Erdos Eco-Town Project of Inner Mongolia

Economic Evaluation of the Ecosan System

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October, 2007

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Chapter I Objective, Content and Method of Study

1.1 Objective and Significance of Study

Entrusted by SEI, this study takes the Phase-I project of Haozhaokui Community Ecosan System of Dongsheng District, Erdos City as the study subject to find out the economical efficiency of the ecosan system by comparing with the conventional sanitation system. The study assesses the sustainability of the ecosan system of the small town from the economic point of view, and proposes practical policy suggestions.

Ecosan system upholds the advanced concept of cyclic utilization of waste water and solid wasters and provides comprehensive treatment approaches on basis of the promotion of closed cycling system of nitrogen-phosphorus nutrients and water reuse and cycling system. The ecosan system can recycle the nutrient contents of human excrement by means of agricultural use, which facilitates the preservation of fertility, ensures foodstuff safety, reduce water pollution and recycle the biological energy. Therefore, the ecosan system enables the economic utilization of water and the recycling of human excrement. In recent years, the ecosan system has been paid close attention to, and extensive research findings have been accumulated in various parts of the world. The ecosan system is further developed through international exchange activities.

China is a country in short of water. In particular, the per capita water resources possession in Dongsheng City of Inner Mongolia, where this research project takes place, is only 300 cubic meters, which is about 1/7[*] of national average level. An advanced and effective water saving and recycling method can promote the sustainable development of Dongsheng City, a water-deficient area.

The ecosan system project, compared with other investment projects, can not only exert an influence on investors but the country, society and regional economic development as well. Therefore, the assessment of the economical efficiency of the project is critical for the feasibility of the project. Besides taking its influence on investors into account, the assessment of this environmental protection project of public utility shall also consider its impact on the society and the country. For the purpose of this environmental protection project, priorities shall be given to the macroeconomic benefit and social benefit of the project. The financial evaluation solely on the profitability of investors cannot represent the actual benefits of this project.

The urban ecosan system, especially the construction of ecosan system (source separated system), only takes its first steps in China. The rationalized application of technologies and effective investment and construction methods and effects are all highly concerned by the people. Meanwhile, we can also draw an important lesson from the further promotion of the ecosan system in urban areas. The efforts made by Erdos and SEI allow this project to take leadership in the application of ecosan system. In China, Erdos is considered a small city. In order to speed up the process of urbanization, China is currently strengthening the construction of small- and

[*] According to World Bank, the per capita water resource of China only reaches 2200 cubic meters, which is only 1/4 of the per capita water resources possession of the world.

medium-sized cities. Therefore, the construction and operational result of the ecosan system of Haozhaokui Community of Dongsheng District, Erdos will facilitate the construction of environmental protection facilities of small towns.

1.2 Major Research Contents

As a kind of sustainable sewage management and sanitation system in the aspect of ecology and economy, the ecosan system upholds the brand-new concept of ecological economy by transforming the existing sewage/waste collection and treatment system into the sustainable "Recycling Economy".

The Germany architect Leberrecht Migge, in the early 20th century, proposed the concept of eco-toilet. In 1985, the Sweden ecology expert Uno Winblad brought forward the concept of water-free eco-toilet. Besides the sanitary functions, such kind of new products are required to be ecologically friendly. The water-free eco-toilet is expected to accomplish "zero-pollution, zero-infection and zero-waste-discharge" as well as "reduction, harmlessness and resource" oriented development.

The research contents of this project are as follows:

(1) The ecosan system, including the construction costs of the toilet system, the waster supply system, and the domestic sewage & solid waste treatment system; the cost of operation; the benefits; the expense and benefit arisen from the environmental impact of the material flow of the aforesaid system.

(2) Cost estimate of the conventional sanitation system of Dongsheng District; statistical analysis on the construction cost of the conventional sanitation system of Haozhaokui Community if such a system is adopted, including the toilet system, the sewage collection and delivery system and the sewage treatment plant, as well as the cost for sludge disposal. Meanwhile, the corresponding operating costs and benefits shall also be calculated.

(3) The comparison & evaluation mechanism and evaluation study on the ecosan system and the conventional sanitation system, so as to find out the difference between the ecosan system and the conventional sanitation system/conventional flushing sanitary facilities integrated with reclaimed water reuse from the aspects of construction cost, operating cost and related benefits.

(4) To study the problems arisen from the scale-up of ecosan system, and conduct comparative studies on the costs and benefits of the scaled-up ecosan system and the conventional sanitation system.

(5) Policy suggestions for promoting the sustainable development of ecosan system.

1.3 Study subject

1.3.1 Background of Dongsheng District

(1) Geography

Being the political, cultural and economic center and transportation junction of Erdos City, Dongsheng District is located on the top saddle of Dongsheng ridge, which is at the structural high in the heart of Erdos highland of Inner Mongolia. Characterized by the typical continental climate of the arid zone of Central Asia (moderate temperature zone), Dongsheng has a geographic location of 39° 48′ north and 110° 00′ east. Dongsheng is characterized by the semiarid continental highland monsoonal climate, which is warm and heat in summer and long and cold in winter. Besides the great temperature difference, the area is also sufficient in wind and deficient in precipitation, with mean annual precipitation being 396.4mm and average evaporative capacity being 2200mm. The geological structure of this area is mainly featured by Cretaceous sand stones, with Jurassic strata exposed at certain areas. The surface layer is mainly in the form of sandy soil and gravel soil. Owing to its climatic, precipitation and geological features, Dongsheng District is barren in soil and sparse in vegetation cover, and is suffering from severe water loss and soil erosion.

(2) Economic development

Dongsheng District is a new industrial zone giving priority to the development of such industries as coal, weaving, construction material, chemical engineering and foodstuff. In 2005, the GDP of Dongsheng District hit RMB 12.71 billion, representing a growth of 31.1% over the last year, while the financial revenue and the average per capita disposable income of urban residents reached RMB 2.94 (a growth of 128.7%) billion and RMB 11,819 (a growth of 27.0%) respectively. According to the Erdos Daily dated May 16, 2007, the GDP of Dongsheng District hits RMB 18.7 billion in 2006, with its financial revenue reaching RMB 5.05 billion, ranking top among 101 counties of the autonomous region in respect of the gross amount and the growth rate of its financial revenue. With the average per capita disposable income of urban residents reaching RMB 14,091 and the per capita net income of peasants reaching RMB 5,430, the proportion of the primary, secondary and tertiary industries has been adjusted as 1:39:60. With the development level of aggregative economy maintaining leadership in the autonomous region, Dongsheng District is ranked 25th among top 100 counties & cities of China, and has been well improved in its overall competitiveness. Along with the rapid development of economy, the shortage of water resources has become a key factor restricting the economic development of local areas.

(3) Water supply and drainage

In 1999, the entire city was in severe shortage of water, and the water supply fell behind the development of the city. In September 2000, the service discharge reached 8000 t/d (intake from the shallow layer of the river shoal), which can satisfy demands basically. In October 13, 2005, Dongyuan Water Supply Co., Ltd (government owned) managed to introduce the water of Yellow River into Dongsheng District, allowing the daily service discharge to reach 22,000 tons, all of which are surface water from the shallow layer. Currently, the daily service charge can hit 30,000 cubic meters. There is no well water source in the urban area (only a 600m^3/day water well nearby the square).

Currently, Dongsheng has three water-supply sources: 1) East Wulanmulun river valley on the south of the city; 2) Hantaichuan upstream valley to the north of the city (14km); both are subsoil water from infiltration gallery; 3) subsoil water in the urban area and from the pumping well of Haojiagebo. The gross production of the existing water sources can hit 25,000 m^3/day.

Currently, no backup water source can be found within 10-kilometer reach of Dongsheng District. The only solution is to introduce the water of Yellow River. Upon argumentation and preliminary design, the Phase-I project in 2005 brought about a service discharge of 50,000 m^3/day, and the Phase-II project in 2010 is expected to achieve a service discharge of 100,000 m^3/day. The total distance of water delivery reaches 100km, with a gross lift of 485.9m and five booster stations. Currently, the project has entered into the construction phase.

Upon actual investigations and calculations, the per capita domestic water consumption of Dongsheng District was 80L/day in 2003.

In "Groundwater Resource Management & Water Saving Office of Dongsheng District, Erdos City: The Water Saving Plan of Dongsheng District, Erdos City of 2005-2010" (April 2004), the balance of supply and demand of the gross water resources of Dongsheng District is analyzed, and the result indicates that there are still discrepancies between the supply and demand of water in Dongsheng District. The daily water shortage in 2005 was 18,000 m^3, and that in 2010 is expected to reach 3000 m^3.

The sewage collection areas of Dongsheng is 75% of its total urban area, which is 32 km2. Before 1986, the pipeline system of Dongsheng was a combined system, and was only transformed into a shunt system after 1987.

The industrial wastewater amounts to 40% of the gross sewage discharge of Dongsheng District, while domestic sewage constitutes the remaining 60%.

There are total three sewage plants: North District Sewage Treatment Plant, South District Sewage Treatment Plant and Dinghao Decontamination Station.

North District Sewage Treatment Plant: With the Phase-I project completed in 1999, the plant was fully constructed and put into production in 2001 with a capacity reaching 20,000 tons/day. The plant was expanded in 2005 in order to reach a capacity of 40,000 m^3/day. The expansion project was completed in 2006. The Phase-I project was financed by national debt, with a gross investment (including the pipeline network and the pumping station) reaching RMB 73,260,000. With budget hitting RMB 26,000,000, the expansion project was self-financing and further funded by state allocation. The aforesaid inputs reach RMB 100 million. While applying the two-stage bio-membrane process, the water discharge of the sewage treatment plant can reach Class-II standards in respect of certain key indicators.

With construction completed in 2003, the South District Sewage Treatment Plant has a design treatment capacity of 2000 m^3/day, while the actual treatment capacity is 1800-1900 m^3/day. With construction cost reaching RMB 6-7 million, the plant produces about 60 tons of waste sludge per day.

Currently, the urban drainage pipelines breaks into four categories: main pipe, branch pipe, sub-branch pipe and drainage pipe. The gross length of main pipes and branch pipes in Erdos hits 229 km, with 300-400mm PVC pipes used in old urban areas and 500mm PE pipes used in the new district.

In 2006, researchers of this project conducted an investigation on Dongsheng Sewage Treatment Company. The result showed that the direct operating cost of the sewage treatment plants is RMB 0.5/m^3 (labor, drug consumption and energy consumption). If the pipeline maintenance is included, the gross direct operating cost will be RMB 1.0/m^3. The operation at full load of 27,000 tons/day can serve a total population of 400,000. Actually, as a result of population movement, the actual population served is only 320,000. There are totally 45 managerial personnel, including 12 in the north station (2 are casual laborers) and 10 in the south station. They are responsible for the construction, maintenance and management of the pipeline network.

According to related requirements of "Circular on the Tariff Adjustment for Water Supply/Drainage in Dongsheng District, Erdos City" ([2006] No.1498), the tariff for water supply was adjusted to RMB 3.5/m^3 (RMB 0.4/m^3 for sewage treatment) from September 1, 2006, to RMB 3.6/m^3 (RMB 0.4/m^3 for sewage treatment) from September 1, 2007, and to RMB 3.7/m^3 (RMB 0.4/m^3 for sewage treatment) from September 1, 2008. In addition, households with actual water consumption with 9 tons will be charged on the fundamental tariff. Otherwise, the charge rate will be 1.5 times of the Class-I water tariff. According to "The Comprehensive Working Plan for Energy Saving and Discharge Reduction" issued by National Development & Reform Commission on June 3, 2007, the charge rate for sewage drainage will be further raised.

The tariff for industrial water consumption was raised from RMB 4.4/m^3 to RMB 5.5/m^3, and that for industrial wastewater discharge was raised from RMB 0.45/m^3 to RMB 0.70/m^3.

According to "The Comprehensive Working Plan for Energy Saving and Discharge Reduction" issued on June 3, 2007 (by National Development & Reform Commission and etc), all urban areas of China will begin to charge the sewage treatment fee, and the charging standard will be gradually raised. Generally, each cubic meter of sewage will be charged RMB 0.8. Meanwhile, the charging standard for garbage treatment will also be raised, and the charge mode will be improved. At present, a majority of cities have adjusted their sewage treatment fees.

Generally, on basis of the present economic development condition of Dongsheng District and the principle of "to charge those who cause pollution", and in consideration of urging water-saving in water-deficient areas and making the water rate more reasonable, as well as the actual sewage treatment tariff of Dongsheng District, the sewage treatment charge of RMB 0.4/m^3 on urban residents is considered on the low side. In this study, the sewage treatment fee adopts RMB 0.8/m^3.

The shortage of water resources has become a key factor restricting the economic development of local areas. Dongsheng is making efforts to carry out water reclamation, and the reclaimed water of Dongsheng Sewage Treatment Plant will be delivered to Guodian Power Plant (2×300 MW) and Mengtai Thermal Power Plant (2× 250 MW), both of which will reuse the water after simple retreatment.

1.3.2 The ecosan system of Haozhaokui Community of Dongsheng District

Haozhaokui Ecological Community applied with the ecosan system is constructed under the cooperation between Dongsheng District Government of Erdos (Inner Mongolia, PRC) and Stockholm International Environment Research Institute of Sweden (SEI) and Swedish International Development Cooperation Agency. The cooperation is aimed to study the feasibility of the application of ecosan system in urban areas, and to construct and promote ecosan system throughout China and the rest areas of China. This community is the only research project featured by the scaled-up application of source separated ecosan system in multistory buildings.

Haozhaokui Community is an ecological community integrating eco-toilet, domestic sewage and solid waste processing facilities. In March 2003, SEI concluded a cooperation LOI with Erdos City, and then a cooperative agreement was reached between both sides (September 2003 - December 2007). In April 2004, Dongsheng

District Government signed a construction agreement with Daxing Construction Company.

19.73 hectares of lands are developed during the Phase-I project of Haozhaokui Community, covering a total construction area of 115,600 square meters. 43 apartment buildings are installed with water-free eco-toilet, with 14 buildings being 5-story buildings (the 4th story to 5th story belong to one household) and others being 4-story buildings. There are totally 832 households, covering a total floor area of 100,000 square meters. The community is featured by a greening rate of 48% and a plot ratio of 0.78. Besides the residential buildings, there are also pedestrian mall, school, kindergarten, club, square, shopping center, parking area and etc. The residential construction was completed in 2005, and the earliest residents have been living in the community for 23 months as of the date of this report (January 2006 – November 2007). Currently, all construction works have been completed. The appearance of the community and the interior sanitation system are shown in Fig. 1-1.

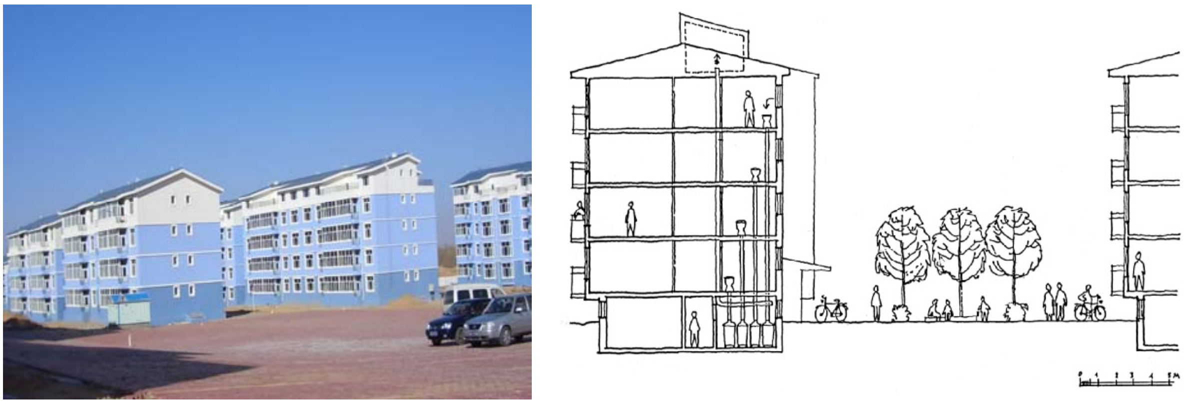
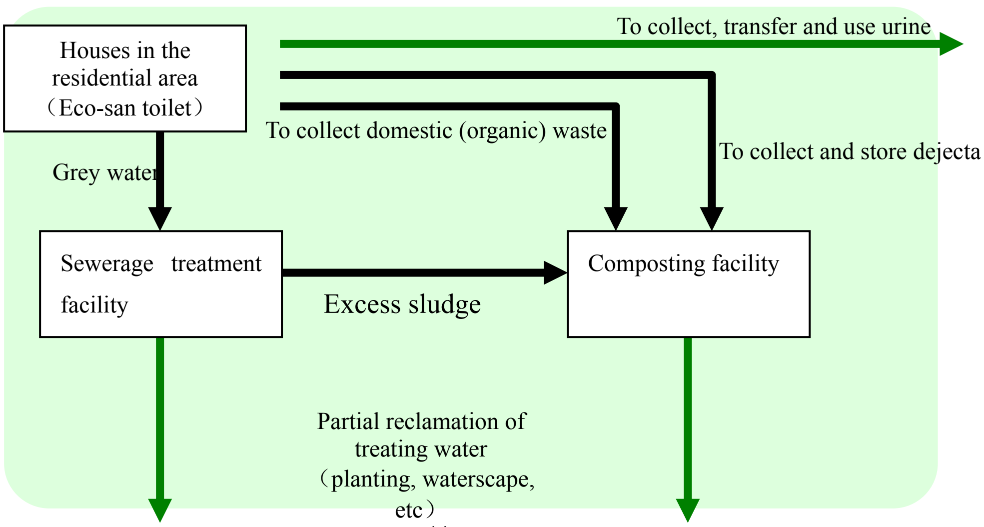


Figure1-1 Ecosan System inside Haozhaokui Community and Its Building of Dongsheng District

The features of Haozhaokui ecosan residential area in Dongsheng District are as follows:

- Modern urban housing;
- Ecosan toilet separating feces and urine. To collect feces and urine by source-separation dry toilet. The domestic sewage would not be polluted by feces and urine.
- To adopt decentralized wastewater treatment system. The decentralized wastewater treatment system may assure that the daily domestic sewage of residenters would not be drained into municipal sewage conduit but treated directly by the grey water treatment plant inside the residential area. The treated grey water would be stored in the after-treatment pool inside the residential area and then for reclamation by proper way;
- Source separation of solid waste and organic substance;
- To sort, reserve, compost, and recycle by Eco-station. The feces would be produced into fertilizer for agriculture use by composting, and the urine would be diluted directly for agriculture fertilizer;
- To reuse all organic substance and nutriment from household waste for agriculture use.

The schematic diagram of pollutants control and utilization in Haozhaokui Community is shown as Figure 1-2.



Permitted discharge of treating water

Utilization of composting product

Figure 1-2 Pollutants Control and Utilization in Haozhaokui Residential Area

The design capacity of Decentralized Wastewater Treatment Facility in Haozhaokui Community Eco-station is 250m^3/d, and its direct flow is as Figure 1-3.

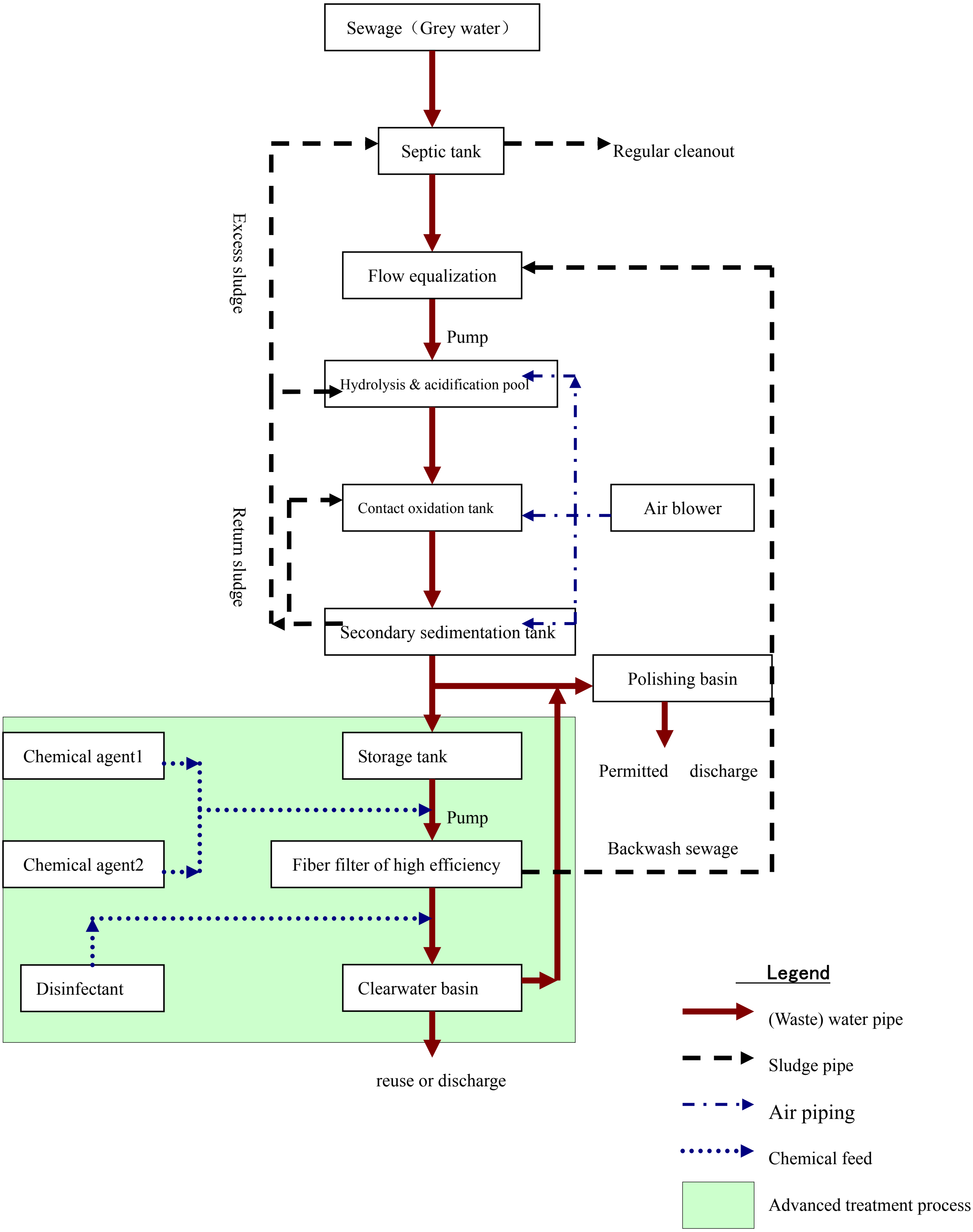


Figure 1-3 Flow Process Chart of Decentralized Wastewater Treatment System in Haozhaokui Residential Area

1.4 Research Basis

（1）Relevant national laws and regulations for environmental protection and resource utilization in China;

（2）Relevant national technical document in China;

（3）Relevant national economic evaluation technique parameters in China; relevant economic evaluation technique in World Bank and ADB; local economic technical data in Mongolia;

（4）Document and data relating to project performance and construction provided by the Project Office of Dongsheng Eco District of SEI;

（5)The present situation of city, environmental protection, water saving, plan of Erdos and Dongsheng government and relevant document;

（6）The data and information investigated and approved by the project member;

（7）Other documents relating to this project study.

