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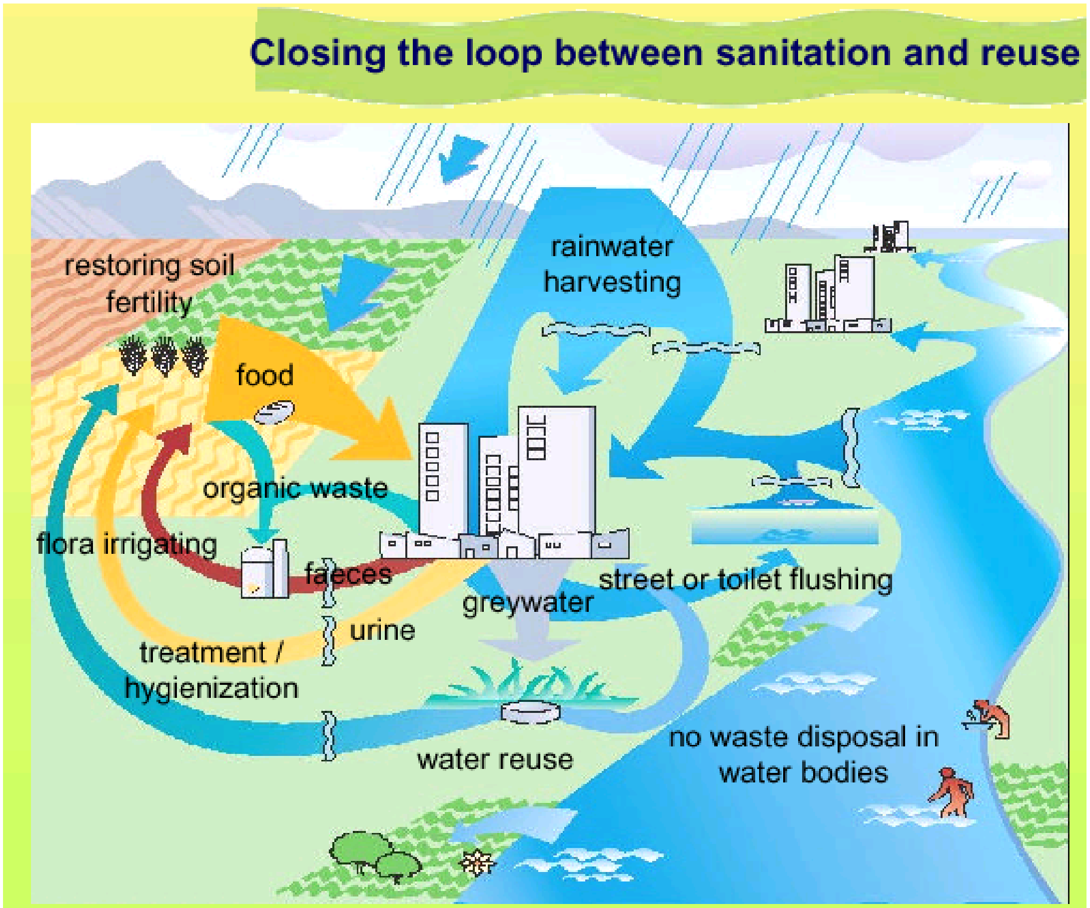

Applying the Ecosan Concept for Integrated Wastewater Management at a New Conference Centre and Tourist Resort in Kunshan, China

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Applying the Ecosan Concept for Integrated Wastewater Management at a New Conference Centre and Tourist Resort in Kunshan, China

Master of Science Thesis
by
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Abstract

Ecosan is the "philosophy" concept for sustainable ecological sanitation in order to respect ecological integrity, conserves and protect freshwater, promote healthy living, as well as recycle nutrients from human excreta for agricultural production.

The Honor Power Foundation is funding the development of Master Plan for Kunshan Aqua Zone (KAZ) in Kunshan, China (near Shanghai). The aim of this project is to build an ecologically sustainable facility which deals in various ways with the theme of "water" on an area of 52 ha for both tourist and holistic health aims. In the other words, the mission involving with this project is developing a demonstration project, which will show the visitors an ecological and sustainable approach of using water.

There are five main buildings in KAZ, the international conference centre, the water education centre, the wellness centre, the flora exhibition centre and the centre culture tower. These buildings will be built very close to the water. Almost the 40% area is covered by water at KAZ.

A literature review was carried out focussing on ecosan in urban China. Most of ecosan projects are in the inception phase, while only one entire "ecosan-town" is under construction in Dong Sheng, north of China. Due to all these projects focus on residential area, KAZ would be first full-scale project for applying ecosan concept in a conference centre / tourist resort in China.

The data about location of KAZ, the local climate, geography condition, agriculture irrigation and surrounding sanitation activities, and the proposed development plan for KAZ were collected at Kunshan Saint-Mean Biotech Co. LTD from 24th October to 15th December 2004. These data indicated that the KAZ would be a suitable place for ecosan demonstration project.

Two scenarios were developed and described in detail. Scenario 1 is the conventional sanitation system-combine grey and black water, while scenario 2 is designed as ecosan system-separate yellow, brown and grey water. Water flow and nitrogen mass balances of both scenarios were performed. Important results were that applying scenario 2 for integrated wastewater management at KAZ is benefit of holistic development.

The estimated person number is around 800,000 per year at KAZ. These people would contribute to 4 ton nitrogen per year and would utilize around 40,000, 28,000 cubic meters water per year for scenario 1, scenario 2 respectively. Actually, only 1,400 cubic meters fresh water is need in scenario 2 because the storm water and grey water will be recycled at KAZ. That means that scenario 2 need much less municipal water supply than scenario 1, moreover, a large number of valuable fertilizers will be produced in scenario 2, while much wastewater and waste will be discharged in scenario 1.

Recommendations are to make more detailed and professional analysis on rainfall patterns over year, on sustainable criteria, and on cost estimation for both scenarios. Refining the design calculation for peak demands and progressing the design calculations for the WPF (Water Processing Facility) are also needed to do in the future.

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1 Introduction

1.1 Background

Nowadays, water scarcity becomes an increasingly severe problem in the Yangtze River Delta, China. In recent decades, rapid economic growth and urbanization both increased the pressure on the water supply and intensified the water pollution. Relieving the bottleneck effect of water shortage to socio-economic development is taking on new urgency in China. Policies aimed at ensuring sustainable water use have two aspects: economize the use of water resources and reduce water pollution. This thesis addresses these two aspects by theoretical study of the Kunshan Aqua Zone project (KAZ for short).

The Master Plan of the KAZ Project is being designed based on an integrated approach for an ecologically sustainable centre on an area of 52 ha for both tourist and holistic health aims. The aim of this Master Plan is to develop an ecologically sustainable facility which deals in various ways with the theme of "water". It is collaboration between Kunshan Saint-Means Biotech Co. LTD. of China and the Foundation China-Europe Dialogue and Exchange for Sustainable Development (CE-DESD). The Master Plan is currently at a "conceptual" phase.

Kunshan Saint-Means Biotech Co. LTD. (SM for short), established in March 2003 in Kunshan of China, is one of the companies of Honor Power Foundation (HPF for short). The main mission of SM is management and implement of the KAZ project, which will be financed by HPF (more information about HPF is in section 3.3.1).

Meanwhile, the CE-DESD Foundation is not profit-oriented. Its purpose is to promote, facilitate authentic international partnerships for sustainable economic activity, development and peace between China and Europe, to cultivate the awareness of man and his natural environment, and to stimulate harmony between these, to perform all other activities associated with the above in the widest sense, such as promoting intercultural dialogue, organising seminars, conferences, training courses and linking-and-exchange programmes and providing project management, communication and logistic services for partnerships..

This MSc thesis will focus on the application of Ecological Sanitation (ecosan) options for wastewater treatment and management for this KAZ.

1.2 Objectives of This Study

There is a general objective: evaluate alternatives technologies which follow the paradigm of the ecosan concept for wastewater treatment and management at KAZ. Specifically speaking, ecosan stands for turning former waste into a useful and marketable resource --- a more holistic approach towards ecologically and economically sound sanitation. The key objective of this approach is not to promote a certain technology, but rather a new philosophy of dealing with what has been regarded as wastewater in the past.

Specific objectives of this thesis are:

- Gather relevant data at Kunshan, such as location of KAZ, the local climate, soil condition, flora/fauna, sanitation and agriculture irrigation activities in surrounding of KAZ, and the development planning of KAZ.
- Develop two scenarios for sanitation. Scenario 1 is conventional sanitation system; while Scenario 2 is ecosan system.
- Prepare basic concept to design for two scenarios.
- Critically compare the two scenarios, and make a recommendation regarding what should be implemented at KAZ.

2 Literature Review: Ecosan in Urban China

2.1 Principles of Ecosan

2.1.1 The Concept of Ecosan

"Ecologically sustainable sanitation", or "ecosan" for short, is defined as an approach to sanitation which respects ecological integrity, conserves and protects freshwater, promotes healthy living, and recycles nutrients from human excreta for agricultural production (Esrey *et al*, 1998)

Shown as Figure 2-1 (GTZ, 2004a): ideally, ecosan systems enable the complete recovery of all nutrients from faeces, urine and grey water to the benefit of agriculture, and the minimisation of water pollution. At the same time they ensure that water is used economically and is reused to the greatest possible extent, particularly for irrigation purposes. An even broader understanding of the term could also include the use, storage and infiltration of rainwater, treatment and recycling of solid organic wastes, minimisation of the energy input for wastewater disposal and utilisation of the energy content of solid and liquid wastes (GTZ, 2004b).

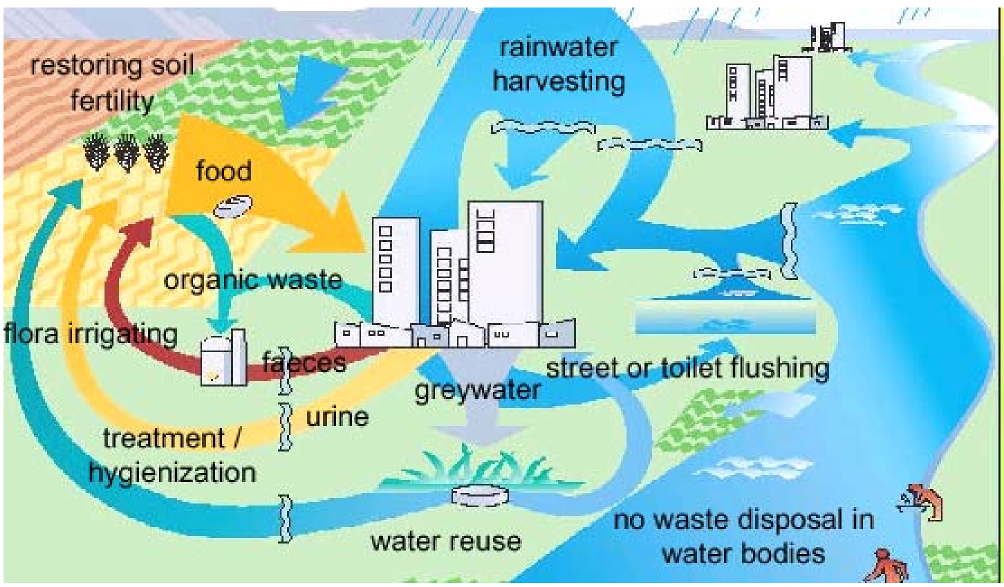

Figure 2-1: Closing the loop between sanitation and reuse (GTZ, 2004a)

Ecosan systems offer appropriate and sustainable solutions for different circumstances and demands. They permit acceptable and affordable sanitation for poor and rural areas, as well as for high-income areas and industrialised countries. ecosan should not be seen as a low-cost, second-class system, which is only for the poor (Winblad, 2002).

There is a common mis-conception that only dry sanitation system (no-mix system) as ecosan, however, this is not true. As long as the sanitation system is sustainable (environmentally, economically), it can be called an ecosan system.

All in all, ecosan represents a new basic understanding of wastewater handling in which faeces and urine are not considered as pollutants but instead as useful resources. In nature, there is no waste. All products of living things are used as raw materials by others as part of a cycle.

2.1.2 Advantages of Ecosan Concept

A more holistic approach towards ecologically and economically sound sanitation is offered by the concepts referred to as "ecological sanitation". The key objective of this approach is not to promote a certain technology, but rather a new philosophy of dealing with what has been regarded as wastewater in the past. The systems of this approach are based on the systematic implementation of a material-flow-oriented recycling process as a holistic alternative to conventional solutions. Ideally, ecological sanitation systems enable the complete recovery of all nutrients from faeces, urine and grey water to the benefit of agriculture, and the minimisation of water pollution, while at the same time ensuring that water is used economically and is reused to the greatest possible extent, particularly for irrigation purposes. (GTZ, 2004c)

If this vision of ecosan could be realized, then it would confer a great many advantages to the environment, and agriculture, world-wide.

If ecosan could be adopted on a large scale, it would protect our groundwater, streams, lakes and the sea from faecal contamination. Less water would be consumed. Farmers would require less expensive commercial fertilizer, much of which today washes out of the soil into water, thereby contributing to environmental degradation. Ecosan allows us to make use of the high fertilizer value of urine and the soil-enriching properties of dried or composted faeces.

Urine is rich in nitrogen, phosphorus and potassium. Urine can be diluted with water and put directly on vegetable gardens and agricultural fields or saved in underground tanks for later use.

Human faeces can be turned into a valuable soil conditioner rich in carbon, providing both good soil structure and a good medium for essential soil micro-organisms. With ecosan we can replenish the world's soils, both for agricultural use and to restore wasteland, and continue to enrich those soils more and more over time. Returning human urine and sanitized faeces to soils on a regular basis has the potential to replenish soil nutrients to levels at which productivity will become sustainable. (Winblad and Simpson-Hebert, 2004)

Recycling human excreta would reduce the greenhouse effect if practised on a large scale as part of a comprehensive programme to increase the carbon content of soils. Most efforts to address the atmospheric build-up of carbon dioxide (CO_2), which is believed to be causing climate change, have focused on reducing the CO_2 emissions from fossil fuel burning and the clearing of rain forests. However, scientists have recently begun to focus on the ability of soils to serve as a sink for excess atmospheric carbon. (In soils carbon is stored in the form of humus and decaying organic matter.) A number of factors influence the accumulation of carbon in soils. Returning sanitized human excreta to degraded lands would play a significant role in this process by increasing the amount of carbon in the soil, enhancing soil fertility, increasing plant growth and hence the amount of CO_2 fixed from the atmosphere through photosynthesis.

A modest doubling of the amount of carbon in non-forest soils, from the current low level of 1% (as a result of erosion) to 2% over the course of 100 years would balance the net annual increase of atmospheric carbon over that time. (Winblad and Simpson-Hebert, 2004)

2.1.3 Challenges of Ecosan Concept

Although an ecosan concept tries to find appropriate, sustainable solutions for the local situation and has various advantages compared to a conventional sewage system, there are still some challenges. Besides the risks for public health by using human faeces and urine in agriculture, several hindrances for implementation, operation and use have to be considered.

Firstly, there are several hindrances related to implementation.
- In urban area, no local demand of fertilizer and irrigation water
- Long distance for the transport of urine/faeces to treatment places
- Misuse of the toilet, in particular with urine separation toilets
- Low prices for artificial fertilizer

Secondly, lack of relevant technologies can challenge the recycle wastewater or waste.
- Lack of experts who know how to implement and operate new ecosan related technologies
- Lack of mature demonstration cases about ecosan project
- A technology deficit in developing countries, such as lack of ecosan workshops and training courses

Thirdly, existing policies also discourage the wastewater recycle.
- Lack of motivation and participation in planning processes, as most governments still prefer the conventional sewage and central system, mostly because of ignorance of better local solution (Jurga, 2003 and Jurga *et al*, 2003a)
- The cheap/subsidized prices for municipal water supply
- Lack of the guidelines for the safe use of urine and faeces in China

2.2 Applications of Ecosan in China

2.2.1 Overview of Ecosan Projects in China

In China, the use of human excreta as a fertilizer has a history of more than 2,000 years. Over 90% of human excreta are still used in agriculture today, but most of them are not sanitized. An approach based on sanitary improvement and safe recycling of the nutrients in human excreta has been greeted with official and popular enthusiasm (Winblad, 2002).

The ecosan activities in China presented by Ina Jurga in 2004 are shown on Figure 2-4 and Table 2-1 (Jurga, 2004). Most of the projects carried by GTZ are in inception phase; others done by different organizations only focus on the rural area. Ecosan toilets can be applied in water scarce areas or remote villages, such as in Yongning village, Guangxi Province (Zhang and Luo, 2001). Some grey water or wastewater recycle equipments have been set up in the hotels, restaurants, to demonstrate that ecosan can also be applied in semi-urban area.

Lots of information shows that up to now, the activities relating to ecosan have mostly comprised projects focusing on residential areas, only few projects relate to the tourist areas. Most of the projects carried out at private houses in rural area respectively, while only one entire "Ecosan town" (Dong Sheng, Inner Mongolia) is under construction (EcosanRes, 2004).

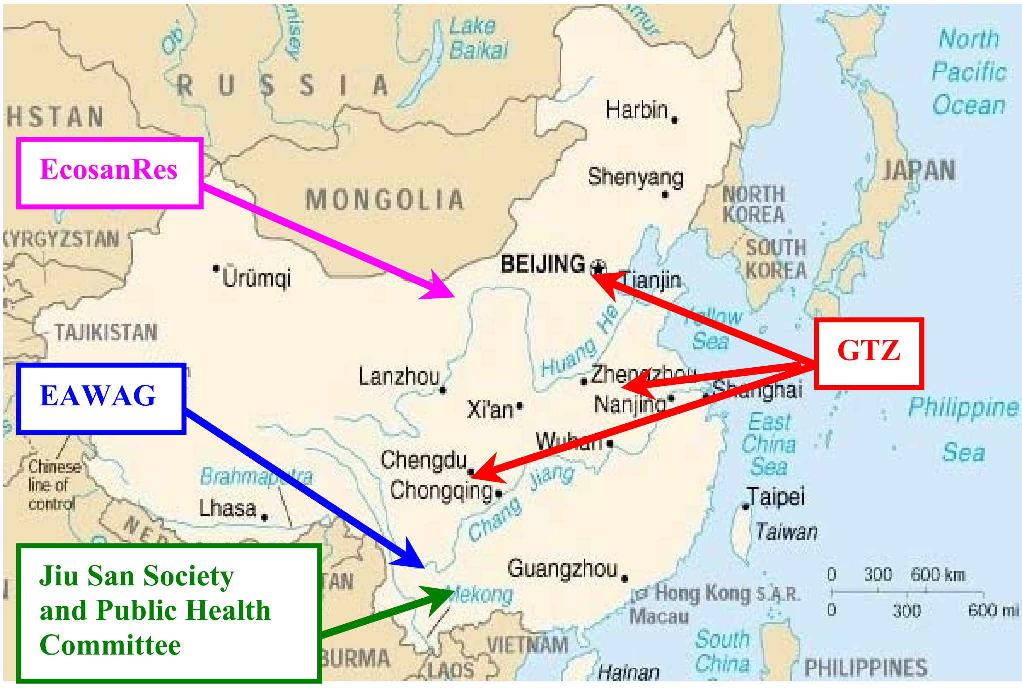

Figure 2-4: Distribution of Chinese Ecosan projects (Jurga, 2004)

Table 2-1: Activites regarding ecosan in China by various organisations (Jurga, 2004)

Organizations	Location	Activities
GTZ	Yang Song township, Beijing Changzhou village, Jiangsu Province Chengdu, Sichuan Province	Inception phase for Ecosan concept Inception phase for decentralized wastewater treatment Inception phase for decentralized wastewater treatment + ecosan, technology modification
EcosanRes	Dongcheng, Inner Mongolia	New urine diversion toilet design
EAWAG	Kunming, Yunnan Province	Rural sanitation Feasibility for Urban application
Jiu San Society and Public Health Committee	Guanxi Province	Rural sanitation, education on National level

In fact, in urban areas, it is also important to apply the ecosan concept. Ecosan will minimize the water pollution. The application of the ecosan concept at KAZ will be a demonstration project for an ecosan concept in tourist resort and conference centre..

Similarly, some Chinese projects on biogas production, or on decentralized wastewater treatment systems, can be thought of as the application of ecosan concept (e.g. in rural China, manure from animals and humans is digested together in anaerobic digesters). In Yongning ecosan-village, Guangxi, the biogas is produced from digested manure of humans (Zhang and Luo, 2001).

2.2.2 Ecosan Applications for Similar Urban Facilities

To demonstrate the application of ecosan principles in township planning in China, a baseline study of Yangsong Township, 45 km northeast from Beijing, was carried out in the summer 2002 by GTZ. The intention of this proposal is to show the practical implementation of water conservation and nutrient reuse in urban areas by using grey water and organic wastes from individual households for irrigation, toilet flushing and agriculture. It is essential to harness the scarce water resources to ensure an adequate supply of safe drinking water for all citizens. This project for an ecosan strategy was supported by GTZ (Gallinat *et al*, 2002).

To show that it is possible to build and operate an urban centre using sustainable approaches to sanitation, water use, solid waste and infrastructure, a bold new research and development project has been undertaken by the City of Dong Sheng, Inner Mongolia, China. It collaborates with the EcosanRes Programme and Sida (Swedish International Development Cooperation Agency). This represents the first major attempt in China (and the world) to build from the ground up an entire functioning modern town using sustainable water and sanitation practices. This project will undergo a period of development and testing prior to full-scale implementation in 2005 and 2006 (EcosanRes, 2004). This is a good example for an urban application in North China, while the KAZ would be another example for South China on a smaller scale.

2.2.3 A Vision of Ecosan for the Future

After some years of scientific research, technological development and practical experience on the earth, the concept of ecosan becomes more widely accepted and practised. However, there are still some challenges, such as widespread extension of pilot studies into urban and peri-urban areas, awareness-building at all levels of society and all stakeholders, and so on.

2.3 Overview of Relevant Ecosan Technologies

In its practical application, ecosan is typically (but not always) using three techniques: diversion, sanitization and recycling (Winblad, 2003). Diversion describes the wastewater collection and transportation, sanitization is for contamination and pathogen removal, while the recycling means reuse or reclaimed water, nutrients, organic matter and energy.

