The relationship is shown in figure 7.2 (Yuan, 2007).

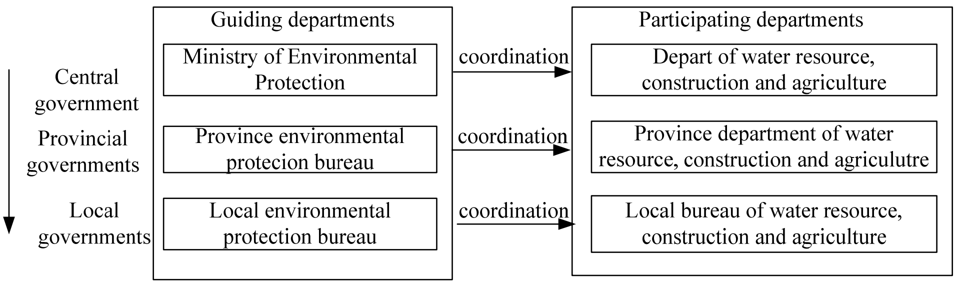

Figure 7.2. Governmental management structure of environmental protection in China

When it comes to wastewater treatment, environmental protection departments undertake the establishment and enforcement of development planning, policies, laws and standards, as well as monitoring and reporting on water quality. Water resource departments provide information regarding the capacity for pollution assimilation of the water environment, and suggests the maximum quantity of pollution discharge. Construction departments mainly supervise the discharge of industrial wastewater. Agricultural departments are responsible for control of non-point pollution from agricultural activities.

As part of environmental protection measures in China, DWWT should also be managed according to the basic structure described above. Although DWWT projects used in small towns and villages have positive effect on water quality improvement of overall basin areas, more benefits are reflected from improvements on local water quality and habitat environment. Therefore, DWWT in rural areas can be defined as local public property, which indicates that the local government should undertake the major responsibility for construction, operation and maintenance of the DWWT facilities. The responsibilities of different levels of government with regard to development of DWWT are described in table 7.3.

Table 7.3. Governmental responsibilities in regard to DWWT development

Central government	*Provincial governments*	*Local governments*
Public education on environmental protection	Public education on environmental protection	Construction of sewage local pipeline systems
Establish related legal system and standards regarding to DWWT design, construction, operation and effluence water quality	Establish local laws and standards	Conduct bidding process for DWWT construction and operation
Make national DWWT development planning	Make local DWWT development planning	Subsidize on operation of DWWT facilities
Set training outline and certification system for DWWT companies and employees	Training DWWT participating companies	Take charge in collection of sewage charge
Include DWWT development into evaluation system of local officials	Issue certification on companies	Supervision on business admittance and service performance of BOT participating companies
Compile and publish DWWT technology guideline	Improve local investment environment	Collection of raw data regarding construction and operation of DWWT
Provide financial support on DWWT for specific areas		

7.1.2.2. Principal factors in DWWT management systems of China

The relationships among governments, companies, users and research institutes are illustrated in figure 7.3. In the figure, BOT and DBO are both management modes of

DWWT project, which will be discussed in section 7.2.