1.5 Research Methods

1.5.1 Working Route

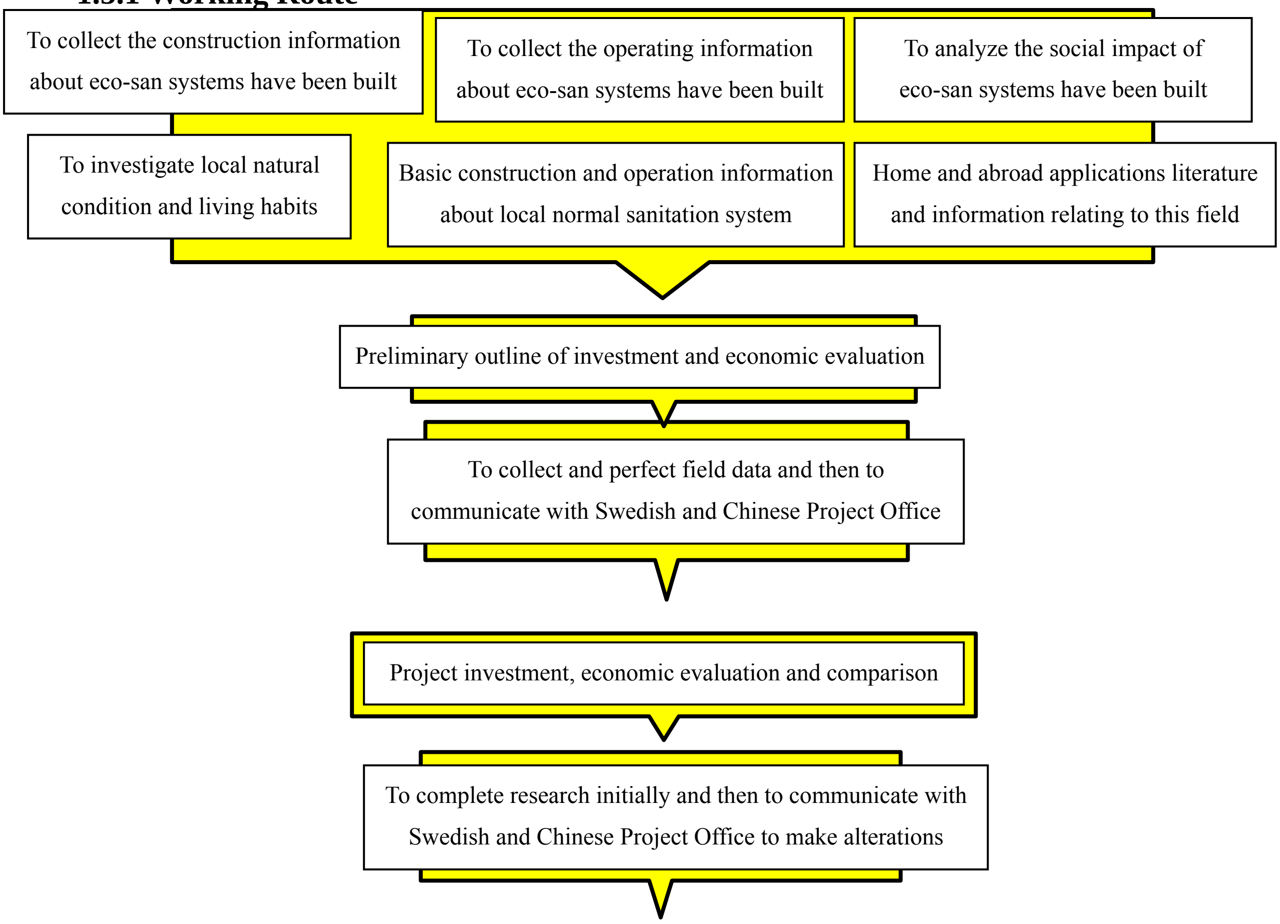


Figure1-4 Working and Technical Route Map of This Project

1.5.2 Research Methods

The economic evaluation in this study is mainly for economic analysis of present situation of Ecosan System in Erdos demonstrating residential area (832 households and 2912 people). It not only works over optimum size of similar system, but also performs the economic analysis simultaneously. The economic analysis combines the methods of international organizations (like World Bank) with the regulation or ways of National Development and Reform Commission. The key data of Ecosan System in Mid-Erdos demonstrating residential area is provided by SEI Project Office and acquired by the project researchers.

The concrete research methods of this project are as follows:

（1）To unite the toilets, water supply, water treatment, solid waste and other systems required by human habitat of small towns as a whole one and then to comprehensively compare the construction cost, operating cost and benefit of Ecosan System with those of conventional sanitation system.

（2） To analyze and compare local economic development plan (short-term and long-term), including the cost and benefit of environment.

（3）The economic evaluation technique should mainly adopt cost-benefit analysis and comply with the principle of distinguishing cost from benefit and principle of with and without comparison. The measurement of social investment for project (project investment) refers to grand total of monetary expression for all sorts of social resources and labor services required by building-up the project and reaching the predetermined state of treating relevant pollution as well as the social capital consumed during the project operation, including fixed investment of social resources consumed directly by the project construction and fixed investment of social resources consumed indirectly).

（4）To work over the available scale on the basis of the present result of economic evaluation for eco residential area and then to do the concept design for Ecosan System according to such scale. Meanwhile, to carry out economic evaluation by cost-benefit method.

Chapter Ⅱ Status Description of the Recent Domestic and Oversea Studies and Applications of Ecosan System

2.1 Development of Ecosan System

2.1.1 Applications and Problems of Conventional Sanitation

In 20th Century, flush toilets were prevailing; water pollution was deteriorating while wastewater treatment process was further perfected. However, as the global population increases quickly and urbanization quickens its steps, the problem of water pollution goes worse rather than being settled. More than 90% wastewater without sound treatment is poured into environment. There are approximately 1 billion people who use flush toilets, 70% of the wastewater from which is poured into environment without treatment. According to the recent global urban water pollution controlling approach, the so-called conventional sanitation should be applied as often as possible within the allowance of economy to collect and treat wastewater, that is to say, to utilize separated or combined drainage system to collect wastewater from dwellings (including wastewater from flush toilets, kitchens, process of bathing, washing hands, faces and clothes), then transfer it to wastewater treatment plants for treatment. To meet the requirements of wastewater discharge and utilization, wastewater treatment plants should treat wastewater discharged from urban pipelines to different levels, such as primary treatment, enhanced primary treatment, secondary treatment and tertiary treatment. Table2-1 summarizes different pollutant reduction percentatge of such treatment processes[1].

Table 2-1 Pollutant reduction through different methods of wastewater treatment

treated water quality index	primary treatment	enhanced primary treatment	secondary treatment	tertiary treatment
BOD	30mg/L	50-70%	90-95%	＞95%
TSS	60 mg/L	80-90%	90-95%	＞95%
TN	15 mg/L	25%	40%	＞80%
TP	15 mg/L	75%	90%	＞90%

Construction of conventional wastewater collecting and treatment system demands great investment. Additionally, as wastewater treatment goes to a further and further level, investment of conventional wastewater treatment facilities will increase as well. And charges for conventional wastewater collecting and everyday operation & maintenance are relatively higher. Charge for operation & maintenance is firmly related to the selected drainage system and treatment process.

Conventional wastewater collecting and treatment system plays a fairy important role in human civilization and urban development. For a long period, conventional wastewater collecting and treatment system will still benefit public and environment health protection a lot.

Though conventional wastewater collecting and treatment system is important in human civilization progress, there are some problems related with its promotion and application as follows:

（1）Construction of flush toilets, drainage pipe works and wastewater treatment plants asks for a great quantity of capitals. What’s more, the charge for operation & maintenance is really unbearable for many countries. But flush toilets are often connected with concentrate wastewater collecting and treatment system which demands high standards of management and technique, so high expense is inevitable. Besides, concentrated wastewater collecting is easy to cause water pollution such as nutrient overload of water bodies. Due to the lack of funds, in many domestic and oversea cities, wastewater from flush toilets is often directly discharged into natural water bodies and results in surface water pollution.

（2）Recently, the lack of water resources becomes more and more severe. According to statistics, each people annually use approx.1.5 myl of clean water to flush his faeces and urine, which is quite a waste of water under the circumstance of water deficiency today. And it is unrealistic for those (40% of the global population) who are suffering from seasonal water shortage to use flushing toilets. Table 2 - 2 shows the statistics for domestic sewage features [2].

Table 2-2 Statistics for domestic sewage features

annual load （kg/annual• person）	urine （yellow water） 500（L/annual• person）	faeces（black water） 50（L/annual • person）	grey water 25000－100000（L/annual • person）
N approx.4 - 5	87%	10%	3%
P approx.0.75	50%	40%	10%
K approx.1.80	54%	12%	34%
COD approx.30	12%	47%	41%

Table 2 - 2 indicates that wastewater except that for flushing toilets carries less pollutants. Extreta contains many pollutants as well as nutrient substances which if could be separately handled will dramatically lower expenses of wastewater treatment expense and facilitate recycling of nutrient substances.

Ecosan system is a kind of approach to control pollution from the source. To apply ecosan systems, quantity of output of wastewater and input of water supply would be reduced dramatically. See table 2 - 3[3]. As a part of ecosan systems, composting toilets and urine-diverting toilets save more water than conventional flushing toilets and the water-saving closet. Besides, composting toilets even preserve more resources than vacuum lavatories. To sum up, ecosan facilities reduce water discharge and provide favorable conditions for wastewater treatment.

Table 2-3 Water consumptions of different types of toilets per person per day

toilet facilities	conventional type（without water-saving measures）	flushing toilet with two kinds of flushing water quantity*	composting toilet	vacuum toilet	urine diverting toilet
Flushing water quantity each time（L）	9	4 or 9	0 or 2	1	0.2or 9
Water consumption per person per day（L）	45	25	1	5	10

* Note: Water-saving flashing closest has been promoted in towns in China recently. Flushing closet usually has two flushing quantities, that is, 3L each time for urinate, 6L each time for excrement.

（3）In conventional sanitation and water discharge modes, useful nutrients in human extreta are wasted in vain, which not only causes resource loss and but also becomes the pollution source. Due to nutrient deficiency, a large scale of land resulted in degradation.

Take the element of phosphorus, a most important soil nutrient which is merely inferior to nitrogen in agriculture for example. Different from nitrogen, phosphorus keeps its existence mainly in the form of natural ores such as phosphate rock. It is a kind of non-renewable valuable resources most of which flows mono-directionally after artificial exploitation or natural weathering. It is estimated that as far as 2025, the global annual demand on phosphorus will reach 250 million tons, the main drive of which is the increasing food production [4].

In the recent years, as the crop production is enhanced, the land lack in phosphorus in China is expanding as well. Those areas that formerly don't demand much for phosphatic fertilizer effect now also expose severe phosphorus deficiency, such as the broad Huanghuaihai Plain, Loess Plateau in the northwest, even Xinjiang Region where there is a large scale of land with phosphorus shortage. In the fertile rice soil in central China and south China, thanks to the application of organic fertilizer, there is sufficient phosphorus to meet the needs of crops; however, in a large quantity of acid dry land and a part of barren paddy field, phosphorus deficiency remains rather serious [5]. Since 2000, the Land & Resources Department of China has listed phosphorus among the twenty commodities which won't be sufficient for the development of national economy. So, the deficiency of phosphorus resource will severely restrict China phosphate fertilizer industry which would exert further influence on agriculture production.

Phosphorus is limited, even take the amount recyclable into account, it cannot sustain for 200 years. Recently, annual extraction quantity of phosphorus is 40 million tons of P_2O_5 from 140 million tons of ores with high expense and low output [4]. Once after phosphorus turns into soluble matters from granular ore, most part of it will transform into water environment through urban drainage system in the form of partly treated wastewater and completely untreated wastewater, process of which will accelerate nutrients overload of water body and cause phenomena such as water bloom and do harm to zoology and health. So, it is very necessary to make the utilization of nutrients a closing loop [1].

According to Table 2-2, such major nutrient matters as nitrogen, phosphorus and otassium contained in sewage are mainly found in urine and faeces. Suppose extreta can be separated and then applied in agriculture production, there will be a virtuous cycle of nutrients utilization and recycle.

2.1.2 Development of Ecosan System

（1）Development of ecosan System

Ecological sanitation system is a new approach that can completely replace conventional sanitation system. Through recycling beneficial nutrients for agriculture from faeces, urine and water and applying source pollution controlling, it brings down water pollution.

As early as 20th Century, Leberrecht Migge, a German architect had put forward the concept of ecological sanitation system, and carried out the study on its applications in urban area [5].

While consistently doing further research on basic strategies to settle water crisis, people also consider drainage system profoundly and challenge to conventional water consumption mode and drainage system. Many countries in the world carried out study on sanitation system and drainage system improvement in succession.

In 1970s, Sweden succeeded in developing non-water toilet facilities and exported them overseas. In 80s, the USA and Canada built composting toilets as well. During these decades, Germany, Norway, even more countries, carried out relevant studies and practices one after another. Supported by international organizations, many Asian and African developing counties, such as Vietnam and Zimbabwe put ecosan system into practice [5].

The UN Millenary Conference in September 2000 highlighted the emergency of taking measures to confront the urgent situation of fresh water supply. It also clearly put forward that it should gradually put an end to the former unsustainable developing mode of water resource, and change in water management strategies will take place in levels of regions and the whole country.

In October 2000，an international forum on ecosan system opened in Bonn, Germany. The theme was closing the loop of wastewater management and sanitation system. 200 experts from countries all over the world attended this meeting. It showed that problems in relation to ecosan system had attached extensive attention in the world wide and relevant information network had been established. The forum suggested that demonstration projects of ecosan system should be carried out in the range of urban area.

Water Conference held in Stockholm in August 2004 hosted an exhibition on ecosan system. In the Third World Ecosan Conference in Durban in 2005, experts examined profoundly the safety and feasibility of ecosan system; in addition, the experienced delegates all agreed that ecological sanitation had been an important approach for future sanitation development.

In the World Water Forum in March 2006, ecosan system was also a hot topic.

In August 2007，the International Ecosan Conference took place in E’erduosi in

Inner Mongolia Automatic Region in China. On the meeting they exchanged views on the feasibility, key technologies, development status and trend of the application of ecosan system in small town and areas such as ecosan project in Haozhaokui Community and showed the achievement of ecosan system construction in countries all over the world.

（2）History of extreta applications in China

Agriculture in China has a long history of extreta applications. As recorded in history, it is estimated that perhaps as early as Shang Dynasty approximately three thousand years ago, people had applied human extreta [6].

In rural areas of China, extreta is often used as fertilizer. Such status lasted until the late 1970s and early 1980s. Later, chemical fertilizer was utilized more and more extensively. Since 1980, the consumption of chemical fertilizer has excelled that of organic fertilizer. Chemical fertilizer becomes the most important access of nutrients for crops. At the present time, only 35% of fertilizer input in China is from organic fertilizer [7].

However, through these twenty years' practice, people found that the sole application of chemical fertilizer only consumes organisms in soil but not makes up for that, and consequently, the soil fertility drops dramatically. The more fertilizer is used, the lower the fertility of the land becomes and the more harden the soil becomes; consequently, the soil fertility will drop continually, and thus demands to utilize more fertilizer. These insoluble problems make organic fertilizer regain people's attention because organic fertilizer has such advantages as follows:

①Organic fertilizer contains complete organic nutrients

Organic fertilizer contains several major elements such as nitrogen, phosphorus, otassium 的, and minor elements such as Ca, Mg, Fe and Mn necessary for plants' growth, what's more，most of them exist in the form of organism. The releasing process is slow and uniform, and the fertility lasts for a long time.

②Organic fertilizer can improve soil quality

Organic fertilizer can increase the content of organic matters in the soil, and enhance the resistance ability of the soil. Only a minor part of nutrients in organic fertilizer can be directly utilized, most of it can only be used after decomposition. In the process of microorganism decomposition, there will come out CO_2 together with many kinds of acids (including organic acid and mineral acid) which will regulate the property of acid and alkali of soil, accelerate the granule structure to come into being, enhance buffer capacity and improve soil. CO_2 which is not absorbed by plants will dissolve in water and form H_2CO_3. H_2CO_3 and other kinds of organic acids, mineral acids together facilitate dissolution of some indissoluble mineral nutrients thus increase content of effective nutrients in the soil [7].

③Organic fertilizer can enhance drought resistance

Organic fertilizer can enhance water retaining and supply capacity of the soil. Humus is hydrophilic colloid with strong water capacity. In the soil there are many granules which are made from humus and clay. Inside the granules, there are many capillary pores capable of water retaining for plants. Another benefit of humus is that it has larger specific heat and lower heat conductivity resulting in slow temperature change of the soil which is helpful for plants' growth.

④Organic fertilizer can reduce the content of nutrients kept in the soil and enhance fertility.

When chemical fertilizer comes into the soil, some of its nutrients will be kept by the soil; consequently, the effectiveness of the nutrients will be brought down. If organic fertilizer and chemical fertilizer are utilized together, since the mixture of the two lessens chemical fertilizer's contract with the soil, the quantity restrained by the soil can be reduced. What's more, the mixed utilization of organic fertilizer and phosphate fertilizer can also add the solubility of phosphorus and enhance the activity of dicalcium phosphate which will facilitate crops' phosphorus absorption.

⑤Organic fertilizer can accelerate crop maturity

Humus is usually of brownish black color. Then with organic fertilizer, the soil will appear blacker and gain stronger light absorption capacity. During the decomposition of organic fertilizer in the soil, there will be a great quantity of heat created to increase the temperature of the soil, accelerate the metabolism of plants, stimulate the seed to shoot up and finally advance crop maturity.

⑥Organic fertilizer will bring higher economic benefit

It is not permitted to use chemical fertilizer within three years in organic agriculture, where fertilizer must only come from human extreta, poultry faeces, green manure, and leguminous plants, etc. The so-called green products refer to those products that won't do harm to zoology or pollute environment and do good to human health during the processes of production, processing, transportation and consumption. Nowadays, the public pay more and more attention to health, and green foods are very popular with them. One can see that prices of green products are higher than ordinary agriculture products, so the utilization of organic fertilizer will create higher economic benefit for farmers.

Such benefits are only possessed by organic fertilizers but not chemical fertilizer which cannot realize some effects of organic fertilizers. So, it is necessary to cultivate more sources of fertilizer and to utilize organic fertilizer as much as possible in order to exert fertilizer efficiency, keep soil fertility and gain agriculture products of high productivity and good quality.

2.2 Composition and classification of ecosan system

2.2.1 Composition of ecosan system

According to the operation flow, ecosan system can be divided into three parts: collecting, transportation and treatment.

（1）collecting system

Faeces and urine should be collected respectively. Faeces will drop into faece reservation buckets through collecting pipes while urine will be kept in urine reservation tanks through urine collecting pipes and gathered regularly.

（2）transportation system

Respectively collected urine and faeces will be carried to the management site by vehicle regularly after several months' accumulation. Household grey water will be discharged to community treatment stations or wastewater treatment plants through drainage pipe line.

（3）treatment system

Faeces can be used as manure in agriculture after sanitization by composting or other methods; urine is also a kind of good nitrogenous fertilizer after dilution; household grey water can be used as water supply of afforesting and irrigation after treatment in grey water station, or be reused after treatment in centralized wastewater plants.

2.2.2 Classification of ecosan system

（1）Classification according to primary treatment methods

Primary treatment refers to collect faeces in ecosan system. Its aim is to eliminate peculiar smell, decrease flies and kill pathogens [8]. As per different operation modes, ecosan system can be classified as three types: facilities of dehydrating, composting and land composting.

① dehydrating ecosan system

The principle for dehydrating is to keep faeces dry for a certain period of time in order to kill most pathogenesis. So, urine and faeces should be separated to avoid water enter the processing chamber, and sawdust, ash specification and ventilation should be applied to accelerate dryness.

Dehydration can remove most moisture and quickly exterminate pathogens and eliminate odor and flies. During the process of dehydration, urine and faeces can be collected separately. After dryness, with smaller solidity, extreta will come into an individual processing chamber and will be removed to another place for second treatment after six to twelve months' separation from outside world.

Double-vault system in Vietnam is typical among rural dehydrating ecosan system. It contains two processing chambers for usage in turn. One is used for collecting faeces and urine, the other is for dehydrating. Faeces after dehydration can be utilized as fertilizer. This design is widely applied, for example, there has been such kind of ecosan system in China, Mexico and other countries [9].

Dehydrating ecosan system can also be utilized in urban area. In the urban center of Salvador, there are 130 households who adopt Lasf ecosan toilets, a kind of double-vault dehydrating ecological toilet. The operation result shows the usage of such toilets goes well, and there is no odor or flies.

②composting ecosan system

Composting is a method to make use of the biological and chemical responses of organic substances to realize aerobic effect or anaerobic effect thus to decompose organic substance into humus. This kind of sanitation system often requires six to eight months' reservation, after that, a part of decomposed material will be transformed to the site for secondary treatment.

It has a history of over 50 years to adopt composting toilets in holiday resorts in Sweden. Take Clivus in Stockholm for example, stools and chamber pots in the local toilets are connected with underground composting chambers. Faeces and organic rubbish from kitchens and households can be put into processing chambers at the same time for composting and regular shifting out [9].

③ Soil composting ecosan system

In soil composting ecosan system, the sites for composting are residents' own farmlands or shallow pits suitable for the operation in rural areas. Such system has been applied in Ladakh in India and in Zimbabwe, etc.

Microorganisms will survive for quite different periods as results of the mentioned methods[9], please see Table 2-4. Each quarter should take processing effect, expenses of construction and operation, climate and other elements into account before selecting the appropriate approach.

Table 2-4 Survival periods of several kinds of microorganisms under different conditions （days）

conditions	bacteria	virus	protozoon	helminth
soil	400	175	10	several months
faeces（20-30℃）	90	100	30	several months
composting（anaerobic under the surrounding temperature ）	60	60	30	several months
high-temperature composting （50-60℃）	7	7	7	7

Note： Protozoa do not include cryptosporidium parvum. Helminthes mainly refer to ascarides which die slower than other ova.

（2） classified according to secondary treatment methods

Secondary treatment means processing after extreta collecting to achieve hygiene standards applicable for agriculture use. There are some methods to control and eliminate pathogens: aerobic high-temperature composting, anaerobic or aerobic digestion, heat drying (to heat up till the temperature is above 80 ℃ and then to airslake and dry), Pasteurization (to do the treatment for 30 min under 70℃), ionizing radiation treatment (to apply β ray or γ ray), chemical treatment, digestion, ova sinking, etc. Considering expenses of construction and operation, and the skillfulness of technology, here is the summary of the current popular and effective methods [10].

①Ecosan system with alkalization treatment

Pathogens can be killed by adding alkaline substances. When pH value reaches 9, most pathogens will be killed within six to twelve months. In large-scale systems, carbamide is often used to change pH values, meanwhile in faeces, it will decompose into ammonia which can kill pathogens effectively. Besides, the adding of ammonia can also enhance the fertility of the end products after treatment. 3% carbamide-nitrogen will bring pH value to 9.3. To keep this condition for five days, no bacillus coli and salmonella will be found and 90% of ascarid ova will be killed [11].

②Ecosan system with burning treatment

Burning is a kind of aerobic treatment to decompose organisms almost completely and is also a reliable sanitization method to eliminate such pathogens difficult to be killed, such as intestinal tract ascarids. Through burning, most nitrogen and sulfur will dissipate in smoke, and all phosphorus and potassium will remain in ash to be used as fertilizer later.

③Ecosan system with high-temperature aerobic composting

High-temperature aerobic composting is a kind of composting treatment under aerobic condition at a temperature between 50℃ and 60℃. High temperature will accelerate the death of pathogens. Aerobic microorganism will decompose organic matters, and sometimes the temperature will arrive to 80℃. The degradation process demands a great deal of oxygen, meanwhile, the pH value will become higher and then humus will come into being. To maintain high-temperature function, the composting process should be well operated and managed.