2.3.1 Diversion

2.3.1.1 The Concept of Diversion

Diversion means that waste streams are collected respectively in a specially designed toilet/sanitation system (Winblad, 2003). In other words, diversion is separation of faeces, urine, grey water and storm water directly at source. In short, it means don't mix. This can be very useful in achieving the "ecosan paradigm". In the KAZ case, wound not mix:

- Human urine with faeces;
- Black water with grey water;
- Wastewater with storm water

2.3.1.2 Benefits for Diversion of Waste Streams

Ecosan concept with source control can solve many problems of conventional sanitation systems. Based on the literature (Esrey *et al*, 1998, Lens *et al*, 2001, TTDT, 2005 and Fittschen and Hahn, 1998), many good reasons for not mixing waste streams are concluded, such as saving flushing water, simplifying sanitation processes, and making the recycling of water flow and nutrients easily.

Firstly, the obvious important benefit for separating urine from faeces is saving flushing water. As shown in Table 2-4, with low- and non-flush water urine diversion toilets, the volume of flush water consumption can be reduced largely.

Table 2-4: Flush water consumption daily per capita of different types of toilet (Li, 2005, DF, 2005)

Toilet types	Conventional without water saving measurement	Flush cistern with two different amounts of water	Urine diversion toilets with low flush	Dry toilet without flush
Water consumption per flush faeces (L/time)	9	9	5	0
Water consumption per flush urine (L/time)	9	4	0.15	0.1
Water amount[a] (L/c/d)	45	25	5.6	0.4

[a]: Assume: Daily one faeces flush and four urine flushes per capita.

Secondly, diversion can simplify sanitation processes. Different types of wastewater and waste have their own characteristics, so they require different treatments. Once mixed, these water streams are more difficult to treat.

As shown in Table 2-5 and Table 2-6, yellow water remains relatively free from pathogenic organisms. As it has a high nutrient content, it can be used as valuable nutrient rich liquid fertilizer after simple sanitation processes. Brown water contains most of the pathogens in human excreta and is the main source for transmission of enteric infectious disease and parasites. Separating brown water can keep the volume of potentially dangerous material small. Grey water has a low content of nutrients and further treatment only needs to concentrate on organic matter removal. Since the flow of storm water is very high and its quality is much better than domestic wastewater, it is better to treat it for reuse respectively.

Table 2-5: Wastewater and waste palette (Lens *et.al*, 2001)

Type of waste	Contents
Classic water	Wastewater from toilet, bath, kitchen, wash (mixed)
Black water	Wastewater from toilet
Grey water	Wastewater from bath, kitchen, wash
Light grey water	Wastewater from bath, wash
Yellow water	Urine with urine flush water
Brown water	Faeces with faeces flush water
Blue water	Strom water
Green waste	Organic solid waste

Table 2-6: Characteristics of waste streams (Werner *at al*. 2003)

Fraction	Characteristic
Yellow water	• Less hygienically critical • Contains the largest proportion of nutrients available to plants • May contain hormones or medical residues
Brown water	• Hygienically critical • Consists of organics, nutrients and trace elements • Improves soil quality and increases water retainability
Grey water	• Of no major hygienic concern • Volumetrically the largest portion of wastewater • Contains almost no nutrients • May contain washing powders.
Blue water	• Of no major hygienic concern • Contains almost no nutrients
Green waste	• Consists of organics, nutrients

Thirdly, separation treatment of different domestic wastewater flows makes the recycling of nutrients and water easily.

As shown in Table 2-7 and Figure 2-9, human urine is the largest contributor of nutrients to domestic wastewater (Fittschen and Hahn, 1998). Pure urine, containing more than 80% of the total nitrogen and 50% of phosphors and potassium, can be used as a valuable nutrient rich liquid fertilizer, reuse these nutrients into the earth and plants. The faeces have high organic matter which can be anaerobic digestion to produce biogas or composted to solid fertilizer. Grey water with largest fraction of total wastewater flow can be ready for reuse water after simple techniques treatment.

Table 2-7: Characteristic of the main components of household wastewater (Otterpohl *et al*, 2001 ;Esrey *et al*, 2001, Fittschen and Hahn, 1998, Wittgren *et al*, 2003)[a]

Loads (g/c/d)	Yellow water	Brown water	Grey water	Green waste	Total
Nitrogen (N)	11.0	1.5	0.5	1.5	14.5
Phosphorus (P)	1.0	0.5 - 0.8	0.2 - 0.5	0.3	2-2.6
Potassium (K)	2.5	0.6 – 1.0	1.6	0.2	4.9-5.3

[a] Explanation: The figures vary naturally by type of diet, location, climate, age, activity and health status.

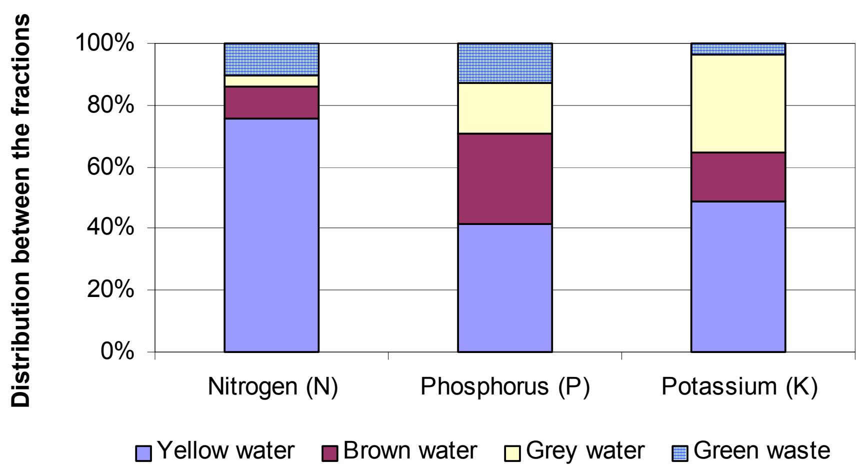

Figure 2-9:Nitrogen, Phosphorus and Potassium loads represented in wastewater in percentage of total loads (Otterpohl *et al*, 2001)

2.3.1.3 Available Technologies for Urine and Faeces Diversion in KAZ

Yellow, black, grey and blue water can be collected respectively, and then transferred by different sewage systems. The urine volume is so small that it is normally transported by tanker, not by a separate sewage system.

The most important tool for source control is the toilet system. It is in not usually very prestigious or scientifically rewarding to deal with toilets, but it is one of the most important questions for the survival of human beings on earth in the long run. In the last few years there has been a rapid development of new sanitation systems. More experts are taking a wider view on the overall aspects rather than just cleaning the wastewater (GSI, 2005).

Below in Figure 2-12 is shown a South African urine-diverting pedestal and urinal (left) in plastic. A urine-diverting squatting pan in fibreglass (right) is promoted in China. Both kinds are installed indoors in the bathroom, and the content is being emptied from outside the house. These toilets are dry sanitation toilet.

Figure 2-12: Urine diversion toilet (Drangert, 2003)

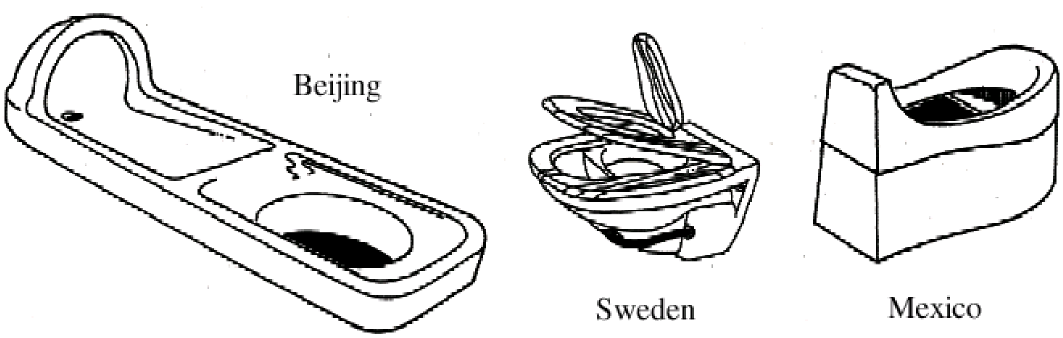

Figure 2-15: Excrement separation type toilets (Esrey *at al*, 1998)

Figure 2-15 demonstrates a choice of toilets usable for source control sanitation. Urine and faeces can be collected respectively by specially designed toilet. Generally, the toilet is slightly longer to incorporate two separate bowels. A front bowl collects the urine while the rear one is used for faecal material. There are two separate outlet pipes; one takes the faecal matter with or without flush water, the other transports the urine to a separate tank. Here the urine is stored to be collected once or twice a year for use as an agricultural fertilizer. An added advantage to separation toilets is that the urine is flushed away using only 0.1 L of water, thus conserving water and reducing volumes to be disposed via percolation areas to groundwater (GSI, 2005).

Ecosan-compatible toilets can be “dry” or “wet” (with flush water). For the remainder o this literature review, “wet” ecosan-compatible toilets are be focused, because these will be more acceptable for the users at KAZ (“dry” toilets have the disadvantage that ash or lime has to be added after defecation to remove moisture).

A partial flow separation for the urine is particularly advisable due to its low volume and the high concentration of nutrients it contains. In order to obtain the yellow water fraction devices such as urine separation toilets or waterless urinals can be used (Esrey *et al*, 1998).

Urine separation toilets are now widely available. See Figure 2-18, the toilet has two separate outlets: a conventional outlet for faeces and paper located in the back part of the bowl, and an outlet for urine (see red arrow), which is closed by a movable plug. While the toilet seat is in use, the plug is mechanically opened by a lever. Urine flows to the front inlet. Standing up closes the plug again. The two parts of the toilet bowl are not separated by a barricade. As soon as the toilet is flushed, the plug closes. Only as needed would faeces and paper be washed away with minimal amounts of water through the rear outlet. In this way, urine is taken away undiluted (ROEVAC, 2005).

Figure 2-18: ROEDIGER no mix toilet (ROEVAC, 2005)

In the model "Dubbletten" by the Swedish company BB-Innovation & Co Inc., shown in Figure 2-21 left picture, (Dubbletten, 2005) the bowl is separated into two parts: a small urinal in the front, and a bowl for faeces, that has a bulge to prevent overflows. Both bowls have independent flushing systems, for urine it uses 0.12 – 0.15 L, and the faeces bowl is flushed with 4 - 6 L. The toilet of the Swedish company Wost Man ecology AB (see Figure 2-21 right picture) (DF, 2005) is working with the same two flushing systems. Only the design of the bowl is a bit different: a dam wall will keep the substances separated.

 

Figure 2-21: Separation toilet (Dubbletten, 2005, DF, 2005)

For KAZ, “Dubbletten”-type toilets are proposed to use (see also section 4.3.1.3). Both squatting and sitting urine diversion toilet will be equipped. In China, people prefer to use squatting toilet, since the body do not need touch the toilet. But the sitting toilet will also be provided in order to satisfy the western guests’ habits and be convenient for disabled persons.

To sum up, the recommended diversion methods for KAZ are:

1. Equip low flush urine diversion toilets, such as “Dubbletten”-type toilets;
2. Equip indoor yellow/brown water pipes for each independent building (e.g. five main buildings, the cottages and eight outdoor public toilets). These pipes would collect the separated urine/facese because they are the links between the urine diversion toilets and the urine/faeces tanks in each basement. The urine/faeces tanks can be emptied or transported to yellow/brown water treatment centre in KAZ by trucks once a week;
3. Build the grey water sewerage which can collect and convey the grey water to a grey water treatment centre in KAZ;
4. Construct the blue sewerage for collecting and conveying storm water to a storm water treatment centre in KAZ;
5. Equip the organic waste separation rubbish bin, and then transporting them by truck to solid waste treatment centre in KAZ once a day.

2.3.2 Sanitization

Sanitization means that pathogenic organisms and inorganic contaminations in waste streams are reduced to a harmless level by appropriate treatment (Winblad, 2003).

The treatment in on-site processing chambers can be regarded as a primary treatment. For large-scale projects, such as KAZ, it is necessary to have a secondary treatment to ensure that the material is safe enough to be recycled as fertilizer (Winblad and Simpson-Hebert, 2004).

2.3.2.1 Sanitization for Yellow Water – Urine

Yellow water means the wastewater from urine.

Urine contains few disease-producing organisms. When urine is collected from many urban households and transported for reuse in agriculture, the recommended storage time at temperatures of 4–20 °C varies between 1 and 6 months (see Appendix 1 for details) depending on the type of crop to be fertilized (Winblad and Simpson-Hebert, 2004). During storage the urine should be contained in a sealed tank or container. This prevents humans and animals coming into contact with the urine and hinders evaporation of ammonia, thus decreasing the risk of odour and loss of plant-available nitrogen.

The urine should preferably not be diluted. Undiluted urine provides a harsher environment for micro-organisms, increases the die-off rate of pathogens and prevents the breeding of mosquitoes (Vinnerås, 2002). Thus, the less water that dilutes the urine is the better.

2.3.2.2 Sanitization for Brown Water – Faeces

Brown water means the wastewater from faeces. More than 120 different types of viruses may be excreted in faeces (Schönning and Stenström, 2004).

The main concerns about the safety of excreta are with the faeces. The most important pathways for the transmission of diseases from faeces are hands, flies, water, soil as well as food that have been contaminated by any of the first four factors. The F-diagram below summarizes these main pathways. Each of these factors has been given a name beginning with the letter 'F' in order to make it more easily remembered (Esrey *et al*, 1998).

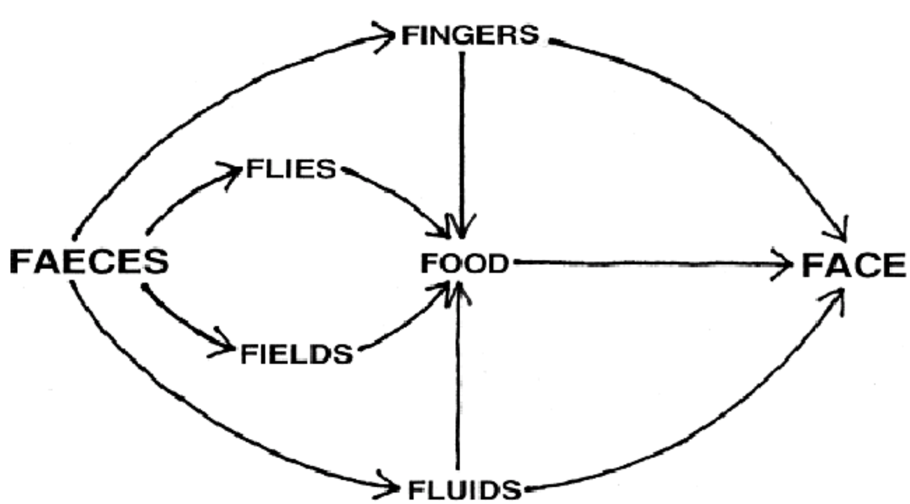

Figure 2-24: The F-diagram summarizes the main ways faecal pathogens are spread by contaminating fingers, flies, fields, food and fluids and then eventually being swallowed (Esrey *et al*, 1998)

Form a risk perspective, the exposure to untreated faeces is always considered unsafe, due to the potential presence of pathogens. So the faeces must be sanitized.

One purpose of an ecosan system is to form a set of barriers between faeces and flies, fields and fluids (Esrey *et al*, 1998). There are usually two steps for faeces treatment processes: primary processing and secondary processing. Both systems are designed to use some of the physiochemical and biological factors listed in Appendix 2 to kill disease organisms in faeces (Winblad and Simpson-Hebert, 2004).

The primary processing in an ecosan system is generally either through dehydration or decomposition, but a combination of both is also possible. The purpose of primary processing is to reduce the volume and weight of faecal material to facilitate storage, transport and further (secondary) treatment (Winblad, 2003). The purpose of secondary processing is to make human faeces safe enough to return to the soil (Winblad and Simpson-Hebert, 2004).

All the currently used treatment methods (see Appendix 3), except storage, are based on either temperature or pH (for urea in combination with ammonia). Other factors also affect microbial survival but are less easily controlled or measured.

To sum up, faeces contain most of the pathogens in human excreta and are the main source for transmission of enteric infectious diseases and parasites. Therefore we should treat faeces based on the principles as below (Winblad and Simpson-Hebert, 2004):
Keep the volume of dangerous material small by diverting the urine and not adding water to the faeces. For KAZ, some water will be added to the faeces.
Prevent the dispersal of material containing pathogens by storing it in some kind of secure device (processing chamber, tank) until safe for recycling.
Reduce the volume and weight of pathogenic material by dehydration and/or decomposition to facilitate storage, transport and further treatment.
Reduce pathogens to a harmless state by sanitization through primary treatment on site (dehydration/decomposition, increase in pH, retention) followed by secondary treatment on/off site (high temperature composting, increase in pH by the addition of lime or urea, and, if necessary, carbonization or incineration). For KAZ, after increasing in pH, the brown water will be combined with anaerobic digestion and composting.

2.3.2.3 Sanitization for Grey Water – Shower and Washing Water

Grey water means the wastewater from the kitchen (passed by grease trap), washing machine, shower and bath. It may be reused for other purposes, especially landscape irrigation.

In grey water, larger particles, fibres and grease should be removed at source to prevent clogging of the pipe system. Outlets from kitchen sinks, showers, bathtubs, washing machines and other fixtures and appliances should therefore be fitted with appropriate screens, filters or water traps. For grey water from restaurants where large amounts of grease and oil are handled, special grease traps may be necessary to protect the pipe system from clogging.

A characteristic of grey water is that it often has high concentrations of easily degradable organic material like fat, oil and other substances from cooking, as well as soap and tensides (surfactants) from detergents.

In pre-treatment suspended solids are removed mechanically by gravity, screens, seals or filters. The need for removal of suspended solids depends on how the water will be treated and used. The septic tank concept is an efficient and reliable technique that is useful in most treatment systems in rural as well as urban areas.

The most appropriate method for reducing levels of micro-organisms, organic pollutants is to use constructed wetland or attached aerobic biofilm techniques. In these techniques, the biological degradation of organics typically takes place in aerated conditions (Winblad and Simpson-Hebert, 2004). The treatment options range from extensive land applications to intensive applications, such as trickling filters and biorotors (see Figure 2-26).

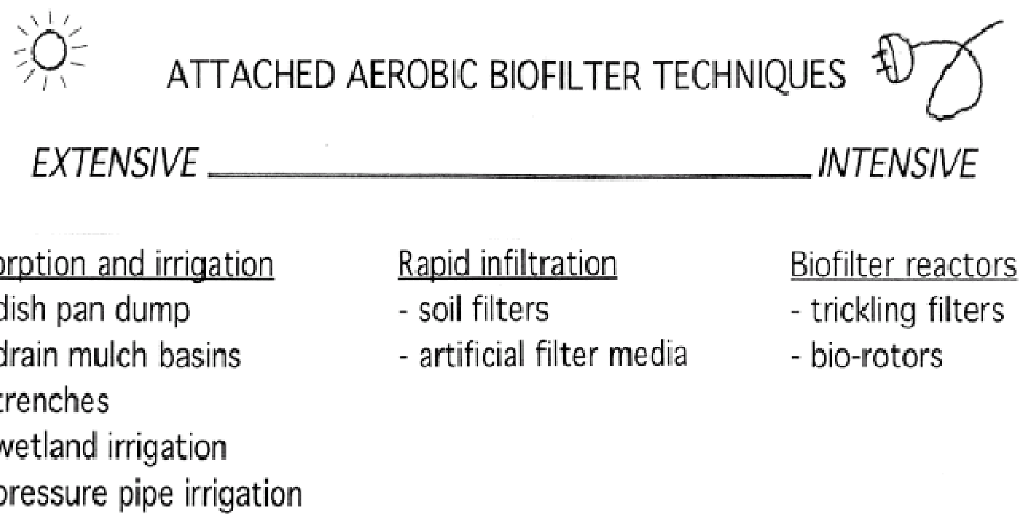

Figure 2-26: Examples of attached aerobic biofilm techniques (Winblad and Simpson-Hebert, 2004)

On the left of Figure 2-26 are extensive applications that require little technical input, but often a large land area. On the right are intensive applications that require more input of technical equipment and energy, but less land. Where climatic conditions are favorable, aquatic systems, such as ponds and wetlands, can be used for grey water (Winblad and Simpson-Hebert, 2004).

In KAZ, the constructed wetlands are recommended because of the little technical, energy input, and low construction and O&M cost. It is especially suited for resorts since the nature treatment.

2.3.2.4 Sanitization for Blue Water – Storm Water

Blue water means the storm water collected from roofs and roads.

Because of the low contaminant, blue water can be stored in special cistern after removal the first flush. After passed by sediment trap, it is filtrated in sand filter chamber. The effluent from sand filter chamber can be use for flushing toilet, irrigating garden, and other untouchable body uses. The blue water should be safe to use shower, body washing, or other touchable body uses, after treated by membrane filtration and chlorine disinfection processes.

2.3.2.5 The Recommended sanitization technologies for KAZ

The recommended sanitization technologies for KAZ are:

1. Yellow water – urine with dilution water: storage 6 months in urine tank at room temperature, then produce liquid fertilizer;
2. Brown water – faeces with or without water: anaerobic digestion to produce biogas, or compost with green waste (organic waste) to solid fertilizer;
3. Grey water – washing, cleaning and shower water: construct artificial wetland or bio-treatment;
4. Blue water – storm water: sedimentation and sand infiltration for untouchable body water, membrane infiltration technology for touchable body water.

2.3.3 Recycling

Recycling means that the end products of the diversion-sanitization process are returned to the topsoil where they can be utilized by plants (Winblad, 2003). In KAZ, it means reuse the water flow and nutrients.

2.3.3.1 The Available Water Flow Recycling for KAZ

Grey water, while representing the largest fraction of the total wastewater flow, has only a very low nutrient content. Therefore, the further treatment can only concentrate on organic matter removal to a high quality using simple techniques such as constructed wetlands and is thereafter ready for reuse. The effluent is a good resource for reuse water, because it is the largest fraction. This water can be put to particularly good use in agricultural irrigation (especially in water scarce regions) (GTZ, 2003a).