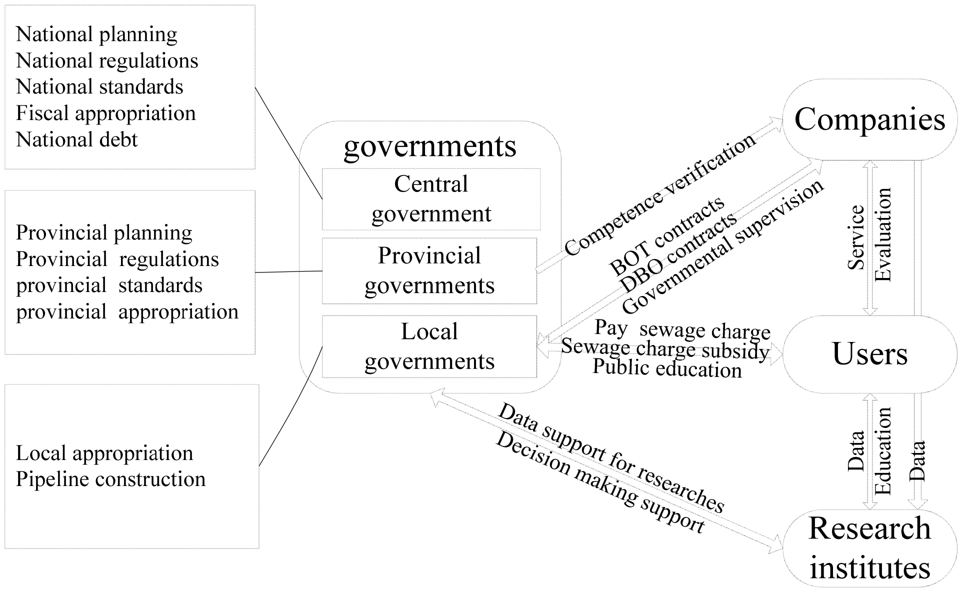

Figure 7.3. Relationships of participants in DWWT management system of China

Six principal factors of China's DWWT management system are reflected from the figure 7.3.: technology research, laws and standards, planning, financial channels, management supervision and public education.

I. Technology researches

Here, technology research does not mean development of new treatment technologies, but to study the application of existing technologies based on the natural and economical conditions of local areas. The basis of research is sufficient collection and documentation of raw data, therefore it requires the governments, companies and users to act as information sources, to provide information regarding to DWWT development, construction and operation cost, operation performance, etc.

II. Laws and standards

Laws are the highest enforced regulations for social measures. In China, the environmental law system is constituted of the constitutional law, basic laws, special laws, local regulations and department conventions. A special law for DWWT should be established to legally support the development of DWWT. Meanwhile, the provincial governments should further establish relevant local regulations.

Environmental standards are the most intelligible and transparent criteria to assess environmental conditions and environmental protection measures. DWWT has many differences from centralized wastewater treatment which is used in urban areas of China. Therefore, a series of specific standards should be set regarding design, construction and operation of DWWT. The national DWWT standards should include the overall framework and general requirements; the local governments are expected to establish more detailed and practical standards according to the national standards and local characteristics.

III. Planning

Planning includes the proposed development agenda as well as the consideration of coordination between society, economy and environment. China's environmental protection actions comply with a top-down management mechanism, and the financial resources are limited, which further emphasize the importance of planning. Like the establishment of laws and standards, the elaboration of detailed DWWT development planning should be the task of local governments. Planning at the level of the central government should focus on the total amount and provincial distribution of treatment capacity and investment.

IV. Financial channels

Appropriate financial structure should be provided to support the planning. The major investors in environment protection in China are the central and local governments; other supplementary financial channels are also required. Financial channels for DWWT are discussed in chapter 6 of this report.

V. Government supervision

Government supervision aims to ensure implementation of the development planning and the operation performance of existing facilities. The contents of government supervision can be classified as admittance supervision, project procedure supervision, price supervision and operation performance supervision. This study recommends three different project management modes during the early phase of DWWT development (which will be discussed in section 7.2).

VI. Public education

The awareness and cooperation of the public is very important for promotion of DWWT. The objects of education are residents, government officials and entrepreneurs. Education contents for residents include an introduction of the current situation of the water environment, new wastewater treatment technologies and basic knowledge about relevant laws, to make them aware of their obligations to environmental protection. The governmental officials should be informed with updated laws, policies and new technologies regarding environmental protection, as well as their roles, obligations and authorities in DWWT project activities. Entrepreneurs should learn about the potential opportunities and risks in the new DWWT market.

7.2. Project management modes

Management mode is the method of how to manage a project. In different management modes, the procedures of the project activity and the role of each participant will be different. Management mode is related to various aspects of a project, including financial channels, ownership, operation rights and efficiency.

The existing management modes in centralized wastewater treatment in China are introduced first. Then, potential management modes will be recommended based on features of DWWT in China.