According to China *Sanitary Standard for the Non-hazardous Treatment of Night Soil* （GB 7959-1987）, Sanitary standards for high-temperature composting are: the highest composting temperature arrives above 50℃-55℃ and lasts for 5 to 7 days; mortality of ascarid ova reaches 95- 100%; fecal bacteria value is 10^{-1}-10^{-2}, what's more, the breeding of flies should be effectively controlled, and around compost body, there should be no maggots, chrysalides or flies of new eclosion.

④Ecosan system with a long period of storage

If it is not appropriate or convenient to deal with the extreta, it can be reserved by methods such as packaging. To store faeces under dry circumstance or high-temperature condition is also a secondary treatment. When the surrounding temperature increases, the number of pathogens will decrease.

⑤Ecosan system with anaerobic digestion processing

According to different temperatures, the anaerobic digestion processing can be classified into three types: normal-temperature digestion, moderate- temperature digestion and high-temperature digestion. Please see Table 2-5.

Table 2-5 Comparison of Three Kinds of Anaerobic Fermentation Processing

service conditions	normal-temperature digestion	mesophilic anaerobia digestion	thermophilic digestion
temperature	change according to natural temperature	35℃-38℃	50℃-65℃
features	instable methane production; low efficiency of organic matters transformation	stable methane production; high efficiency of organic matters transformation	high decomposition speed of organic matters; high methane production
scope of application	small scale digestion system for villages, such as villages	large or moderate -scale methane project	fecal sanitization treatment
digestion time	longer than 30d	20 d -30 d	10 d -20 d

Though high-temperature digestion processing can produce methane, it is rather complicated for the large expense of investment and operation and complicated management, so in the current stage, the more popular way to realize fecal sanitization treatment is to adopt high-temperature aerobic composting processing.

2.2.3 Ecosan system that has been successfully carried out in some countries

Competent authorities in every country are supporting ecological sanitation in many ways, and studies and practices on ecosan system are spreading throughout the world.

（1）Ecosan facilities in Kisoro Town in the southwest of Uganda

At the present time, most practices on ecosan system are carried out in rural areas, but they are not sufficient in urban area. Kisoro Town which lies in the southwest of Uganda has adopted ecosan system; what's more, there are valuable experiences on the application of ecosan facilities in public.

Kisoro Town is a newly established town in the boundary area. It has a mean sea level of 2,000 m and a population of 10,000. Though there is a great rainfall (1,500 mm per year), and the dry season (two months) is short, the geologic setting of volcano leads to surface water deficiency. Owing to the fertile land, population density here is the highest all over Uganda. However, there are only a few springs and wells, such available water resources are comparably insufficient.

As early as 1999 and 2000, there have been 250 ecosan toilets built in Kisoro Town, among which, there are composting toilets and dehydrating ones as well. These sanitation facilities are promoted in households, organizations and in public (administrative office of municipal council administrative office, training center for primary school teachers). There have been 107 separate household dehydrating toilets constructed, among which, 37 are attached to houses, the other 70 are built in the nearby courtyard of houses. To ensure effective usage, constructors nail graphical illustration boards in the local language and English on the toilet wall or doors, giving a clear instruction of the ash-scattering method and requiring everyone to use unfilled toilets. Users actively follow the using method and achieve a good effect [13].

（2）Ecosan facilities in Cd. Juárez，Chihuahua in Mexico

The applicability of ecosan system should be ensured prior to implementation and only after that should the appropriate type of ecosan system be selected. Through two phases of study on it, Cd.Juárez, Chihuahua in Mexico showed that the ecosan system had been successfully operated in the local area.

Cd.Juárez, Chihuahua, a city of Mexico, is located in the borderline between Mexico and America, which has a population of almost 1.4 million. The utilization of ecosan system covers 3 communities in a shortage of public water supply and sanitation facilities.

During the first phase, about 90 single-vault dry composting toilets were built, and the method to reduce fecal coliform bacteria in biological solids was decided. The result showed that after three months, water content in more than half of biological solids fell below 40%.

During the second phase of the application study, four different types of ecosan toilets were constructed (5 of each type were built): single-vault urine-diverting toilet; double-vault urine-diverting toilet; single-vault composting toilet; double-vault composting toilet. The study did an analysis on the efficiency of the reduction of fecal coliform bacteria, construction and cost of toilets as well as users' satisfaction, in addition, the study also demonstrated the applicability of such toilets in xerothermic areas [14].

（3）Application of Lasf toilets in Salvador

During 1992 to 1994, in support of International Development Bank, government of Salvador constructed 50,623 Lasf toilets with a total investment of 12 million US dollars. A questionnaire survey targeting to 6,380 households conducted in 1994 indicated that 39% of the toilets were in good condition; 25% are not used properly; 36% are not utilized at all. The main reason is that the construction of such toilets only relied on contractors without participation of communities and without training for communities afterwards. So, resident education was very important. And it was necessary to carry out individuation education including family visits, women education, publicity materials sending, etc. A reinvestigation was conducted after the first education week with the result that 72% of the toilets were in good condition; 18% are not properly used; 10% are not used at all. The contrast of the former result and the latter one showed that the abnormal usage didn't result from technology incompetence but the absence of people's good command of such technology. The experience received was that the promotion should take the family and individual as the unit to facilitate the offering of on-site guidance.

（4）Ecosan facilities in Guangxi, China

The application of ecosan toilets in Guangxi in China achieved a great success. There urine-diverting toilets were used to collect faeces and urine separately. After hydration and sanitization, the faeces are utilized in agriculture. Faeces reserved in the processing chamber for one year can reach standards of sanitization [15]. This project was supported by Swedish International Development Cooperation Agency. Considering the local practical situation, the project made full use of technology and reached good effects in every part of Guangxi (such as North Guangxi, South Guangxi and Central Guangxi, areas without sufficient water and that with abundant rainfall, inhabitant of different peoples, such as Han, Zhuang, Miao, Yao, etc). At the present, Guangxi has built over 90,000 urine-diverting ecosan toilets, and the public's acceptance has reached 92.5%, the satisfaction has achieved 87.5%.

The results of the investigation show that among the monitored 45 households equipped with ecosan toilets in Nanning and Guilin, the percentage of households who keep their toilets almost odorless is 91.1%, and the percentage of households in whose toilets there are almost no flies is 89.9%. Operation and maintenance of the toilets in the monitored households are comparatively better. The effect testing of fecal sanitization indicates that after 3 months, faeces in above 75% of toilets can realize sanitization, and after one year, that in all of the toilets can realize sanitization [16].

The successful promotion in Guangxi, China demonstrates the importance of government's support, construction of demonstration sites and technology developments.

①government's support

In order to stimulate farmers' enthusiasm to build ecological toilets, government offered 30-50 yuan as subsidy equal to the price of a squatting pan to each household, and households pay for the rest cost. By this means, people's enthusiasm to participate was greatly raised.

②construction of demonstration sites

Ecological toilets should be firstly introduced to those more enlightened key households. And when households nearby find that this kind of toilets are very convenient, they will accept them willingly. Good demonstration construction will greatly enhance farmers' enthusiasm.

③technology development

Adapting to its own circumstance, the local has developed a kind of squatting pan with urine diversion which only costs 50 yuan and wins national patent. The practice during the technology development indicates that the local people will accept ecosan system only if it is of advanced technology and low cost.

2.3 Discharge and energy required by ecosan system

2.3.1 Discharge

（1）nutrients

In ecosan system, faeces, urine and wastewater are separately collected and treated, enabling water and nutrients (such as nitrogen, phosphorus, etc.) to be recycled and bringing a closing cycling loop into being.

In the flow process, nitrogen and phosphorus come into ecosan system through extreta. Since it demands no flushing water or only a little, the amount of water contaminated by extreta is greatly reduced. Secondly, composting and wastewater treatment facilities not only treat pollutants but also bring about such products as compost during the processing process. Thirdly, compost is widely used in crop farming. Nitrogen and phosphorus contained in crops are associated with residents' life through the consumption of agriculture products, and other nutrients not utilized by plants are accumulated in the soil. Fourthly, part of nitrogen and phosphorus in the reclaimed water discharged from households is removed after the treatment, and the remains are reused.

（2）extreta

Nitrogen and phosphorus in faeces and urine can be used as good soil conditioner. In ecosan system, different components are treated separately, for example, faeces are collected to be handled and composted, while urine is collected and reserved which after proper treatment can be used as fertilizer. In ecosan system, all the nutrients will be applied. Over 80% of nitrogen and phosphorus in household pollutants are applied in agriculture production after transformation.

Faeces and rubbish can be treated together when composting treatment is adopted. In faeces, there is a great quantity of thermophilic microorganisms which will increase the quantity and species of microorganism musculomyces. And the fast bacteria breeding will accelerate organism decomposition. Under the action of synergetic effect, microorganism musculomyces metabolize anti-oxidation substance and form a complicated and stable ecological system to increase nitrogen content in compost and inhibit the breeding of harmful microorganisms. The compound composting of matured faeces and waste will enhance biological degradation rate and shorten the composting period from 32 days to 12 days; in addition, the composting products contain higher fertility [17]. So, the application of the compound composting of faeces and waste is preferable to rubbish composting since it quickens the biological degradation and shortens the decomposition time. Due to the more activity, the utilization of matured faeces composing reaches higher decomposition efficiency.

（3）grey water

As the living standard of people's life is continuously improving, urban water consumption becomes larger and larger and water deficiency is deteriorating, and urban water resources exploration has gone to an extreme, so wastewater reuse is imperative under such situation.

On-site collecting and treatment of grey water can release the burden of urban water supply and discharge system, protect groundwater resources and improve urban afforesting and environment protection. The quality of treated grey water is not as good as drinking water, but it meets the needs of afforesting which can save much water of good quality, and consequently increase “water supply”. What’s more, on-site collecting and treatment of grey water can reduce the load of urban wastewater treatment plants and decrease the expense of the construction and daily operation of concentrated wastewater treatment facilities.

There is a great difference among domestic grey water from different facilities, such as kitchen basin, wash tub, bathing room, washing machine on the water amount and pollutant substances. Please see Table 2-5[12].

Table 2-5 Wastewater discharge quantity and pollutant content of each facility per day

facilities	amount of water %	organisms (BOD) %	total nitrogen (TN) %	total phosphorus (TP) %
kitchen basin	18.0	70.9	41.4	54.4
rinsing sink	4.1	2.0	19.3	27.2
wash tub	31.4	1.2	17.2	6.8
bathing room	13.4	9.8	7.6	8.2
washing machine	33.0	16.1	14.5	3.4
gross（per person per day）	201L	25.4g	1.45g	0.147g

According to the data in Table 2-5，water discharged from kitchens contains the most pollutants which should be treated. And the wastewater in wash tub has the least amount of BOD and TP which can be just simply treated and discharged. Such operation can reduce the investment in the treating process. Wastewater treatment can be classified into four systems as bellow:

①to deal with after compounding all of the wastewater from households

②to deal with after compounding wastewater from the kitchen basin, rinsing sink, bathing room and washing machine. Wastewater from the wash tub can be discharged after simple treatment.

③to deal with after compounding wastewater from the kitchen basin, rinsing sink and bathing room. Wastewater from wash tub and washing machine can be discharged after simple treatment.

④to deal with after compounding wastewater from the kitchen basin, rinsing sink and washing machine. Wastewater from the wash tub and bathing room can be discharged without treatment.

Reclaimed grey water which meets applicable standards can be used as：

①water consumption in city planning： Water consumptions in garden greening, landscape, clean water supply and fire fighting are included.

②water consumption in agriculture：It can save much valuable fresh water resources to apply reclaimed grey water to irrigate farm land and vegetable land in the city outskirt.

③water consumption in industry：At the present, industry enterprises remain the main consumer in urban water consumption. To apply reclaimed water to replace quantities of water of good quality can save a lot of water resources.

④other water consumption：It mainly includes water for cleansing cars, etc.

2.3.2 Energy Flow

（1） Overview

Energy flow means the input and output of energy in testing system after the structure and limits of the reaction system are established. Input energy covers natural input energy and artificial assisting energy; output energy covers energy contained in products, byproducts and wastes.

J. Wilsenach and M. van Loosdrecht applied AQUASIM 2.0 to simulate dynamic urine-diverting system and conventional sanitation system [26]. The energy consumption includes the following seven items：ventilation, dehydrating, sludge burning, pumping, compounding in the reactor, quantity of heat and the methane productivity, among which, energy consumption in pumping and compounding in the reactor is always neglected.

Table 2-6 Energy requirements of urine-diverting system and compared systems（negative stands for net energy output）

urine diverting ratio（%）	0	50	65	75	85
amount of sludge（kg/d）	2111	1917	1888	1881	1760
amount of urine（kg/d）	0	45000	58500	67500	76500
total energy amount（MJ/d）	15302	-6204	-5671	-5467	-4666
W/person	6.25	-1.60	-1.46	-1.41	-1.20

Sludge treatment in urine-diverting system requires less energy than in conventional system. Energy produced by the methane burning is as three times as that in conventional system. The energy consumption of ventilation in the conventional system is four times as much as the total consumption of ventilation and sludge production in ecosan system. The model indicates that there may be net energy output by urine-diverting system.

（2）Energy consumption of ventilation

To ensure the indoor air quality when ecosan source separation is applied, there is usually ventilation facilities set in this kind of system. Table2-6 shows energy consumptions of house ventilation facilities in the four districts of Toarp Ecological Community where there are totally 37 households. To put environmental protection concept into practice, the whole community adopts dry ecosan toilets.

Table 2-6 Energy consumption of ventilation systems

districts	Snurredass	Linden	Ekoloo	Wm-ekologen
house types	one level	one level	two levels	one or two level
power of ventilation facilities	30W（predicted value）	29W（predicted value） 21W（value for normal operation） 37W（maximum value）	32W（predicted value） 22W（value for normal operation） 37W（maximum value）	32W（predicted value） 22W（value for normal operation） 37W（maximum value）

（3）Energy consumption of transportation

Urine-diverting ecosan system collects much urine, a kind of fertilizer of good quality. Urine reservation pots are collected regularly in the communities and transformed to the nearby farm land after treatment. The transportation costs labors and petrol, etc. It is estimated that every person annually needs 44 MJ to handle urine by truck (the transportation distance is calculated by 33 kilometers), but every person annually can save 33 MJ to deal with wastewater in sewers and 63 MJ to produce corresponding compost, thus every person annually can save 63 MJ [22].

（4）Fertility

The collected extrema after treatment can be used in agriculture as a kind of fertilizer and energy engendered from ecosan system. The fertility of treated extrema is compared to that of chemical fertilizer.

The test was carried out in a glasshouse covering an area of 500 m^2(10m×50 m) in Alta Palmira，Temixco，Morelos in Mexico. 16 lettuces were planted in each plot. Test of this study was designed to apply random methods, and be classified into four steps of treatment (urine collecting, urine composting, composting and comparison) and ternate repetition. The amount of fertilizer used in each plot should be 150 kg N/ hectare. Biological and mathematical analysis (leaf area, coverage and fresh weight) is done on the lettuces. Statistical testing applies analysis of variance and Tukey Testing. The results showed that lettuces planted in the plot with urine grew best; that planted in the plot with compost grew second best; that planted in the plot with the composition of compost and urine grew third best. The former tests on Yanmai, sugar beet and celery also acquired similar results. Such results indicate human urine was the best fertilizer for such vegetables, what’s more, satisfactory results were observed while utilizing composting products to plant lettuces [23].

In addition, faece fertilizer can be utilized to reduce the phenomenon of nutrients loss due to rain leaching. It is found that the harvest of crops with chemical fertilizers is not as good as that with human faeces.

Relevant experiments were carried out in China. During 2001－2002, Gansu Agriculture University carried out tests in Nangou Village, Huichuan Town, Weiyuan County, Gansu Province, and totally established 30 plots. In each plot, there were three lines of potatoes with each line 15 individual potatoes. They were respectively utilized nitrogen fertilizer(the pure nitrogen content in carbamide is 46%), phosphorus fertilizer (P_2O_5 content in ordinary calcium superphosphate is 14%) and organic fertilizer (faece fertilizer). The results showed that organic fertilzer can help the productivity of fresh potato tubs most [25].

（5）Energy consumption in wastewater treatment

Energy consumption in wastewater treatment is usually about 0.25-1.8kW·h/m^3.Specific data and scale is related to factors such as processing technique [28、29].

A case analysis is done on a reclaimed water treatment station with a scale of 1000m^3/day in the northern part of China. Raw water quality, influent quality is BOD_5=180mg/L，COD_{Cr}=300mg/L，SS=250mg/L，major indexes of water quality after treatment is BOD_5<10mg/L，SS<5mg/L，COD_{Cr}<50mg/L. Structures of reclaimed water processing technique are as follows: regulation tanks, hydrolytic acidification tanks, and contact oxidation tanks, vertical sedimentation tanks, filtering tanks, sterilizing facilities, blast aeration facilities, pump lifting facilities, wastewater treatment plants and sludge concentration tanks. Electric charge of treating one ton of water is 0.65yuan/m^3，the local electric charge is 0.399yuan/kWh，so the electricity consumption of one ton of water is 1.625kW·h/m^3[18].

Energy consumption and processing charge are firmly related to processing methods. It is calculated [19] that average operating cost by the method of biological contact oxidation process is 1.74 yuan/m^3 , lower than that by the method of rotating biological disk method which costs 4.52 yuan/m^3. The total average cost by the application of biological contact oxidation process is 2.26 yuan/m^3，while that by the application of rotating biological process is 7.19 yuan/m^3. Average energy consumption of municipal wastewater treatment is 0.25kW·h/m^3 far less than reclaimed water treatment due to the large scale of municipal wastewater treatment. When the wastewater treatment plant serves more than 100,000 persons, the average energy consumption is 27.1kW·h/（cap·a）, while when it serves less than 1000 persons, the average energy consumption is 71.3 kW·h/（cap·a). The latter one is 2.6 times as many as the former [20].

However, as social economy is continuously developing, water resources become more and more deficient. Water resources availability per capita in China is 747 m^3. Water reuse is more economic than long-distance water diversion, seawater desalination and artificial rainfall. Take the practice in Dalian for example[21], seawater desalination costs 8.5 yuan/m^3; introducing water of Biliuhe Reservoir into Dalian costs 2.3 yuan/m^3; introducing water of Yingnahe Reservoir, Zhuanjiaolou Reservoir and Zhuweizi Reservoir into Dalian costs 3.6 yuan/m^3; reclaimed water reuse costs 2.0 yuan/m^3.

2.4 Brief summary of this chapter

Ecosan system is a closed-loop circulating system that saves much fresh water resources and controls pollution from the source. Sanitized extreta through this system can increase production when used in agriculture. Faeces and urine are considered as resource rather than pollutant. Nutrients such as nitrogen and phosphorus can be recycled. So, ecosan system is in line with the strategy of sustainable development and circulating economy.

Many countries in the world are engaged in the research on applications of ecosan system and have developed many different types of ecosan system. Some international organizations and state governments favor the development of ecological sanitation very much, and boost it by instituting rules and providing funds and have established a number of demonstration projects[30、31]. Such projects not only benefit the local environment improvement and agriculture development, but also provide valuable experiences which are quite helpful for ecosan system promotion throughout the world.

Meanwhile, ecosan system encounters many challenges. For example, construction in different regions and under various weathers and cultures and customs of local residents is a common problem during the promotion. But the largest challenge is how to bring ecosan system into effect in urban area. More studies on the cohesion, renewal and reconstruction of conventional drainage network in the crowed urban area should be taken.

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Chapter Ⅲ Economic Comparative Analysis of Ecosan and Conventional Sanitation System

3.1 Investment Calculation and Analysis on Ecosan System

3.1.1 Composition of Investment and Selection of Rate

Fixed capital investment should cover all engineering and construction costs required for accomplishing the designed benefits and scale, including engineering costs (equipment, installation, building construction, tools and instruments), other cost of engineering construction (including supervision of construction, test study on design, training of operating personnel and other relating expenses of future facilities operation, etc.), basic contingency fund and interest during engineering construction. Total investment of construction project includes fixed capital investment and current capital. Please refer to Figure3-1[1]

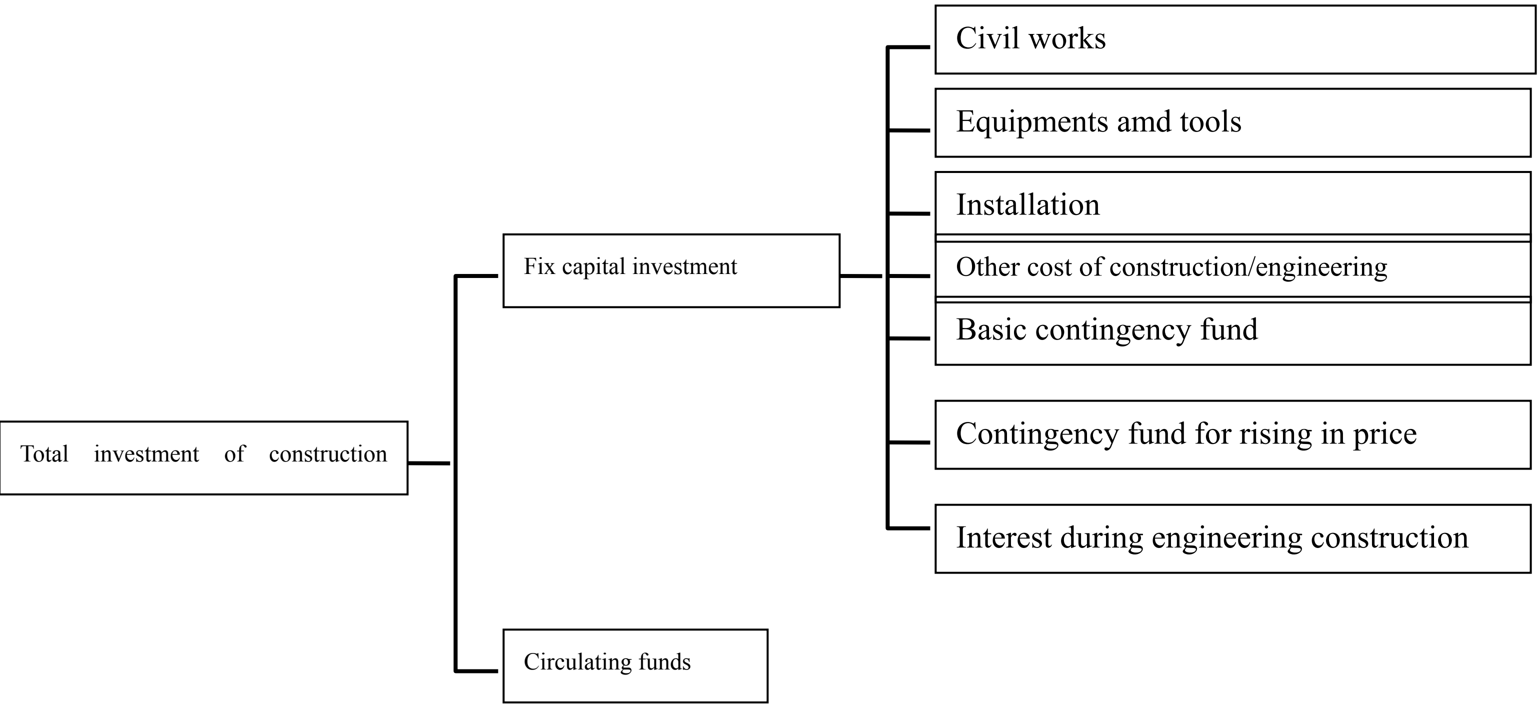


Figure3-1 Total Investment of Construction Project Investment of Construction

Fixed asset investment for the resource utilization of Haozhaokui Eco Residential

Area in Dongsheng District mainly includes two parts: Ecosan System and Eco-station.
The costs and benefits as mentioned here are calculated in accordance the future occupancy rate of 70%, 80% and 100% for the first two years. It shall be noted that the current ecosan system is at the initial phase, and many costs are higher than those under normal conditions. In addition, as a modern-type system, the embodiment of benefits is related to many aspects, and the project objective is yet to accomplish.
Construction cost is calculated on the basis of partial completed engineering investment data and partial predicted data provided by Swedish SEI Project Office. The engineering investment data adopted in this report derives from the final examination result of the local construction cost consulting firm on the final cost.