After treatment, grey water is used for irrigation or returned to nature. The following recipients (end uses) can be identified (Winblad and Simpson-Hebert, 2004, Köttner, 2002):

- discharge to surface water
- use in irrigation
- recycle as reclaimed water

Discharge to surface water
Discharge to surface water is often the easiest and most natural way to return treated grey water to the environment. If the water is treated in a soil filter or a trickling filter, it can normally be discharged in open ditches and drained away together with storm water. Treated grey water can be used for landscaping, like the creation of wetlands and dams in parks. The water may, however, in spite of treatment, still contain oxygen-consuming substances or nutrients that are too high to produce attractive and stable aquatic ecosystems. In this case, the treated grey water would have to be given a second

treatment, for example by letting water trickle through the root zone in a trench before it is discharged into a pond.

Use in irrigation
When grey water is used for irrigation special precautions are required. The following recommendations should always be followed:
• Method of application: Water should be applied to the soil or sub-surface rather than sprinkled.
• Choice of crop: Crops where leaves or stems are not eaten directly as well as fruit trees and bushes are most suitable for grey water irrigation.
• Waiting period: When irrigating edible crops, a certain waiting time between irrigation and harvest should be observed.

Recycle as reclaimed water
The grey water can be reused for flushing toilet, washing the street, cleaning the car.

2.3.3.2 The Available Nitrogen Recycling for KAZ

One of the main goals of ecological sanitation is to capture the nutrients present in human excreta and recycle them back to agriculture (Schönning and Stenström 2004).

As mentioned before, pure urine, contains the highest proportion of natural nutrients (nitrogen, phosphorus and potassium), which are directly available to plants and equally effective as mineral fertilizers. Urine can be used as a valuable nutrient-rich liquid fertilizer. Once collected the urine can either be used directly in the garden, infiltrated into an evapo-transpiration bed, or stored on site for later collection either as liquid fertilizer or further processed into a dry powder fertilizer (Winblad, 2003).

The human faeces obtained after separation show valuable soil improvement qualities (an improved structure and an increase in the water retention capacity). They are treated, if necessary together with organic waste and according to local conditions (climate, power demand and socio cultural acceptance etc), using the processes of either dehydration, composting, anaerobic digestion, stabilization, soilisation or fermentation. Thus, the organics and nutrients contained in faeces can be used in concentrated and hygienically safe form as a dry fertilizer, compost or fluid fertilizer. Dependent on the type of treatment, energy can be produced if necessary in the form of biogas after anaerobic digestion (Köttner, 2002).

2.3.3.3 The Recommended Recycling Approaches for KAZ

The recommended recycling approaches for KAZ are:

1. Liquid fertilizer coming from yellow water: irrigate flowers, herbs, trees, and grasses in KAZ or its surroundings area;
2. Biogas coming from brown water anaerobic digestion: use as energy in KAZ;
3. Solid fertilizer coming from brown and green waste composting: irrigate surrounding farmer lands;
4. Treated water coming from grey water: irrigate flowers, herbs, trees, and grasses in KAZ or discharge into the surface water body inside KAZ;

5. Treated water coming from blue water: untouchable body water can be use for flushing toilets, washing clothes, cleaning rooms, while the touchable body water can be use for shower, cleaning face and hand.

2.3.4 Selected Options for Ecosan Technologies for KAZ

Based on the literature review, the following technologies were selected for KAZ (see Figure 2-29).

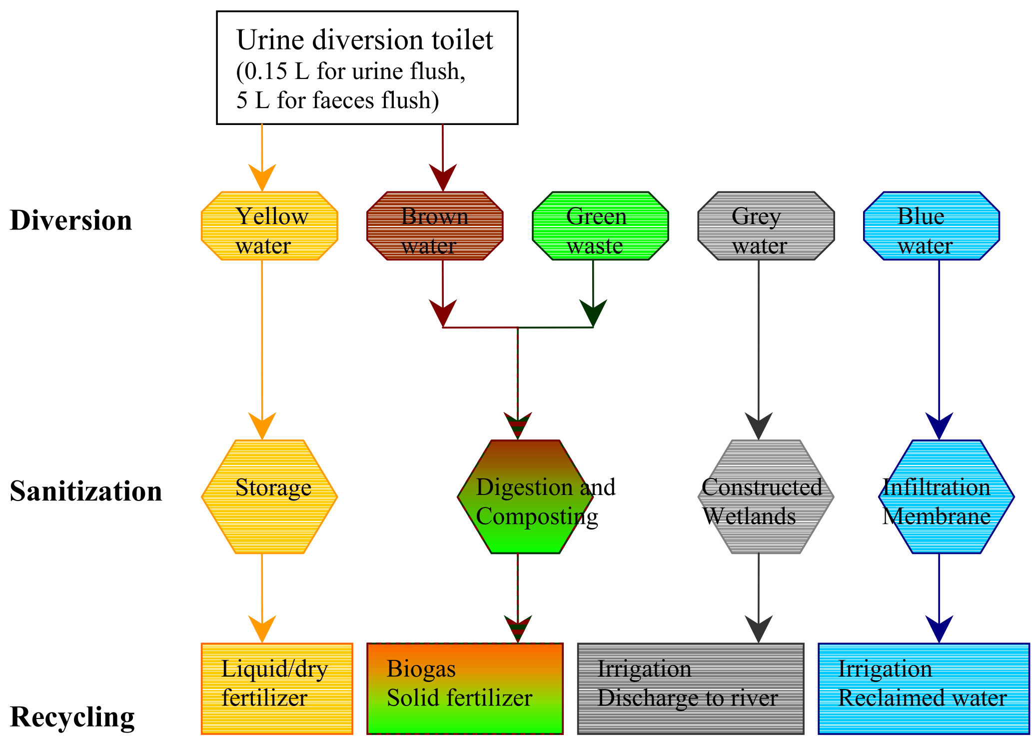

Figure 2-29: Diversion of substances and their specific sanitization and recycling approaches in KAZ

3 Design Data of KAZ

The following data are collected by a variety of means in KAZ from 23 October 2004 to 15 December 2004.

- Most of data about the location, climate, soil condition, come from the Kunshan Saint Means Biotech Co. LTD. in China (Saint Means as short);
- The map of Kunshan water system is offered by Kunshan Water Resource Bureau;
- The data of water pollution situation is gained from the Kunshan Environmental Bureau;
- I took some pictures and talked with local farmer, citizen to learn about use of toilet waste, after that, these data are checked by internet or literature to make sure.

The data give a wide overview of the conditions in KAZ, because the holistic Ecosan concept always includes a variety of fields. Therefore the following chapter will describe the situation regarding climate, geography, agriculture and water of KAZ.

3.1 General Conditions of KAZ

3.1.1 Location

As shown on Figure 3-1, Kunshan is located in the southeast of Jiangsu Province, China. With metropolitan Shanghai to the east and the renowned ancient city Suzhou to the west, Kunshan can take full advantage of both the development in Shanghai Pudong and the successful experience of Suzhou Industrial Park, which is near the Taihu Lake, one of the most seriously polluted lakes in China (KETD, 2004) (Tang and Wang, 2001).

Kunshan is a new medium city in the Yangtse (Chang Jiang) River Delta, which is one of most the densely populated and most active areas of economic and social development in China. The total area of Kunshan City is 921.3 km^2, where 23.1% is covered by water. The GDP (Gross Domestic Product) per capita in Kunshan is above than $4085 in 2003 (KETD, 2004) compared to China national GNI (Gross National Income) per capita, $1100 (World Bank, 2005).

Figure 3-1: The location of Kunshan City

Kunshan Aqua Zone, the area for the new tourist facility, is located in the Kunbei district, in the northeast part of Kunshan City. Now, there is rural area, the land is use for agriculture.

KAZ is to the east of Yangcheng Lake, the west of Kuilei Lake, and the north of Loujiang River (Gu, 2004). Shown in Figure 3-4, KAZ (Pink area), which is about 10 kilometres distance from Kunshan City centre (Red star), comprises a lot of water features (Dark blue line).

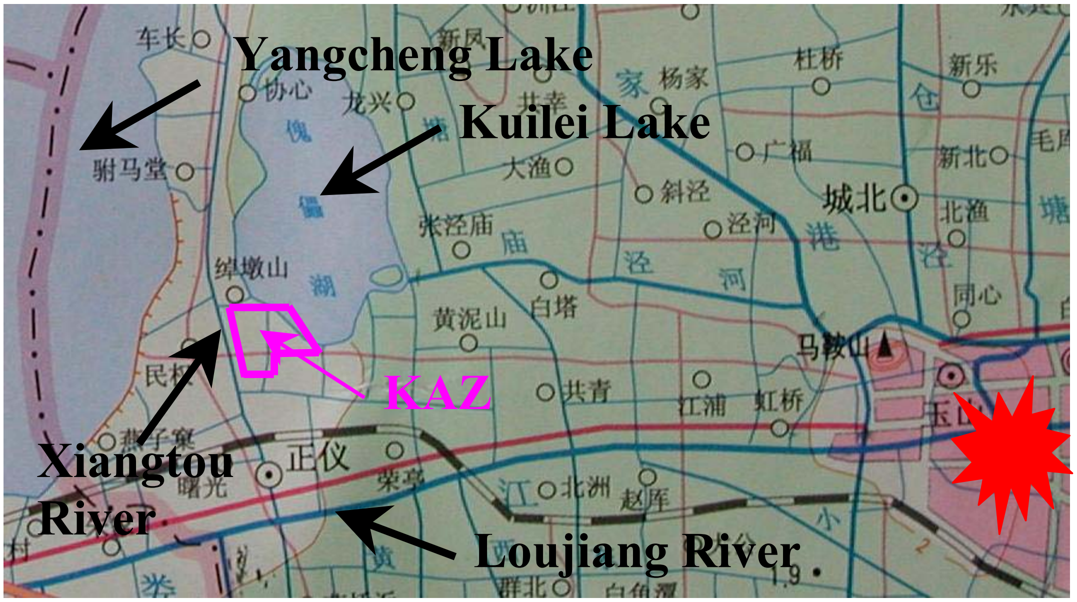

Figure 3-4: Location of KAZ (The star on the right is location of Kunshan city centre)

All of surface water in KAZ comes from Xiangtou River, which is the west boundary of KAZ. Also there are a lot of small brooks and ponds within KAZ and these watercourses connect each other to make a "water net", which is shown on the Figure 3-6, and Figure 3-8.

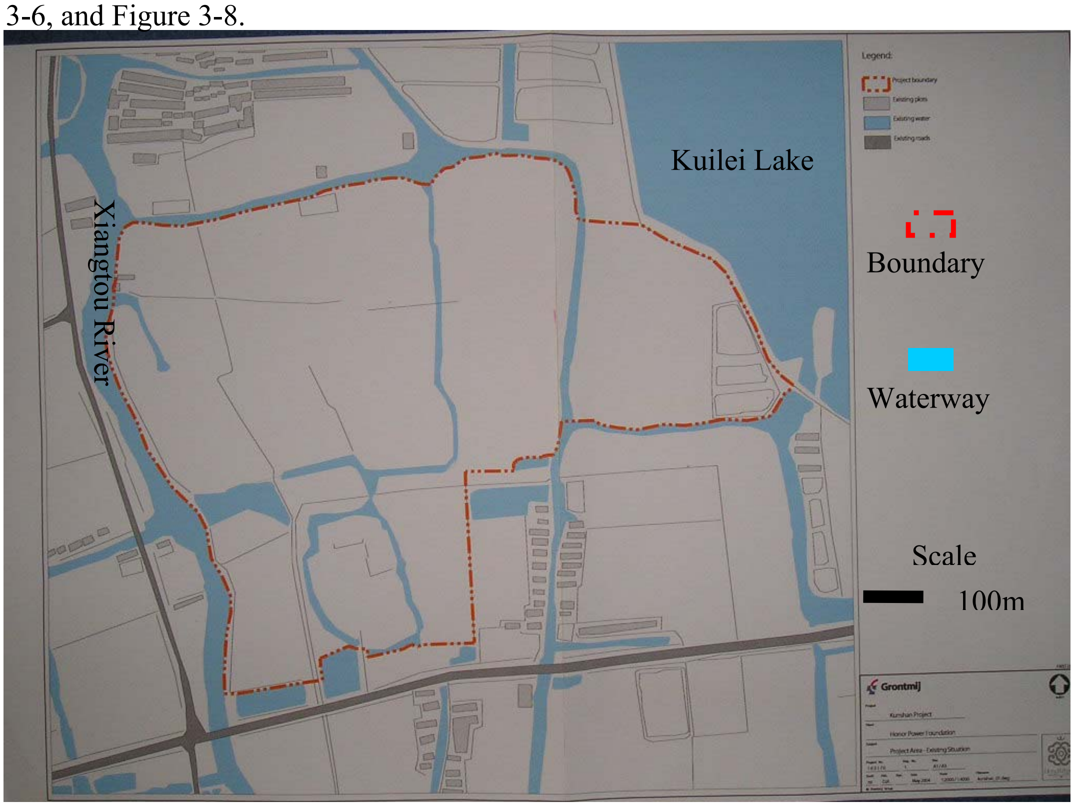

Figure 3-6: Existing waterway situation of Kunshan Aqua Zone (Ramsundersingh, 2004) (Dashed and dotted line is boundary of KAZ)

Figure 3-8: Brooks in KAZ in November 2004

3.1.2 Local Climate

Kunshan has a benefit of distinct seasons, warm and humid climate, adequate sunshine and rich rainfall (KEDT, 2004).

Kunshan has a generally warm, even hot climate, the north subtropical zone conditioned by the southern monsoon climate. For the last 50 years, the average annual temperature was 15.5℃, and the highest temperature reached 39℃(August 1st, 2003), while the lowest one got -11.7℃ in night time (Jan.31st, 1977). The frost free period has 240 days in a year (Gu, 2004).

Shown in Appendix 4, the atmosphere is very humid (full of moisture, humidity can reach 70% throughout the year). The levels of rainfall are high - the average annual precipitation over the year is averaging 827mm to 1577mm (average annual is 1127mm) during the period from 1986 to 2003. The maximum daily rainfall was 156.2mm, whereas the minimum was 42.6mm. The average annual evaporation capacity ranges from 1151 to 1576 mm. Similarly, the average annual sunshine time is 2185 hours, and the annual percentage of sunshine is 49%, equating 197 sunny days per year (Gu, 2004).

An even distribution of rainfall over the year is assumed, because the data on seasonal variation was not available to me.

3.1.3 Local Soil Conditions

Kunshan Aqua Zone is located in the river sides and lake lowland, its landform is low limnetic plain, and the land type belongs to River-lake low-lying wet land, yielding chiefly tropophilous weeds and reeds (NIGL, 1991).

Most of the soil is viscous loess soil with the bearing capacity of 8 -10 tons/m^2 (KETD, 2004). This kind of soil is suitable for paddy (rice plant), vegetable, corn, wheat (Wang, 1991).

There is a high ground water level in KAZ, the annual average depth of ground water level is 1.5m. The level can reach 1.1-1.2m during the rainy period, while it falls to 1.8m in dry period (Gu, 2004).

3.1.4 Local Flora and Fauna

There are many natural plants and animals in Kunshan area (see Table 3-1).

Table 3-1: Flora and Fauna in Kunshan (Wang, 1991 and NIGL, 1991)

Trees	Pines, Cypress, Willow, Mulberry, Poplar, Metasequoia, Chinar, Gingkgo
Hydrophytes	Water lettuce, Water peanut, Hyacinth, Floating waterweed, Water chestnut, Water bamboo, Reed, Duckweed, Water lily, and different types of Chinese herbs
Fauna	Crab, Silver carp, Bighead carp, Common carp, Grass carp, Shrimp, Clam, Eel, Loach

The trees in KAZ are shown in Figure 3-11.

Figure 3-11: Trees in KAZ in November 2004

Shown in Figure 3-13, some hydrophytes, such as water peanut, reed, duckweed, water bamboo, can purify water by consuming contaminants. Especially, water peanut is the most effective hydrophytes, it grows fast and easily (CWF, 1999).

Also, several of these hydrophytes are called ‘water green fertilizer’, such as water peanut, hyacinth, floating waterweed (Wang, 1991). They can be used as fertilizer to in agriculture (CWF, 1999).

Figure 3-13: Water plants in KAZ in November 2004

Yangcheng Lake is famous for its crab. For last ten year the demand of culturing crab is increased as the local a crab grower said to me. The crabs are fed in Yangcheng Lake and its surrounding rivers and ponds. At mean while, fishers and crab growers also feed carp, eel and loach.

3.1.5 Surroundings of KAZ

The follwing information has been collected through the discussion with farmers and visiting Zhengyi town and Cuodun village.

Zhengyi town is only 2 km distance from KAZ to the south. The main residents in Zhengyi are farmer and crab-man. There are large agriculture lands around Zhengyi. Farmers culture rice, corn, wheat and vegetable; while crab growers feed crab and fish in Yangcheng Lake, Xiangtou River or in some small pools, streams.

1 km away to the north of KAZ, there is a 500 household village, called Cuodun village. The residents live on agriculture. Also they culture the same plants as Zhengyi.

Shown in Figure 3-15, the local farmer is using the toilet waste mixed with river water to fertilize the vegetables. The toilet waste come from the septic tank connected with household toilet or public toilet. This activity is very common both in Zhengyi and Cuodun. Also the fishers like to use livestock or human being faeces for feeding fish. Although without adequate sanitization of human excreta, it seems no harm to the human health because Chinese always eat the cooked foods.

Figure 3-15: Left: The farmer of Zhengyi town irrigate the vegetables by toilet waste mixed with river water in November 2004; right: public toilet in Zhengyi Town

3.1.6 Sanitation Activities in Surroundings of KAZ

It is observed that as November 2004 both in Zhengyi and in Cuodun, the drinking water comes from the tap water, conveyed by the municipal water supply system. The well water (groundwater) or river water is used for washing. The residents like cleaning the vegetables, night-soil pots, and washing clothes, even bathing in the river nearby their house. As shown in Figure 3-17: the man was cleaning vegetables for cooking (left picture), while the lady was cleaning her night-soil pots (right picture) in the same Xiangtou river. This is custom to use river water for cleaning.

Figure 3-17: People clean vegetables and night-soil pot in Xiangtou River, Zhengyi part in November 2004

In Zhengyi town, there are two districts, the new one and old one. In the new district, there is a sewer system, the wastewater can be conveyed by pipes, and then discharged to the surface water-body without treatment; whereas, in the old district, there are a lot of hundred-year-old houses near the Xiangtou River, these houses are not connect with sewer system, so the resident use river water for cleaning, and then discharged grey water to the river, most of toilet waste is collected into the household septic tank, then irrigated to fertilise crops such as corns, vegetables (see Figure 3-15). Figure 3-19 shows the old houses in Zhengyi. Cuodun village have the same habits as old district of

Zhengyi.

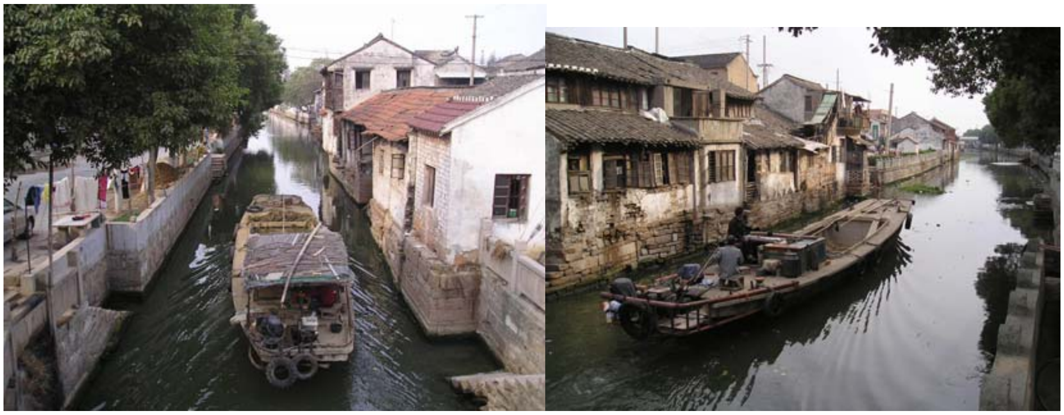

Figure 3-19: The old houses in Zhengyi town in November 2004

3.2 Neighbour Rivers and Lakes of KAZ

3.2.1 Location and Relationship

The channels in KAZ highly depend on Xiangtou River, passed by in the west margin of KAZ.

Seen in Figure 3-21, Xiangtou River (the bold blue line) has its source in Manli Lake. Actually, Manli Lake’s main source is Yangcheng Lake. Also there are five other sources for Xiangtou River; four begin at Yangcheng Lake directly (the thin blue line), and the fifth one comes from the Yeyoujing channel (the thin blue dashed line), which is between Yangcheng Lake and Kuilei Lake. Eventually, the Xiangtou River meets the Loujiang River after running by the KAZ and Zhengyi town. So Loujiang River can be called downstream of KAZ.

Figure 3-23 shows the Xiangtou River. Figure 3-25 shows the Yangcheng Lake and Kuilei Lake. From visiting Yangcheng Lake, It is observed that around 50 crab growers are feeding crabs, fish in eastern Yangcheng Lake, which is famous as its crabs. The delicious crabs attract thousands of visitors from whole China, even some persons take special trip from Shanghai, Beijing, Taiwan, and Hongkong only for tasting Yangcheng Lake crabs. As shown in Yangcheng Lake picture (Figure 3-25 left), there are many nets to fence crabs out. However, Kuilei Lake (Figure 3-25 right) is protected by government as resource of water supply of Kunshan City.

Figure 3-21: The location and relationship of Neighbour rivers and lakes of KAZ

Figure 3-23: Xiangtou River (left one is in KAZ, right one is in the Zhengyi town)

Figure 3-25: Yangcheng Lake (left) and Kuilei Lake (right)

3.2.2 Water Quality of Neighbour Lakes and Rivers

Yangcheng Lake, Manli Lake (upstream of KAZ) and Loujiang River (downstream of KAZ) and Kuilei Lake (nearby KAZ) water quality is shown in Table 3-2. The surface water quality is decreasing year by year during 2001-2003. Till 2003, the quality only reached the Chinese national Grade V (explanation is shown on Appendix 5), which is only satisfactory for agricultural irrigation.