7.2.1. Introduction and comparison of project management modes

The existing management modes in wastewater treatment of China could be classified into two types. The first is "governmental dominance", in which local governments take full responsibility in managing the project, and relevant companies only provide services according to contracts. The other is "company participation", in which companies own parts of the management authorities in the project.

7.2.1.1. Governmental dominance

In the mode of governmental dominance, local governments will be entirely responsible for the investment, design, construction, operation and maintenance of the treatment facilities. Parts of the services will be provided by external companies based on contracts. However, the government is the owner and coordinator all through the project activities.

The greatest advantage of this mode is to maintain the governmental control on public utilities, and ensure that the local governments have the rights to coordinate and adjust the design, construction and operation of project activities according to requirements of local development. In most countries, industries related to the countries' economic lifeline and key areas are directly or indirectly controlled by the government to guarantee the stability of the society and economy.

On the other hand, the project mode of government dominance usually does not comply with the market discipline which focuses on free market. In governmentally dominated project, the activities of companies are influenced by the enforcement measures of the governments. Therefore, total social welfare could not reach its maximum value in theory.

7.2.1.2 Company participation

In the mode of company participation, the companies will not only provide basic services, but also undertake parts of the management responsibilities. Various management modes in this group are defined by different roles of the companies.

I. BOO (Build-Own-Operate) mode

In BOO mode, companies invest in public utilities in return of franchise rights authorized by the governments. Private companies get the ownership of the facilities without time limit unless the franchise rights are taken back by the governments for serious mistakes of the companies. Local governments supervise the activities of the companies in terms of operation quality and service price. BOO mode can be used for low profit projects, in which more benefits are expected by the investors for compensation, in this case, unlimited ownership (Jibang Consulting company, 2007).

II. BOT (Build-Operate-Transfer) and quasi-BOT mode

BOT is a government-company cooperation project mode in which the companies and governments share the resources, risks and profits (Guo et al, 2006). In BOT mode, the companies will be responsible for the construction of the projects, own the operation right during the designated period, and after then transfer back to the local government. The local governments have the options to choose a new operator or continue hiring the original company under a new contract. Usually, the companies provide most or all the investment. BOT mode can be used in areas where the sewage charge systems are well established (to ensure the revenue of the companies), and it is the most common company participation project mode in China (Jibang Consulting company, 2007).

The difference between Quasi-BOT and BOT lies in the financial structure: local governments can be part of the investors of the proposed projects in Quasi-BOT. The governmental investment can be in forms of a fund injection, or others like right of land use (Fu et al, 2004). The participation of the local government as a stakeholder will substantially increase the confidence, and limit the financial pressure and investment risk of the companies. The stakeholder position also provides the local governments more power for adjustment of the sewage charge level. Quasi-BOT mode is suitable for cooperation projects between local governments and small companies which have low risk tolerance, as well as projects supported by national debt. It should be pointed out that Quasi-BOT have higher requirements on the preciseness of the contracts between companies and local governments. Otherwise there will be a higher risk for disputes over rights and interest distribution.

III. BOOT (Build-Own-Operate-Transfer) mode

In BOOT mode, the companies invest and coordinate the construction and operation of the project. The ownership of the project belongs to the company for a limited time, and is then transferred to the government unconditionally. BOOT is considered an extended form of the BOT mode by giving ownership of the projects to companies for a certain period. Compared to the broad application of BOT, the BOOT mode has been used in relatively few projects in China.

IV. DBO (Design-Build-Operate) mode

In DBO mode, the investor can be both local governments and private companies (in most cases, government). All the project activities will be conducted by one company which is chosen by the investor through bidding. The investor will pay the company after each phase of the project is finished. The designated company will be responsible for all risks related to the project activities; the investor will be free of most risks except business risk, e.g. exchange rate floating and inflation.

Comparison of these management modes are shown in table 7.4.