Land-use fee is calculated on the basis of 25000 Yuan/Mu. The eco-station and grey water treatment plant cover an area of 6000m^2, so the land-use fee is 227,273 Yuan.

Calculation of other expenses should consider the project feature (EPC, contracting, trial, etc.). The construction cost of ecosan system and eco-station includes environment assessment and design investigation fees; construction unit facility expenses; construction insurance; cost of introducing technique and imported equipment, construction contracting fee and so on. The experiment, supervision, production preparation and management costs are included in the project investment data provided by SEI Project Office. "Other costs" only include the joint start-up cost (1.0% of the equipment cost). [2、3]:

Contingency fund refers to expenses in case of things unexpected, mainly including expenses resulted from design change and possible engineering increasement. The data provided by Swedish SEI Project Office has already covered such content, so it will not be set out here to calculate.

Because the investment adopts self-possessed fund, there is no interest during construction. In addition, in order to maintain normal production and operating activities, it is necessary to prepare proper current capital which calculated by 1.0% of the construction cost.
As to the investment construction of Ecosan System in Haozhaokui Community, please refer to Table 3-1.

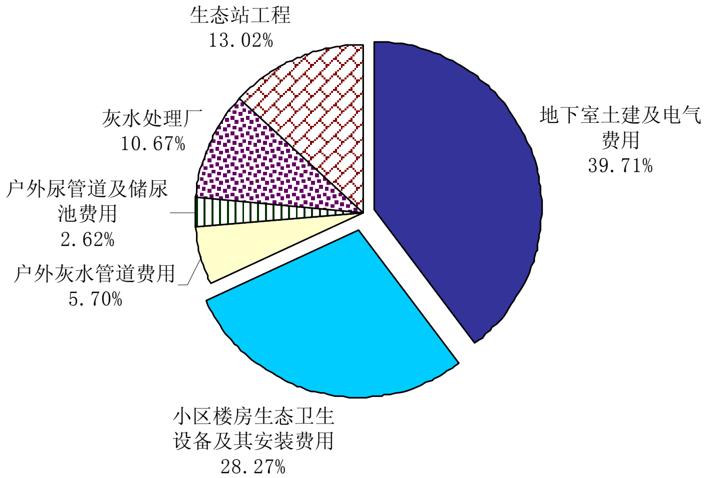
The Investment Construction of Ecosan System in Haozhaokui Community

S/N	Terms	Cost (Yuan)
1	Total investment of civil works and equipment	9,469,790
1.1	Expenses of basement civil works and electricity after plane optimum arrangement of the building	3,667,456
1.2	Ecosan equipment of the residential area building and its installment fees	2,610,816
1.2.1	Toilet bowl	416,000
1.2.2	Urinal	58,240
1.2.3	Soil pipe	486,720
1.2.4	Soil bucket	249,600
1.2.5	Tank	603,200
1.2.6	Fan	62,400

1.2.7	Primary erect ventilating pipe	170,560
1.2.8	Branch ventilating pipe	166,400
1.2.9	Basement electricity	51,584
1.2.10	Urine drain system	346,112
1.3	Outdoor ash-water pipe fees	526,656
1.4	Outdoor Urine pipe and urine storage pool fees	242,112
1.5	Grey water treatment plant (including sedimentation pool)	985,531
1.6	Eco-station project	968,109
1.6.1	Composting plant	167,152
1.6.2	Solid waste plant	110,391
1.6.3	Office building	221,418
1.6.4	Eco-station roadway	172,775
1.6.5	Fence	54,267
1.6.6	Grand entrance	11,345
1.6.7	Other projects	100,761
1.6.8	Planting	130,000
1.7	Equipment purchase: Urine-Absorbing vehicle and soil bucket transportation vehicle	234,000
2	Land-use fee	227,273
3	Other fees	26,108
4	Current capital	94,687
5	Total investment of the project（1+2+3+4）	9,582,748

3.1.2 Analysis on Composition of Investment

The total investment of Haozhaokui Eco Residential Area Project is 9,582,748 Yuan. Considering without Land-use fee, other fees and current capital spending, the fixed capital investment is 9,234,680 Yuan, including residence engineering construction fee(involving basement civil works and electricity project after plane optimum arrangement of the building, ecosan equipment of the district building and its installment project) which reaches a total of 6,278,272 Yuan, outdoor pipe and urine storage pool fees 768,768 Yuan, grey water treatment plant investment cost 985,531 Yuan and Eco-station project investment cost 968,109 Yuan (involving urine-Absorbing vehicle and soil bucket transportation vehicle purchase). As to the cost proportion of each construction part of this project, please refer to Figure 3-2.



生态站工程 eco-station project

灰水处理厂 grey water treatment plant

户外尿管道及储尿池费用 costs for the outdoor urine pipe and urine storage pool

户外灰水管道费用 cost for the outdoor greywater pipe

地下室土建及电气费用 Costs for the civil work and electric work of basement

Figure 3-2 Investment Proportion of Each Ecosan System Construction Part of Haozhaokui Eco Residential Area

-Calculated according to the 2912 resident population of Haozhaokui Eco Residential Area (832 household×3.5 persons/household), the average capital investment for each household in this ecosan system is 11,099 Yuan, and the average construction cost for each person in this Ecosan System is 3,171 Yuan.

-As it is seen from Figure 3-2, among the construction cost of Ecosan System, 68% is the indoor engineering part (civil works cost and equipment purchase and installment fees, etc.) which carries weight in the overall system construction cost. Because lacking of relevant standard and case which can be used for reference home and abroad, and the sanitary wares as well as ductworks are customized productions, the indoor engineering fee is rather high during project construction. As increasement of similar engineering amount, batch production of sanitary wares and optimization of building construction, the indoor engineering cost of each household will tend towards reduction.

The design grey water treatment capacity of Haozhaokui Eco Residential Area Eco-station is 250m^3/d which can meet the requirement of reuse water quality. The daily treatment cost of average water engineering is 3,942 Yuan. According to the operating situation of grey water-treatment equipment in Northern China, the engineering investment varies as the different scale from 1656 Yuan/ m^3·d to 8404 Yuan / m^3·d adopting contact oxidation method and physicochemical techniques. (The annual growth rate of fixed capital investment price index is 5.88%[4] calculated by the data of 2006). For the facility of 15 service life, the social discount rate is 10%; For the residential area treats domestic sewage as raw wastewater, the disposal quantity is more than 750m3/d or the population is more than 10,000[5] according to study . Hereby, the grey water treatment scale of Haozhaokui Eco Residential Area

Eco-station is still outside the range of economics scale.

3.2 Analysis on Ecosan System Operating Cost

System operating cost mainly includes total cost, running cost and direct operating cost.

3.2.1 Total Ecosan System Operating Cost

Total cost = purchased materials and power + salary and welfare expense + depreciation charge + repair and maintenance cost + financial cost - byproduct recovery

（1）Purchased materials and power

①Expenditure on power

Mainly includes electric cost of fans and water pumps. (Other electric lighting equipment can be neglected because it accounts for a very small percentage.)

Expenditure on power= N·θ·T·d（Yuan/a） （3-1）

In this formula:

N—actual sum of power consumption of all electric equipments, kW.

θ—Power factor, calculated by average value 0.7；

T—Equipment operating time all year around, h；

d—Unit price of electric cost，Yuan/kWh，calculated by 0.493Yuan/kW·h.

②Chemical agent consumption cost

Chemical agent consumption cost=Q （ a_1 b_1+ a_2 b_2 … ）$\times 10^{-6}$（Yuan/a） （3-2）

In this formula: Q—Quantity of water to be treated，m^3/a;

a_1 ,a_2—Average dosing of chemical agent（like flocculation agent, disinfecting agent, etc.), mg / L;

b_1 ,b_2—Unit price of chemical agent, Yuan/t.

Calculated by the design unit of grey water system, the chemical agent consumption is 0.15Yuan/m^3[6].

③Addition agent consumption;

Addition agent consumption of waterless toilet=N_0·w·G·M（Yuan/a） （3-3）

In this formula: N_0—Total number of households in this district，832 households;

w—Total number of weeks in one year, 52 weeks；

G—Weekly addition agent consumption for each household, 2.00kg/household·week;

M—Addition agent cost，0.45 Yuan/kg。

After normal operation, saw dust should be added one to one. Annual amount of saw dust＝3000×50/1000＝150 square, 190 Yuan/square, total sum is 28500 Yuan. It shall be noted that the current sawdust adding amount is higher than necessary. It is because that the user is not yet familiar with the use of eco-toilet. According to requirements for normal use, the sawdust adding amount shall not exceed the amount of feces excreted.

④Microorganisms agent addition for composting, 10304 Yuan/a。

（2）Salary and Welfare Expense

According to requirements for normal running, the entire staff of eco-station shall be ten. Monthly wages for each person is calculated on the basis of 1200 Yuan.

（3）Depreciation Cost

Depreciation charge is calculated by composite life method, and the depreciable life is determined on the basis of facility and engineering experience. Table 3-1 lists some main depreciation life of building fixed capital[7]. This study adopts the average depreciation life of 20 years. According to the state specified standards for water supply and sewerage work. The net salvage should be 4% of the fixed capital investment during discarding of fixed assets[2]. Thereby, the general basic depreciation rate is 4.8%.

Table 3-1 Depreciation Life of Fixed Capital of Partial Installation and Equipment

Term	Depreciation life（a）	Term	Depreciation life（a）
Clearwater basin/sewage reservoir	30	Sedimentation tank	20
Other buildings	30	Compressed air unit	19
Pipeline	30	Mechanical equipment	18
Water pump	20	Electrical equipment	18
Transmission facilities	28	Automatic control equipment	10

（4）Repair and Maintenance Cost

Repair and maintenance cost includes routine maintenance and regular repair cost as well as management fee, etc. The annual cost is estimated by 2.4% of system fixed capital investment (equipment and civil works expenses)[7].

（5）Byproduct Recovery

The environmental facilities in Erdos have not been operated under the marketing mode and the pollutant discharge fee still cannot reflect real price of pollution control, so this study takes the present sewage and pollution discharge fee for byproduct recovery. In addition, byproduct recovery projects here also includes water charge of reclaimed water and net charge of fertilizer recycling for agricultural purpose.

Water charge of reclaimed water : calculated by 1.0Yuan/m^3 (Refer to An Official Reply of Reclaimed water Pricing of Draining Corporation in Baotou City) (Nei Ji Jia Zi[2003], No.1256, September 4, 2003)

Net charge of fertilizer recycling for agricultural purpose: The fecaluria excreted by each person annually is equivalent to 32.6kg ammonium bicarbonate, 0.85kg diammonium phosphate and 1.5kg potassium sulphate which may be converted into money (23 Yuan per person, 66,000 Yuan for 2912 persons.)

Sewage and pollution discharge fee: According to relevant state specified standards (Comprehensive Action Program of Energy Saving and Pollutant Reduction published by National Development and Reform Commission on June 3, 2007). It is calculated by 0.80 Yuan/m3.

Charge of indoor waterless ecosan toilet system management: It has not been clearly defined in eco residential area management till now, so this part may be neglected for the moment. For relevant description and suggestion, please refer to correlative content in “3.5.2 Comprehensive Comparative Analysis on Cost and Benefit of Ecosan System and Conventional Sanitation System” of this report.

According to the above requirement, when the occupancy rate is as high as 100%, the average total cost of Ecosan System in Haozhaokui Community is 782,769 Yuan/a.

Table 3-2 Operating Cost Sheet of Ecosan System in Haozhaokui Eco Residential Area

Unit: Yuan

S/N	Terms	Year of occupation		
	Year of occupation（Year）	1	2	3-20
	Occupation rate	70%	80%	100%
1	Salary	144,000	144,000	144,000
2	Electric charge, fuel oil fee and chemical agent consumption	83,434	95,353	119,191
3	Other material expenses (Composting addition Microorganisms agent and saw dust)	27,163	31,043	38,804
4	Depreciation	459,972	459,972	459,972
5	Repair and maintenance cost	133,613	133,613	133,613
6	Total cost (1+2+3+4+5)	848,182	863,981	895,580
6.1	Including:（1）fixed cost	737,585	737,585	737,585
6.2	（2）variable cost	110,596	126,396	157,995
7	Running cost（6-4）	388,210	404,009	435,608

3.2.2 Charge Changes' Influence on Direct Operating Cost of Ecosan System

The gross cost of the ecosan system is RMB 895,580 per year, with direct operating costs as follows: purchased materials and power + salary and welfare expense + repair and maintenance cost - byproduct recovery (byproduct recovery refers to resource recovery, including the annual sewage treatment charge, the annual grey water charge, the annual composting product and income from urine sale, totally RMB 127,615). The direct operating cost of Haozhaokui Community's Ecosan System is 307,993Yuan/a.

As there is an abysmal lack of water resources and the increasement of sewerage treatment cost, the sewerage treatment cost and water charge of reclaimed water are bound to rise continually, but it won't have any great influence on direct operating cost. For instance, when the sewerage treatment cost rises up to 1.50Yuan/m3, direct operating cost of Ecosan System would be 277,832Yuan/a, which is 9.79% lower than original operating cost. When the water charge of reclaimed water rises to 1.5Yuan/m3 from present 1.0Yuan/m3, direct operating cost of Ecosan System would be 294,420 Yuan/a, which is 4.41% lower than original operating cost. We can see that the increase of sewage treatment charge and grey water charge will not affect the direct operating cost greatly. The main reason is that the water-saving efficiency is remarkable in eco-district. Surveys shows that per capita water use of Haozhaokui

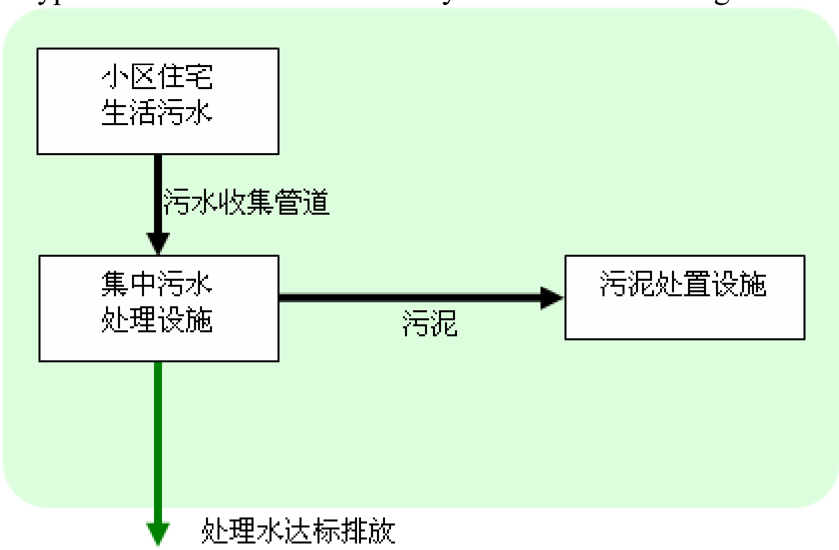
Community is only 47.7L/person·day, which leads to small treatment quantity of reclaimed water and discharge of sewage. There won't be good profit from it.

The cash flow within the project period (two years for the construction period, 20 years for the operating period) is analyzed on basis of the pollutant treatment cost and the treatment charge collected. Assuming that all funds are internally generated funds and taking no account of taxes and subsidies, the accumulated net benefit will be RMB -13,250,298 if the basic return rate of 4% is adopted. The net present value is smaller than zero, and the financial evaluation of the ecosan system is infeasible.

3.3 Investment Analysis and Calculation on Conventional Sanitation System of Same Scale

3.3.1 Conventional Sanitation System Composition

If Ecosan System hasn't been adopted in Haozhaokui Community, the schematic diagram of typical conventional sanitation system would be as Figure 3-3.



小区住宅生活污水 Domestic sewage of the community

污水收集管道 Sewage collecting pipe

集中污水处理设施 Centralized sewage treatment installation

污泥 Sewage sludge

污泥处置设施 Sludge disposal facility

Discharge of treated water

Figure 3-3 Typical Conventional Sanitation System

In this system, water-flush sanitary wares are adopted inside the house. Dejection with water catchment collected in house-drainage, then drained into district sewer, and the sewage is transferred into sewage treatment plant by the municipal drainage pipe line near the residential area for centralized disposal. After being treated to meet the States discharge standard, the water would be drained into nearby water body, and after must treatment for the excess sludge generated during sewerage treatment, it would be disposed of(such as sanitary landfill and so on).

According to water use quota in Dongsheng District and population in Haozhaokui Eco Residential Area of 2912, the feed water quantity is 80L/day • person, the reduction coefficient for discharge of sewage water is 0.85, and daily discharge of sewage water is 198m^3. According to the living habits of inhabitant in Dongsheng District, drainage design BOD_5 is 400mg/L.

The discharge standard of sewage treatment plant should comply with secondary standard design of Discharge Standard of Pollutants for Municipal Sewage Treatment Plant（GB18918-2002）[8]. In view of the great deal of industrial sewage in municipal sewage of northern Dongsheng Town, present sewage treatment processes of northern Dongsheng District are adopted in the course of analysis and calculation, that is two-stage bio-contact oxidation process. The design scale is 40,000m^3/d, and the design discharge BOD_5 is 30mg/L.

3.3.2 Investment Analysis & Calculation of Conventional Sanitation System

The investment estimate of conventional sanitation system mainly adopts the relevant investment data of sewage treatment plant of northern Dongsheng District and municipal pipe line construction, data of similar engineering budget, relevant national standards, design manual and research report. First, it calculates the investment cost of unit collection and treatment, the construction of refuse landfill site. Then it carries out necessary conversion and discount (taking the rise in prices into consideration). The fluctuation amplitude index of engineering materials is quoted from the data of government department [4], and the parameter selection is as for June, 2007. As to the result of calculation, please refer to Table 3-3.

Table 3-3 Investment Composition Sheet of Conventional Sanitation System of the Same Scale as Haozhaokui Community

S/N	Terms	Cost (Yuan)	Remarks
1.	Total expense of sanitation equipment, pipe line and installment inside the community	2,620,800	832 households, 3150 Yuan/household, including: • Sanitary ware 600Yuan/household • Indoor pipe line, 800Yuan/household • Exterior drainage pipe, 700Yuan/household • Installment and other expense, 1050Yuan/household
2.	Municipal pipe line investment	375,309	1,895 Yuan/m^3·d, according to statistical report of World Bank, the municipal pipe line investment on Mongolia of China accounts for 52.5%[22] of total investment of water system.
3.	Construction cost of secondary sewage treatment plant and pumping station (cost after adjustment)	339,565	1,715 Yuan/m^3·d, annual mean price index of fixed asset investment in Mongolia from 2000 to 2005 is 2.37%[4].
4.	Construction cost of sludge landfill disposal	679,382	• Annually generated moisture percentage is 80% and excess sludge is 236 Ton. • Organic refuse: 531 Ton/a • Normal operational life of design landfill is 20 years.
5.	Land-use fee for sewage treatment plant and landfill site of solid waste	116,329	38 Yuan/m^2
6.	Other expenses	152,861	• Experimental expenses: Calculated by 0.7% of construction cost (that is the sum of the above Term 1, 2, 3, 4 and 5); • Supervision fee of construction: Calculated by 2.0% of construction cost;

			• Joint commissioning fee: Calculated by 1.0% of construction cost (including staff training and purchase of office furniture).
7.	Current capital	41,314	Calculated by 1.0% of construction cost（that is the sum of the above Term 1, 2, 3, 4 and 5）
	Total	4,325,559	

According to 3-3, the fixed capital investment of conventional sanitation system is 4,284,246 Yuan. Taking the current capital into consideration, the total investment of construction is 4,325,55 Yuan.

3.4 Analysis and Calculation on Operating Cost of Conventional Sanitation System

Total cost with Ecosan System mainly includes the following cost items, which are calculated on the basis of 20 years.

- Cost of purchased materials and power
    - ✧ Current drain of sewage disposal
    - ✧ Chemical agent of sewage treattment
    - ✧ Freight of solid waste
- Salary and welfare
- Depreciation charge
- Repair and maintenance fee
- Byproduct recovery

Calculation details are as follows:

（1）Sewerage treatment: According to actual expenditure incurred by sewerage treatment plant and the maintenance charge of pipe line, the value used in this analysis is 1.0Yuan/Ton (including current drain of sewage disposal, chemical agent of sewage disposal, salary and welfare costs. The salary and welfare costs are calculated by 33% of actual operating cost thereinto). But the system charges the inhabitant 0.8Yuan/Ton for sewage actually.

（2）Annually generated moisture percentage is 80% and the excess sludge is 235.959 Ton/a. The organic refuse is calculated by 531 Ton/a, the freight is calculated by 1Yuan/km·Ton, and the transfer distance by 10km.

（3）Landfill operating cost: 45Yuan/Ton[9] (sludge disposal).

（4）The repair charge and daily maintenance cost is calculated by 2.40% of the original value of fixed assets[7].

As to the operating cost of conventional sanitation system of the same Scale as

Haozhaokui Community, please refer to Table 3-4.

Table 3-4 Operating Cost Sheet of Conventional Sanitation System Unit: Yuan

S/N	Terms	Year of occupation		
	Year of occupation	1	2	3-20
	Occupation rate	70%	80%	100%
1	Salary	23,851	23,851	23,851
2	Sewerage treatment	33,897	38,740	48,425
3	Waste transfer	5,372	6,139	7,674
4	Landfill operating cost	24,173	27,626	34,533
5	Depreciation	207,627	207,627	207,627
6	Repair and maintenance cost	96,361	96,361	96,361
7	Total cost (1+2+3+4+5+6)	391,281	354,088	360,650
7.1	Including（1）fixed cost	327,839	327,839	327,839
7.2	（2）variable cost	63,442	26,249	32,811
8	Running cost（7-5）	224,129	192,718	210,844

Thus, when the occupation rate is as high as 100%, the total cost of conventional sanitation system is 360,650Yuan/a (48% of the ecosan system). Direct operation cost is as follows: purchased materials and power + salary and welfare costs + repair and maintenance cost - byproduct recovery (yby product recovery includes the annual sewage treatment charge of RMB 57,821). When the occupation rate is as high as 100%, the direct operation cost of Haozhaokui Community eco-system is 153,023Yuan/a. All of the above shows that according to present pollutant disposal cost and the disposal charge, there is no financial profit for conventional sanitation system. The cash flow within the project period (two years for the construction period, 20 years for the operating period) is analyzed. Assuming that all funds are internally generated funds and taking no account of taxes and subsidies, the accumulated net benefit will be RMB -6,154,596 if the basic return rate of 4% is adopted. The net present value is smaller than zero, and the financial evaluation of the conventional ecosan system is infeasible.