The one reason perhaps is the over feeding crab and fish in Yangcheng Lake, the faeces of crab and the dead crab body may pollute the Lake. The other reason may possibly connect with Taihu Lake, which connects with Yangcheng Lake indirectly. Due to the pollution of Taihu is more serious than before, recently, it may affect water quality of Yangcheng Lake.

The water quality of Xiangtou River is likely to deteriorate further in the coming years. In other words, the quality of surface water at KAZ would be worse than now, because all of surface water at KAZ comes from Xiangtou River.

Table 3-2: The main average annual pollutants of surface water near KAZ from 2001 to 2003 (Gu, 2004)[a]

(unit： mg/L)

Name	Year	DO	COD_{Mn}	BOD	NH_3-N	VP	TN	TP	Grade
Yangcheng Lake	2001	8.6	4.2	2.1	0.11	0.001	1.49	0.05	IV
	2002	8.0	5.1	2.8	0.19	0.001	1.26	0.05	IV
	2003	7.8	5.4	2.4	0.34	0.001	1.90	0.04	V
Loujiang River	2001	4.4	6.2	3.9	1.72	0.002	-	-	V
	2002	2.8	6.5	5.0	1.36	0.002	-	-	IV
	2003	4.6	7.0	5.4	1.85	0.002	-	0.27	V
Kuilei Lake	2001	9.1	4.1	2.1	0.11	0.001	1.18	0.04	IV
	2002	8.3	4.8	2.3	0.27	0.001	1.62	0.05	V
	2003	8.0	5.3	2.5	0.27	0.001	1.80	0.04	V
Manli Lake	2001	7.4	5.2	2.1	0.22	0.001	-	-	-
	2002	8.2	5.3	1.7	0.53	0.002	-	-	-
	2003	8.0	5.5	2.3	0.35	0.001	-	-	-

[a] Explanation:

- DO (Dissolved Oxygen), COD_{Mn} (Chemical Oxygen Demand–measured by Permanganese method, it different from COD_{Cr}, measured by Dichromate method), BOD (Bio-chemical Oxygen Demand), NH_3-N (Ammonia Nitrogen), VP (Volatility Phenol), TN (Total Nitrogen), TP (Total Phosphorous).
- Above "grade" is Chinese national standard of surface water (see Appendix 5, "V" is lowest level, "I" is highest level).

3.3 Development Planning of KAZ

3.3.1 Vision of Honor Power Foundation

The Kunshan Aqua Zone is administered by Kunshan Saint Means Biotech. Co. LTD. which is funded by Honor Power Foundation, HPF as short.

The vision of HPF is promoting the development of human being depending on the idea of balance and harmony. It plans to do a series of demonstrated projects in China in order to alleviate the problem of overuse of the earth. (see www.honorpower.com)

The main mission of HPF is protecting the environment, growing together, and improving value. Specifically speaking, protecting environment means saving our planet, resuming natural resources, controlling diseases by practices; growing together emphasizes on the balance and harmony of life space by the method of inspiration chatting and symposium; the final goal of improving value is upgrading the whole world economic benefits by international economic and trade centre. (see www.honorpower.com)

3.3.2 The Mission of KAZ Project

The conceptual Master Plan of KAZ Project is being designed based on an integrated approach for an ecologically sustainable tourist facility, adjacent to the existing Kunshan City. The overall theme of this facility is "water" (from Oesha Ramsundersingh's PPT presentation at Shanghai in 24th Oct. 2004)

The mission of this project was explained by Atem Ramsundersingh in KAZ project area on 17th July, 2004. It is to develop an educational space, a place for educational purposes, for inspiration, and it should be based on experiences, people come to experiences themselves, rather than they have to read the book to believe. KAZ will be an area which should rebalance the water and land resources in every physical and non-physical aspects of life.

The mission also can be explained as: rebalancing water and land resources as an educative, inspiring, and experiential example for balance and harmony the physical and non-physical aspects of life in a sustainable way. Physical aspect includes human being, the nature, and all the physical resources, whereas, non-physical aspects comprises mental, health, mental being, and the well-being to connect with these resources.

3.3.3 The Proposed Design of KAZ

The description about proposed design comes from Oesha Ramsundersingh's internal report for 1st draft design of KAZ at Shanghai in October, 2004. As shown in Figure 3-27, and Table 3-3, there are five main buildings in KAZ, the total area of which is approximate 52 ha. Most of the buildings will be built very close to the water. Almost 40% of the area is covered by water in KAZ.

The northeast quadrant is international conference/water education centre. The suggestion of the design for this centre is based on the reference project Jean Marie Tjibaou Cultural Centre Noumea (New Caledonia, South Pacific). The centre consists of conference rooms, a library, temporary and permanent exhibitions, offices, and a large auditorium. In the conference centre one finds temporary and permanent exhibitions focused on the information on water, water use, water research, water treatment. The main theme will be about water in China, especially the water system in the area of the Taihu Lake Basin.

The north part is cottages area, residential spots, where people can stay if they want.

The northwest quadrant is wellness centre. The suggestion for the design of the wellness centre is based on the Classical Chinese Garden in Jiangsu Province, the Jiangnan Gardens which are centred in the network of water areas of Tai Hu. The references are to the nine gardens in Suzhou, which are inscribed in the World Heritage List of UNESCO. The central theme is balancing the body and mind with ancient treatment and therapy; this is done with emphasis on the medicinal use of Chinese flora.

The southwest quadrant is flora exhibition centre. The suggestion of the design of the flora exhibition centre is the shape of two halves of a lotus with in total seven petals, inspired by the reference project Lotus Temple in Delhi (India). A lotus flower opens its petals for people to collect knowledge about the central theme, Chinese flora. Linked with this centre are also the flowers and herbs fields around the centre.

The centre area is culture tower. It can offer tourists information of KAZ and showing traditional Chinese culture, customs and theatre. The tower is highest building in KAZ, on the top of tower, visitors can watch panorama of KAZ. Culture centre with a very nice design tower symbolizes the connection between human being and heaven.

The southeast quadrant of the area is not part of KAZ.

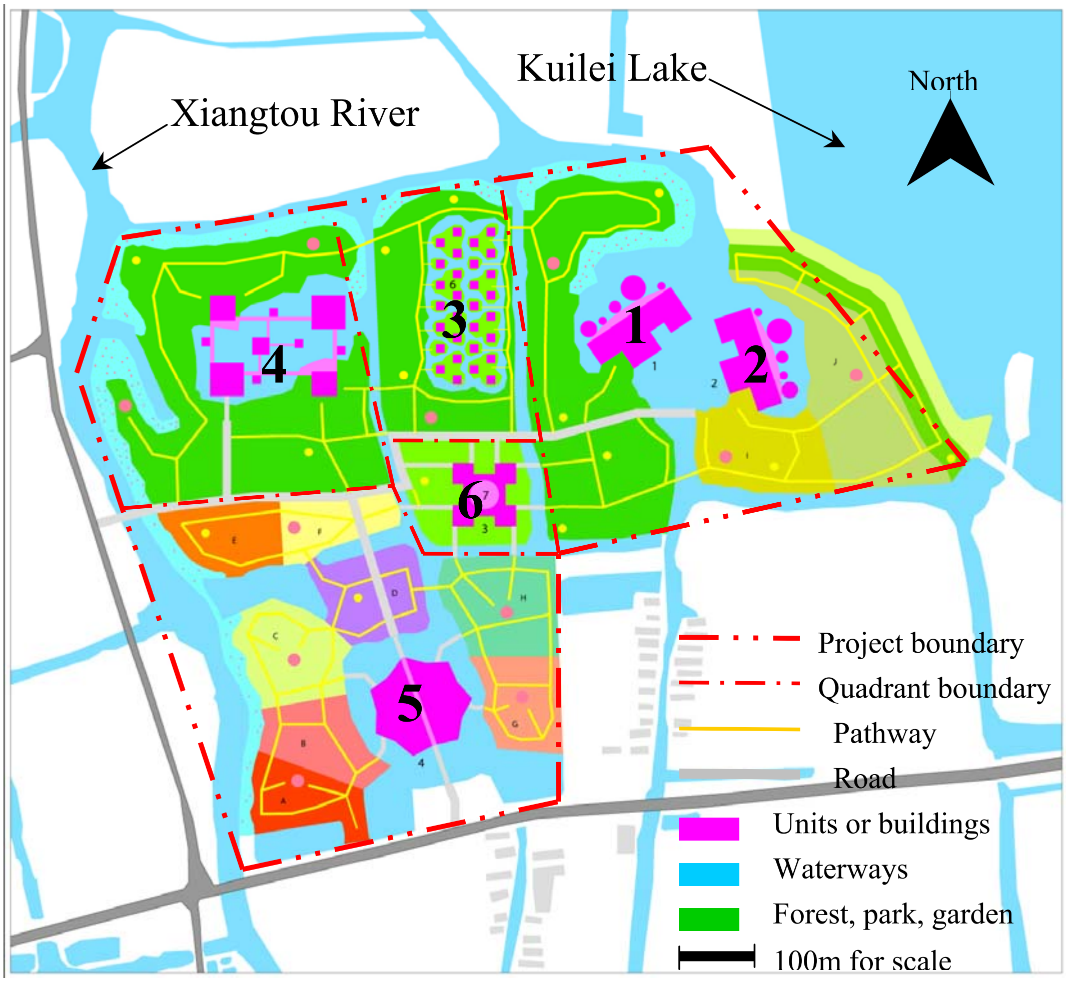

Figure 3-27:The conceptual Master Plan for KAZ

Table 3-3: The function of each building in KAZ

No.	Name of building	Quadrant	Area (L*W)	Function
1	Conference centre	Northeast	7.2ha (160m*450m)	Facilitate meetings according to the "innovative/creative" methods
2	Water education centre	Northeast	10.5ha (350m*300m)	Facilitate education about water in China
3	Cottages area	North	4.8ha (160m*300m)	Accommodation for Overnight guests
4	Wellness centre	Northwest	10.5ha (300m*350m)	Provide a total care process of body and mind according to Chinese healing methods
5	Floral exhibition centre	Southwest	16.8ha (420m*400m)	Exhibit traditional Chinese flora and herbs
6	Culture centre tower	Centre	2.1ha (150m*140m)	Show the traditional Chinese culture, custom and theatre

3.3.4 Predicted Number of visitor in KAZ

Discussed with KAZ designers at KAZ in November 2004, the estimated Number of visitor is around 800,000 per year; detail is shown Table 3-4.

The Number of visitor would vary with seasons. More visitors like to visit there during the summer time. The peak perhaps would be much higher than the average in Chinese public holiday, such as in the beginning of May and October. Nevertheless, the average amount is important data for wastewater design calculations. Later, all calculation connected with person number will use the average number.

Table 3-4: Estimated person number in KAZ[a]

	Conference centre	Education centre	Cabin area	Wellness centre	Flora centre	Culture tower	Total
Overnight visitor/d	0	0	200	0	0	0	**200**
Day visitor/d	100	200	0	0	100	100	**500**
Half Day visitor/d	100	300	0	250	400	400	**1450**
Average visitor/d	200	500	200	250	500	500	**2150**

[a] Explanation:

- The number of Overnight, day, and half day staff is included in that of Overnight, day, and half day visitor, respectively.

3.3.5 Predicted Quantity of Organic Solid Waste

In Kunshan area, around 400 kilogram organic solid waste is produced per day. The calculation is shown in Table 3-5.

Table 3-5: Amount of organic solid waste produced in KAZ[a]

Items	Organic waste (kg/d/c)	Person number (c/d)	Organic waste amount (kg/d)
Overnight visitor	**0.5**	200	100
Day visitor	**0.3**	500	150
Half Day visitor	**0.1**	1450	145
Total	-	2150	**395**

[a] Assume:

- The Overnight visitor would produce 1.0 kg solid waste per day (Li *et.al*, 2004)
- 50% solid waste is for organic solid waste is assumed.
- Person number is shown in Table 3-4.

3.4 Sustainability of KAZ for Ecosan Project

It is believed that KAZ would be a suitable place for an ecosan demonstrated project.

1. KAZ would attract more visitors
   - The visitors can access to KAZ easily, since there are convenient transport links

between Shanghai/Suzhou and KAZ.

- It would like to visit KAZ, not only for attraction at KAZ, but also for delicious Yangcheng Lake crabs.
- As the fist full-scale ecosan project at a conference centre/tourist resort in China, it would attract more scholars, experts, engineers, students, and tourists to visit or hold the conference/symposium at KAZ.

2. The local customs and climate is suitable for ecosan project
   - It is easy for surrounding farmers to accept the ecosan concept, because recycling toilet waste as fertilizer in agriculture is custom in China.
   - Abundant water plants will offer the more chooses for constructed wetlands.
   - Humid climate is suitable for urine storage, faeces sanitization. Especially, the relatively warm climate (e.g. little snow fall, few freezing days) is appropriate for using constructed wetlands for grey water treatment.
3. The development plan also matches with applying ecosan concept at KAZ
   - Using ecosan principle at KAZ fits perfectly with the overall aim and vision of HPF, who is funding the project.
   - The mission involving with this project is developing a demonstration project, which will show the visitors an ecological and sustainable approach of using water.

4 Two Scenarios for Sanitation System in KAZ

4.1 Common Calculations and Introductions for Both Scenarios

4.1.1 Predicted Domestic Water Consumption in KAZ

The average times of domestic water using activities in KAZ are varied by different types of persons (see Table 4-1).

Table 4-1: The average times of different domestic water uses for each type person in KAZ (time/c/d)[a]

Activities	Drinking	Cooking	Urine flush	Faeces flush	Hand wash	Face clean	Bath / shower	Laundry	Other
Overnight	8	3	4	1	8	2	1	0.2	1
Day	4	1	2	0.3	3.3	0	0	0	0.5
Half day	2	0	1	0.1	1.1	0	0.2	0	0.3

[a] Explanation:

- Average times for water consumption is assumed based on daily knowledge in China, such as: most of people need eat three times per day, take 4 urines and 1 faeces per day, clean hands after toilet and before eating, wash faces before and after the sleep, take shower/bath once per day, wash clothes once per week.
- Above "Cooking" includes all activities related with cook, such as food cleaning, and dishes washing.
- Above, "Other" means the other unmentioned water using activities.

The domestic water consumption amount depends on the water equipments. That means, if water saving equipments are used, the water consumption should be less than conventional one. Also in both scenarios, the domestic water consumption amount should be different, because the different types of toilets would be equipped. As presented in section 2.3.1.3, the low-flush urine diversion toilets are recommended in scenario 2.

4.1.2 Predicted Quantity of Storm Water/Run-off

4.1.2.1 Predicted Catchment's Area for Storm Water in KAZ

As shown in Table 4-3 and Figure 4-1, there are three types of surface area in KAZ. Although the total surface water area is 20 ha, the storm water contributing to this area can not be collected by pipes. Actually, the 6 ha building area (including road, pathway, and bridge area) and 27 ha plant area belong to storm water catchment's area.

Table 4-3: The area distribution of KAZ[a]

Area (ha)	Conference centre	Education centre	Cabins area	Wellness centre	Flora centre	Culture tower	Total
Surface water area	2.4	2.1	1.2	5.7	7.8	0.3	20
Building area	1.2	1.2	0.1	1	1.8	0.6	6
Garden area	3.6	7.2	3.5	3.8	7.2	1.2	27
Total area	7.2	10.5	4.8	10.5	16.8	2.1	52

[a] Explanation:

- Surface water area is the area of the rivers and channels within in KAZ
- Building area includes the building, pavilion, street, pathway, and bridge area.
- Garden area means the area of trees, flowers, herbs and grass.
- The area of each building is measured from Figure 3-27.

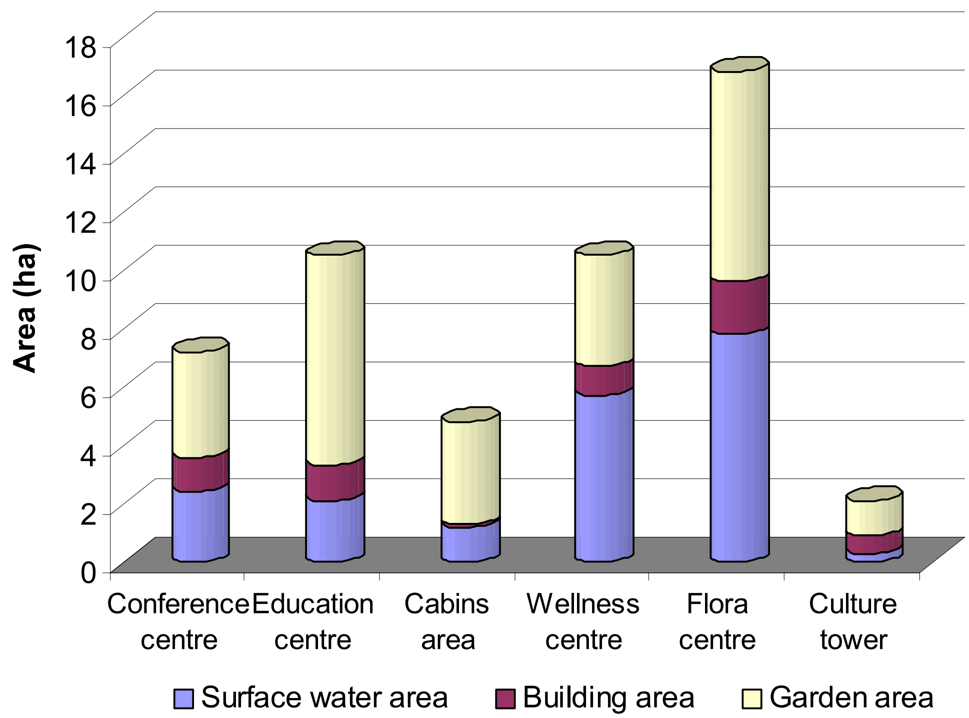

Figure 4-1: The cylinder chart for area distribution in KAZ

4.1.2.2 Predicted Quantity of Storm Water in KAZ

The estimated amount of rainfall is around 585,000 cubic meters per year in KAZ (see Table 4-4).

Table 4-4: Predicted quantity of rainfall in KAZ[a]

	A (ha)	p (mm/y)	r	Q (10^3 m^3/y)	Q_C (10^3 m^3/y)
Surface water area	20	1,127	-	220	-
Building area	6	1,127	0.7	66	47
Garden area	27	1,127	0.2	299	60
Total	52	1,127	-	**585**	-

[a] Explanation:

- The catchment's area (A) can be got from Table 4-3
- The annual precipitation (p) comes from section 3.1.2
- Run off coefficient (r) can be got from Appendix 6, based on the cement tile roofs, the concrete lined street ground in the building area, and the compacted loess soil in the garden area (see section 3.1.3).
- Rainfall/catchment's storm water calculation equations are shown on below:

  Q = A * p
  Q: Rainfall
  A: Catchment's area
  p: Annual precipitation

  Q_C = A* r * p (Mbugua, 2002)
  Q_C: Catchment's storm water amount
  A: Catchment's area
  r: Run off coefficient
  p: Annual precipitation

Actually, it is very difficult to catch the rain which falls into the surface water. Hence the rain catchment's area is the building area and the garden area in KAZ. The total catchment's storm water amount is 106 m^3/y, which is equal to 47,000 m^3/y in building area (Table 4-4) plus 60,000 m^3/y in garden area (Table 4-4).

In the garden area, most of storm water would infiltrate into soil. Based on ignoring the ground water influence, the infiltration storm water is 239 m^3/y, which is equal to 299,000 m^3/y (total rainfall) (Table 4-4) minus 60 m^3/y (catchment's storm water amount) (Table 4-4).

Except for catchment's storm water and infiltration storm water, the rest is uncollected storm water, 240 m^3/y. The uncollected storm water is discharged into surface water directly or indirectly.

As shown in Figure 4-3, the total storm water can be divided into three parts. Around 20 percent (106 m^3/y) storm water could be collected by pipes in both building and garden area. Around 40 percent (239 m^3/y) would infiltrate into the soil in garden area, and another 40 percent (240 m^3/y) would be discharged into the surface water body in KAZ.

In order to simplify the calculation, assume the average daily rainfall equal annual rainfall divided by 356. That means there is 1600 m^3/d rainfall, including 291 m^3/d collected storm water, 655 m^3/d infiltrated storm water, 657 m^3/d discharged storm water in KAZ.

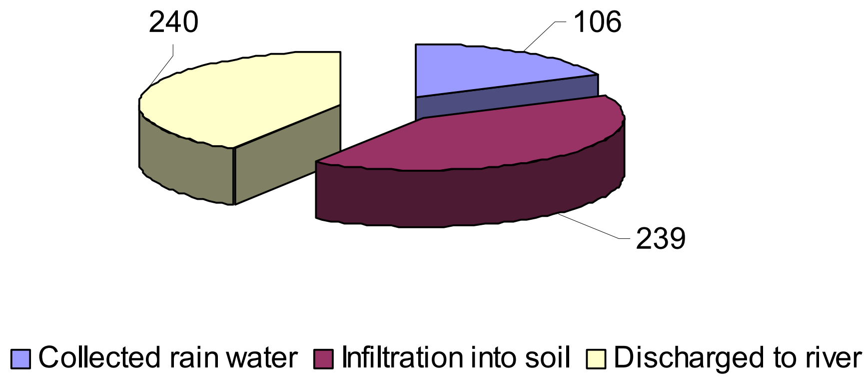

Figure 4-3: The storm water distribution (10^3 m^3/y)

4.1.3 Predicted Water Consumption for Irrigating Garden in KAZ

Generally speaking, the water quantity for irrigating the garden and the irrigating frequency are varied by types of grass and flowers, also they are varied by seasons, by water irrigation habits. In conceptual master plan phase of KAZ, it is enough to predicate the approximate amount. Therefore, average daily water consumption would be used for calculation.

Around 930m^3/ha/d water would be consumed in the 27 ha garden area (Table 4-3) based on average water consumption for irrigating garden is 35 m^3/ha/d (Waskom and Neibauer, 2005). Fortunately, the infiltrated storm water could water garden as well as irrigating water. So the garden area only needs about 270 m^3/d irrigating water. (Needed irrigating water = total water amount for irrigating garden – infiltrated storm water = 930 m^3/ha/d – 655 m^3/ha/d (see Figure 4-3) = 273 m^3/ha/d)

4.1.4 Predicted Quantity of Nitrogen Production in KAZ

As calculated in Table 4-6, around 11.2 kg nitrogen would be produced in KAZ per day based on the assumption of the amount of nitrogen production in KAZ is 14.5 g, 6.8 g, 3.4 g for Overnight, day, half Day visitor per day (see Table 4-5).