Table 7.4. Description of different project modes

mode	**Design**	**Construction**	**Operation**	**Maintenance**	**Investor**	**ownership**
BOO		←	→		Company	X
BOOT		←	→		Company	X, −
BOT		←	→		Company	−
DBO	←	—	→		government	−

X：company gets ownership　　　−：government gets ownership

Table 7.5. Advantages and disadvantages of different project modes

Management mode	Advantages	Disadvantages
BOO/BOOT	Less financial pressure for local government Company has better incentive	Government has less control power on the project due to loss of ownership
BOT	Less financial pressure for local government Government will recollect operation right in the future Government has ownership	The company has incentive to operate well only during its operation period, the long term operation performance could not be assured
DBO	High efficiency and shorter project timeline Improved bidding process to choose the most competitive company Government has ownership and operation right	Government investment is required (in most cases)； Less experience in China

7.2.2. Recommended project modes for DWWT in China

Based on the features of the available project modes and the characteristics of DWWT projects, which are described as low treatment capacity, large total investment requirement and lack of management experience, three project modes are recommended to be used for DWWT development during the years from 2011 to 2015 in China. These management modes are government dominance, BOT and DBO. The characteristics of each of them when applied in DWWT will be discussed in the following aspects:

- Current application situation in China;
- Advantages and disadvantages for DWWT application;
- Potential application areas for DWWT in China

7.2.2.1. Governmental dominance

I. Current application of governmental dominance mode in China

Governmental dominance is the most widely used project mode in construction and operation of public utilities in China. Although marketization is encouraged by the government in recent years, the uneven distribution of economical levels in China indicates that it is very difficult to attract private investment in small towns and villages in the middle and western areas with poor economical situations. Meanwhile, there are still conservative thinking around parts of China's governmental officials, who believe that transferring public utilities to companies will lead to negative consequences such as bad construction quality and unsatisfactory performance. For these reasons, governmental dominance will be a very important option in DWWT development in the short term.

II. Advantages and disadvantages regarding governmental dominance mode in DWWT

Since government dominance mode has been used for a long time in China, its potential advantages and disadvantages when used in DWWT are not difficult to identify. The advantages include:

Maximum social resources to promote DWWT development

Governments, as the administrators of the country and local areas, can easily get access to social resources to provide support and assistance for DWWT projects. In the early phase, immature technology, lack of management experience and high market risk are all negative factors for private investors. Therefore, it is necessary for the local governments to exploit the local market for DWWT, providing successful project cases and increasing the interest and confidence of private investors. Moreover, the executive power and credibility of the governments will help to integrate relevant departments to assist the promotion of DWWT. For example, the governmentally dominated projects have more advantages in getting financial support from national debt investment, loan from commercial banks and international finance groups.

Governments keep the ownership, easy for management and supervision

For single DWWT projects, the government dominance mode will give more power to the government for supervising the project activities. For the DWWT industry, governmental ownership is an advantage for coordinating the development of DWWT and preventing negative influences caused by the profit oriented measures of the companies. For instance, in BOT mode, the company may propose a higher construction cost to win the bidding, and reduce the actual expenditure in real construction.

Flexible mechanism for government to adjust sewage charge level

Under the current condition of sewage charge collection in urban areas, there is a potential contradiction between the company's demand for profit and the inadequate willingness and capacity of the local residents to pay sewage charge. In governmentally dominated projects, the local governments have higher control power to adjust the sewage charge level. In extreme cases, the local governments can entirely afford the operation cost for a certain period, and consider sewage charge collection when the local economy grows stronger.

On the other hand, the governmental dominance mode has the following disadvantages:

High financial pressure on local governments

According to the analysis of construction cost and financial pressure in section 6.1, it will be a considerable financial burden for local governments to undertake full responsibility of DWWT construction.

Lack of communication mechanism between the service providers of different phases of the project

In governmentally dominated projects, the designers, constructors and operators mainly focus on their own work under the contracts. There is no communication mechanism between them to ensure consistency on technological details of the projects, and no retroactive mechanism for the work of each service provider. The potential consequence is unsatisfied performance of the facilities, and disputes on distribution of responsibilities when malfunction happens.