3.5 Comparative Analysis on Cost Effectiveness of Ecosan System and Conventional Sanitation System

Any economic activity of human society, including policy and development project, may have effects on environment and natural resources configuration. So it is necessary to evaluate the range of these effects, to decide whether to issue or execute certain policy or not, to decide whether to develop and construct certain project or not. Cost-effectiveness analysis is the major technical method to evaluate these effects[10、11].

Cost-effectiveness analysis method evaluates the project's effect on environment, then brings people's concern about environment into feasibility study of the project. Sometimes cost-effectiveness analysis method is also called cost benefit analysis, economic analysis, benefit-cost analysis, national economic analysis and national economic evaluation, etc. Most government department and international body adopt cost-effectiveness analysis method as major evaluation method of project[12].

Cost-effectiveness analysis method views the project from the whole country or society, which is different from financial analysis or evaluation. Financial analysis is used to analyze certain inspection project's benefit for individual or manufacturer, which relates to actual payment with currency. The analytical process is on the basis of actual price paid by project entity for input and actual price received from output sales. For the existence of market distortion created by government or private department, economic value of input and output sometimes is different from financial value [10、11]. Custom duty, export duty and subsidy, consumption tax and sales tax, production subsidy as well as quantitative limitation are the common distortions created by the government.

3.5.1 Identification and Calculation of the Cost Benefit of the Ecosan System

（1）Shadow price of the engineering and operating costs

During financial analysis, the data of some costs are insufficient to represent the related economic value, and related costs shall be adjusted in order to reflect prices of the input, output, labour force and land.

Prices needing adjustment:

①The shadow price of land

The land of this project is allocated by the state with a favorable price of RMB 25000/mu. Considering the transaction price of similar lands of Dongsheng District in 2004, the shadow price of this project is adjusted to RMB 50000/mu.

②The labor costs

The conversion coefficient of the shadow wage shall be 1.0.

③Price of project inputs and outputs

Inputs and outputs are calculated in line with the domestic prices, while the engineering construction cost shall less the taxes. According to relevant provisions of "Composition of Construction and Installation Costs" (Construction Standard [2003] 206), the tax rate shall be 3.35%.

（2）Project Benefit Identification

①Cost Generated by Water Saving

Compared with conventional sanitation system project, Ecosan System project may reduce water consumption and save relevant water charge after the execution of the project because Ecosan System owns the water saving function and reclamation function after advanced treatment of sewage. If take the additional charge of long-distance water diversion and penalty of overproof water consumption into consideration, the saved cost for this term would be higher. According to the investigation on inhabitant from occupation to May, 2007 in this study, the water saving rate of Haozhaokui Community is 40%.

Chinese department concerned published The Circular on Promoting Water Pricing Reform for Water Conservation and Water Resources Protection (State Council General Office [2004] No. 36) which defined the charge of water price and orientation of structural reform relating to water. This document specifies the four parts of urban water price, that are charge for water resources, water supply price of water conservancy project, urban water supply price and sewage treatment charge.

The new Method of Managing Water Price for Water Conservancy Project (Order No.4 by Ministry of Water Resources and National Development and Reform Commission) executed in January, 2004 brought the water supply price of water conservancy project into merchandise control category for the first time, which changes the management pattern of treating water supply price of water conservancy project as administrative undertaking charges.

The represents of water saving are social net income and national income. Among the over 600 cities in China in 1998, about 400 cities were wanting in water (110 cities were suffering severe water shortages; the industrial and urban water deficit is 5.8 billion tons; the direct industrial and urban economic loss resulted from water shortage was as high as 160 billion Yuan annually which means that every 1 m^3 of water deficit would cause 27.6 Yuan of loss. Whereas, every 1 m^3 of water saving means 27.6 Yuan of benefit. Chinese Hydraulic Engineering Society undertook Water-saving Society Establishment Project on 2006. This survey shows that among the 669 cities, about 400 were wanting in water (100 cities were suffering severe water shortages; annual water deficit is 6 billion m^3; the direct industrial and urban economic loss as high as 230 billion Yuan annually which means that every 1 m^3 of water deficit would cause 39.3 Yuan of loss[14].) Other surveys show that every ton of water newly adds 90.9Yuan/ m^3 of industrial output value in China[15]. Erdos is a new industrial city suffering severe water shortages in Northern China, but there are few statistical datum about water-saving proceeds at present. In order to show the net proceeds benefited by water saving, this study adopts 27.6Yuan/m^3, the average water-saving proceeds recorded in relevant document, as analytical and calculated data.

②Saving Operating Cost of Urban Sanitary Installation

The Ecosan System's on-site controlling over district sewage and partial organic waste may reduce not only the discharge of sewage to municipal pipe network but also the waste dumping to waste landfill site annually. What's more, it relieves the pressure of sanitary installation and reduces construction and maintenance cost of municipal facilities[16]. Comparing with Ecosan System, conventional sanitation system lacks of proceeds generated by waste minimization and by construction and operation of waste disposal facilities. At present, operating cost of drainage facility in Dongsheng District is about 1.0Yuan/m^3. (Such data is adopted by this study.)

③Benefit Generated by Resource Utilization

After the performance of Ecosan System project and conventional sanitation system project (taking sewage reuse into consideration), reclaimed water reuse will bring relevant proceeds. At present there is still not any charge regulation about reclaimed water. This study adopts Mongolia's relevant documents to Baotou City (Inner Mongolia Pricing [2003] No.1256, September 4, 2003). The charge of reclaimed water reuse is 1.0Yuan/m^3. Relevant documents show that reasonable charge of reclaimed water should not exceed 60%-80% of domestic water.[17]

In addition, the use of dry toilets system and compost may reclaim nitrogen and phosphorus resources. Therefore, the fertilizer utilization of Ecosan System would produce 25,000 Yuan of annual net benefit. The food administration system executed in China at present includes pollution-free, green, organic food as well as Grade A or Grade AA green food and so on. The "pollution-free", "green" and "organic food" should subject to the major standard of without using or using little chemical composition (chemical fertilizer, pesticide or food additive, etc.) and the organic food enjoys the supreme grade. The benefit produced by organic food is three to five times higher than that of common food[18]. For adopting organic fertilizer, the agricultural value-rising of fertilizer products of Ecosan System is obviously well. But because there isn't any factual data about the project at present, the annual mean value-rising 10,000 Yuan is adopted here for initial estimation.

④Other

For indoor waterless ecosan toilet system, the management is very important. The property charge of residential area is 0.75Yuan/m^2·Month presently. But it doesn't take the management charge part of indoor waterless ecosan toilet system into consideration, which is unreasonable. It had better to arrange 0.15Yuan/m^2·Month as management charge of indoor waterless ecosan toilet system. In this way, apart from management charge of indoor waterless ecosan toilet system for residential area, other property charge would be 0.60Yuan/m^2·Month. According to investigation, the property charge of newly-built residences in Dongsheng District is less than 0.60Yuan/m^2·Month, so such kind of charge arrangement is reasonable. Because it has not been carried out yet, this study doesn't calculate the management charge.

（2）Analysis of Economic Cost Generated by Project Environmental Impact

The economic evaluation steps of environmental impact are proposed according to the ADB documents[19], including the creation of impact factor directory and environmental impact directory, screening and analysis, quantization of impact, monetization of impact, evaluation of factor analysis and introduction of evaluation result into economic analysis. Because the quantity of basic data during evaluation process is very large and there is little information about it, the literature screening is mainly adopted here initially to analyze economic evaluation of environmental impact after the performance of Ecosan System and conventional sanitation system (taking the wastewater reclamation into consideration) and to estimate benefit and cost.

According to relevant research findings, the cost of environmental degradation for water pollution in China is 4.71Yuan/ m^3, including the economic loss in rural communities' health caused by water pollution, economic loss from water shortage due to water pollution, additional treatment cost of industrial water caused by water pollution, Crop reduction from water shortage due to water pollution, additional treatment and protection cost of urban domestic water caused by water pollution, etc.. Because sewage disposal exists within Ecosan System and conventional sanitation system and it does comply with the effluent quality standard, it is generally agreed that the benefit for reducing cost of environmental degradation by discharge of treating water per unit volume is consistent.

In summary, the summary of Ecosan System cost and benefit is shown as Table 3-5. According to this table, the indirect benefit belongs to external benefits. The monetization in this study is on the basis of relevant research literature in China.

Table 3-5 The Benefit and Cost of Ecosan System in Haozhaokui Eco Residential Area Unit: RMB Yuan

Benefit		
Items		**Cost（Yuan）**
Direct benefit	Charge of sewage treatment（Occupation rate 100%）	34,470（calculated by 47.7L/Person·Day，altogether 2912 people, the sewage treatment charge is 0.8 Yuan /m^3 ）
	Annual benefit from reclaimed water production（Occupation rate 100%）	27,145（Treatment quantity of reclaimed water is 82.634m^3/d; considering the reserved water amount of 10%, the treatment charge of reclaimed water is 1.0 Yuan/m^3）
	Annual benefit from composting product and urine（Occupation rate 100%）	66,000
	Salvage value of fixed assets	383,310 and salvage value rate is 4%[7]）
Indirect benefit	Cost of reducing urban sewage and waste treatment facilities	1,690,238 (32.3L/Person·Day, altogether 2912 people[9、16]）
	Reduction of the construction cost of water supply facilities	376,320 (32.3L/Person·Day, altogether 2912 people, 4000 Yuan/ton.day[7])
	Cost of reducing environmental degradation for water pollution（Occupation rate 100%）	202,942 (calculated by 47.7L/Person·Day-sewage quantity，altogether 2912 people, the cost of environmental degradation is 4.71 Yuan /m3, including the economic loss in rural communities' health caused by water pollution, economic loss from water shortage due to water pollution, additional treatment cost of industrial water caused by water pollution, Crop reduction from water shortage due to water pollution, additional treatment and protection cost of urban domestic water caused by water pollution, etc [21])
	Annual benefit from waste and sludge minimisation（Occupation rate 100%）	34,470（calculated by 2912 persons, sewage reduction of 32.3L/Person·Day, organic waste reduction of 531 ton/year[9]）
	Annual cost of reducing sewage treatment（Occupation rate 100%）	29,188（calculated by 32.3L/Person·Day，altogether 2912 people [16]）
	Annual benefit from water saving（Occupation rate 100%）	947,762（benefit form water saving is 27.6 Yuan/ton[13]）
	Annual increased benefits from agriculture（estimation）（Occupation rate 100%）	10,000 [17]
Cost		
Items		**Cost（Yuan）**
Fixed capital investment		9,510,687 （calculated by actual

	expenditure incurred supposing the invested funds during the first year of construction period is 40%, the second year is 60%.）[9、16]
Yearly operating cost	435,608 （calculated by actual expenditure incurred [2、3、11]）

Table 3-6 shows the benefit and cost of conventional sanitation system. Suppose that this system will construct a sewage treatment plant and relevant pipe lines (40,000 ton/day), which is similar to the current sewage collection and disposal situation in Dongsheng District. The scale of this residential area is consistent with Haozhaokui Community, and the water consumption is 80L/Person·Day, and the sewage reduction coefficient is 0.85[20]. Indoor sewage collected in house-drainage, then drained into residential area sewer, and the sewage is transferred into sewage treatment plant by the municipal drainage pipe line for centralized disposal.

Table 3-6 Benefit and Cost of Conventional Sanitation System Unit: RMB Yuan

Benefit		
Terms		**Cost（Yuan）**
Direct benefit	Annual charge of sewage treatment (Occupation rate100%)	68,024 （calculated by 80L/Person·Day，altogether 2912 people, the sewage treatment charge is 0.8 Yuan /m^3 ）
	Salvage value of fixed assets	190,872 （salvage value rate 4% [7]）
Indirect benefit	Cost of reducing environmental degradation for water pollution（Occupation rate100%）	340,419 (calculated by 60.0L/Person·Day-sewage quantity，altogether 2912 people, the cost of environmental degradation is 4.71 Yuan /m3, including the economic loss in rural communities' health caused by water pollution, economic loss from water shortage due to water pollution, additional treatment cost of industrial water caused by water pollution, Crop reduction from water shortage due to water pollution, additional treatment and protection cost of urban domestic water caused by water pollution, etc [21])
Cost		
Terms		**Cost（Yuan）**
Fixed asset investment		4,311,743（calculated by scale and technology on the basis of relevant technical standards, norms and handbooks. The input capital during the first year of construction period is 40%, and the second year is 60% [9、16]）
Yearly operating cost		210,844 （calculated by scale and technology on the basis of relevant technical standards, norms and handbooks.[2、3、11]）

The calculation of direct benefit does not cover the benefit from charge of sludge and waste in conventional sanitation system, because the charge of solid waste hasn't been in full operation yet in Dongsheng District. The industrial wastewater accounts for about 40% in urban sewage of Dongsheng District, so after drying of sludge, direct landfill is adopted by sewage treatment plant of conventional sanitation system and there is no utilization benefit.

3.5.2 Comprehensive Comparative Analysis for Benefit and Cost of Ecosan System and Conventional Sanitation System

（1）Evaluation criteria of cost-benefit[10、11]

①Economic net present value

Economic net present value (ENPV) is the absolute index to reflect the project's net contribution to national economy. It is the present value sum by converting the net benefit during calculation period of projects (benefit deduct cost) into the construction starting point on the basis of social discount rate. The calculation formula is shown as Formula 3-4.

$$ENPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1 + i_s)^t} \qquad (3\text{-}4)$$

In this formula,

B_t、C_t —Total benefit and total cost occurred during the t year;

n — calculation period of projects;

i_s —Social discount rate, according to the documents specified by National Development and Reform Commission, Ministry of Construction of the People's Republic of China, for the project owning long-term benefit from environmental protection, the social discount rate should be less than 8%. This study adopts 8% temporarily.

When the economic net present value ≥ zero, the project would be optional.

②Economic Internal Rate Return

Economic internal rate return (EIRR) is the relative index to reflect the project's contribution to national economy. The calculation formula is shown as Formula 3-5.

$$\sum_{t=0}^{n} \frac{B_t - C_t}{(1 + EIRR)^t} = 0 \qquad (3\text{-}5)$$

In Formula 3-5,

EIRR—Economic internal rate return.

Other symbols in Formula 3-5 is as the same as Formula 3-4.

Generally, when the economic internal rate return ≥ social discount rate, the project would be acceptable.

③Economic Net Present Value Rate

Economic net present value rate (ENPVR) is the ratio of project net present value to total present value of investment and it is also known as net present value for present value of unit investment. Such kind of index can reflect the unit investment's net contribution to national economy. The calculation formula is shown as Formula 3-6.

$$\text{ENPVR} = \frac{\text{ENPV}}{I_p} \quad (3\text{-}6)$$

In Formula 3-6,

ENPVR—Economic net present value rate;

I_p—Net present value of investment.

Generally, the project with higher economic net present value rate shall be selected for use with priority.

（2）Comprehensive Comparative Analysis for Benefit and Cost of Ecosan System and Conventional Sanitation System

Suppose the construction period of Ecosan System and conventional sanitation system of the same scale are both two years, and the capital input proportions during these two years are 40% for the first year and 60% for the second year separately.

When the adopted social discount rate is 8%, the economic effectiveness of Ecosan System and conventional sanitation system is shown as Table 3-7.

Table 3-7 Economic Effectiveness Comparison for Ecosan System and Conventional Sanitation System of the Same Scale

Index	Ecosan System	Conventional sanitation system
economic net present value of Ecosan System (ENPV)	796,240 Yuan	-2,510,212 Yuan

Therefore, the ENPV of Ecosan System is larger than zero in the light of economic net present value, which shows that the system of Haozhaokui Eco Residential Area is feasible economically. By contraries, the ENPV of conventional sanitation system is less than zero, which shows that the conventional sanitation system is infeasible economically. The main reasons are as follows: the investment amount of conventional sanitation system is rather large; the charge of pollutants discharge is low; there is no water-saving benefit; the sewage resource recovery is unsatisfactory, etc. What’s more, the social discount rate is also the influence factor.

The foreign social discount rate varies from institution to institution and from country to country. For example, the American social discount rate is 1.6%-3.2% (evaluation period of applicable project is from three years to thirty years, but the social discount rate of ADB is 10%-12%. According to the pertinent provisions of China, the appropriate social discount rate adopted in environmental protection project should be 8%, but there is no specific value yet. When social discount rate adopted in this project is less than 8%, the ENPV of Ecosan System is always higher than the ENPV of conventional sanitation system, which means that Ecosan System is better than conventional sanitation system in the sight of the whole society. The main reason is that Ecosan System enjoys higher water-saving efficiency and the contaminant resource recovery is satisfactory, which do produce benefit.

Table 3-7 Benefit-cost Sheet for Ecosan System in Haozhaokui Community　Unit: RMB Yuan

S/N	Terms	Construction period		Period of Occupation				
	Year	1	2	3	4	5	6	7
	Occupation rate			70%	80%	100%	100%	100%
1	Benefit flow（B）	826,623	1,239,935	946,384	1,081,582	1,351,978	1,351,978	1,351,978
1.1	Cost of reducing urban sewage and waste treatment facilities	676,095	1,014,143					
1.2	Annual charge of sewage treatment			24,129	27,576	34,470	34,470	34,470
1.3	Annual charge of reclaimed water treatment			19,002	21,716	27,145	27,145	27,145
1.4	Annual sales income of composting production and urine			46,200	52,800	66,000	66,000	66,000
1.5	Annual benefit from waste and sludge minimisation			24,129	27,576	34,470	34,470	34,470
1.6	Annual cost of reducing sewage treatment			20,432	23,351	29,188	29,188	29,188
1.7	Reduction of the construction cost for water supply facilities	150,528	225,792					
1.8	Annual benefit from water saving			663,433	758,210	947,762	947,762	947,762
1.9	Annual benefit from crop increasement			7,000	8,000	10,000	10,000	10,000
1.10	Cost of reducing environmental degradation for water pollution			142,060	162,354	202,942	202,942	202,942
1.11	Salvage value of fixed assets							
2	Cost flow (C)	3,804,275	5,706,412	388,210	404,009	435,608	435,608	435,608
2.1	Fixed capital investment	3,804,275	5,706,412					
2.2	Annual operating cost			388,210	404,009	435,608	435,608	435,608
3	Net benefit flow（B－C）	-2,977,652	-4,466,477	558,175	677,573	916,370	916,370	916,370
4	Accumulated net benefit flow∑（B－C）	10,666,700						
5	Discount coefficient（$1+i_s$）$^{-n}$	1.00	0.93	0.86	0.79	0.74	0.68	0.63
6	Current value of net benefit flow（B－C）（$1+i_s$）$^{-n}$	-2,977,652	-4,135,627	478,545	537,879	673,559	623,666	577,468
7	Accumulated current value of net benefit flow (economic net present value) ENPV=∑（B－C）（$1+i_s$）$^{-n}$	796,240						

Table 3-7 Benefit-cost Sheet for Ecosan System in Haozhaokui Community (Continuation 1)   Unit: RMB Yuan

S/N	Terms	Period of Occupation							
	Year	8	9	10	11	12	13	14	15
	Occupation rate	100%	100%	100%	100%	100%	100%	100%	100%
1	Benefit flow（B）	1,351,978	1,351,978	1,351,978	1,351,978	1,351,978	1,351,978	1,351,978	1,351,978
1.1	Cost of reducing urban sewage and waste treatment facilities								
1.2	Annual charge of sewage treatment	34,470	34,470	34,470	34,470	34,470	34,470	34,470	34,470
1.3	Annual charge of reclaimed water treatment	27,145	27,145	27,145	27,145	27,145	27,145	27,145	27,145
1.4	Annual sales income of composting production and urine	66,000	66,000	66,000	66,000	66,000	66,000	66,000	66,000
1.5	Annual benefit from waste and sludge minimisation	34,470	34,470	34,470	34,470	34,470	34,470	34,470	34,470
1.6	Annual cost of reducing sewage treatment	29,188	29,188	29,188	29,188	29,188	29,188	29,188	29,188
1.7	Reduction of the construction cost for water supply facilities								
1.8	Annual benefit from water saving	947,762	947,762	947,762	947,762	947,762	947,762	947,762	947,762
1.9	Annual benefit from crop increasement	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
1.10	Cost of reducing environmental degradation for water pollution	202,942	202,942	202,942	202,942	202,942	202,942	202,942	202,942
1.11	Salvage value of fixed assets								
2	Cost flow (C)	435,608	435,608	435,608	435,608	435,608	435,608	435,608	435,608
2.1	Fixed capital investment								
2.2	Annual operating cost	435,608	435,608	435,608	435,608	435,608	435,608	435,608	435,608
3	Net benefit flow（B－C）	916,370	916,370	916,370	916,370	916,370	916,370	916,370	916,370
4	Accumulated net benefit flow Σ（B－C）								
5	Discount coefficient $(1+i_s)^{-n}$	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34
6	Current value of net benefit flow（B－C）$(1+i_s)^{-n}$	534,693	495,086	458,413	424,456	393,015	363,903	336,947	311,988

7	Accumulated current value of net benefit flow (economic net present value) $ENPV=\Sigma(B-C)(1+i_s)^{-n}$								

Table 3-7 Benefit-cost Sheet for Ecosan System in Haozhaokui Community (Continuation 2) Unit: RMB Yuan

S/N	Terms	Period of Occupation						
	Year	16	17	18	19	20	21	22
	Occupation rate	100%	100%	100%	100%	100%	100%	100%
1	Benefit flow（B）	1,351,978	1,351,978	1,351,978	1,351,978	1,351,978	1,351,978	1,732,405
1.1	Cost of reducing urban sewage and waste treatment facilities							
1.2	Annual charge of sewage treatment	34,470	34,470	34,470	34,470	34,470	34,470	34,470
1.3	Annual charge of reclaimed water treatment	27,145	27,145	27,145	27,145	27,145	27,145	27,145
1.4	Annual sales income of composting production and urine	66,000	66,000	66,000	66,000	66,000	66,000	66,000
1.5	Annual benefit from waste and sludge minimisation	34,470	34,470	34,470	34,470	34,470	34,470	34,470
1.6	Annual cost of reducing sewage treatment	29,188	29,188	29,188	29,188	29,188	29,188	29,188
1.7	Reduction of the construction cost for water supply facilities							
1.8	Annual benefit from water saving	947,762	947,762	947,762	947,762	947,762	947,762	947,762
1.9	Annual benefit from crop increasement	10,000	10,000	10,000	10,000	10,000	10,000	10,000
1.10	Cost of reducing environmental degradation for water pollution	202,942	202,942	202,942	202,942	202,942	202,942	202,942
1.11	Salvage value of fixed assets							380,427
2	Cost flow (C)	435,608	435,608	435,608	435,608	435,608	435,608	435,608
2.1	Fixed capital investment							
2.2	Annual operating cost	435,608	435,608	435,608	435,608	435,608	435,608	435,608
3	Net benefit flow（B－C）	916,370	916,370	916,370	916,370	916,370	916,370	1,296,797
4	Accumulated net benefit flow Σ（B－C）							
5	Discount coefficient $(1+i_s)^{-n}$	0.32	0.29	0.27	0.25	0.23	0.21	0.20
6	Current value of net benefit flow $(B-C)(1+i_s)^{-n}$	288,878	267,480	247,666	229,321	212,334	196,605	257,616
7	Accumulated current value of net benefit flow (economic net present value) $ENPV=\Sigma(B-C)(1+i_s)^{-n}$							

Table 3-8 Benefit-cost Sheet for Conventional Sanitation System of the Same Scale with Haozhaokui Community Unit: RMB Yuan