11.2 kg/d nitrogen is produced means more than 4,000 kg nitrogen would be produced in KAZ per year, which can be used for 40 ha garden area or 36 ha agriculture area (if garden area, agriculture area need 100 kg/ha/y, 112 kg/ha/y nitrogen fertilizer (Pinsem and Winneras, 2003), respectively). In other words, around 5.3 kg the nitrogen, which is produced by one over night person per year, can be used for 530 m^2 garden area or 470 m^2 agriculture area.

Table 4-5: Human nitrogen production (g/c/d)[a]

Visitor types	Yellow water	Brown water	Grey water	Green waste	Total
Overnight visitor	11.0	1.5	0.5	1.5	**14.5**
Day visitor	5.5	0.5	0.3	0.6	**6.8**
Half Day visitor	2.8	0.2	0.2	0.3	**3.4**

[a] Explanation:

- The nitrogen production for Overnight visitor is presented in Table 2-7.
- Based on different times for domestic water use activities distributing (see Table 4-1), Day visitor and half Day visitor nitrogen production is assumed. For example, Day visitor need 2 times urine per day, while Overnight visitor need 4, so the Day visitor only contributes 50% nitrogen to yellow water, compared with Overnight visitor.

Table 4-6: The amount of human nitrogen production in KAZ (kg/d)[a]

Visitor types	Yellow water	Brown water	Grey water	Green waste	Total
Overnight visitor	2.2	0.3	0.1	0.3	-
Day visitor	2.8	0.2	0.1	0.3	-
Half Day visitor	4.0	0.2	0.2	0.4	-
Total	8.9	0.7	0.4	1.0	**11.2**

[a] Explanation:

- Based on Table 3-4, the number of Overnight visitor, Day visitor, and half Day visitor is 200, 500, 1450 capita per day in KAZ.
- The amount of nitrogen production per capita is shown in Table 4-5.
- The amount of nitrogen (kg/d) = Number of visitor (c/d)* The amount of nitrogen production per capita (g/c/d).* 10^{-3} kg/g. For example, the amount nitrogen from yellow water contributed by Day visitor = 500 c/d * 5.5 g/c/d * 10^{-3} kg/g = 2.8 kg/d.

As shown in Figure 4-5, around 80% nitrogen comes from the urine (yellow water), while the faeces (brown water), the grey water, and the organic solid waste (green waste) are only contributing 7%, 4%, and 9% nitrogen, respectively.

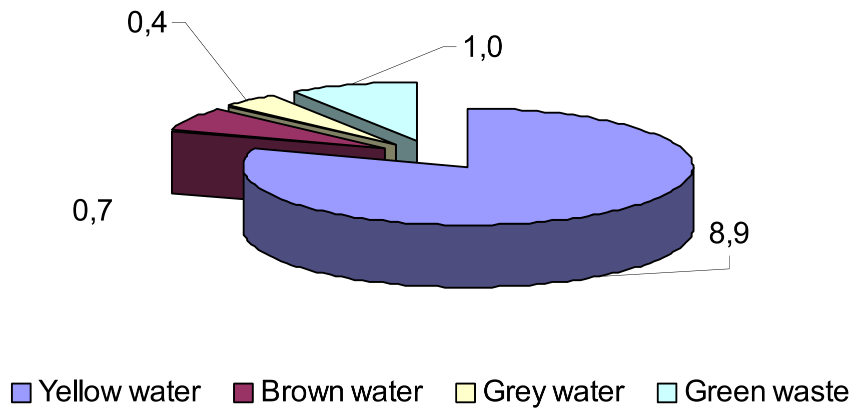

Figure 4-5: Estimated nitrogen production distribution in KAZ (kg/d)

4.1.5 Principles of Mass Balance Analysis for Both Scenarios

The general mass balance for a system consists of four components. It describes the accumulation of mass in the system as function of the mass input into the system, mass output from the system and mass transformation in the system:

Accumulation = Input – Output + Transformation

The exchange of mass between a system and its surroundings occurs through the system boundaries (Bijlsma, 1999).

In KAZ, the "system boundaries" is defined as the boundaries of KAZ, as shown in Figure 3-6 or Figure 3-27. Based on the neglect of the influences of groundwater and surface water, based on the assumption of the all infiltrated storm water can be consumed by plants, also based on the assumption of there is no water/nitrogen loss during transformation processes, the meanings of each factor are describes as following:

For water flow balance:

- The "Input" is described as the flow of supplied water,
- The "Output" is described as the flow of discharged water,
- The "Transformation" is described as the water consumption of water by plants in KAZ,
- The "Accumulation" term is zero, because only steady state situation is considered.

For nitrogen balance:

- The "Input" is described as the amount of nitrogen produced by person in KAZ
- The "Output" is described as the amount of nitrogen discharged and consumed outside KAZ
- The "Transformation" is described as the amount by nitrogen consumed by plants in KAZ
- The "Accumulation" term is zero, because only steady state situation is considered.

Due to "Transformation" in KAZ means the water/nitrogen is transformed into plants, the direction of "Transformation" is negative. The formula is corrected as below without direction.

Output = Input – Transformation

There are detailed water flow balance and nitrogen balance analyses for both scenarios in section 4.2.2, 4.2.3, 4.3.2, and 4.3.3.

4.2 Scenario 1—Conventional System: Grey and Black Water Combined

4.2.1 Concept Design

In KAZ, the conventional system could be designed that the different types of household wastewater are mixed and then transported by sewer system to municipal centralized wastewater treatment plant (WWTP). After primary and secondary treatment in WWTP, it is discharged into the Loujiang River. Storm water can be conveyed by storm water pipes to nearby streams or channels. These storm water pipes would be connected with the roof cutters of building and the surfaces of roads, pathways. As shown in Figure 4-7, besides using for drinking and cooking, the potable water also is used for toilet flush, washing, shower and irrigation, while wastewater and storm water is flushed and discharged to the rivers.

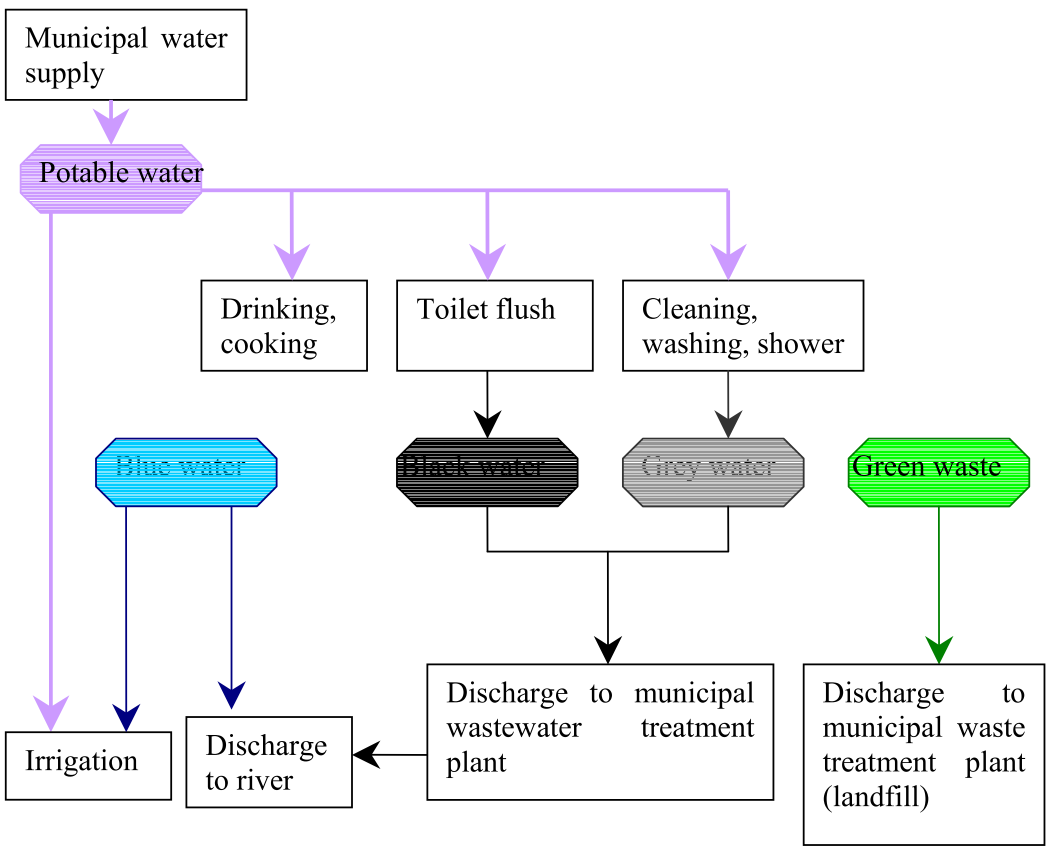

Figure 4-7: Schematic diagram for water flow of scenario 1 in KAZ

In KAZ, the conventional sewer system can be design as Figure 4-9, Figure 4-11. The all of wastewater coming from each toilet, kitchen and shower room is collected by sewer system in KAZ, and then be transported to municipal wastewater treatment plant. The storm water collected from roof cutters and roads is discharged into nearby streams and channels directly. The surface water body would play a storm water sewer role in KAZ.

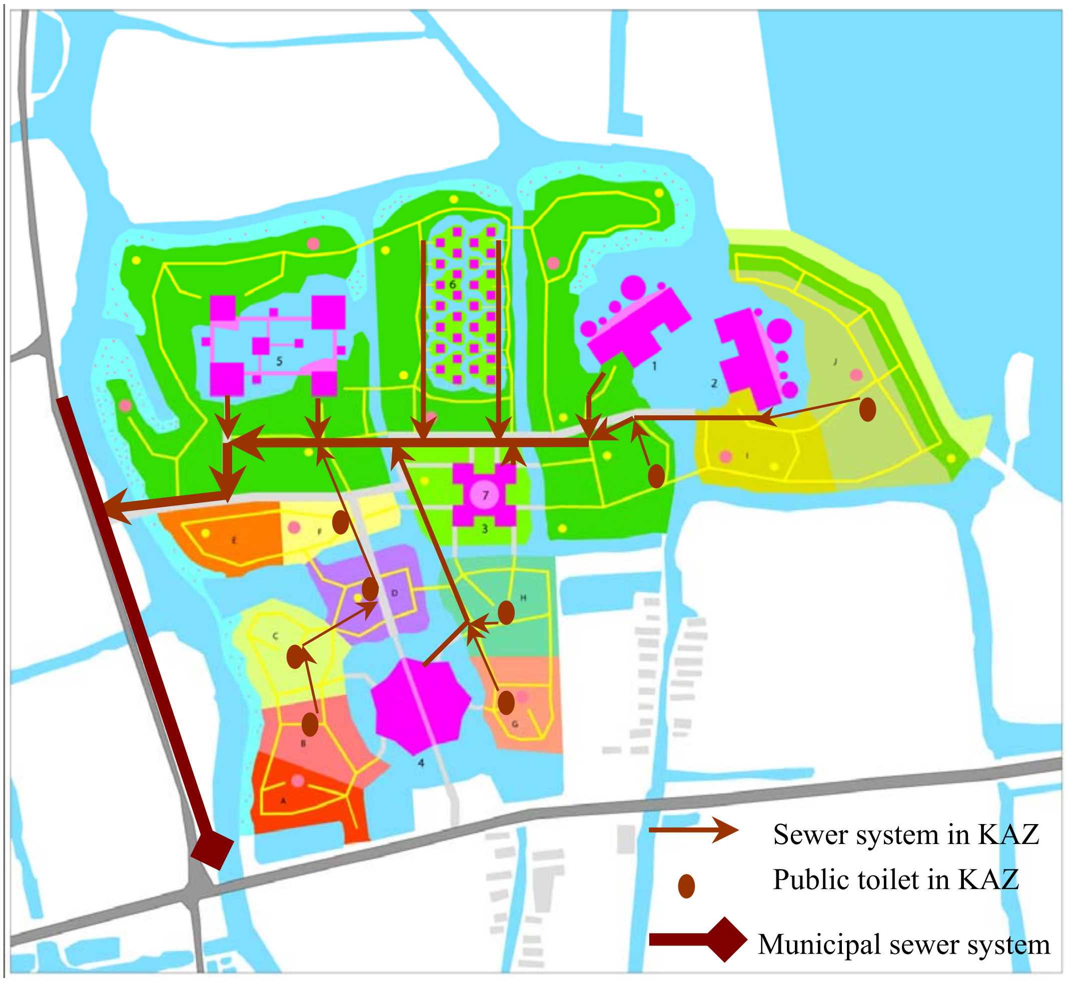

Figure 4-9:The sketch sewer design for scenario 1 in KAZ

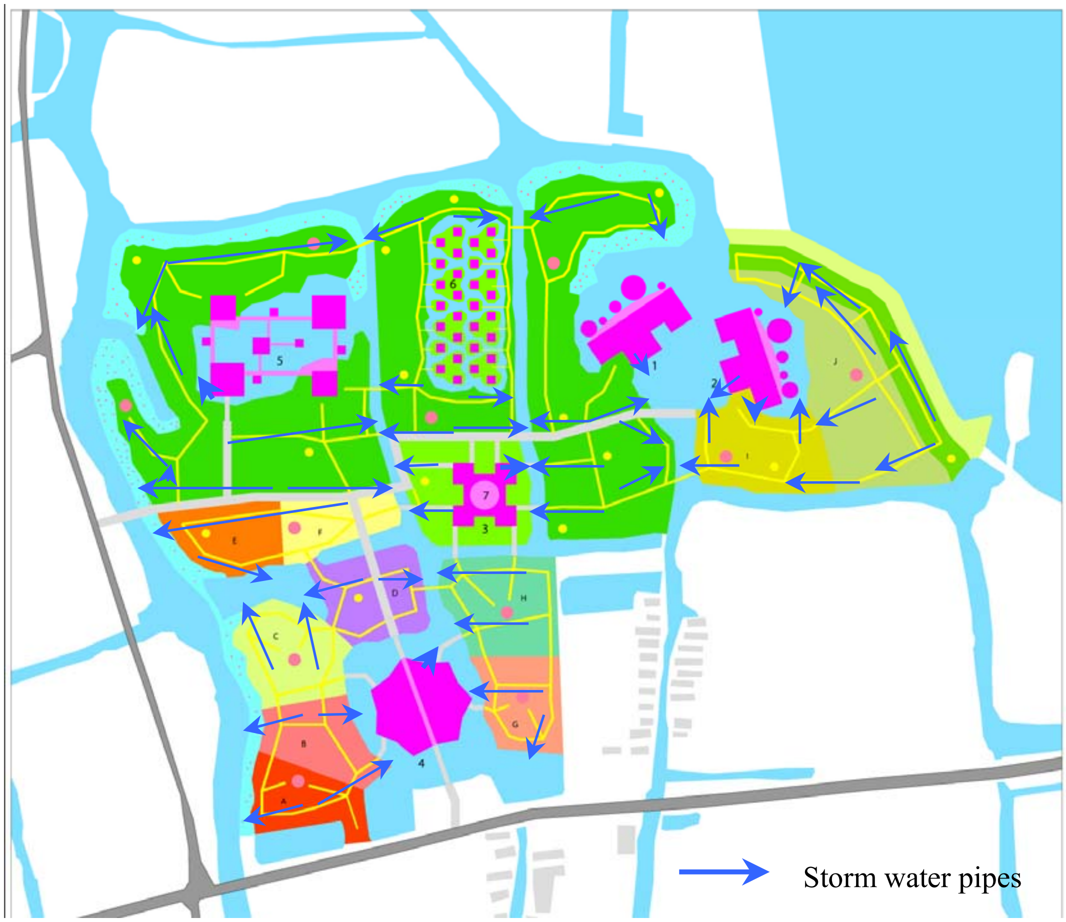

Figure 4-11: The sketch storm water sewer design for scenario 1 in KAZ

4.2.2 Water Flow Balance

4.2.2.1 Predicted Water Consumption

The total volume of domestic water consumption is calculated in Table 4-9, around 120 m^3/d domestic water is needed in KAZ, based on 211L/c/d, 41 L/c/d, and 37 L/c/d water for Overnight, day and half Day visitor, respectively (see Table 4-8).

Table 4-7:Domestic unit water consumption for scenario 1 (L/c/time)[a]

Activities	Drin king	Cooki ng	Urine flush	Faece s flush	Hand wash	Face clean	Bath/ shower	Lan udry	Other
Volume	0.25	5	9	9	2	3	100	60	15

[a] Explanation:

- Based on Trifunovic (2003), the domestic unit water consumption is assumed as shown above.
- Above "cooking activity" includes the food preparation and dish washing.
- Above "Other" is un-mentioned water consumption in this table.

Table 4-8: Water consumption for domestic uses in scenario 1 (L/c/d)[a]

Activities	Drinking	Cooking	Urine flush	Faeces flush	Hand wash	Face clean	Bath/shower	Laundry	Other	Total
Overnight visitor	2	15	36	9	16	6	100	12	15	**211**
Day visitor	1	5	18	2.7	6.6	0	0	0	7.5	**41**
Half Day visitor	0.5	0	9	0.9	2.2	0	20	0	4.5	**37**

[a] Explanation:

- The water consumption for ach activity (L/c/d)= Domestic unit water consumption (L/c/time) * Times of each activity (t/c/d)
- Domestic unit water consumption is based on Table 4-7.
- Times of each activity are shown in Table 4-1.

Table 4-9: Domestic water consumption for scenario 1 (m^3/d)[a]

Visitor types	Number of visitor (c/d)	Domestic water quantity (L/c/d)	Total water quantity (m^3/d)
Overnight visitor	200	211	42
Day visitor	500	41	20
Half Day visitor	1450	37	54
Person in KAZ	2150	-	**116**

[a] Explanation:

- Number of visitor can be got from Table 3-4.
- Domestic water quantity per person comes from Table 4-8.
- Total water quantity (m^3/y) = Number of visitor (c/d) * domestic water quantity per person (L/c/d) * 10^{-3} (m^3/L)

Compared with the domestic uses, the water consumption for irrigating garden would be much higher than domestic water. As shown in section 4.1.3, around 930 m^3/d irrigating water is needed. Hence, the distribution pan for water consumption in KAZ is drawn in Figure 4-13.

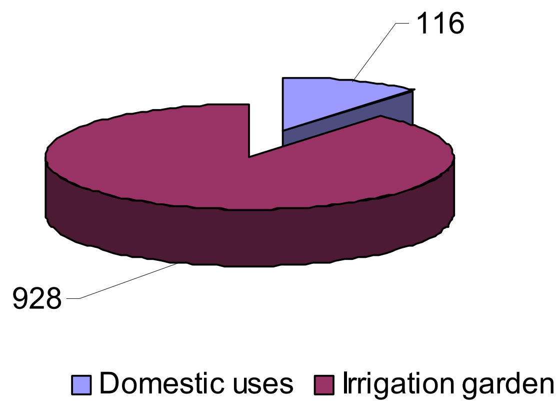

Figure 4-13: Estimated distribution of total water consumption for scenario 1 in KAZ (m^3/d)

To sum up, the total water consumption would be around 1,000 m^3/d water for KAZ, about 90 percent of which is irrigated the garden, while only 10 percent is consumed by domestic uses. All water should be supplied by municipal water supply or infiltrated storm water.

4.2.2.2 Predicted Wastewater Production Quantity and Quality

Conventional system, also can called as flush-and-discharge systems, requires large amounts of water for flushing (Winblad and Simpson-Hebert, 2004).

Ignoring the gap between human drinking water and human excreta, all the domestic uses water would be discharged to sewer system. Estimated wastewater production quantity is $116m^3/d$, which is equal to the domestic water consumption (Table 4-9). The classic wastewater includes all domestic wastewater for toilet flushing, face&hand cleaning, shower/bath, clothes washing, cooking, dish washing and room cleaning.

The wastewater quality of KAZ is predicted as following Table 4-10, based on the assumption of $116m^3/d$ wastewater produce (see Table 4-9) and daily 750 PE (the unit of Population Equivalent expresses the volume of wastewater produce, 1 PE is equal to daily 80 g COD, 60 g BOD, 70 SS, 13 g N, and 2 g P (Lens *et al*., 2001)).

As shown in Table 4-10, the estimated wastewater concentration is higher than hotel medial strength wastewater. The reason may be that most of visitors only urinate and defecate without bath/laundry in KAZ, the contaminates cannot be diluted.

Table 4-10: Estimated wastewater quality in KAZ for scenario 1 (mg/L)

Parameters	COD	BOD	SS	Nitrogen	Phosphorous
Estimated wastewater in KAZ	**517**	**390**	**450**	**85**	**13**
Hotel medial strength wastewater (Metcalf and Eddy, 2003)	430	190	210	40	7
Concentrated domestic wastewater (Lens *et al.*, 2001)	560	350	450	80	23

4.2.2.3 Water Flow Balance in KAZ

Based on the principles of section: 4.1.5, some water flow balance explanations for scenario 1 is presented:

- The input water flow is 2019 m^3/d, including 390 m^3/d water flow from municipal water supply and 1603 m^3/d storm water flow
- The output water flow is 1064 m^3/d, including 116 m^3/d wastewater and 948 m^3/d uncollected storm water
- The transformation water flow is 928 m^3/d, which is consumed by the plants in KAZ

The detail are drawn in Figure 4-15 and explained as following.

As presented in section 4.2.2.1 and Table 4-9, the total water consumption is around 1,040 m^3/d (116 m^3/d for domestic uses, 928 m^3/d for garden irrigation). The municipal water supply should offer 390m^3/d water, since the infiltrated storm water could contribute 655 m^3/d water to irrigate garden (Figure 4-3). So there are two types of water input for KAZ, 1603 m^3/d storm water flow, and 389m^3/d potable water flow from municipal water

The output water flow is 1064 m^3/d. Around 116 m^3/d wastewater is produced by domestic uses, so all of the domestic wastewater is discharged into the municipal wastewater treatment plant (WWTP) (see section 4.2.2.2), while 948 m^3/d storm water runs into the surface water body (see section 4.1.2.2 or Figure 4-3).