Lack of governmental incentive, operation performance could not be assured

China is a developing country, and most of the rural areas are still poor. Therefore, there are huge demands for public utility constructions and industry investments. Some of the local officials (probably most) prefer to use the limited money on more economically beneficial areas such as road paving or local industries, rather than supporting environmental protection like DWWT construction. Moreover, the current evaluation methods on local governments' performance of environmental protection usually focus on the quantity of built treatment capacity, so even if the treatment facilities are built, there is not enough incentive for the local governments to ensure good operation of the facilities. It should be noticed that in the poor areas where the environmental ambition and the economic level is weak, the collection of sewage charge will meet more obstacles, which indicates more barriers for the operation of the facilities

III. Potential application areas of governmental dominance mode in DWWT development of China

Due to the current situations with inadequate project experience and limited sewage charge payment capacity of the rural residents, the project mode of governmental dominance, which has the advantages of long application experiences and easy governmental management, is feasible in most areas of China. However, considering the marketization trend in public utilities and the financial situation of local governments, supplementary project modes are required as well.

7.2.2.2. BOT （Build-Operate-Transfer）

I. Current application situation of BOT mode in China

BOT is the most widely used management mode in new wastewater treatment facilities in China. The application situation of BOT in China is discussed in section 6.2.2.3 "corporate investment".

II. Advantages and disadvantages regarding BOT mode in DWWT

The advantages of BOT applied in DWWT are described as below.

Relieve financial pressure of local governments

The financial pressure on local governments are repeatedly mentioned in this study, and fiscal investment from the central government in forms of national debt or appropriation usually require complex and long approval processes, which may lead to delay of the project timeline. As investors in BOT projects, the companies have adequate financial resources to undertake the cost in construction and operation, and therefore substantially relieve the local governments of the financial pressure.

Enhance management level and operation performances

In existing centralized wastewater treatment plants of China, there are widely seen problems of unmatched pipeline systems and loose management, which lead to serious loss of treatment capacity and poor treatment performance. The features of DWWT projects indicate that here these problems will be even more serious than in centralized wastewater treatment. BOT is an investment behavior of companies, whose requirement for cost recovery and profit will hopefully provide an incentive to achieve full operation of built treatment capacity and good effluent water quality, and at the same time reduce management cost of the local governments.

Introduce advanced technology, and develop DWWT based on local conditions

DWWT facilities are more likely to be influenced by natural environment for the reasons that the treatment capacity is smaller and natural treatment technologies are usually applied. Therefore, appropriate choices of treatment technology and operation measure for each area's specific natural circumstance are very important. In the improved BOT mode (DBOT), the companies will be more active in choosing proper technology, and the governments need only to establish certain standards and guidelines for DWWT design and construction, rather than putting excessive resources into technical details.

Despite all the advantages, BOT also show some weakness when applied in the initial phase of DWWT.

Defective legal system for BOT in China

Sound legal system would help to standardize and facilitate the development of BOT application in public utilities, create stable investment environment and increase the confidence of investors. However, this kind of systems is not well established in China yet (Guo et al, 2006). DWWT projects are small scale investments, the number of projects, if promoted, will be enormous, and these projects will be distributed in the remote rural areas. Many impropriate measures like nontransparent bidding processes are likely to happen if the BOT mode is still conducted without strict and reasonable laws. This defect will increase the investment risk for BOT projects, which will reduce the interest of risk averse investors.

Unfavorable investment environment in small towns and villages of China

As a market oriented project mode, BOT requires stable investment environment, including policy support from local governments, adequate sewage charge payment capacity of the residents, etc. However, under the current immature sewage charge collection mechanism, a large number of centralized wastewater treatment plants built in urban areas are relying on governmental subsidy to maintain ordinary operation. In small towns and villages, this problem will be more serious considering the low economical level and lack of environmental protection awareness of local residents. Moreover, the limited economical strength of local governments indicates that it will be a burden to subsidize wastewater treatment in the long term. If the operation cost could not be recovered, there is no reason for companies to invest in DWWT projects.

High investment on unit treatment capacity

BOT wastewater treatment projects have a preferable treatment capacity between 10000 and 30000 tons/d in China. Higher treatment capacity is likely to be hindered by inappropriate pipeline systems; lower treatment capacity, on the other hand, will have a relatively high unit construction cost because the early phase expenditure will take a greater proportion in total investment, which will make the project less attractive to investors (Liu & Guo, 2005). A feasible solution to this problem is to bind two or more DWWT facilities together in a single BOT project. In this way, the unit construction cost will be reduced.