S/N	Terms	Construction period		Period of Occupation				
	Year	1	2	3	4	5	6	7
	Occupation rate			70%	80%	100%	100%	100%
1	Benefit flow（B）	0	0	278,768	318,592	398,240	398,240	398,240
1.1	Charge of sewerage treatment			40,474	46,257	57,821	57,821	57,821
1.2	Cost of reducing environmental degradation for water pollution			238,293	272,335	340,419	340,419	340,419
1.3	Salvage value of fixed assets							
2	Cost flow (C)	1,724,697	2,587,046	183,655	192,718	210,844	210,844	210,844
2.1	Fixed capital investment	1,724,697	2,587,046					
2.2	Annual operating cost			183,655	192,718	210,844	210,844	210,844
3	Net benefit flow（B－C）	-1,724,697	-2,587,046	95,113	125,874	187,396	187,396	187,396
4	Accumulated net benefit flow∑（B－C）	-545,163						
5	Discount coefficient（1＋is）$^{-n}$	1.00	0.93	0.86	0.79	0.74	0.68	0.63
6	Current value of net benefit flow（B－C）（1＋is）$^{-n}$	-1,724,697	-2,395,413	81,544	99,923	137,741	127,538	118,091
7	Accumulated current value of net benefit flow (economic net present value) ENPV=Σ（B－C）（1＋is）$^{-n}$	-2,510,212						

Table 3-8 Benefit-cost Sheet for Conventional Sanitation System of the Same Scale with Haozhaokui Community (Continuation 1)

Unit: RMB Yuan

S/N	Terms	Period of Occupation							
	Year	8	9	10	11	12	13	14	15
	Occupation rate	100%	100%	100%	100%	100%	100%	100%	100%
1	Benefit flow（B）	398,240	398,240	398,240	398,240	398,240	398,240	398,240	398,240
1.1	Charge of sewerage treatment	57,821	57,821	57,821	57,821	57,821	57,821	57,821	57,821
1.2	Cost of reducing environmental degradation for water pollution	340,419	340,419	340,419	340,419	340,419	340,419	340,419	340,419
1.3	Salvage value of fixed assets								
2	Cost flow (C)	210,844	210,844	210,844	210,844	210,844	210,844	210,844	210,844
2.1	Fixed capital investment								
2.2	Annual operating cost	210,844	210,844	210,844	210,844	210,844	210,844	210,844	210,844
3	Net benefit flow（B－C）	187,396	187,396	187,396	187,396	187,396	187,396	187,396	187,396
4	Accumulated net benefit flow∑（B－C）								
5	Discount coefficient（1＋is）$^{-n}$	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34
6	Current value of net benefit flow（B－C）（1＋is）$^{-n}$	109,344	101,244	93,745	86,800	80,371	74,417	68,905	63,801
7	Accumulated current value of net benefit flow (economic net present value) ENPV=Σ（B－C）（1＋is）$^{-n}$								

Table 3-8 Benefit-cost Sheet for Conventional Sanitation System of the Same Scale with Haozhaokui Community (Continuation 2)

Unit: RMB Yuan

S/N	Terms	Period of Occupation						
	Year	16	17	18	19	20	21	22
	Occupation rate	100%	100%	100%	100%	100%	100%	100%
1	Benefit flow（B）	398,240	398,240	398,240	398,240	398,240	398,240	570,710
1.1	Charge of sewerage treatment	57,821	57,821	57,821	57,821	57,821	57,821	57,821
1.2	Cost of reducing environmental degradation for water pollution	340,419	340,419	340,419	340,419	340,419	340,419	340,419
1.3	Salvage value of fixed assets							172,470
2	Cost flow (C)	210,844	210,844	210,844	210,844	210,844	210,844	210,844
2.1	Fixed capital investment							
2.2	Annual operating cost	210,844	210,844	210,844	210,844	210,844	210,844	210,844
3	Net benefit flow（B－C）	187,396	187,396	187,396	187,396	187,396	187,396	359,865
4	Accumulated net benefit flow∑（B－C）							
5	Discount coefficient（1＋is）$^{-n}$	0.32	0.29	0.27	0.25	0.23	0.21	0.20
6	Current value of net benefit flow（B－C）（1＋is）$^{-n}$	59,075	54,699	50,647	46,896	43,422	40,205	71,489
7	Accumulated current value of net benefit flow (economic net present value) ENPV=Σ（B－C）（1＋is）$^{-n}$							

3.6 Brief Summary of This Chapter

According to the data analysis of financial investment, the total investment amount of Ecosan System in Haozhaokui Community is 9,582,748 Yuan, which is 2.21 times as much as that of conventional sanitation system of the same scale; when the occupation rate of Haozhaokui Community is 100%, the annual operating cost (including water and fertilizer reclamation) of Ecosan System in Haozhaokui Community is 307,993Yuan which is 2.15 times as much as that of conventional sanitation system of the same scale. Therefore, in line with the data of financial analysis the Ecosan System in Haozhaokui Community and conventional sanitation system of the same scale are both infeasible on the basis of financial evaluation method.

Compared with the conventional sanitation system, the ecosan system stresses on the recycle use of materials and has multiple positive impacts on the environemtn. Therefore, the economic evaluation of sanitation system project should on the basis of the whole country or society. The economic analysis and calculation of this chapter shows that Haozhaoukui Ecosan System in Residential Area has obvious economical efficiency compared to conventional sanitation system of the same scale on the basis of taking the direct benefit and indirect benefit into consideration. The detailed performances are：Calculated by cost-benefit method, the economic net present value (ENPV) of Ecosan System is 796,240 Yuan and its benefit contribution is mainly from water saving and reclaimation of nitrogen and phosphorous nourishment; but ENPV of conventional sanitation system is -2,510,212 Yuan. Project is feasible only if ENPV＞0 according to feasibility study. Therefore, the conventional sanitation system of the same scale is uneconomical grounded on current cash flow.

Basing on the aforesaid analysis, in order to ensure the sustainable operation of Haozhaokui Community Project, we suggest that the government department should promulgate related policies and supplement measures to encourage and promote water saving and reclamation of organic matters (feces and organic wastes), so as to ensure that the benefit from resource reclamation and saving would emerge in a reasonable form of monetization, as well as to facilitate the development of the ecosan system.

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CHAPTER IV Research on the Optimum Size of Ecosan Systems & Its Economic Evaluation

4.1 Principles of indicator system establishment for the best available size

This chapter carries out the discussion on the optimum size for the centralized construction of the ecosan system, the system composition and the same system in existence in Haozhaokui Community. As described in former chapters, Haozhaokui Community currently boasts the largest ecosan system in towns all over the world. However, its size is yet not optimum with regard to various factors such as economy. Researches show that, for example, the decentralized sewage disposal system of Haozhaokui Community is not the most economic in scale in China alone. Relevant indicator system is involved in the analysis of the optimum size. Indicators are closely related to the situation where they are adopted. Following principles must be observed when establishing the indicator system [1] （1）Principle of whole completeness：

As an organic entirety, the indicator system should not only reflect from various angles the primary characteristics and conditions of the system under evaluation, but also reflect its dynamic variation and its development trend.

（2）Principle of science：Specific indicators should be selected on the scientific basis of a full acknowledgement and research of the system and should be in a position to reflect the connotation of the research subject and the extent to which the objective is realized.

（3）Principle of operability：Indicator system is not one that is the bigger the better. Difficulty and reliability of indicator quantization & data acquisition should be taken into consideration while choosing those typical composite indicators and leading indicators whenever possible. （4）Principle of regionality：Adjust measures to local conditions since the regional systems for sustainable development in different areas features differently due to the difference in time space. And indicators with local characteristics should be established by combining with the research on regional features.

（5）Principle of hierarchiality：The indicator system is hierarchical according to the structure of research system. And the indicators are classified on such basis so that the structure of the indicator system becomes more clear and convenient to use.

（6）Principle of combining dynamicality and stability：Contents of the indicator system are inadvisable to change over frequently. In a given period，the indicator system should remain relatively stable except that it should be gradually adjusted with the development of regional systems or it should be provided with dynamicality.

（7）Principle of relative independentability： In order to reduce the redundancy of information, efforts should be made for various indicators in the indicator system to remain relatively independentable.

（8）Principle of being both qualitative and quantitative：Indicators should be quantified as much as possible. Those indicators hard to be quantified at current acquaintance level but with material significance can be described as stationarity indices. （9）Principle of being policy friendly：Everything is under development. There is no exception for indicators. Therefore, appraisal target value or threshold value of the indicators must take on their dynamicality. Being policy friendly means the selected indicator system and its target value conform to various applicable guidelines and policies of the city.

4.2 Establishment of the indicator system

Through investigation on references by combining local features, with discussion among the study group time after time as well as an informal discussion with local government officials and experts, it has been determined that the indicator system should be established from five aspects of management, environmental protection, economy, society and supporting facilities. **4.2.1 Technical considerations for the ecosan system**

（1）Stability of the system

Stability of the system is one of the key factors that affect the popularization of the ecosan system. As for systems of small scale, occasional system failure can only bring impacts to the daily life of minor residents without causing large-scale influence. With the scale enlargement of the ecosan system, the influence of system failure will be amplified, leading to the raised requirement on system stability.

（2）Special designs for systems of different scales Current ecosan system does not apply to all buildings. Owing to the special requirements in its service, current ecosan system is comparatively more applicable in ordinary residential buildings. When the ecosan system is enlarged, it came down to the problems of design and operational guidance for service in public places.

（3）How to integrate with the existing system

The integration of ecosan system with conventional sanitary system is a headache for all areas implementing ecosan systems. Ecosan system is always combined together with decentralized sewage disposal system with no need for municipal blow-off lines. Meanwhile, the construction of both blow-off lines and centralized sewage treatment plants has undergone development to a greater or lesser degree. It is a practical problem how to coordinate the application of these two systems. （4）Buffer capacity of the system

In the large scale systems, ill-usage or other abnormal conducts of single users will bring little effects to the ecosan system as a whole. In another word, the large scale system boasts strong buffer capacity. （5）Necessary comfortability

Peculiar smell, mosquitoes and other problems to certain extent still exist in current ecosan systems. Similar problems will affect more residents with the expansion of the construction scale. **4.2.2 Economic factor**

（1）Construction cost

According to the scale effect，the larger the ecosan system, the lower construction cost per capital. By enlarging the scale of ecosan systems, we can reduce the construction cost of the systems.

（2）Operating cost

The centralized management of a large-scale ecosan system can lower its general and administrative expense on average.

（3）Effects on local agriculture

Ecosan systems of different scales have different effects on local agriculture. Small-scale ecosan systems can bring little effects to agriculture, while large-scale ecosan systems can boost the development of organic agriculture in local areas and bear fairly great value potential if large amount of organic manure is provided to a certain degree for the local agriculture. （4）Increase jobs for local people

The operation and management of ecosan systems are more complicated than conventional sanitary systems and they need more manpower. Large-scale popularization of ecosystems will increase job opportunities in local areas.

4.2.3 Environmental impact

（1）Water-saving effect

It is evident that water-saving effect of the ecosan system is directly proportional to its application scale. One of the ultimate goals of popularization of ecosan systems is to substantially conserve water resources so as to relieve the shortage of water resources and protect the water source area. （2）Reduction of sewage discharge

Residential buildings with ecosan systems have a discharge capacity of 20%-30% less than conventional residential buildings. Pressure on sewage disposal is relieved, and the negative environmental influence of domestic sewage is degraded.

（3）Reduction of waste discharge

Solid waste is sorted and compost of organic material with excremental is made in the ecosan system, thus substantially reducing the discharge amount of household refuse.

4.2.4 Management factor

During its enlargement, ecosan systems face a series of management problems as discussed below:

（1）Problem of system failure

Belonging to technical problems, system failure is influencing the current management of ecosan systems. It is evident that，in large-scale systems, system failure will lead to greater difficulty in management because more users are involved. As for small-scale ecosan systems which are even utilized as single-household system in rural areas, occasional system failure will seldom or not bring along management problems at all.

（2）Daily operation & management

With regard to daily operation and management, a larger-scale management system ensures more effectively the classified collection of garbage, the collection & utilization of urine and faeces, disposal & reclamation of grey water, etc. （3）Risk of infectious disease

During outbreak of diseases, large-scale ecosan systems bring about greater hidden hygienic trouble.

（4）Policy guiding

Regional policies exert influence over the development of ecosan systems; meanwhile, the popularization and expansion of ecosan systems will also promote local environmental protection and the construction of eco-towns.

4.2.5 Factor of supporting facilities

（1）Methods of fecaluria utilizing The amount of manure produced by ecosan systems should match the demand of local agriculture on manure. The over-sized manure will result in both economic and environmental loss. （2）Source of additives to toilets

Toilets of ecosan systems need the additives of sawdust or culms, the source of which is likely to come into question in large-scale ecosan systems. **4.2.6 Other factors**

（1）City appearance

Under general circumstances, feces and urine from residential quarters are destined for secondary treatment. Following composting and disposal, urine is destined for agricultural land. During transportation, secondary pollution should be avoided without sprinkling or splashing. It is obvious that the larger the scale, the greater influence over the city appearance it will bring.

（2）Residents' habits

To some extent, it is reasonable that in some areas people repel fecal matter and believe feces have potential hazard. Local conventional customs should be fully taken into consideration when carrying out ecosan systems. From the point of initial popularization, the larger scale of ecosan systems to be constructed, the greater resistance resulting from the residents' habits will become.

（3）Promotion of environmental awareness

Ecosan system is a carrier for publicizing the protection of environment and ecology. The running of a favorable ecosan system will effectively promote ecological and environmental awareness of local residents. Environmental awareness refers to people's knowledge and reflection of the relations between environment and themselves. In China, a lot of policies and measures on environment protection are currently not implemented effectively. The destruction of ecological environment has not been put under effective control in many places. In addition to the superficial aspect of pursuing economic growth， one important reason is the weakness and loss of public environmental awareness. Only by convincing social groups and individuals of the relations between ecological environment and human existence as well as the harm ecological crisis will bring to the mankind, can the conscientious environment protection become a reality. Public receptivity and support is the key to success.

Cultivation of public environmental and resource awareness: People’s awareness and habits are important social capital, without which the room for running the price system and managerial system of resources will become smaller. It is especially important to strengthen the cultivation of moral consciousness of environmental protection. In areas where water resource is in short, it is predominant to permeate environmental awareness to the public and cultivate their moral consciousness. It is an efficient instrument for the normal operation of ecosan systems by publicizing and advising the correct methods of application and relevant knowledge of environment through TV, newspaper and other media. Emphasis should be placed upon those aged with low degree of education and low income. Practicability, functionality and easy acceptance should be stressed with regard to the ecosan facilities and their usage mode.

Easy breakdown, bad smell and complexity in use are among the problems the residents have put forward. Under current conditions, these problems are in objective existence and not able to solve in short time. Therefore, publicity should be strengthened to promote the residents' awareness so as to make it a habit of the residents to use the ecosan system.

4.3 Determination of weight

4.3.1 Method of weight determination

Weight method of social survey is to be determined so that relevant information on social facts will be collected, and description & explanation will be made. Questionnaire survey used in the investigation is a way of data collection for the investigators to ask for opinions and acquire the knowledge of the situation with questionnaire designed in uniform [2].

4.3.2 Gradation of the designed questionnaire

Designed questionnaire adopts gradation from 1 to 9, among which 1, 3, 5, 7 and 9 represent very unimportant, unimportant, common, important, and very important respectively.

4.3.3 Method of analyzing on investigation and survey findings

Following the social investigation，make analysis and translate the scores marked by experts into weight value.

Translate the outcome of the investigation into weight on the basis of the following gradation： 1--0 point；3--25 points；5--50 points；7--75 points；9--100 points；

Weight between primary targets is determined before the point value of this index is divided into point values of all sub-objectives under the index[3]. Primary targets include technological factor, economic factor, factor of environmental impact, management factor, factor of supporting facilities and other factors.

4.3.4 Analytic results of the investigation

The subdivision, investigation and statistics of all factors are detailed in Table 4-1. The weight values of all factors are the results of the investigation, and are determined by researchers after refering to related literatures [3] and considering the specific characters of this project.

Table 4-1 Statistics of weight value investigation and survey findings

Technological factor	**0.23**
Stability of the system	0.06
Special designs for systems of different scales	0.03
How to integrate with the existing system	0.06
Buffer capacity of the system	0.02
Necessary comfortablility	0.06
Economic factor	**0.20**
Construction cost	0.09
Running cost	0.07
Effects on local agriculture	0.02
Increase jobs for local people	0.02
Factor of environmental impacts	**0.15**

Water-saving effect	0.05	
Reduction of sewage discharge	0.05	
Reduction of encouraged waste effluent	0.05	
Management factor		**0.15**
Problem of system failure	0.05	
Daily operation & management	0.03	
Hidden trouble of infectious diseases	0.03	
Policy guiding	0.04	
Factor of supporting facilities		**0.14**
Methods of fecaluria utilizing	0.07	
Source of additives to toilets	0.07	
Other factors		**0.13**
City appearance	0.04	
Residents' habits	0.05	
Promotion of environmental awareness	0.04	
Total		**1.00**

4.4 Scale evaluation

4.4.1 Evaluation outcome

Table 4-2 Statistics of evaluation results

Parameter	Conventional sanitary system	Ecosan system					
		Size 1（1000-4000 persons）	Size 2（10000 - 20000 persons）	Size 3（20000 - 40000 persons）	Size 4（40000 - 80000 persons）	Size 5（80000－150000 persons）	Size 6（over 150000 persons）
Technological factor							
Stability of the system	9	7	7	6	5	3	2
Special designs for systems of different scales	10	7	7	7	7	7	7
How to integrate with the existing system	10	9	8	8	6	5	4
Buffer capacity of the system	9	5	6	7	8	8	8
Necessary comfortablility	10	8	7	7	6	5	5
Economic factor							
Construction cost	9	5	6	7	7	8	8
Running cost	9	5	6	7	7	8	8
Effects on local agriculture	0	3	5	7	8	9	9
Increase jobs for local people	0	2	3	6	8	8	9
Factor of environmental impacts							
Water-saving effect	0	2	4	6	7	8	9
Reduction of sewage discharge	0	2	4	6	7	8	9
Reduction of encouraged waste effluent	0	2	4	6	7	8	9
Management factor							
Problem of system failure	9	8	7	7	5	4	3
Daily operation & management	0	3	5	7	7	8	8
Hidden trouble of infectious diseases	8	8	7	7	5	4	3
Policy guiding	0	3	5	7	7	8	8
Factor of supporting facilities							
Methods of fecaluria utilizing	10	9	8	8	7	6	5
Source of additives to toilets	10	9	8	8	7	6	5
Other factors							
City appearance	10	9	8	8	7	6	4
Residents' habits	10	9	9	8	7	6	5
Promotion of environmental awareness	0	4	6	7	7	8	8
Total score	**6.65**	**6.03**	**6.41**	**7.06**	**6.66**	**6.55**	**6.25**

4.4.2 Evaluation and analysis

Table 4-2 indicates that the highest score will be achieved when the size of ecosan system is between 20000 and 40000 persons, while the score will drop when the size is above or below that.

An optimum size evaluation system is established as the basis of evaluating and marking ecosan system of different scales and conventional sanitation system. By this means, influences of size changes on every aspect will be acquired which provides basis for appropriate planning.

4.5 Comparison and analysis on costs and benefits of ecosan and conventional sanitation systems after scaling up

4.5.1Considerations on processes of ecosan system and conventional sanitation system after scaling up

（1）Size

On the basis of the mentioned study on the optimum size and residential quarters where domestic wastewater is treated as raw water, the decided enlarged size is 10000 households, i.e., 35000 persons in a dwelling district.

Water consumption and pollutant output in the dwelling district is designed to increase linearly on the same scale.

In ecosan systems, water consumption quota is 48L/ person per day, reduction coefficient is 0.85 and designed wastewater treatment scale is 1428 m^3/d. The adopted indoor water-free ecological toilets is the same as that in Haozhaokui Community, and other initiatives and conditions to control pollutants are similar to those in Haozhaokui Community.

In conventional sanitation systems, water consumption quota is 80L/ person per day, reduction coefficient is 0.85, and designed wastewater treatment scale is 2380 m^3/d.

（2）Methods/processes of pollutants treatment, control and utilization in the dwelling district

Treatment, controlling and utilization methods/processes of pollutants in the dwelling district with ecosan system can be informed from Graph 1-2 and Graph 1-3. The dwelling district is equipped with an ecological station or a wastewater treatment station. And it can be divided into 6 to 8 residential quarters.

Methods/processes of pollutants treatment, control and utilization in the dwelling district with conventional sanitation system can be informed from Graph 3-3.

4.5.2 Investment changes of the two systems after scaling up

Since the pollutant controlling size is enlarged, the total investment in construction certainly will increase, that in unit pollutant treatment such as that in unit wastewater treatment (civil engineering, facilities) will decrease, and pipelines for wastewater and reuse of recycled water will increase, besides, there will be more vehicles accordingly.

4.5.3 Estimation of the costs for the investment and operation of the two systems after scaling up

Relevant parameters applied during the estimation of the costs of investment and operation is the same as the mentioned if there is no instruction.

As to the investment estimation on ecosan systems, it is calculated according to productivity indexes [4]. Please see Formula（4-1）for reference.

$$Y_2 = Y_1 \times (X_2 / X_1)^n \times CF \qquad (4\text{-}1)$$

In the Formula：

Y_2 — investment of planned projects;

Y_1 — investment of established projects;

X_2 — productivity of planned projects, take the value of 10000 households in calculation;

X_1 — productivity of established projects, take the value of 832 households in calculation;

CF — integrated coefficient of quota, unit price, expense alteration, etc during the construction intervals of established and planned projects, take 1.0 in calculation;

n — productivity index, as to those to achieve the size by increasing facilities of the same specification, take the value of 0.8-0.9, 0.9 in calculation.

Formula（4-1）is adopted to calculate “cost of ecosan facilities and installment in buildings of residential quarters”, “grey water treatment plant (including sedimentation tank)” and “ecological station project”. According to the calculation in this way, investment in these three items will drop approx. 22%. Other construction items of ecosan system after scaling up, including basement construction, electricity consumption (such as for ventilation), compost added microbial agent and sawdust, etc, are calculated in proportion to Haozhaokui Community.

Take the value of 30 as the number of management staffs in the residential quarter to calculate.

Table 4-3 Investment analysis on ecosan system after scaling up

project item	cost (yuan)
1. total investment of civil engineering and facilities	101,477,796
（1）cost of underground civil engineering and electricity after optimized plane layout of the buildings	44,080,000
（2）cost of ecosan facilities and installment in buildings of residential quarters	24,471,764
（3）cost of outdoor grey water pipelines	6,330,000
（4）cost of outdoor urine pipelines and processing chambers	2,910,000
（5）grey water treatment plant (including sedimentation tank)	9,237,603
（6）ecological station project	11,635,929
（7）Facility purchase: urine-absorbing vehicle,	2,812,500

faeces-carrying vehicle, etc.	
2. land expropriation	2,731,643
3. other costs	313,800
4. circulating funds	1,042,903
5. total investment of projects	**105,566,142**

As to conventional sanitation system, its investment is calculated by the same method as referred in Chapter Three, i.e., to mainly apply the index of investment in unit quantity of processing water.

Table 4-4 Investment structure table of conventional sanitation system of the same size as Haozhaokui Community

Sl. No.	project item	cost (yuan)
1.	total cost of sanitation facility, pipelines and arrangement in the residential quarter	31,500,000
2.	investment in municipal pipelines	4,510,920
3.	construction cost of secondary wastewater treatment plant and pumping station	4,081,309
4.	construction cost of sludge landfill processing project	13,820,539
5.	wastewater treatment plant and solid waste landfill site	2,367,617
6.	other costs	2,082,374
7.	circulating funds	562,804
	total	**58,925,563**

The above calculation results show that the total investment of ecosan system is 1.79 times as much as that of conventional sanitation system, but the running cost of ecosan system is only 1.14 times of the latter because of the decrease of unit investment after scaling-up and facility improvement. For details, please see Table4-5 and Table 4-6. Owing to the reclamation of grey water and composting products in the ecosan system, the direct operating cost (purchased raw materials and power + salary and welfare expense + repair and maintenance cost - byproduct recovery) will be RMB 2,065,323, while the direct operating cost of the conventional sanitation system is RMB 2,413,737. The operating cost of the ecosan system is only 85.5% of the conventional system.