As presented in section 4.1.3, the total water consumption for garden plants is around 928 m^3/d. The infiltrated storm water could contribute 655 m^3/d water, and the municipal water supply would offer 273 m^3/d.

To sum up, there is no water flows recycle in scenario 1. The water is used, and then discharged as wastewater directly.

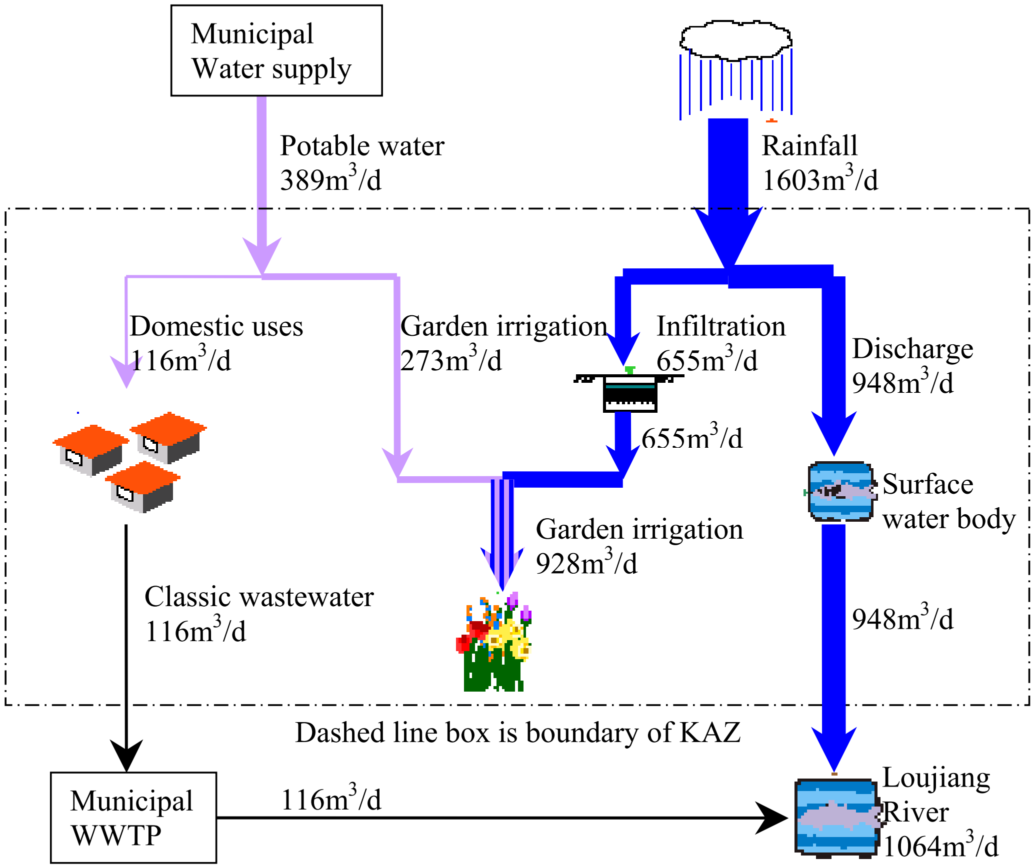

Figure 4-15: Water flow balance for scenario 1 in KAZ

4.2.3 Nitrogen Balance

Based on the principles of section: 4.1.5, some nitrogen balance explanations for scenario 1 is presented:

- The input nitrogen amount is 11.2 kg/d (see Table 4-6), including 8.9 kg/d nitrogen from human urine, 0.7 kg/d from human faeces, 0.4 kg/d from domestic grey water, and 1 kg/d from organic solid waste.
- The output nitrogen amount is also 11.2 kg/d, including 10.2 kg/d from domestic wastewater and 1 kg/d from organic waste.
- The transformation nitrogen would not exist.

The detail are drawn Figure 4-17 and explained as following.

The around 11.2 kg nitrogen is produced in KAZ per day. 10.2 kg nitrogen mixed with wastewater is discharged to municipal wastewater treatment plant (WWTP). After primary and secondary treatment, the effluence is discharged into the Loujiang River, and the sludge is used for agriculture.

1 kg nitrogen coming from organic solid waste is conveyed to municipal solid waste treatment plant (SWTP). In SWTP, the nitrogen is filled in the land.

To sum up, there is no nitrogen recycles for scenario 1 in KAZ. All nitrogen which is produced in KAZ is discharged to wastewater sewerage or conveyed to municipal solid waste treatment plant.

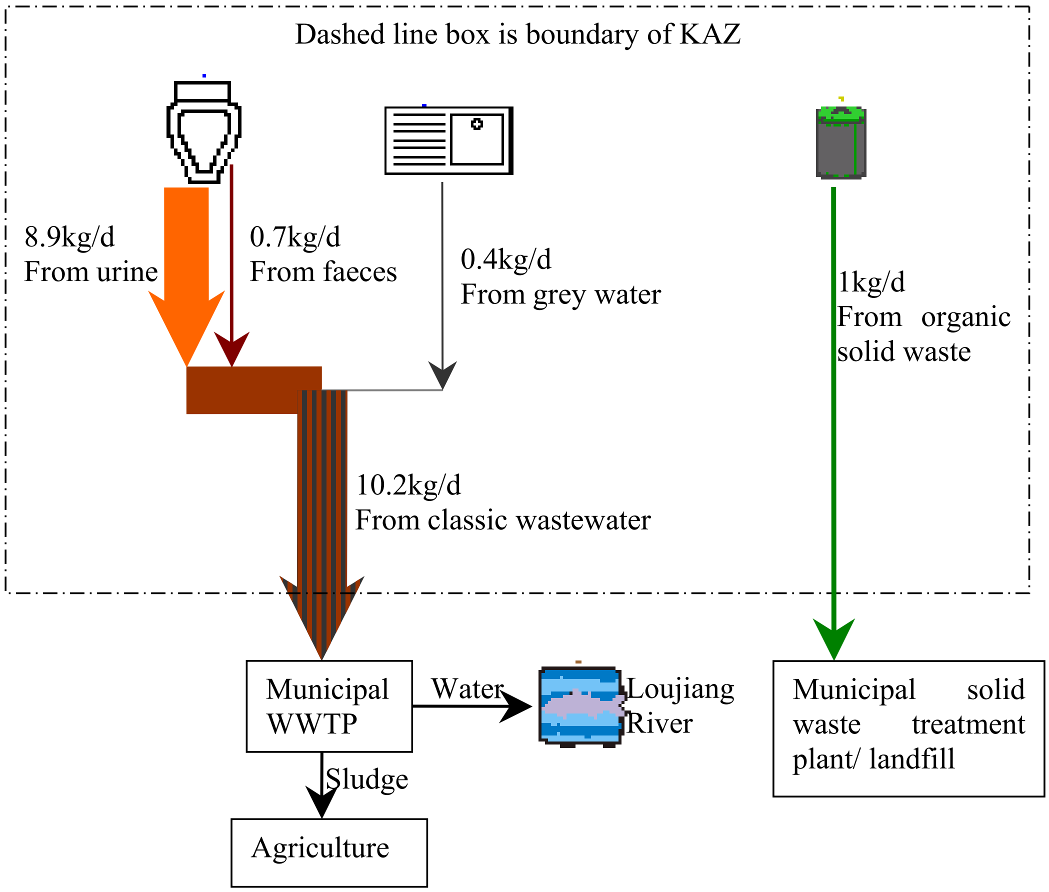

Figure 4-17: Nitrogen balance in KAZ for scenario 1

4.3 Scenario 2—Ecosan System: Grey, Yellow, and Brown Water Separated

4.3.1 Concept Design

Scenario 2 for the sustainable sanitation system at KAZ is ecosan system. Ecosan system is a sustainable ecological way to recycle the water. As shown in Figure 4-19, ecosan system at KAZ means separating different type wastewater at source, and then treating them by different technologies, finally, recycling water and nutrient.

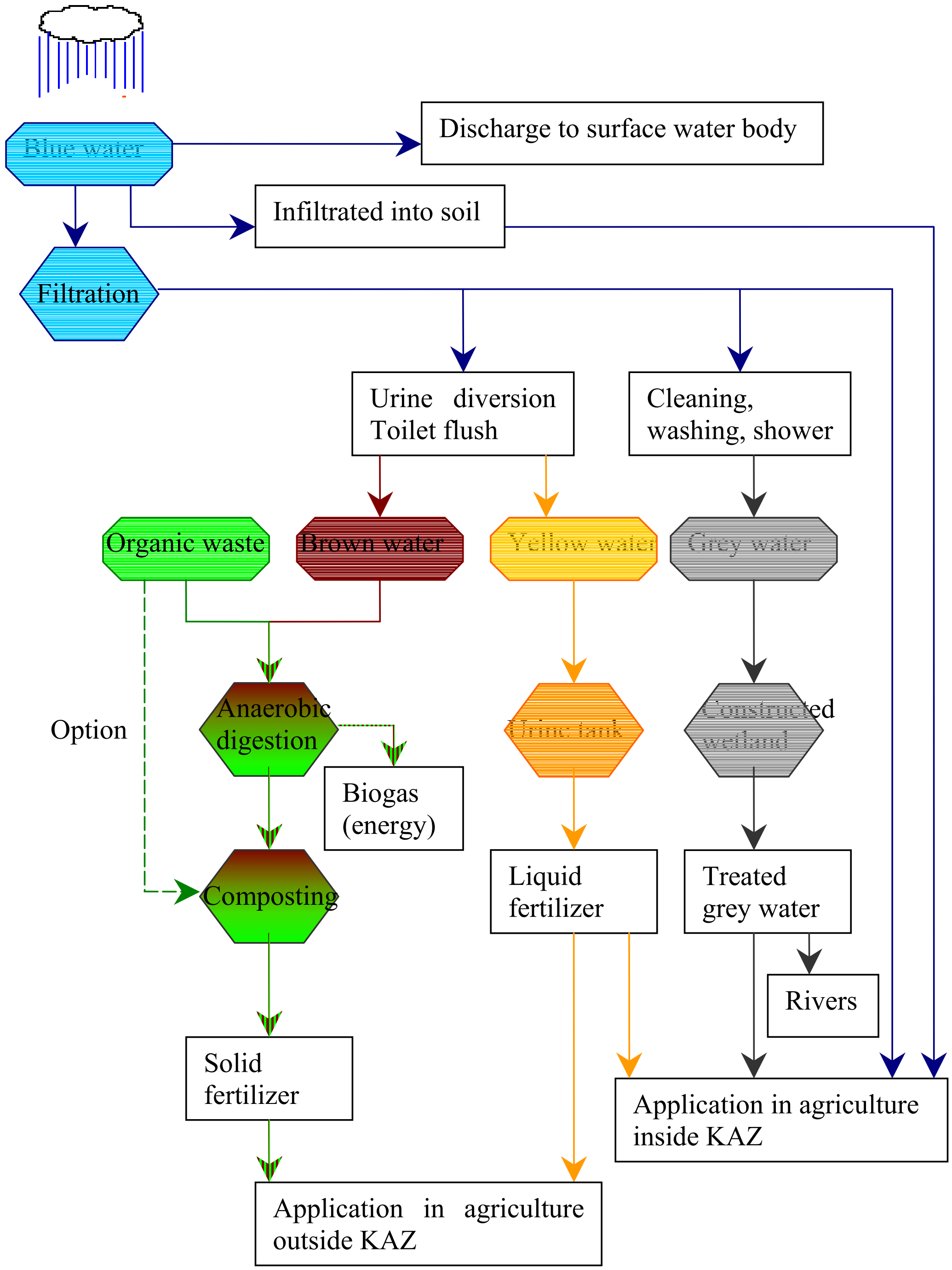

Figure 4-19: Schematic diagram of ecosan wastewater system in KAZ

In KAZ, the ecosan system should be designed as Figure 4-21 and Figure 4-23. There will be a "Water Processing Facility" (WPF).

The WPF is a treatment centre for yellow, brown, grey, blue water and green waste. All types of wastewater in KAZ are conveyed to WPF, and then are treated to reclaim or discharge into water body. The WPF is composed of a yellow water storage tank, a brow water digestion/composting plant, a grey treatment plant, and a blue water purified plant. Although the WPF is a wastewater treatment place, it would look totally different to the conventional wastewater treatment plant, since there is no smell, no too much noise. WPF would look like a garden.

The constructer wetland for grey water treatment looks beautiful, because a lot of water plants grow there, it shows the visitor the nature scenery. The yellow water tanks are constructed underground, their covers would be planted by the flowers, herbs and grasses. The brown water and green waste anaerobic digestion tanks and composting tanks would be paint colourfully, just like pavilions in the garden. The blue water filtration belt, looks like the pools. The storm water is purified by sand filtration, even membrane filtration technologies.

Ecosan project not only is sustainable, ecological, but also is beautiful and healthy.

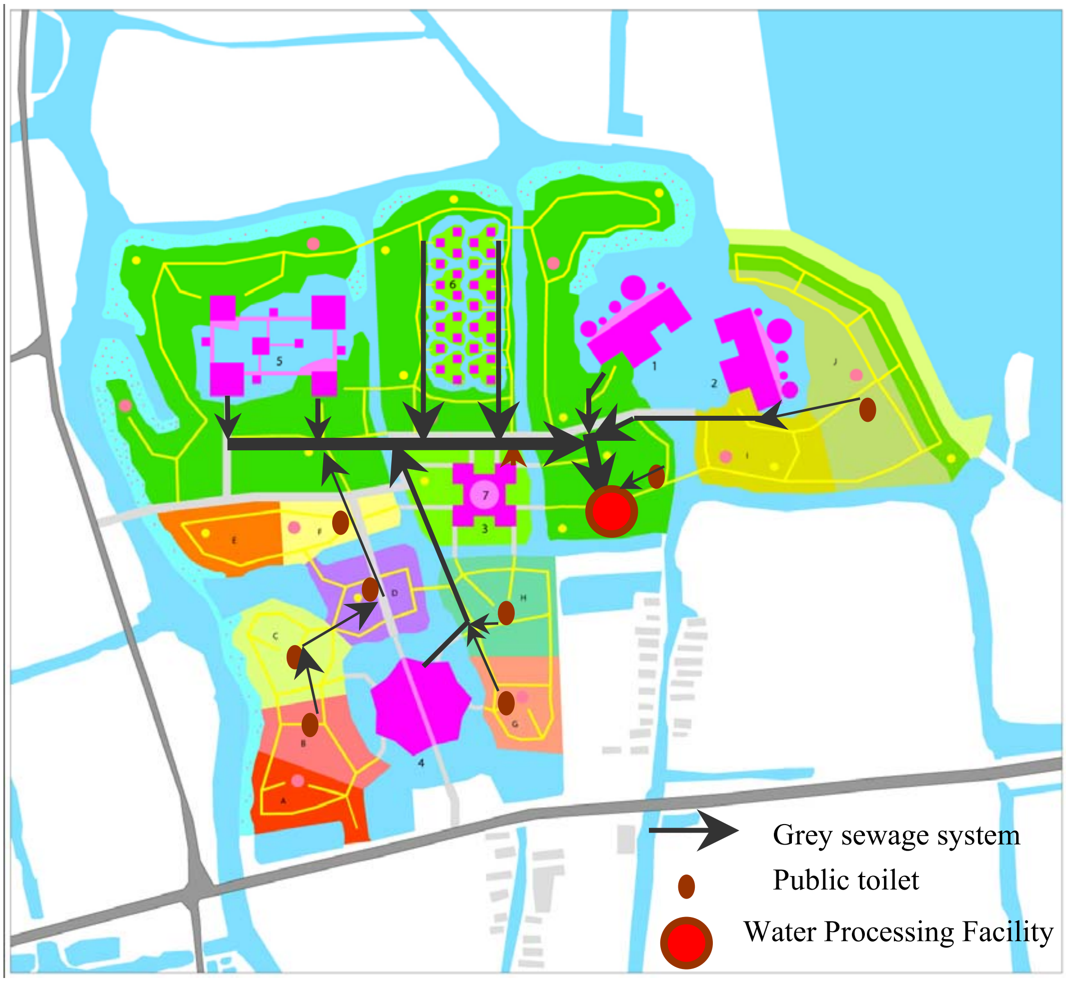

Figure 4-21:The sketch grey water sewer system design for scenario 2 in KAZ

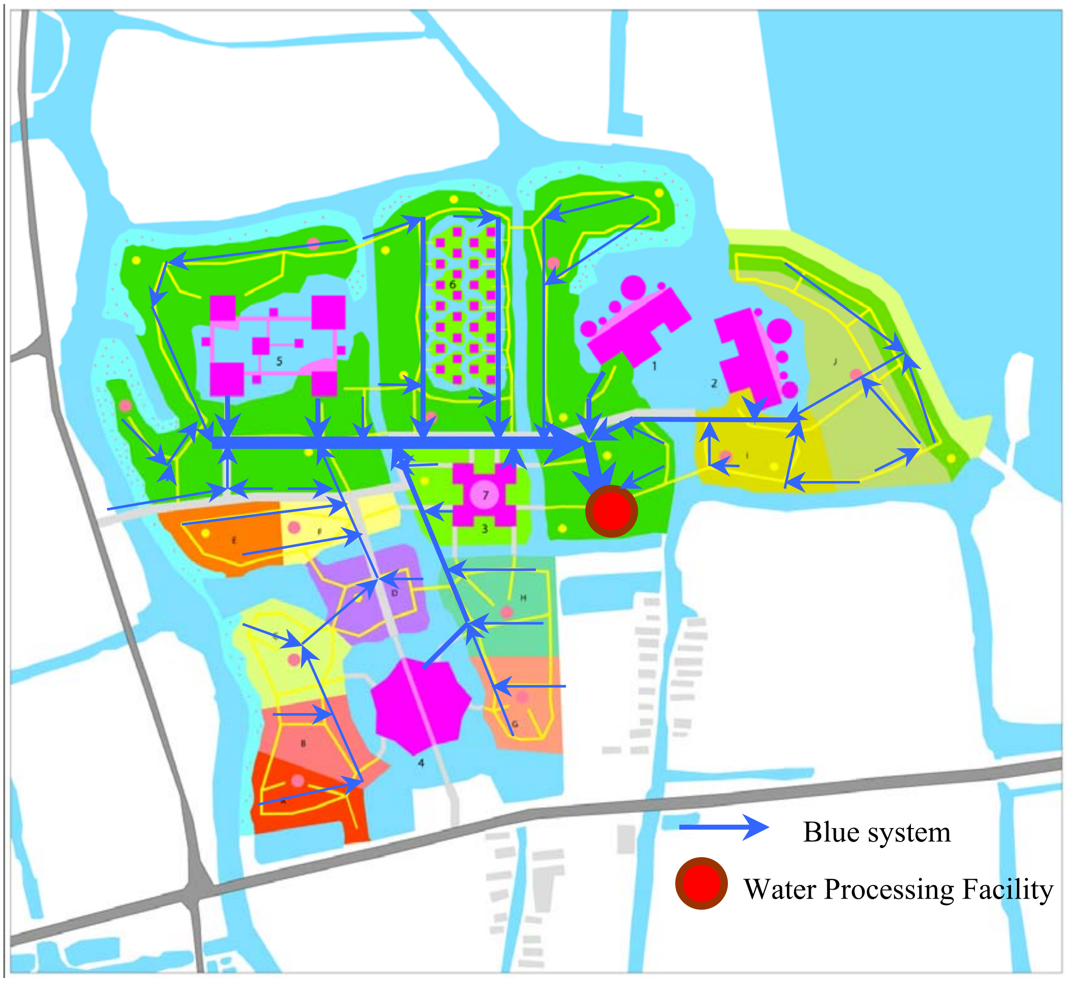

Figure 4-23:The sketch blue sewage system design for scenario 2 storm water in KAZ

4.3.1.1 Storm Water Design

As shown in Figure 4-19, after filtration and disinfection, the storm water is reclaimed to flush toilets, irrigate plants, clean streets, wash clothes, and so on. In the other words, the storm water can be used for domestic uses expect for drinking and cooking.

Just like storm water collection system in Nanjing Wanfuyuan Community (I visited there in November 2004 and took some pictures), the storm water can be collected from the surface of roads (Figure 4-25) and roof cutters of each building (Figure 4-27), and then transported by blue sewerage to WPF (Figure 4-23). In WPF, the blue water can be treated by the membrane filtration and disinfection process, then reuse as irrigating plants, flushing toilet, cleaning streets (Figure 4-29 left picture), scenery water (Figure 4-29 right picture), even can use as washing clothes and shower.

Based on the low maintenance and the large flow, the sedimentation and sand filtration are main processes for storm water. But other treatment processes, like coagulation, membrane filtration, disinfection could also be used before or after sand filtration to match with different requirments.

Figure 4-25: The storm water collection equipments for street in Nanjing Wanfuyuan Community

Figure 4-27: The storm water collection pipes for roofs in Nanjing Wanfuyuan Community

Figure 4-29: Reuse storm water for streets cleaning and for scenery in Nanjing Wanfuyuan Community

4.3.1.2 Grey Water Design

Grey water can be transported by grey (water) sewerage to WPF, and then passed through the sedimentation tank with grid, constructed wetland, and disinfection tank. Finally, the effluent can be discharged to nearby water body or recycled to irrigate the garden of KAZ.

The constructed wetlands are used to treat grey water because of low maintenance. But other treatment processes like SBR (sequencing batch reactor), biofilm processes etc. could also be used as an alternative.

4.3.1.3 Yellow Water Design

Urine diversion toilets are proposed for KAZ. The low flush urine diversion toilet is recommended, such as Figure 2-21 left picture, Dubbletten toilet.

Urine tanks are put in the basements of each building and connected with urine pipes. All urine is collected from each toilet or urinal to urine tanks by urine pipes. Every week, the urine would be emptied and conveyed to WPF. In WPF, there are special urine storage tanks to store urine around 6 months before irrigating as liquid fertilizer.

Due to urine contains few disease producing organisms, the low diluted urine can be safely used after 6 months storage at 4-20 ºC.

4.3.1.4 Brown Water Design

The faeces just like urine, can be collected by indoor brown water pipes, and then stored in faeces tank for one week before transported by faeces truck to WPF. In WPF, faeces are anaerobic digested or composted with the organic solid waste.