III. Potential application of BOT mode in DWWT development of China

The eastern areas of China have better economical conditions, a more favorable investment environment, better established sewage charge collection mechanisms and higher requirements from local governments and local residents for environmental protection and improvement. For all these reasons, BOT mode should first be introduced in these areas. Moreover, DWWT projects with relatively large treatment capacities are more attractive to BOT investors.

7.2.2.3. DBO (Design-Build-Operate)

I. Current application situation of DBO mode in China

DBO mode is widely used in developed countries, but there are very few existing wastewater treatment projects using DBO in China. Application of the DBO mode in environmental protection public utilities is recommended in *Decision on implementation of conception of scientific development on environmental protection* published by the State Council in the year of 2005. When it comes to DBO application in DWWT, the financial resources could be local governments or national debt investment from central government. Therefore, although there's no existing case, DBO has the potential to be applied in DWWT in China.

II. Advantages and disadvantages regarding DBO mode in DWWT

Based on the current situation for DWWT development in small towns and villages of China, as well as the characteristics of DBO, the advantages of DBO mode applied in DWWT can be summarized as below.

High project efficiency

In governmentally dominated projects, the local governments have to entrust external designers, constructors and operators to provide relevant service. BOT investors also outsource parts of the project activities to third parties. In both project modes, it is a challenge to coordinate the independent measures of different parties. In the DBO mode, one company is responsible for all activities. Therefore, many disputes among project parties can be avoided (Sun et al, 2008).

Attract more competent companies to ensure the project quality

In DWWT projects, design and construction in the early phase substantially influence the future performance of operation and maintenance. In governmentally dominated projects, the operator could not get involved in early phases activities, but will take over the operation responsibility after the construction is completed. Without knowing the design and construction details of the projects, the operator usually has inadequate basis on how to perform good operation service. In DBO mode, the overall responsibilities of the projects imply that only companies with superior knowledge and experiences in wastewater treatment industry can undertake the task.

This kind of selection mechanism also exists in BOT mode. However, operation cost is usually the only indicator for choice of bid winner in BOT bidding; therefore companies have the incentive to reduce real construction cost. This measure will inevitably influence the quality of the treatment facilities, especially after the transfer of operation right. Compared to BOT investors, bid winners in DBO project will get payment for design and construction directly from the government based on actual expenditure, so the bidding companies have no incentive to provide fake budget planning on project design and construction, which means the government will have more reliable references for choice of the winner.

Local governments hold ownership and operation right

BOT projects get company investment by giving up the operation right of public utilities for a certain period, and the operation payment in the long contracted period is already fixed at the beginning of the project. Under these measures, the local government suffers loss of management power over the public properties. In DBO projects, the local governments always keep the ownership and operation right of the facilities and the contracted operation period is usually much shorter than BOT. This gives the local government more space for management and supervision (Qin, 2008).

Small financial risk for companies

The cost and expenditure of the company in each part of the project activities will be covered instantly by the local government, so the companies do not undertake the financial risks as BOT investors, who have to rely on the collection of sewage to recover original investment and make profit.

DBO and BOT are both company participation project modes, so they have similar weakness, such as a defective legal system and large initial expenditures. Moreover, as a pure management mode without investment behavior, DBO aims only at providing a high efficiency management approach for proposed projects that are already financed. Therefore DBO could not be expected to solve the financial restraint in the development of DWWT.

III. Potential application areas for the DBO mode in DWWT development in China

DBO aims to simplify the management structure of the project, optimize project procedure and enhance construction and operation quality, which are urgently required in China's DWWT development. The introduction of the DBO mode is a challenge to the conventional project mode in wastewater treatment industry, and the number of existing DBO projects in China is extremely limited. Therefore it is recommended that DBO should first be applied in projects financed by the local government in rich areas like the Taihu basin, to improve the application of DBO by governmental supervision under better economical conditions. When this project mode is more mature in China, its potential to be used under different financial conditions should be further exploited.