Table 4-5 Calculation table on ecosan system operating cost after scaling up

Unit: Yuan

Sl. No.	item	move-in time (year)		
	length of stay（year）	1	2	3-22
	move-in percentage	70%	80%	100%
1	salary	432,000	432,000	432,000
2	electric charge, fuel charge and agent	1,002,807	1,146,065	1,432,582

	consumption			
3	other material charges (compost added microbial agent, sawdust)	326,476	373,115	466,394
4	depreciation	5,067,175	5,067,175	5,067,175
5	charge for repair and maintenance	1,377,547	1,377,547	1,377,547
6	gross costs (1+2+3+4+5)	8,206,005	8,395,903	8,775,698
6.1	among which：（1）fixed costs	6,876,722	6,876,722	6,876,722
6.2	（2）variable costs	1,329,283	1,519,181	1,898,976
7	management cost （6-4）	**3,138,830**	**3,328,728**	**3,708,523**

Table 4-6 Calculation table on conventional sanitation system operating cost after scaling up unit：yuan

Sl. No.	Item	Move-in time (year)		
	move-in length（year）	1	2	3-22
	move-in percentage	70%	80%	100%
1	salary	337,260	337,260	337,260
2	wastewater treatment	479,318	547,792	684,740
3	Organic waste transportation	109,277	124,888	156,111
4	landfill operating fee	491,748	561,998	702,497
5	depreciation	2,828,427	2,828,427	2,828,427
6	charge for repair and maintenance	1,350,729	1,350,729	1,350,729
7	gross costs (1+2+3+4+5+6-7)	5,596,760	5,751,094	6,059,764
7.1	among which：(1)fixed costs	4,516,416	4,516,416	4,516,416
7.2	（2）variable costs	1,080,343	1,234,678	1,543,348
8	management costs（8-5）	**2,768,333**	**2,922,667**	**3,231,337**

4.5.4 Evaluation and comparison of the costs and benefits of the two systems after scaling up

The same size of ecosan system and conventional sanitation system are also supposed to be completed in two years. Rates of the capitals invested during the two-year construction period are 40% in the first year and the other 60% in the second year respectively. Other parameters are as same as the mentioned. The identification, parameter-taking and calculation method of the costs and benefits of ecosan system is similar to "3.5 Comparative analysis of the costs and benefits of the ecosan system and the conventional sanitation system".

Calculated economic results of the two systems can be informed from Table 4-7 and Table 4-8.

Table 4-7 Benefit-cost flow of ecosan system after scaling up

Unit: RMB Yuan

Sl. No.	item	construction period		length of stay				
	time	1	2	3	4	5	6	7
	move-in percentage			70%	80%	100%	100%	100%
1	benefit flow（B）	11,327,976	16,991,963	11,697,652	13,368,745	16,710,931	16,710,931	16,710,931
1.1	construction cost for urban wastewater reduction and waste disposal	9,518,745	14,278,117					
1.2	annual charge for wastewater treatment			341,191	389,932	487,415	487,415	487,415
1.3	annual charge for reclaimed water treatment			253,761	290,012	362,515	362,515	362,515
1.4	annual income from composting products and urine sales			555,288	634,615	793,269	793,269	793,269
1.5	annual benefit from waste sludge reduction			191,646	219,024	273,781	273,781	273,781
1.6	expense on annual wastewater reduction			288,912	330,185	412,731	412,731	412,731
1.7	reduction of the construction cost of water supply facilities	1,809,231	2,713,846					
1.8	annual benefit from water-saving			7,973,958	9,113,095	11,391,369	11,391,369	11,391,369
1.9	cost of environment degradation caused by the reduction of water pollution			2,008,761	2,295,726	2,869,658	2,869,658	2,869,658
1.10	annual benefit from agriculture production increase			84,135	96,154	120,192	120,192	120,192
1.11	salvage value of fixed assets							
2	cost flow(C)	42,003,389	63,005,083	3,138,830	3,328,728	3,708,523	3,708,523	3,708,523
2.1	fixed asset investment	42,003,389	63,005,083					
2.2	annual management cost			3,138,830	3,328,728	3,708,523	3,708,523	3,708,523
3	net benefit flow（B－C）	-30,675,413	-46,013,119	8,558,821	10,040,017	13,002,408	13,002,408	13,002,408
4	Accumulated net benefit flow ∑（B－C）	180,176,289						

5	discount coefficient（1＋i_s）$^{-n}$	1.00	0.93	0.86	0.79	0.74	0.68	0.63
6	net benefit flow present value （B－C）（1＋i_s）$^{-n}$	-30,675,413	-42,604,740	7,337,810	7,970,089	9,557,158	8,849,220	8,193,722
7	accumulated net benefit flow present value（economic net present value）ENPV=∑（B－C）（1＋i_s）$^{-n}$	39,600,691						

Table 4-7 Benefit-cost flow of ecosan system after scaling up（Continued 1）

Unit: RMB Yuan

Sl. No.	item								
	time	8	9	10	11	12	13	14	15
	move-in percentage	100%	100%	100%	100%	100%	100%	100%	100%
1	benefit flow（B）	16,710,931	16,710,931	16,710,931	16,710,931	16,710,931	16,710,931	16,710,931	16,710,931
1.1	construction cost for urban wastewater reduction and waste disposal								
1.2	annual charge for wastewater treatment	487,415	487,415	487,415	487,415	487,415	487,415	487,415	487,415
1.3	annual charge for reclaimed water treatment	362,515	362,515	362,515	362,515	362,515	362,515	362,515	362,515
1.4	annual income from composting products and urine sales	793,269	793,269	793,269	793,269	793,269	793,269	793,269	793,269
1.5	annual benefit from waste sludge reduction	273,781	273,781	273,781	273,781	273,781	273,781	273,781	273,781
1.6	expense on annual wastewater reduction	412,731	412,731	412,731	412,731	412,731	412,731	412,731	412,731
1.7	reduction of the construction cost of water supply facilities								
1.8	annual benefit from water-saving	11,391,369	11,391,369	11,391,369	11,391,369	11,391,369	11,391,369	11,391,369	11,391,369
1.9	cost of environment degradation due to the reduction of water pollution	2,869,658	2,869,658	2,869,658	2,869,658	2,869,658	2,869,658	2,869,658	2,869,658
1.10	annual benefit from agriculture production increase	120,192	120,192	120,192	120,192	120,192	120,192	120,192	120,192
1.11	salvage value of fixed assets								
2	cost flow (C)	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523
2.1	fixed asset investment								
2.2	annual management cost	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523
3	net benefit flow （B－C）	13,002,408	13,002,408	13,002,408	13,002,408	13,002,408	13,002,408	13,002,408	13,002,408
4	accumulated net benefit flow ∑（B－C）								

5	discount coefficient（$1+i_s$）$^{-n}$	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34
6	net benefit flow present value （B－C）（$1+i_s$）$^{-n}$	7,586,780	7,024,796	6,504,441	6,022,631	5,576,510	5,163,435	4,780,958	4,426,813
7	accumulated net benefit flow present value（economic net present value）ENPV=∑（B－C）（$1+i_s$）$^{-n}$								

Table 4-7 Benefit-cost flow of ecosan system after scaling up（Continued 2）

Unit: RMB Yuan

Sl. No.	item							
	time	16	17	18	19	20	21	22
	move-in percentage	100%	100%	100%	100%	100%	100%	100%
1	benefit flow（B）	16,710,931	16,710,931	16,710,931	16,710,931	16,710,931	16,710,931	20,933,576
1.1	construction cost for urban wastewater reduction and waste disposal							
1.2	annual charge for wastewater treatment	487,415	487,415	487,415	487,415	487,415	487,415	487,415
1.3	annual charge for reclaimed water treatment	362,515	362,515	362,515	362,515	362,515	362,515	362,515
1.4	annual income from composting products and urine sales	793,269	793,269	793,269	793,269	793,269	793,269	793,269
1.5	annual benefit from waste sludge reduction	273,781	273,781	273,781	273,781	273,781	273,781	273,781
1.6	expense on annual wastewater reduction	412,731	412,731	412,731	412,731	412,731	412,731	412,731
1.7	reduction of the construction cost of water supply facilities							
1.8	annual benefit from water-saving	11,391,369	11,391,369	11,391,369	11,391,369	11,391,369	11,391,369	11,391,369
1.9	cost of environment degradation due to the reduction of water pollution	2,869,658	2,869,658	2,869,658	2,869,658	2,869,658	2,869,658	2,869,658
1.10	annual benefit from agriculture production increase	120,192	120,192	120,192	120,192	120,192	120,192	120,192
1.11	salvage value of fixed assets							4,222,646
2	cost flow (C)	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523
2.1	fixed asset investment							
2.2	annual management cost	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523	3,708,523
3	net benefit flow（B－C）	13,002,408	13,002,408	13,002,408	13,002,408	13,002,408	13,002,408	17,225,053
4	accumulated net benefit flow ∑（B－C）							
5	discount coefficient $（1＋i_s）^{-n}$	0.32	0.29	0.27	0.25	0.23	0.21	0.20

6	net benefit flow present value （B－C）（1＋i_s）$^{-n}$	4,098,901	3,795,279	3,514,147	3,253,840	3,012,815	2,789,643	3,421,856
7	accumulated net benefit flow present value（economic net present value）ENPV=∑（B－C）（1＋i_s）$^{-n}$							

Table 4-8 Benefit-cost flow of conventional sanitation system after scaling up

Unit: RMB Yuan

Sl. No.	item	construction period		length of stay				
	time	1	2	3	4	5	6	7
	move-in percentage			70%	80%	100%	100%	100%
1	benefit flow （B）			3,941,854	4,504,976	5,631,220	5,631,220	5,631,220
1.1	charge for wastewater treatment			572,320	654,080	817,600	817,600	817,600
1.2	cost of environment degradation due to the reduction of water pollution			3,369,534	3,850,896	4,813,620	4,813,620	4,813,620
1.3	salvage value of fixed assets							
2	cost flow (C)	23,818,258	35,727,387	2,768,333	2,922,667	3,231,337	3,231,337	3,231,337
2.1	fixed asset investment	23,818,258	35,727,387					
2.2	annual management cost			2,768,333	2,922,667	3,231,337	3,231,337	3,231,337
3	net benefit flow （B－C）	-23,818,258	-35,727,387	1,173,521	1,582,309	2,399,883	2,399,883	2,399,883
4	accumulated net benefit flow∑（B－C）	-11,234,898						
5	discount coefficient（1＋is）$^{-n}$	1.00	0.93	0.86	0.79	0.74	0.68	0.63
6	net benefit flow present value （B－C）（1＋is）$^{-n}$	-23,818,258	-33,080,914	1,006,105	1,256,088	1,763,986	1,633,320	1,512,333
7	accumulated net benefit flow present value（economic net present value） ENPV=∑（B－C）（1＋is）$^{-n}$	-36,314,318						

Table 4-8 Benefit-cost flow of conventional sanitation system after scaling up（Continued 1）

Unit: RMB Yuan

Sl. No.	item								
	time	8	9	10	11	12	13	14	15
	move-in percentage	100%	100%	100%	100%	100%	100%	100%	100%
1	benefit flow（B）	5,631,220	5,631,220	5,631,220	5,631,220	5,631,220	5,631,220	5,631,220	5,631,220
1.1	charge for wastewater treatment	817,600	817,600	817,600	817,600	817,600	817,600	817,600	817,600
1.2	cost of environment degradation due to the reduction of water pollution	4,813,620	4,813,620	4,813,620	4,813,620	4,813,620	4,813,620	4,813,620	4,813,620
1.3	salvage value of fixed assets								
2	cost flow (C)	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337
2.1	fixed asset investment								
2.2	annual management cost	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337
3	net benefit flow（B－C）	2,399,883	2,399,883	2,399,883	2,399,883	2,399,883	2,399,883	2,399,883	2,399,883
4	accumulated net benefit flow∑（B－C）								
5	discount coefficient（1＋is）$^{-n}$	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34
6	net benefit flow present value（B－C）（1＋is）$^{-n}$	1,400,309	1,296,582	1,200,539	1,111,610	1,029,269	953,027	882,432	817,067
7	accumulated net benefit flow present value（economic net present value）ENPV=∑（B－C）（1＋is）$^{-n}$								

Table 4-8 Benefit-cost flow of conventional sanitation system after scaling up（Continued 2）

Unit: RMB Yuan

Sl. No.	item							
	time	16	17	18	19	20	21	22
	move-in percentage	100%	100%	100%	100%	100%	100%	100%
1	benefit flow （B）	5,631,220	5,631,220	5,631,220	5,631,220	5,631,220	5,631,220	7,988,243
1.1	charge for wastewater treatment	817,600	817,600	817,600	817,600	817,600	817,600	817,600
1.2	cost of environment degradation due to the reduction of water pollution	4,813,620	4,813,620	4,813,620	4,813,620	4,813,620	4,813,620	4,813,620
1.3	salvage value of fixed assets							2,357,023
2	cost flow (C)	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337
2.1	fixed asset investment							
2.2	annual management cost	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337	3,231,337
3	net benefit flow（B－C）	2,399,883	2,399,883	2,399,883	2,399,883	2,399,883	2,399,883	4,756,906
4	accumulated net benefit flow∑（B－C）							
5	discount coefficient（1＋is）$^{-n}$	0.32	0.29	0.27	0.25	0.23	0.21	0.20
6	net benefit flow present value （B－C）（1＋is）$^{-n}$	756,543	700,503	648,614	600,568	556,082	514,891	944,987
7	accumulated net benefit flow present value（economic net present value） ENPV=∑（B－C）（1＋is）$^{-n}$							

According to Table 4-7 and Table 4-8, when social discount rate is 8%, the economic net present value (ENPV) of the ecosan system is 39,600,691 yuan, above zero; while ENPV of scale-up conventional sanitation system is -36,314,31 yuan, below zero. Therefore, while evaluating the project from the social view, the conventional sanitation system is not economically applicable after scaling up.

4.6 Brief summary of this chapter

An optimum size evaluation system established as the base for evaluating and marking different scales of ecosan and conventional sanitation systems indicates influences of size changes on every aspect and provides a basis for appropriate planning. The preliminary analysis indicates that the size of ecosan system between 20000 and 40000 persons achieves the highest evaluation score.

Analysis of this study applies the size of 35000 persons, ie, 10000 households and applies cost-benefit method. Analysis and calculation results show that investment in ecosan system is 1.79 times as much as that in conventional sanitation system, but the operating cost of ecosan system is only 85.5% of conventional sanitation system because of the more obvious benefit of ecosan system and less indoor sanitation facility construction cost after scaling up. The economic net present value (ENPV) of ecosan system is above zero (feasible), while that of conventional sanitation system is below zero (infeasible).

But it should be noticed that after scaling up, some unforeseen circumstances certainly will emerge together with additional costs. For example, more composting products and longer transportation distance probably will raise the operating cost.

Large-scale promotion of ecosan system in urban areas is related to many aspects and demands various means and methods. In addition, the optimum size needs further studies to confirm due to the lack of operation review covering a long period. On the basis of the achievements of Haozhaokui Community and the practical circumstance of Dongsheng District in Erdos City, this chapter carries out a preliminary analysis on the optimum size and the investment and economy with such size. The results are available for the further promotion and application of ecosan systems in urban areas, source separation system in residential quarters in particular for reference.

References in this chapter

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Chapter V Study on the Policy for Applicable Technology of Ecosan System

The application of ecosan systems in town areas involves many issues on the two aspects of technological innovation and policy management. Due to the differences in climatic environment, level of urbanization and economic conditions, etc, different regions have their own different characteristics in selection and perfection of the technology; however, the experience in the management of the construction of the ecosan systems usually shows a certain degree of universality. In the course of the construction and management of Haozhaokui Community，the inadequate support from the government, lack of relevant technical experience and construction criteria and the development prospects for the ecosan system of the quarters in the local area are the obstacles that affect the technical maturity and smooth popularization of the ecosan system. And in the course of the construction and popularization of the ecosan systems, the role that the policy factors can play corresponding to the above-mentioned problems can be summed up as follows:

（1）Advance the research, application and popularization of the ecosan system;

（2）Establish reasonable and feasible development plan for its popularization and application in local areas;

（3）Work out criteria that can be followed and standard management and direct the design and construction of the ecosan system, so as to ensure its reasonable and orderly development.

5.1 Encourage the Construction and Popularization of Ecosan Systems through Policy

（1）Formulate reasonable standard of water rate for drinking water, and enhance the residents' water-saving awareness in combination with publicity on water saving.

The climate in some parts of North China is characterized by cold weather, low annual precipitation and uneven distribution of raining months. Take the Dongshen District of Erdos (Erdos) as an example. The area belongs to the continental climate of temperate zone featuring drought, little rain, strong wind and much sand. The average annual precipitation for years has been 385mm, and the average potential evaporation (capacity) for years has been 2243.1mm. Rainfall mainly occurs from July to September, with the amount of precipitation accounting for over 70% of the whole year [1].

According to the *Code of Design for Reclaimed Water Systems in Buildings*（GB 50336-2002），the water consumed for toilet flushing in residential buildings that adopt the flush toilets take up over 20% of the total daily water consumption [2] .

Table 5-1 Proportion of Water Used in Residential Buildings

Item	Toilet Flushing	Kitchen	Bath	Wash	Laundry	Total
Percentage（%）	21~21.3	19~20	29.3~32	6~6.7	22~22.7	100

It can be seen from the above proportion that the effect of Ecosan System in lowering the daily residential water consumption is remarkable. A survey conducted for the study has shown that the water-saving rate for the daily water consumption of residents using the ecosan system can reach as high as 40%. The advantage here is all the more important for the Dongsheng area where it is dry and short of water. The ecosan residential quarters in Dongsheng District of Erdos (Erdos) have adopted the source-separation design, which has resulted in a lower level of the indicators for water consumption, discharge capacity and sewage and pollutants, etc. And because the sewage can be treated in the locale, the expenditure for sewage discharge fee can be reduced under the support of relevant policies.

The current running water rate for living water use（including sewage discharge fee）in Dongsheng District is 3.6 yuan/m^3（as of September 1, 2007）, which is at a higher level in the whole country. According to a survey, the current direct cost（labor cost, medication consumption and energy consumption）for treatment of sewage per cubic meter by the wastewater treatment plant in Dongsheng District is estimated conservatively at 0.5 yuan. If the piping system and the corresponding maintenance cost is taken into consideration, the treatment (including transporting) cost for per cubic-meter water by the conventional sanitary system will be higher. At present the sewage discharge fee born by the residents accounts for less than 50% of the sewage treatment cost while the better half needs government subsidy. As the quantity of living sewage is increasing continuously and the requirement for environmental protection is being elevated, it is far from enough to rely on the state and local government appropriation to solve the issue of sewage treatment fee. The principle of "he who pollutes shall be charged "need to be followed and the sewage discharge fee should be increased properly [3]. There are two effects in adopting such measures. Firstly, more fund can be raised for the construction of urban drainage system, so that the financial pressure of the state and local government in the aspect of urban sewage treatment can be eased; secondly, through increase of sewage discharge fee, the residents' water-saving awareness can be enhanced so as to advance the development of the ecosan system with water-conserving characteristics.

Moreover, as for the system that only adopts separation of feces and urine while the living grey water is discharged into the wastewater treatment plant through the municipal sewage piping, consideration should be given to the fact that the source separation design has reduced the in the content of nitrogen and phosphor in the grey water, and accordingly, the sewage discharge fee should be lowered appropriately. 。

According to the collection standard and calculation method for sewage discharge fee enacted in 2004 by Inner Mongolia Environmental Protection Bureau, the pricing for sewage discharge charge shall abide by the following principle:

① The sewage discharge fee is calculated and collected in the pollutional equivalent according to the type and quantity of the pollutants discharged by the discharger (the enterprise that discharges sewage or pollutants), with the collection standard of 0.7 yuan for each pollutional equivalent.

② For every discharge outlet, the number of the kinds of pollutants levied the sewage discharge fee shall not exceed 3 at most in a descending order of the pollution content.

③ Calculation of sewage discharge fee

- The charge rate for sewage discharge fee:：0.7yuan×sum of the pollutional equivalents of the first 3 pollutants;

- For the pollutants exceeding the national or local discharge standard, an additional rate doubling the base of the charge rate for the sewage discharge fee will be levied on the said kind of pollutants. [4]

Currently discriminative charge based on the types and content of the pollutants in the wastewater discharged from the discharge outlet has not been implemented domestically, the reason therein being that unified pricing is conducted on the account of the local overall level. Nevertheless, from the perspective of the sewage treatment technique, under the condition of a larger scale, the grey water that has not been polluted by the dejecta is easier to reach the required nitrogen and phosphorus discharge standard, thus the stability of the effluent water quality is improved and the additional input of the technology of denitrification and phosphorus removal is saved after the secondary treatment [5] . Based on the long-term projections, it is of vital importance to adopt the charge principle of separate pricing according to the water quality of the sewage with an aim to reduce the quantity of pollutant discharged and the load of the wastewater treatment plant, cut down the sewage treatment cost and at the same time advance the research and application of the technology for separation of the source of domestic wastewater.

The water-saving function of ecosan systems is directly related to the benefit of the users. Through a survey conducted on the residents in the Dongsheng District of Erdos(Erdos), we can see that around 50% of the local residents and over 70% of the government officials have some knowledge of the local shortage of water resources, yet there are still a considerable number of residents and government staff members who have not gained full awareness of the issue. This is a social issue which affects the development of a region where the drought and water shortage are relatively serious. To analyze the cause for the insufficient awareness in the residents of the local water-resource issue, it is mainly because Erdos (Erdos) city has basically solved the problem of domestic water for residents in the Dongsheng District and its neighboring areas as a result of the proper and satisfying efforts in water supply in recent years by means of the medium and small reservoirs and intercepting and directing the underground water from the river valley; besides, the age level of the survey respondents is on the low side，who have less experience of their normal lives being affected by the shortage of local water resources. Furthermore, the deficiency in the strength of the publicity on the current status of the water resource shortage in the local area carried out by the government agencies is one of the important reasons for residents' insufficient understanding. Therefore, it is of viral importance to reinforce the momentum of publicity in water conservation so as to facilitate the long-range development in the application of the regional water resources and the popularization of the ecosan system.

（2）Perfect the attribution and transfer system of the water right and discharge right

The possession and transfer system of the water right and discharge right is the outcome of the regulatory system for water-fetching and sewage-discharge behavior that introduces the market-oriented mechanism. The concept of water right and discharge right will further clarify the right and duty involved in water fetching and sewage discharge and at the same time enable the water conservation and discharge reduction to link more with the actual benefit.

① Perfection of the water right system

The water right means the right to use the water resources. The transfer of water right indicates the phenomenon in which the water right is disconnected from the water right owner and becomes owned by others. The transfer of the right to use the water resources takes mainly two forms which are respectively the assignment by the state and the transfer between the main bodies of the right of use. The so-called assignment of the right of use by the state means that the state assigns the right to use the water resources to the user of the resources within a given term, and the latter should pay the water-right fee to the former. This is called the elementary market of the water right; the so-called transfer of the right of use indicates the action to transfer the right of using the water resources taken by the unit or organization that has obtained the right to use the water resources assigned by the state, including selling, exchange, etc, which is called the secondary market of the water right [6].