4.3.2 Water Flow Balance

4.3.2.1 Predicted Water Consumption

The total volume of domestic water consumption is divided into two parts, one is 7.1 m^3/d potable water, and the other is 79 m^3/d un-potable water. (calculated in Table 4-13). These calculations are based on 172L/c/d, 22 L/c/d, and 28 L/c/d water for Overnight, day and half Day visitor, respectively (see Table 4-12).

Table 4-11:Domestic unit water consumption for scenario 2 (L/c/time)[a]

Activities	Drinking	Cooking	Urine flush	Faeces flush	Hand wash	Face clean	Bath/ shower	Laundry	Other
Volume	0.25	5	0.15	5	2	3	100	60	15

[a] Explanation:

- Based on Trifunovic (2003), the domestic unit water consumption is assumed as shown above.
- Assume use "Dubbletten" urine diversion toilet (Figure 2-21),toilet flushing water consumption is 0.15L/flush urine, 5L/flush faece.
- Above "cook activity" includes the food preparation and dish washing.
- Above "Other" is un-mentioned water consumption in this table.

Table 4-12: Water consumption for domestic uses in scenario 2 (L/c/d)[a]

Activities	Drinking	Cooking	Urine flush	Faeces flush	Hand wash	Face clean	Bath/ shower	Laundry	Other	Total
Overnight visitor	2	15	**0.6**	**5**	16	6	100	12	15	**172**
Day visitor	1	5	**0.3**	**1.5**	6.6	0	0	0	7.5	**22**
Half Day visitor	0.5	0	**0.2**	**0.5**	2.2	0	20	0	4.5	**28**

[a] Explanation:

- The water consumption for domestic uses (L/c/d)= Domestic unit water consumption (L/c/time) * Times of each activity (t/c/d)
- Domestic unit water consumption is based on Table 4-11.
- Times of each use come from .

Table 4-13: Potable and non-potable water consumption for scenario 2 in KAZ (m^3/d)[a]

	Number of visitor (c/d)	Potable water (L/c/d)	Potable water (m^3/d)	Non-potable water (L/c/d)	Non-potable water (m^3/d)
Overnight visitor	200	17	3.4	155	31
Day visitor	500	6	3	16	8
Half Day visitor	1450	0.5	0.7	27	40
Total	-	-	**7.1**	-	**79**

[a] Explanation:

- Number of visitor is presented in Table 3-4.
- Drinking/cooking/total water consumption per person per day is shown in Table 4-12
- Potable water (L/c/d)=the drinking water (L/c/d)+and cooking water (L/c/d)
- Non-potable water (L/c/d) = Total (L/c/d) – Potable water (L/c/d)
- Potable/non-potable water (m^3/d) = Potable/non-potable water (L/c/d) * Number of visitor (c/d) * 10^{-3} (m^3/L)

4.3.2.2 Predicted Yellow, Brown and Grey Water Production Quantity and Quality

Based on assumption of Table 4-14, the total yellow, brown and grey water is estimated as 1.6 m^3/d, 2.5 m^3/d and 81 m^3/d (see Table 4-15).

Table 4-14: Domestic wastewater production for scenario 2 (L/c/d)[a]

Visitor types	Yellow water	Brown water	Grey water
Overnight visitor	2.0	5.1	164
Day visitor	1.0	1.5	19
Half Day visitor	0.5	0.5	27

[a] Explanation:

- Assume: the drinking water is consumed by human body, which means the drinking water cannot discharged to the sewerage system.
- Domestic water quantity per person comes from Table 4-12.
- The assumption that the volume of pure urine and faeces is 500L and 50L per capita per year (Otterpohl *et al*, 2001 and Esrey *et al*,2001), also assume 4 urine and 1 faeces per capita per day, so the pure urine and faeces amount is 0.34L/c/time, 014L/c/time.
- Yellow water (0.49L/c/time)=Pure urine (0.34L/c/time)+urine flush water (0.15L/c/time) (see in Table 4-11)
- Brown water(5.14L/c/time)=Pure faeces(0.14L/c/time)+faeces flush water (5L/c/time) (see in Table 4-11)
- Times of each activity come from
- The yellow/brown water production (L/c/d)= yellow/brown water production (L/c/time) * Times of each activity (t/c/d)
- Grey water quantity (L/c/d) = Total water consumption (L/c/d) - urine flush water (L/c/d) - faeces flush water (L/c/d) – drinking water (L/c/d) (see Table 4-12)

Table 4-15: Domestic wastewater production for scenario 2 (m^3/d)[a]

Visitor types	Number of visitor (c/d)	Yellow water quantity (m^3/d)	Brown water quantity (m^3/d)	Grey water quantity (m^3/d)
Overnight visitor	200	0.4	1.0	33
Day visitor	500	0.5	0.8	10
Half Day visitor	1450	0.7	0.7	39
Total	-	**1.6**	**2.5**	**81**

[a] Explanation:

- Number of visitor can be got from Table 3-4.
- Domestic wastewater production per person comes from Table 4-14.
- Domestic water consumption per person comes from Table 4-12.
- Total wastewater production (m^3/y) = Number of visitor (c/d) * domestic wastewater production per person (L/c/d) * 10^{-3} (m^3/L)

The wastewater quality of KAZ for scenario 2 is predicted as following Table 4-16, based on the calculation of 81 m^3/d yellow water produce(see Table 4-15), and also based on the assumption of daily 750 PE (the unit of Population Equivalent expresses the volume of wastewater produce, 1 PE is equal to 55 g COD for 35 g BOD, 45 SS, 0.5 g N, and 0.3 g P (Lens *et al*., 2001)).

Table 4-16: Estimated grey water quality in KAZ for scenario 2 (mg/L)

Parameters	COD	BOD	SS	Nitrogen	Phosphor ous
Grey water	**515**	**324**	**416**	**4.7**	**2.8**
Domestic wastewater (Lens *et al*., 2001)	200-700	100-400	-	8-30	2-7

Compare with wastewater quality for scenario 1 (see Table 4-10), the concentrations of nitrogen and phosphorous in grey water for scenario 2 are obviously lower due to urine and faeces without mixture.

4.3.2.3 Water Flow Balance in KAZ

Based on the principles of section: 4.1.5, some water flow balance explanations for scenario 2 is presented:

- The input water flow is 1610 m^3/d, including 7 m^3/d water flow from municipal water supply and 1603 m^3/d storm water flow
- The output water flow is 680 m^3/d, including 20 m^3/d treated grey water flow, 657 m^3/d uncollected storm water flow, and around 3 m^3/d water flow from yellow and brown water.
- The transformation water flow is 928 m^3/d, which is consumed by the plants in KAZ

The detail are drawn in Figure 4-31 and explained as following.

As presented in section 4.1.2.2, 4.3.2.1, and 4.3.2.2, the total water consumption is around 1,014 m^3/d (86 m^3/d for domestic uses, 928 m^3/d for garden irrigation). The municipal water supply only need offer 7 m^3/d potable water (see Table 4-13)., since the infiltrated storm water, treated storm water, and treated grey water could contribute 655 m^3/d, 212 m^3/d, 61 m^3/d water to irrigate garden (Figure 4-3). So there are two types of water input for KAZ, 1603 m^3/d storm water flow, and 7 m^3/d potable water flow from municipal water

The output water flow is 677 m^3/d. Around 20 m^3/d treated grey water and 948 m^3/d storm water runs into the surface water body of KAZ (see section 4.1.2.2 or Figure 4-3), and then these water mixed by river water meets Loujing River after running out of KAZ.

As presented in section 4.1.3, the total water consumption for garden plants is around 928 m^3/d. The infiltrated storm water could contribute 655 m^3/d water, and the treated storm and grey water supply would offer 221 m^3/d, 61 m^3/d, respectively.

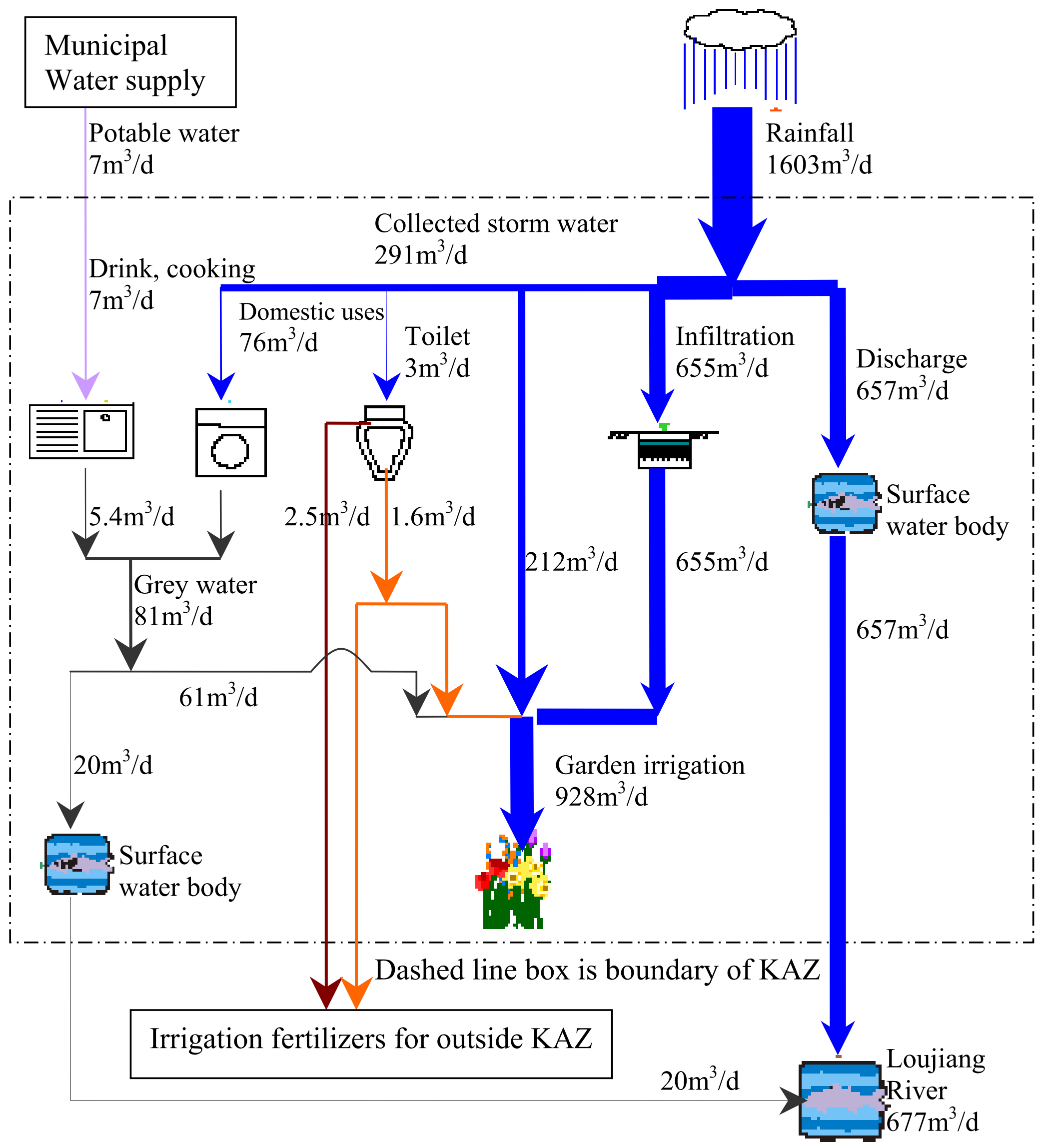

Figure 4-31: Water flow balance in KAZ for scenario 2

In scenario 2, all types of wastewater are separated at source, and then are sanitized. Hence, yellow, brown and grey water is treated and discharged respectively. As shown in Figure 4-31, 1.6 m^3/d, 2.5 m^3/d and 81 m^3/d of yellow, brown and grey water is produced. The yellow and brown water is treated in Water Processing Facility (WPF), after sanitization, they could be used as liquid or solid fertilizers for inside and outside KAZ, while the grey water is treated by constructed wetlands before reuse and discharge.

To sum up, there is some water flows reuse in scenario 2. The grey water and storm water is collected, sanitized, and then reused as irrigation water.

4.3.3 Nitrogen Balance

The ecosan concept emphasizes the recovery of nutrients from the urine, faecal sludge grey water, and organic solid waste. The nutrients benefit local agriculture and, to a certain degree, substitute artificial fertilizer. Ideally ecosan systems enable the complete recovery of all nutrients from faeces, urine and grey water to the benefit of agriculture and the minimisation of water pollution (GTZ, 2004b).

In KAZ, only the nitrogen balance is discussed, because nitrogen is the main nutrient from wastewater and organic waste.

Based on the principles of section: 4.1.5, some nitrogen balance explanations for scenario 2 is presented:

- The input nitrogen amount is 11.2 kg/d (see Table 4-6), including 8.9 kg/d nitrogen from human urine, 0.7 kg/d from human faeces, 0.4 kg/d from domestic grey water, and 1 kg/d from organic solid waste.
- The output nitrogen amount is around 3.6 kg/d, including 1.7 kg/d from solid fertilizer, another 1.7 kg/d from liquid fertilizer, and about 0.1 kg/d from treated grey water.
- The transformation nitrogen is 7.6 kg/d, including the 7.3 kg/d of consumption by garden plants in KAZ, and 0.3 kg/d absorbed nitrogen by constructed wetlands water plants (Plants have to be harvested once per year to keep the system at steady state).

The detail are drawn Figure 4-17 and some explanation is described as following.

As calculation in section 4.1.4, around 11.2 kg nitrogen would be produced in KAZ, about 65 percent of which should contribute to the 27 ha garden area in KAZ, rest of which can be used in 12.7 ha surrounding agriculture lands (see Figure 4-35), based on 112 kg/ha/y nitrogen for agriculture area (Pinsem and Winneras, 2003).

To sum up, there are nitrogen recycles for scenario 2. Most of nitrogen which is produced in KAZ is made as liquid/solid fertilizers, and then is irrigated for plants both inside and outside KAZ.

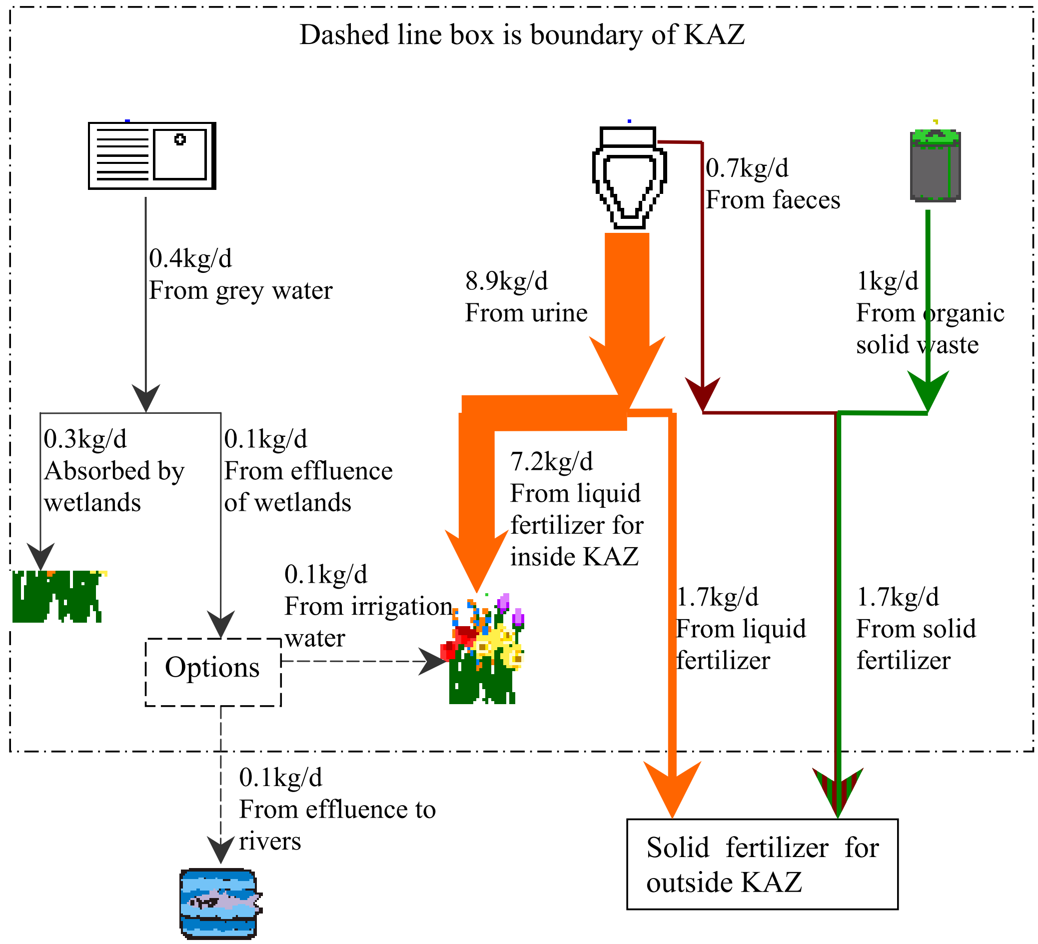

Figure 4-33: Nitrogen balance in KAZ for scenario 2

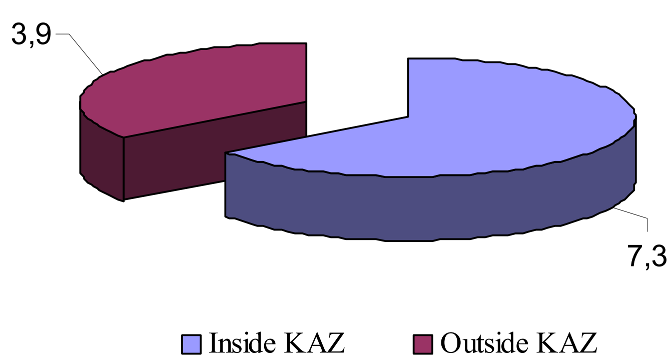

Figure 4-35: Nitrogen consumption distribution for scenario 2 (kg/d)

4.4 Comparisons for Both Scenarios

4.4.1 Indicative Cost Comparison

Due to time limit, it is difficult to make full cost estimations for both scenarios. But parts of cost differences between two scenarios are shown below.

4.4.1.1 Indicative Cost Comparison for Capital Investment

In scenario 1, due to KAZ is designed as the conference centre and the tourist resort, most of water consumption and wastewater production activities would be taken in centralized water uses place, such as the public toilets, kitchens, cottages area, also due to the highest building at KAZ is culture centre tower, less than 35 m height. The following assumptions are presented:

- There are the sanitation equipments in each toilet, kitchen, and shower room.
- All the sanitation equipments should be linked with straight pipes inside the building. These straight pipes are connected with sewerage system in the basements.
- The different types of wastewater are mixed in the sewerage, which means the wastewater coming from different domestic uses is not mixed before discharged into sewerage system. For example, the black water (toilet wastewater) is conveyed from toilets to the sewerage in basements directly without mixing the grey water.

Based above assumptions, the indoor pipes of scenario 1 also could be used in scenario 2 except for adding the urine diversion pipes. For example, the pipes for toilet wastewater in scenario 1 are used for conveying brown water in scenario 2, other pipes are used for the same function in both scenarios. The sewerage for conveying classic wastewater in scenario 1 can be used to convey the grey water in scenario 2.

In both scenarios, the differences are presented as used:

- The urine diversion toilets in scenario 2 are instead of the conventional toilets in scenario 1.
- The yellow pipes (conveyed the urine with low flush water from the urine diversion toilet to the sewerage in the basements) are needed in scenario 2.
- In scenario 2, the urine tank is needed for storage the urine in each building basement and outdoor public toilet basement.
- In scenario 2, the faeces tank also is needed, just like the urine tank.
- In WPF of scenario 2, the constructed wetlands would be built for grey water treatment.
- In WPF of scenario 2, the blue water purified workshop is needed set up.
- In WPF of scenario 2, the yellow water storage tanks should be constructed.
- In WPF of scenario 2, the brown water digester/composted tank also need be equipped.

The capital investment of scenario 2 is likely to be higher scenario 1, due to the additional cost would be spent of constructing equipments and units, which are shown in Table 4-17 and Table 4-18. However the exact cost difference still has to be determined once the concept design is progressed further.

Table 4-17: The additional equipments inside the buildings for scenario 2[a]

Equipments	Number/Length	Volume (m^3)	Explanation
Urine separate toilets	285	-	-
Yellow pipes	300m	-	-
Urine tanks	17	**0.7**/each	Emptied once per week
Faeces tanks	17	**1.0**/each	Emptied once per week

[a] Explanation:

- Assume that each building and outdoor public toilet has one urine/faeces tank. There are 17 buildings and public toilets at KAZ.
- Because the basement place is not big enough, also in order to decrease the capital investment, the urine/faeces tank is emptied once per week.
- Volume = Yellow/brown water volume (m^3/d) * 7 (d/week) / 17 (unit)
- The yellow/brown water volume is 1.6 m^3/d, 2.5 m^3/d (see Figure 4-31)

Table 4-18: Available design for WPF in scenario 2[a]

	Total capability (m^3/d)	HRT (d)	Design volume (m^3)	Total area (m^2)	Number of the parallel units
Constructed wetlands	81	5	405	**810** (20m*41m)	2
Yellow water tanks	1.6	180	288	**144** (12m*12m)	6
Brown water and green waste anaerobic digesters/composting tanks	2.5	30	75	**25** (R=3.5m)[#]	2
Blue water purification belt	291	0.5	146	**146** (10m*15m)	2

[a] Explanation:

- HRT means Hydraulic Retention Time.
- Total capability is shown in Figure 4-31
- Design volume (m^3) = Total capability (m^3/d) * HRT (d)
- Assumption of the height of constructed wetlands, the yellow tanks, and purification belt is 0.5 m, 2m, and 1m respectively.
- Area (m^2) = Design volume (m^3) / Design height (m)
- There are need at least two parallel units for O&M conveniences.
- Due to yellow water need storage 6 months, 6 units are suitable for empty one unit per month.
- [#]: There are two digestions/composting tanks, radius of each tank is 3.5m.

4.4.1.2 Cost Comparison for Water Consumption and Wastewater Discharge Fee

In scenario 1, all water consumption comes from municipal water supply, the classic wastewater is considered as waste water, discharged to municipal wastewater treatment plant, so the fee for 680 m^3/d water supply and 105 m^3/d wastewater treatment is charged.