The features of the recommended management modes and their application areas in China are summarized in table 7.6.

Table 7.6. Summary of the recommended management mode in DWWT of China

Projects modes	Government dominance	BOT	DBO
Current status	Widely used existing and new built projects;	Widely used in new built projects	Few application cases in China
Advantages	Higher government control; Easy coordination of social resources Flexible sewage charge mechanism	Low financial pressure for local government High incentive for good operation performance Specified development based on local conditions	High project efficiency Better company selection process Higher government control than BOT Companies hold less risks
Disadvantages	Financial pressure for local governments Low efficiency	Defective legal system Not applicable in poor areas Small projects are less attracted to companies	Defective legal system Small projects are less attracted to companies Lack of experience in China Financial pressure for local governments
Potential areas	All areas of China	Eastern areas of China in early phase	Eastern areas of China in early phase, and has potential to be used nation-widely

8. Concluding discussion and recommendations

As mentioned in section 1.1, the purpose of this research was to:

1 Indicate the significance of wastewater pollution in small towns and villages of China, by the means of model estimation and define the application areas of DWWT in China.

2 Analyse the solutions for financial problems that would be faced in the development of DWWT in China, during both the construction and operation phase.

3 Analyse the managerial issues, including the establishment of governmental management system and the choice of project management modes.

After the analysis and discussion in the previous chapters, the answers and solutions regarding the purpose of this research is summarized below.

1 It is demonstrated by the model estimation that wastewater from small towns and villages does take a considerable part in the overall water pollution of China, and it should not be ignored in the next "twelfth five-year planning"(2011-2015).

Four potential application areas of DWWT in China are identified, including small towns, villages, natural reserves & travel resorts and urban areas. This research focuses on the areas of small towns and villages. Wastewater treatment facility for single household is not feasible for China due to financial barriers, therefore, treatment facility at the level of the township area is recommended.

2 According to the estimation on construction cost and analysis on financial pressure for each basin area, it turns out that Taihu area has the highest economic strength to undertake the financial demand of DWWT construction. On the other hand, Sanxia area would face the strongest financial barriers because of low economical level, high individual water consumption and high proportion of rural residents. Although China has been promoting marketization of public utilities since 2002, local governments are still the major investors for DWWT as a result of the immaturity of the market. Investment from central government and private companies will be important supplementary financial channels.

Based on the charge level of wastewater in urban areas of China and the output of the case study on operation cost of small scale wastewater treatment facilities, it can be concluded that the residents in small towns and villages of China could not afford the operation cost of DWWT, at least not in the near future. The local governments have the obligation to provide subsidy to maintain the daily operation of the facilities, if DWWT starts to be promoted from 2011.

3 For DWWT development, the governmental management system should be consistent

with the current management structure of environmental protection in China. Considering the experience of foreign countries, six principal factors should be emphasized: 1 technology researches, 2 laws and standards, 3 planning, 4 financial channels, 5 management supervision and 6 public education.

Regarding project management modes, “governmental dominance” is considered as the major form of management mode for construction and operation of DWWT facilities in the early phase; the BOT mode will be used for company invested projects mainly in the eastern coastal areas; the DBO mode, because of its high efficiency and low management cost, has the potential to be widely applied in DWWT projects under different financial conditions.

Due to the slow update on statistics of population and economical information with regard of basin areas in China, the author needed to rely on the data of several years before to conduct the estimations and analysis. Further conclusions in the following chapters, for instance, analysis of financial pressure, are also based on the results of previous estimations. However, since the population and economic growth in China have been stable in the recent years, and there are no major social and economical changes, it can be concluded that the estimations of this research are reasonable.

Further research could be conducted with regard to both time and geographic aspects. For aspect of time, further updated data and information in each basin area can be included in the estimation and analysis, to generate more accurate conclusion; for geographic aspect, each basin area could conduct more detailed researches on e.g. financial pressure for DWWT construction, applicable technology and establishment of management system, based on the unique features of local areas.

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