The design of the ecosan system can reduce the domestic water consumption of the user. Under the precondition of the standard quota for water use, the residents in the eco-community can transform the saved water resource into profit through the transfer of water right on the secondary market, thereby accomplishing the goal of maintaining the system operation and encouraging the use and building of ecosan systems.

Since Erdos (Erdos) city implemented the water right transfer system in the self-flow irrigation area on the south bank of Yellow River in 2005, it has completed construction of 7 projects including the unified production of silicon and electricity of Erdos (Erdos) Group and Phase IV of Dalate Power Plant and the conversion of water right, realizing the amount of converted water totaling 78 million m^3.

In order to advance the development of the ecosan system, the following two points need to be paid attention to by the local authorities in furthering the reform of the water right system:

- Establish a set of legal systems regulating the transfer of water right in accordance with the local characteristics. In the transaction of the water right, clear definition shall be made regarding the nature of water right, the content of the power, and the possibility and condition of transfer, etc. The new *Water Law* and the *Implementation Method for Water Drawing Permit System* have not made clear the definition of the above matters.

- Exploit and regulate the secondary market of water right. The advantage of water conservation of the ecosan system is demonstrated in the conversion on the secondary market of water right, while at present the conversion of water right in Erdos (Erdos) city is mainly represented on the elementary market. The secondary water right transaction is of great importance to liquidizing of water right market, reasonable distribution of water resources and encouragement on water conservation. And while promoting the secondary market of water right, it should be stressed that the laws shall be there to abide by and strictly enforced, earnestly guaranteeing the effective utilization of water resources and the rights and interests of the water right traders.

② Perfection of the policy governing the transaction of the sewage discharge right

The transaction of the sewage discharge right, just as its name implies, is to trade the right of sewage discharge as a kind of commodity. As the owner of the environmental resources, the government can sell the right of sewage discharge to the discharger (the enterprise that discharges sewage or pollutants) , and at the same time the right of discharge can be transferred among the dischargers.[7] As the ecosan system uses the waterless toilet that reduces the sewage discharge, and the grey water discharged can be recycled by self treatment, basically there isn't any outlay for sewage discharge. Under the standard quota of discharge quantity, the user of the ecosan system can sell its superfluous right of discharge and thereby gain economic benefit through reduction of discharge just as the transfer of water right.

Erdos (Erdos) is developed in cashmere and pharmaceutical industries, the unreasonable discharge behavior of the enterprises has caused pollution of part of the water head sites in the neighboring area. Considering the nationwide situation, presently the policies regarding the distribution and transaction of the sewage discharge right are still not complete. Besides, local governments have not been granted the power to develop relevant policies on sewage discharge according to their own characteristics. The following issues shall be given attention to while establishing and enforcing the policy on the discharge right:

- Comprehensively coordinate the relationship between economic development and environmental protection, and reasonably determine the gross amount of the discharge right.
- Establish strict supervisory mechanism to ensure that the discharger emits sewage within the specified scope of the discharge right（including the water quality and quantity）.
- Actively try to combine local characteristics in perfecting the trading system of sewage discharge right.

（3）Encourage the application of urine and feces to agriculture

The ecosan system collects the urine and feces through its special design. The data collected from experience show that the urine contains over 80% of nitrogen and more than 50% of phosphorus in domestic sewage. [8] In agricultural production, urine is a kind of high-quality low-cost fertilizer, and feces also own relatively high fertilizer efficiency and good effect in improving the water-retaining capacity of the soil and the ion buffer capacity. Advance the use of urine and feces as an agricultural fertilizer to transform the fertilizer structure in the local agricultural production, reduce the problems of water-body pollution caused by the use of chemical fertilizers, such as eutrophication，promote the development of green and organic agriculture. Meanwhile, the separate collection of the urine and feces is also of vital importance to reducing the hygienic risk of drainage pipe network and decreasing the load of sewage treatment.

In rural areas, fecaluria can be utilized in the nearby farmland through the residents' self operation, hence no major obstacle exists therein. While in urban areas, the situation is different. Some towns and cities may be far away from agricultural areas, and what's more, the particularity of the city environment and the different living habits of the residents exist, the utilization of the feces and urine faces various difficulties and problems. To solve these problems, apart from the continual technical reformation and renovation in the collection, storage, transport and utilization, the government is required to provide convenient channel and fine social environment for utilization of urine and feces through certain administrative means.

① Promote the utilization of fecaluria in agriculture through active publicity and financial subsidy, and establish a long and stable relationship of supply and use of feces and urine for the agricultural areas and urban areas.

China has several thousand years of manure using history. However, presently the use of chemical fertilizers is very popular. Because it is easy to use and good in effect, chemical fertilizer has become the preferred source of fertilizers in China's agricultural production. Therefore, in order to make farmers accept the use of dejecta as the fertilizer, sufficient guide of public opinion is necessary，and the degree of convenience, price and effect of use should reach or near the level of chemical fertilizers. Government agencies are required to raise the enthusiasm of farmers in using the fecaluria manure through the means of publicity；make use of the government function to coordinate the work among relevant departments, ensure the smooth channel of utilizing the fecaluria manure, and establish a stable relationship of manure supply and demand; offer support to the farmers using dejecta as manure by means of financial subsidy.

② Popularize the innocuous technology and method of fecaluria among farmers and promote reasonable application

Farmers are users of fertilizers, so their understanding of the technology to treat and use the feces and urine is vital to the correct use of fecaluria in farming. Though China has thousands of years of experience in using the feces and urine as farming manure, strict innocuity has not been achieved，and what's more, the agricultural production at present relies mainly on chemical fertilizers，therefore most of the farmers now are not very acquainted with the innocuous and farming technology of fecaluria. In the areas where ecosan systems are popularized, local farmers shall get familiar with the relevant knowledge by means of publicity on popular science and skill training，give full play to the advantage of fecaluria used in farming and try to avoid the possible problems of environmental pollution and pathogenic diffusion.

③ Adjust the market of farm produce, raise the market value of farm products that have adopted organic fertilizers identification system and market price gradient for organic farm products and nuisance-free (non-polluted) food，and highlight the economic benefit of agricultural production adopting the fecaluria manure. Organic farm products are all the agricultural and sideline products that come from the organic agricultural production system, are produced and processed pursuant to international requirement on organic agricultural production and relevant standards and have passed authentication by independent accreditation institutions for organic food. In the course of production and processing, no artificially synthesized chemical fertilizers, pesticides and additives are used and have passed the test and verification by related certificate issuing organizations. Nuisance-free food are the farm produce, forestry products, animal by-products and aquatic products and their processed products whose poisonous and harmful substances are controlled within the permitted range of safety, possessing the three distinct characteristics of safety, high quality and high added value. Adoption of fecaluria in place of chemical fertilizers is the essential link in production of organic farm produce and the further processing of nuisance-free food. Through market adjustment and differentiation of the price gradients for food with different safety grades, the economic benefit of fecaluria separation and utilization can be effectively reflected.

（4）Encourage construction of ecosan systems by means of favorable investment conditions and preferential policies

One of the important significances of the ecosan system lies in promotion of sustainable development of drainage facilities in the town areas, especially in the course of urbanization in developing countries. As for the cities that are short of water, the research, construction and popularization of ecosan systems are especially important for the long-term development of the cities. The government should be farsighted in the course of urban construction, balance the relationship between the local development at the present stage and the long-range sustainable development, and formulate relevant policies to encourage the research and popularization of ecosan systems in the local area.

Some developed countries, like Sweden and Germany, attach great importance to the sustainable development of urban drainage systems, and are actively involved in advancing testing of ecosan systems domestically and in some developing countries. Sweden has introduced the water-free toilet technology into Guangxi, and demonstration sites of rural ecosan systems with the circulatory and closed feces-urine separate-collection type ecosan toilets as the core have been established in Huning, Gulin, Beiliu and Guigang and have been well popularized and applied [9]. The ecosan systems built in town and urban areas differ greatly with those applied in rural areas. Since the application of ecosan systems in town and urban areas is still in the stage of research and experiment, and the requirement of the urban residential buildings for the hygiene and comfort is relatively high, moreover, there is environmental difference between the cities and countryside, therefore the pilot construction of ecosan systems conducted in the urban areas is a complicated systematic engineering. In order to ensure the quality of the design and construction as well as the reasonable and effective operation after completion, the local government is required to render financial assistance, providing special fund to support the research on ecosan systems. In China, housing construction is carried out by real estate developers. At the present level of development, the use of the ecosan systems increases the input of the developers, while the sewage treatment outlay is lowered which is originally born by the urban construction department of the local government. Herein comes the issue of benefit transfer, and the government is the beneficiary. Therefore it is all the more reasonable to require the government to provide the developers with preferential policies such as tax reduction, expense decrease and lowering of land prices, etc.

At the stage of popularization and application of the systems, local governments should encourage the development of ecosan systems by favorable terms in policy. Apart from the above-mentioned increase of economic benefit from water conservation and discharge reduction, it can also encourage the construction and use of ecosan systems by means of rendering preferential treatment in the procedure of land acquisition and approval for the eco-zone projects and giving priority to the water and heating supply for the eco-zones, etc.

5.2 Develop reasonable development plan and code criteria

Compared with the conventional drainage mode, the ecosan system adopts the dispersive sewage-disposal mode, saving the expenditure for massive construction of urban drainage piping systems. Therefore, the popularization of the ecosan system in urban areas will exert important impact on the long-term planning and construction of the urban drainage systems. If it is incorporated into the long-term development strategy of the region, the development mode of the urban drainage systems must be planned on account of its characteristics. Due to the reasons in various respects such as technology and the degree of acceptance of the residents, the actual work in this aspect is difficult to carry out at present. But as the technology of ecosan systems becomes mature, the shortage of water resources is becoming increasingly serious and the ever increasing pressure for the construction of sewage piping network and centralized sewage treatment plants in the course of urbanization, the development of the ecosan systems adopting the source-separation and dispersive treatment method will probably become the preferred option for future urban development planning.

（1）Coordinate with the existing urban drainage infrastructure and plan reasonably

Under the mode of urban development based on the flush toilet, urban sewage piping network and centralized sewage treatment plant at the current stage，the planning for development of ecosan systems should consult the guiding opinions in the *Code for Design of Wastewater Reclamation and Reuse* （GB50336-2002）, takes the urban overall plan as the main basis, and from the perspective of the overall situation，correctly deal with the relationship between water diversion from outside the city and the development and utilization of sewage resources, the relationship between the sewage discharge and sewage reclamation and utilization, and the relationships between centralization and dispersion, new construction and expansion, and the near term and the long term. By means of overall investigation and verification, ensure full utilization of the treated urban wastewater.

Currently the Dongsheng District of Erdos (Erdos) City has a total length of sewage pipelines measured at 200km, the cost of which being 1.30~1.40million yuan, including the main, secondary and branch pipes and excluding household entry pipes and lifting equipment. The total sewage treatment capacity of the entire district is 27,000 tons/day，and the sewage treatment rate has reached 85% according to the government statistics. The ecosan system is suitable to be built in the peri-urban area where drainage pipe network has not been laid, and thereby really fulfilling the effect of saving on infrastructure construction; besides, in the area with drainage pipe network, the form of urine separation can still be adopted to realize partial recovery and utilization of the nitrogen and phosphorus resource, and remarkably lower the pollutant load of the urban sewage treatment plant in the context of large-scale application.

In the course of popularizing the ecosan systems, the concept of modules should be set up, namely, to establish the ecosan community within a proper range of population number, and, within this module, conduct waste sorting and recycling, separation and collection of feces and urine, composting of feces and part of household garbage and disposal of gray water. The established modules should not be too small, According to scale effect, too small a module will increase the cost of gray-water treatment and fecaluria collection and treatment, and very much goes against the unified management of the ecosan system; moreover, the module should not be too big either, otherwise it will increase the expense of construction of the piping and the transport of the fecaluria, and result in major environmental pollution and the hidden danger of communicable diseases. In determining the most suitable scale of ecosan systems, it should be noted that various factors have different impact on the scale of ecosan systems. Some factors（for example, the gray water treatment facilities, composting facilities）are more affected by the scale while others（e.g. greening of residential zones）are less affected. Therefore, in the course of establishing the method for determining the most suitable scale of ecosan systems, the determination of the weight of impact by various factors on the scale is an important content of study. After the weight is determined, the rough range of the most suitable scale of the ecosan system can be worked out through comprehensive analysis of the evaluation of the various factors.

The assessment of the most suitable scale for the construction of ecosan systems can be roughly divided into the following steps:

① Select several groups of feasible scale ranges for ecosan systems to be assessed;

② Analyze the marginal factors affecting the construction of ecosan systems and sort them out, and determine the assessment index；

③ Give weight to various indexes corresponding to different marginal factors through the Expert Analysis Method;;

④ Score each index in conjunction with the factors on various aspects of the local nature, society and economy, etc;

⑤ Integrate the analysis data to select the group with the highest score as the reference range of the most suitable scale for the construction of ecosan systems.

（2）Establish Criteria and Codes

The management of the design and construction of ecosan systems by means of establishing criteria and codes is the effective and necessary measure to ensure the reasonable and sound development of ecosan systems. The establishment of the criteria should consult the existing relevant standards and specifications, and combine the characteristics of the ecosan system themselves. In the course of criterion establishment, the following factors shall be given priority in consideration.

① Selection of the Technology and Building Materials

In regions where the level of economic development and the standard of living are housing are higher，the vacuum toilet and the improved water-free toilet with higher hygienic standard can be adopted; while in rural areas and the conjunction between the city and the countryside (mainly 1- or 2-story buildings)，eco-toilets (e.g. the popularizing mode in the rural areas of Guangxi, China) are more suitable with their simple design of construction and the management by the residents themselves. In view of the difference in the regional natural environment and the level of economic development and the residents’ awareness of environmental protection, determine the mode of technology for the ecosan system that is most applicable to the local situation. Considering the composting treatment of the degradable domestic garbage and excrement, the simple normal-temperature composting technology should be adopted for hot and dry regions; while in the cold or humid regions, high-temperature composting is more applicable to reduce the composting cycle and improve the composting effect. In the regions where the natural conditions are rather severe and it is not suitable to conduct composting treatment, the mode of separating and utilizing only the urine and mixing the feces into the domestic wasterwater for treatment can also be considered. As for the Chinese cities that are short of water like Erdos, the water saving performance of the technology should be the main factor for consideration. In the technology of composting, the ecosan zones (residential quarters) in Erdos have realized composting under high temperature through adding in special bacteria, which can fulfil the requirement for the physical structure and the content of microorganism of the composted products within a comparatively short time.

The selected building materials should possess the characteristic of environmental friendliness, and should not produce impact on the physical health of the inhabitants. The urine transport system should be well kept from being blocked, and should select the appropriate pipes and the inner-tube coating to slow down the speed of the pipe being blocked, and to avoid the crystallization of the urine pipes through proper means so as to ensure the smoothness and normal use of the urine pipes.. The consumables for operation of part of the facilities should be made from the recycled materials and the materials with low environment impact..

② Practicability and Comfort

The design of the system should satisfy the basic requirement for normal life of the users. The design of the toilet stool should take full consideration of the living habits and cultural background of the residents and accords with the relevant standard of hygiene. By means of airproof system, mechanical ventilation and adding medicament, etc, eliminate the issue of indoor smell and propagation of mosquitoes due to storage of dejecta. Ensure the quality of the works, enable the stability of the integral operation to reach the requirement of normal use, and avoid any inconvenience in the life of the users caused by frequent faults. Take full account of the local conditions in the course of formulation of the criteria and codes regarding this respect, meanwhile, it is necessary to combine the relevant experience of the past projects.

In Haozhaokui Community, the issue of smell is one of the main factors that affect the residents’ normal use of the ecosan system. The odd smell caused by blockage of urine pipes and leaking and the problems in the sealing and ventilation of the toilet stools have resulted in negative reaction from part of the users. After the ventilation systems are improved, the urine pipes are repaired and maintained and the oil sealing devices are installed on the urinals, the odd smell has been markedly reduced.

③ Resources and Energy Saving

In the aspect of water conservation, the ecosan system shall reach the required water-saving rate（above 30％）, and the recycle of the treated sewage shall be in conformity with the relevant requirement specified in the *Code of Design for Reclaimed Water Systems in Buildings*（GB50336-2002）and the *Code for Design of Wastewater Reclamation and Reuse Projects*（GB/T 50335-2002）; in addition, in the system that reclaims and reuses the discharged water, the requirement of different utilization approaches for water quality should be fulfilled. In the aspect of compost utilization, the fertilizers produced by composting shall not have any mechanical foreign matter and malodor, and the content of pathogen shall accord with the requirement of the *Control Standards for Urban Wastes for Agricultural Use*（GB8172-1987）and the *Sanitary Standard for the Non-Hazardous Treatment of Night Soil* （GB7959-1987）. The comprehensive index of the composted products may consult the provisions stipulated in the *Standard for Organic Fertilizers*（NY525-2002）. In the aspect of energy utilization, the low energy consumed sewage treatment process shall be adopted and the energy consumption of the ventilation system will be reduced through rational design.

5.3 Brief Summary of the Chapter

As a new type of drainage system, the ecosan system still has problems of various sorts. The function of support from policies and management lies first in promoting the research on the application of ecosan systems in urban and town areas, and reasonably and rapidly solving the various problems existing at present, so as to make it accord more with the requirement for actual application. In the construction and popularization stage of the ecosan system, reasonable policies and management measures can play a good promoting and regulatory role, enabling its reasonable and orderly development, satisfying the demand of living of the residents, realizing the advocated ecological function, and facilitating the sustainable development of the drainage systems in the cities and towns.

The advancement of the development of ecosan systems from policies requires adjustment of the policy on control of water resources, including perfection of the policies on transaction of water right and sewage discharge right and reasonable setting of the water-supply and sewage-discharge prices; promotion of the agricultural use of the feces and urine by administrative means, including establishment of a smooth and stable relationship of the fertilizer supply and demand, awarding appropriate prizes to the farmers using the fecaluria manure and raising the value of the organic farm produce; in addition, administrative and economic support should be given to the organizations and individuals who construct and use ecosan systems.

The planning of the ecosan system shall take full account of the construction status of infrastructure at the current stage, realize the maximization of the function of the existing infrastructure and ecosan systems, and give full consideration to the role and advantage of the ecosan system in the long-term development planning. In China, especially in the inland and northern water-deficient areas, the ecosan system plays an important role in the sustainable development of the region, and therefore should be given full emphasis in the long-term development.

The establishment of the construction criterion and code of ecosan systems shall start with the selection of the technology and materials, practicality and comfort, resource and energy conservation, etc, and consult fully the available content of related standards and codes and the characteristics of the ecosan system. Due to the difference in natural and social conditions, the system modes and parameter indicators accordant with the local characteristics differ greatly, therefore the establishment of the criterion and code for ecosan systems shall take full account of the local factors under the precondition of accordance with the basic principle and shall not be confined to a fixed format.

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Chapter VI Conclusions

As the sustainable sanitary system, the ecosan system has been given attention to by all countries in the world in recent years, and the principle of ecosan system is gradually being accepted by the public. The study aims at Haozhaokui Community, the ecosan community with the largest scale of use in urban areas across the world at present, analyzes the investment and operation cost of the system, and compares the benefit of the ecosan system of Haozhaokui Community with that of the conventional sanitary system by adopting the cost-benefit method. Meanwhile it conducts a initial probe into the most suitable construction scale of the urban ecosan system (source-separation system). Furthermore, it discusses the applicable technical policy for massive construction of ecosan systems in urban and town areas by integrating the construction and implementation experiences learned from Haozhaokui Community. The main findings are as follows:

Under the present condition, the investment in the ecosan systems in Haozhaokui Community is 2.16 times that of the conventional sanitary systems (higher investment in construction). Since it is a demonstration research project, most of the matching sanitary equipment and facilities are non-standard equipments specially designed for this project, which has resulted in the increase of processing costs. Moreover, for such systems, relevant criteria and codes governing the reasonable building structure and indoor pollutant discharge are deficient in China. As a result, the design of the designers is rather conservative. That is why the construction investment of ecosan system is on the high side. Furthermore, the scale is also another cause affecting the unit construction cost. The direct operating cost (including resource reclamation) of the ecosan system of Haozhaokui Community is 2.01 times of that of a similar-scale conventional sanitation system. Comparative speaking, the labor cost of the ecosan system is higher.

By adopting the cost–benefit method, and through identification of the cost-benefit of the ecosan systems and the conventional sanitary systems and converting part of the benefit and outlays, such as the benefit from water conservation and the expenditure for the construction of the control facilities for reducing water pollution, etc to monetization, calculate the net present value of the economy at 8% of the social discount rate. The result shows that economic net present value of the ecosan system is greater than zero, while that of the conventional sanitary system is less than zero. Compared with the conventional sanitary system, in the entire period of the project (22 years, 2 years for construction and 20 years for operation), the static monetary contributions of the benefit of the ecosan system are ranked in turn in the descending order, namely, reduction of the construction cost of urban sewage and waste treatment, water benefit, reduction of the construction cost of water supply facilities, reduction of the cost of environmental degeneration caused by water pollution, sales income from composted products and urine, charge for sewage treatment, the benefit from quantity reduction of waste and sludge, reduced cost for sewage treatment, charge for grey water processing and the benefit due to increased agricultural production. Analytic result has revealed that the ecosan system owns good economical efficiency when seen from the perspective of the state or society.

Through establishment of the five indicators of management, environmental protection, economy, society and matching facilities, an assessment analysis has been conducted of the most suitable scale of construction for the ecosan system (source separation system) in the urban centralized communities. The findings show that the evaluation point value is the highest when the ecosan system scale is at 20000-40000 persons, and this range can be regarded as the most suitable scale for the ecosan system of a centralized community. Based on this conclusion, a simulated community of 10000 households with a population of around 35000 has been built. After analysis and calculation, in view of the decreased construction cost of the indoor sanitary equipment after enlargement of the size, the investment of the ecosan system is 1.79 times higher than that of the conventional sanitary system; the direct operating expense of the ecosan system is 85.5% of the operating expense of the conventional sanitary system, which is somewhat lowered after its scale has been expanded (in terms of the unit operating cost); economic analysis by the cost-benefit method has revealed that the economic net present value (ENPV) of the ecosan system is greater than zero (economically feasible after scaling up), while the ENPV of the conventional sanitary system is less than zero (economically infeasible after scaling up).

The urban ecosan system is a systematic engineering. Massive construction of the ecosan system poses a challenge to us in the aspects of technology, policy, and the cultural quality, living habits and environmental awareness of the residents, etc. After all we are still short of the practice and accumulation in this regard at present, and we still have not realized the many problems that are likely to come up in the massive construction of the ecosan systems. Therefore, the practice and accumulation regarding the ecosan systems in the urban and town areas shall be carried out continuously in the future, so as to go on with the search for the matching technology and relevant policies. We believe that the constantly-improved ecosan system will play a promoting role in pioneering urban ecological civilization.

Acknowledgement

We hereby express our gratitude for the support to our study from the "Ecosan Research Program" under the Stockholm International Environmental Research Institute of Sweden.

The report compilers wish to express their thanks to Madam Xiao Jun and professor Zhu Qiang from the Office of Sino-Swedish Erdos Eco-Town Project for their sincere assistance for the study, Madam Sun Lixia, the responsible person of the Chinese side of the Sino-Swedish Erdos Eco-Town Project for her great support to the study. We also wish to thank Dr. Arno Rosemarin and Mr. Uno Winblad from the Swedish Stockholm International Environmental Research Institute for their warm help.