However, in scenario 2, only 7 m^3/d potable water is needed and no wastewater discharged into municipal sewerage.

As calculated in Table 4-19, compared with 1.1 Euro/d in scenario 2, around 76 Euro/d is spent for water and wastewater in scenario 1. In other words, 27,340 euro is saved from water/wastewater fee per year if applying scenario 2, ecosan system at KAZ.

Table 4-19: The estimated fee for municipal water supply and wastewater in both scenarios

	Unit price (Euro/m^3)	Scenario 1		Scenario 2	
		Amount (m^3/d)	Cost (Euro/d)	Amount (m^3/d)	Cost (Euro/d)
Municipal water supply	0.16	389	62	7	1.1
Municipal wastewater treatment	0.12	116	14	0	0
Total	-	-	**76**	-	**1.1**

[a] Explanation:

- 1 Euro = 10 RMB (Chinese currency)
- The unit price for municipal water supply is 1.6 RMB/m^3; that for municipal wastewater treatment is 1.2RMB/m^3 (Gu, 2004).
- The amount for water consumption and wastewater production is shown in Figure 4-15 and Figure 4-31.
- Cost (Euro/d) = Amount (m^3/d) * (Euro/m^3)

4.4.2 Sustainability Criteria Comparison

Suggestion for criteria for ecosan is health, environment, economy, socio-culture and technical function (Bracken *et al*, 2004 and Bracken *et.al*, 2004a).

Because there are no clear weight factors for the criteria, everyone uses their own interpretation of sustainability. In practice, the indicators with the highest priority should be given the highest weight factors. I have set up a table to compare the two scenarios (Table 4-20). The weightings based on my own assessment for KAZ, e.g. environment factor has the high rating because HPF hope to develop a sustainable demonstrated project.

As section 4.2.2, 4.2.3, 4.3.2, and 4.3.3 mentioned, scenario 2 contributes much benefits to environment than scenario 1. In scenario 2, less fresh water is need than in scenario 1 because the storm water and grey water will be recycled at KAZ. That means that scenario 2 need much less municipal water supply than scenario 1, moreover, a large number of valuable fertilizers will be produced in scenario 2, while much wastewater and waste will be discharged in scenario 1.

From the Table 4-20, we can see that the final score of scenario 2 is higher than scenario 1. Regarding the five aspects evaluated scenario 2 scores higher in environment than scenario 1.

All categories are considered over the entire life cycle of the sanitary system –from resource extraction for its construction to it eventually being taken out of service at the end of its useful life. The detailed explanations for sustainability criteria are shown in .

Though flow balance and nitrogen balance calculations, criteria analyses of both scenarios, ecosan scenario can bring many benefits for KAZ. Such as, protecting environment for minimum contaminants for separating and sanitizing different types wastewater, saving water for reuse storm water and grey water, bring income for biogas, liquid/solid fertilizer production, attracting person visit KAZ for its educational ecosan system.

All in all, scenario 2 is a sustainability approach for nature.

Table 4-20: Comparison of criteria for sustainability assessment between the two scenarios (scale of 1-5 with 5 best beings)

Criteria	Sub-criteria	Weight	Scenario 1 Conventional system	Scenario 2 Ecosan system	Explanations differences between both scenarios
Health		15%	3.5	3.5	
	Risk of infection	7%	4	3	• It is not safe use of urine/faeces, if they are treated by operation mistake in scenario 2.
	Risk of exposure to harmful substances	8%	3	4	• More manure is sanitized in scenario 2
Environment		35%	1.5	4.4	
	Use of natural resources, construction	4%	3	3	
	Use of natural resources, O&M	4%	3	3	
	Discharge to water bodies (COD)	13%	1	5	• Minimum contaminants for separating and sanitizing different types wastewater, much less COD to rivers than scenario 1
	Air emission noise pollution	4%	1	4	• Constructed wetlands is nature treatment, there is less air and noise pollution than scenario 1.
	Resources recovered	5%	1	5	• Saving water for reuse storm water and grey water • Nutrients is recycled in nature.
	Quality of recycled resources	5%	1	5	• Water flow and nutrients recycling.
Economy		20%	3.5	3.8	
	Total costs, including capital and maintenance costs	10%	4	3	• Urine diversion toilet pipes are separated by yellow pipes, more funds and more complex technology are needed in

					scenario 2
	Capacity to pay-user, municipality	2%	3	3	• For user, there is no difference between both scenarios;
	Contribution to local development	8%	3	5	• Water flow and nutrients recycling. • Bring income for biogas, liquid/solid fertilizer production
Socio-culture		10%	4.4	3.9	
	Appropriateness to current local cultural context	1%	5	5	
	Willingness to use	1%	5	4	• Most of people do not know about the urine diversion in scenario 2
	Convenience	2%	5	5	• There is no difference for users of toilets.
	Institutional requirements	2%	3	3	
	Current legal acceptability	1%	5	5	
	Existing legal requirements	1%	5	5	
	System perception (complexity, compatibility)	1%	5	4	• Urine diversion toilets are a little complexity than conventional toilets.
	Ability to address awareness and information needs	1%	3	5	
Technical function		20%	4	4.2	
	System robustness	2%	5	4	• Scenario 2 will be a pilot project, new technology should be less robustness than conventional one.
	Robustness of use of system	2%	5	5	
	Robustness against extreme conditions	1%	5	5	
	Possibility to use local competence for construction	1%	4	2	• Scenario 1 need less capital investment.
	Possibility to use local competence for	1%	4	4	

	O&M				
	Ease of system monitoring	2%	4	3	• Scenario 2 is more complex because urine diversion, so it is not easier monitoring than scenario 1
	Durability / lifetime	3%	4	4	
	Complexity of construction and O&M	3%	4	4	
	Flexibility/adaptability	5%	3	5	• Because urine and faeces is separated in scenario 2, the grey water quality is less various than scenario 1.
Total		100%	**3.0**	**4.1**	

5 Conclusions and Recommendations

5.1 Conclusions

The following conclusions can be drawn from this study:

Ecosan concept

- Ecosan is a holistic approach towards sustainable sanitation.
- Typical (but not always) elements of ecosan are wastewater/waste separation, sanitization and recycling.

KAZ project

- Kunshan Aqua Zone (KAZ for short) would be the first full-scale project for applying ecosan concept in a conference centre/tourist resort in China.
- KAZ would be a suitable place for an ecosan demonstrated project, because relatively warm climate (annual average temperature is 15.5 ºC, annual average frost free period is 240 days) is appropriate for urine storage, faeces sanitization, and grey water treatment by constructed wetlands, because the concept of recycling manures as fertilizers is easy to be accepted by local farmers, also because applying ecosan principle at KAZ fits perfectly with the overall aim and vision of HPF, who is funding the project.
- The total area of KAZ is 52 ha. Almost the 40% of total area is covered by water; more than 50% of area is grown by flowers, herbs, grasses and trees. The estimated person number is around 800,000 per year at KAZ. These people would contribute to 4 ton nitrogen per year, which can be used for 40 ha garden area or 36 ha agriculture area based on garden area, agriculture area need 100 kg, 112 kg nitrogen fertilizer per ha per year, respectively.

Two scenarios for sanitation system in KAZ

- Estimated amount of rainfall is around 580,000 cubic meters per year at KAZ, the maximum volume for collected storm water is around 20 percent of total rainfall, 106 cubic meters per year.
- In scenario 1: conventional system, also can called as flush-and-discharge systems, requires large amounts of fresh water for flushing. The all of wastewater coming from each toilet, kitchen and shower room is collected by sewer system in KAZ, and then be transported to municipal wastewater treatment plant. The storm water collected from roofs and roads is discharged into nearby streams and channels directly. The surface water body would play a storm water sewer role in KAZ.
- In scenario 1, 389 m^3/d water is required from municipals water supply; 116 m^3/d wastewater is discharged to municipal wastewater treatment plant. All 11.2 kg/d nitrogen is discharged to municipal solid waste treatment plants.
- In “Water Processing Facility” (WPF for short) of scenario 2, a place for wastewater/waste sanitization, storm water purification, after treatment and disinfection, the storm water is reclaimed to flush toilets, irrigate plants, clean streets, wash clothes, and other domestic uses expect for drinking and cooking; grey water can be passed through the sedimentation tank with grid, constructed wetland, and disinfection tank, finally, the effluent can be discharged to nearby water body or

recycled to irrigate the garden of KAZ; the yellow water can be sanitized in the yellow water storage tanks; the brown water can be sanitized with organic waste by anaerobic digestion/composting processes before they are irrigated as fertilizers for the agriculture and garden area.
- In scenario 2, only 7 m^3/d potable water is required from municipal water supply, because of the recycling use storm water and grey water. Although around 80 m^3/d grey water is produced, it can be reused for irrigating the garden area inside KAZ. Only 20 m^3/d low contaminant effluent of the constructed wetlands is discharged to the surface water body. 1.6 m^3/d yellow water and 2.5 m^3/d brown water is treated in WPF, and then is used inside and outside KAZ.
- In scenario 2, the 7.2 kg/d nitrogen is recycled inside KAZ as garden irrigation fertilizers, the 3.4 kg/d liquid and solid fertilizers would be recycled outside KAZ.

Comparisons for both scenarios
- Based on indicative cost comparisons of both scenarios, the capital investment of scenario 2 is likely to be higher than scenarios 1, however, 27,340 euro/y of water/wastewater fee is saved in scenario 2 compared with scenario 1. Moreover, the valuable liquid/soil fertilizer is produced in scenario 2.
- Based on sustainable criteria analysis, important result was that applying scenario 2 for integrated wastewater management at KAZ should bring benefits of holistic development, such as conserves water and environment, recovers and recycles nutrients and organic materials.

5.2 Recommendations

Recommendations of future work with regard to KAZ are given as following:

Storm water
- More detailed analysis on rainfall patterns over the year and water requirements of the plants in the flower exhibition area.
- Re-estimate the storm water quantity regarding rainfall equations.
- Estimate the storm water quality.
- Re-estimate the infiltration storm water quantity considering of the geography conditions.

Refine calculations for non-steady situation
- Refine the design calculations for peak demands (e.g. during peak holiday season) instead of only for yearly average visitor number.
- Estimate the water absorbance capability of plants regarding of the soil condition and types of plants in KAZ.
- Refine all calculations based on regarding ground water, surface water and evaporation influences.
- Refine water flow balance based on regarding fire flow, scenery flow and water consumption of wellness centre.
- Refine nitrogen balance regarding the storm water nitrogen input and nitrogen loss during sanitization processes.

Detail calculations and descriptions for scenario 2
- Calculate phosphorus balance.

- Estimated the yellow, brown, and grey water quality in scenario 2.
- Consider the emergency water supply in case scarcity of storm water in scenario 2.
- Describe the detail sanitization technologies for scenario 2
- Progress the design calculations in detail for the Water Processing Facility.
- Implement and monitor the proposed solution for KAZ (scenario 2) and widely publicise the results.
- Estimate the potential social, environmental, and economic profits, which are brought by scenario 2.

Detail comparison for both scenarios

- Make professional cost estimation for both conventional and ecosan scenarios.
- Analyse the sustainable criteria in detail.

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Appendices

Appendix 1: Recommended Swedish guideline storage times for urine mixture[a] based on estimated pathogen content[b] and recommended crop for larger systems[c] (Winblad and Simpson-Hebert, 2004)

Storage temperature	Storage time	Possible pathogens in the urine mixture after storage	Recommended crops4
4°C	>1 month	Viruses, protozoa	Food and fodder crops that are to be processed
4°C	>6 months	Viruses	Food crops that are to be processed, fodder crops[d]
20°C	>1 month	Viruses	Food crops that are be processed, fodder crops[d]
20°C	>1 month	Probably none	All crops[e]

a Urine or urine and water. When diluted it is assumed that the urine mixture has at least pH 8.8 and a nitrogen concentration of at least 1 g/l.

b Gram-positive bacteria and spore-forming bacteria are not included in the underlying risk assessments, but are not normally recognized as causing any of the infections of concern.

c A larger system in this case is a system where the urine mixture is used to fertilize crops that will be consumed by individuals other than members of the household from which the urine was collected.

d Not grasslands for production of fodder.

e For food crops that are consumed raw it is recommended that the urine be applied at least 1 month before harvesting and that it be incorporated into the ground if the edible parts grow above the soil surface.

Appendix 2: Physiochemical and biological factors that affect the survival of micro-organisms in the environment (Winblad and Simpson-Hebert, 2004)

Temperature	Most micro-organisms survive well at low temperatures (below 5°C) and die off rapidly at high temperatures (above 40° C). This is the case in water, soil and sewage and on crops. At temperatures of 55–65°C all types of pathogens (except bacterial spores) die within hours.
pH	Highly alkaline conditions will inactivate micro-organisms. Inactivation is rapid at pH 12 but takes longer at pH 9.
Ammonia	Pathogens in excreta can be inactivated by the addition of ammonia.
Dryness	Moist soil favours the survival of micro-organisms. Dehydration of faeces in an eco-toilet processing chamber will decrease the number of pathogens.
Solar radiation	The survival time of pathogens on soil and crop surfaces will be reduced by UV radiation.
Presence of other organisms	The survival time of micro-organisms may be shortened by the presence of other organisms. Different types of organisms affect each other by predation, release of antagonistic substances or competition for nutrients.
Nutrients	Bacteria adapted to living in the gut are not always capable of competing with other organisms in the general environment for scarce nutrients. This may limit the ability of faecal bacteria to reproduce and survive in the environment.
Oxygen	Most enteric bacteria are anaerobic and thus are likely to be out-competed by other organisms in an aerobic environment.

Appendix 3: The brief introduction for faeces treatment (Esrey *et al*, 1998, Winblad and Simpson-Hebert, 2004)

The purpose of primary processing is to reduce the volume and weight of faecal material to facilitate storage, transport and further (secondary) treatment

Storage: The simplest form of treatment of faeces. The number of pathogens in faecal material during storage will be reduced with time due to natural die off, without further treatment. The type of microorganism and storage conditions governs the time for reduction or elimination. The ambient temperature, pH and moisture etc. will affect the inactivation as well as biological competition. Since the conditions during storage vary, so do the die-off rates, which may make it harder to predict appropriate storage times. Furthermore, just adding soil or sawdust after defecation as a covering and conditioning material should be discouraged.

Alkaline treatment: Addition of ash or lime in the primary treatment of faeces is recommended as it will facilitate pathogen inactivation and decrease the risk for disease transmission during handling and reuse of the material. It also reduces the risk of odour and .flies in the toilet. The additives may influence the choice of secondary treatment options. Further evaluation is needed to establish the amounts and quality of additives that are needed for sufficient pathogen reduction and their influence on secondary treatment.

Dehydration: Faeces are dropped into a processing chamber where they are safely kept out of the environment for a period of 6-12 months, and ash, lime or urea is added after each defecation to lower the moisture content and raise the pH to 9 or higher. The system thus creates condition of dryness; raised pH and time for pathogen die off.

The purpose of secondary processing is to make human faeces safe enough to return to the soil.

Heat treatment: Heat is one of the most effective ways of killing pathogens and is the parameter used to achieve inactivation in some of the most applied processes for e.g. sewage sludge treatment. Composting of faeces: Thermophilic composting is a biological process that requires skilled management to function well. Enough feed of the right composition is important in order to reach temperatures high enough for efficient inactivation of pathogens. Composting is preferably performed as a secondary treatment on a larger scale, and the process should be insulated and monitored in order to assure that thermophilic temperatures (>50 °C) are obtained in all of the material. Small-scale composting at mesophilic temperatures needs to be further evaluated.

Incineration treatment: Incineration of the faeces will minimize the risk for transmission of disease related to the final use of the ash since essentially all pathogens will be removed, the nitrogen will be lost but phosphorous and potassium retained in the remaining ash. Incineration of faeces will render a fertilizer product that is pathogen-free and may have a potential in secondary treatments, both on small-and large-scale levels. Systems utilizing incineration have not yet been properly developed and evaluated.

Appendix 4: The data for the rainfall and river level in Kunshan (Gu, 2004)

Year	River level（m）					Rainfall （mm）			
	Average height	Highest	Date of Highest	Lowest	Date of Lowest	Annual average	Rainfall period (d/y)	Max. date	Date of Max.
1986	2.54	3.24	11 Jul.	2.18	5 Mar.	1150	97	139.6	12 Jun.
1987	2.63	3.29	29 Jul.	2.15	11 Feb.	1371	139	72.3	4 Jun.
1988	2.57	3.12	4 Sept.	2.25	14 Feb.	856	102	110.5	3 Sept.
1989	2.65	3.33	17 Sept.	2.21	6 Jan.	1099	115	76.0	5 Jul.
1990	2.67	3.43	6 Sept.	2.37	3 Aug.	1181	135	170.1	31 Aug.
1991	2.73	3.55	3 Jul.	2.32	19Sept.	1577	124	156.2	2 Jul.
1992	2.60	3.10	1 Sept.	2.22	15 Feb.	837	98	67.1	6 Aug.
1993	2.76	3.62	22 Aug.	2.27	7 Feb.	1352	138	92.6	18 Aug.
1994	2.64	3.02	11 Oct.	2.38	6 Jun.	874	130	65.2	9 Oct.
1995	2.70	3.56	7 Jul.	2.38	15 Feb.	1076	98	120.5	19 May
1996	2.63	3.39	6 Jul.	2.07	4 Mar	980	130	83.2	5 Jul.
1997	2.59	3.10	19 Aug.	2.26	20 Feb.	900	129	63.2	24 Jun.
1998	2.75	3.17	17 Jan.	2.42	7 May	1187	128	65.0	4 Jul.
1999	2.79	3.92	1 Jul.	2.34	1 Mar	1515	131	146.6	30 Jun.
2000	2.71	3.04	20 Aug.	2.37	14 May	1181	143	94.9	25 May
2001	2.75	3.52	24 Jun.	2.42	20 Apr.	1164	110	142.1	23 Jun.
2002	2.81	3.14	16 Aug.	2.54	25 Jan.	1159	134	87.7	21 May
2003	2.77	3.02	22 Mar	2.48	26 May	827	113	42.6	5 Jul.

Appendix 5: Chinese national grade for surface water (GB3838-2002) (CNGSW, 2004)

(mg/L)

Item	DO	COD_{Mn}	BOD	NH_3-N	VP	TN	TP
I	>7.5	<2	<3	<0.15	<0.002	<10	<0.01
II	>6	<4	<3	<0.5	<0.002	<10	<0.01
III	>5	<6	<4	<1.0	<0.005	<20	<0.05
IV	>3	<10	<6	<1.5	<0.01	<20	<0.1
V	>2	<15	<10	<2.0	<0.1	<25	<0.2

DO (Dissolved Oxygen), COD_{Mn} (Chemical Oxygen Demand–measured by Permanganese method) (COD=COD_{Cr}, measured by Dichromate method), BOD (Bio-chemical Oxygen Demand), NH_3-N (Ammonia Nitrogen), VP (Volatility Phenol), TN (Total Nitrogen), TP (Total Phosphorous).

The water quality evaluation criteria shows:

I: Water is suitable for the drinking water source, the national nature protection area.

II: Water is suitable for the 1st grade surface water source area of centralized life, the living roosts of rare and precious aquatic, spawning area of fish and shrimp.

III: Water is suitable for the 2nd grade surface water source area of centralized life, for the fish and shrimp survival, for aquatic product cultivation area, and for swimming area.

IV: Water is suitable to the water for general industrial used and for entertainment without contacting human body.

V: Water is suitable to the agriculture requests and the water for common landscape.

Appendix 6: Run off coefficients for selected surfaces (Zhu and Liu, 1998)

Roof catchments	Run off coefficient	Ground catchments	Run off coefficient
Sheet metal	0.8-0.9	Concrete lined	0.75
Cement tile	0.6-0.7	Cement soil mix	0.3-0.4
Clay tile(machine made)	0.3-0.4	Buried plastic sheet	0.3-0.35
Clay tile(hand made)	0.25-0.3	Compacted loess soil	0.1-0.2

Appendix 8: Explanations for sustainability criteria (Bracken, *et al*, 2004, Bracken, *et.al*, 2004a)

Health

The prime objective of sanitation is to protect and promote human health. The entire sanitary system should therefore be hygienically safe, posing as small a risk as possible of infection. This covers the use of the sanitary installation, collection, transport, treatment and end destination of the treated products.

The risk of infection from leaking sewers to the drinking water pipe system or groundwater should also be included, as there is also risk of being infected when bathing in lakes or the sea nearby an overflow or discharge point from a treatment plant.

Environment

With time, sanitary systems have also been developed in such a way so as to protect the environment against possible detrimental effects. There is a need to consider emissions to different recipients (water, soil and air), and also resource use by different sanitation systems, both during the construction and the operation phase. Moreover, it is important to consider the quality of the treatment product for possible reuse in agriculture.

Economy

The capacity to pay for sanitation among the users is an important criterion for sustainability. However, in the end it may be their willingness to pay that will define within what range the costs, both of construction and O&M ,can vary and services be sustained financially by the population.

Socio-culture

The prime objectives of sanitation might be to protect human health and the environment. However, sustainability in sanitation cannot be based only on these objectives but need to include social criteria as well as they are most crucial to sustainability in use and services provided by the system. It is possible to distinguish at least three different types of important criteria in this category, namely cultural acceptance, institutional requirements, and perceptions on sanitation. The society is more dynamic than human health and the environment and therefore the socio-cultural criteria, like regulation, perceptions on systems etc. might be subject to a more dynamic change through time than criteria considering human health and the environment. How things are seen and their resultant acceptance can change with time (perhaps driven by their own priorities).

Although improved human health and environment are the main objectives to planners and politicians, this might not be enough to sell the sanitation concept to future users .It is also important to recognize that the prime driver for sanitation might be security and status rather than health and environment (Holden, 2003).Another sanitation driver could be the possibility of increased food security if the sanitation solution can provide hygienically safe fertilizers.

Technical function

The technical functions of the sanitation system are definitely important for it to be sustainable. One of the more important ones is probably robustness, both within the system (to be able to receive varying loads) and externally (to be able to withstand varying extreme environmental conditions as well as user abuse of the system).

The technical functioning of the system is seen as perhaps the most flexible group of criteria. Technologies can, to a large extent, be relatively easily adapted to the needs and requirements –it is easier to adapt the technology to the wider needs than vice versa.

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