sustainable sanitation alliance

Case study of sustainable sanitation projects

Urine diversion sanitation in Olympic Forest Park Beijing, China

Fig. 1: Project location

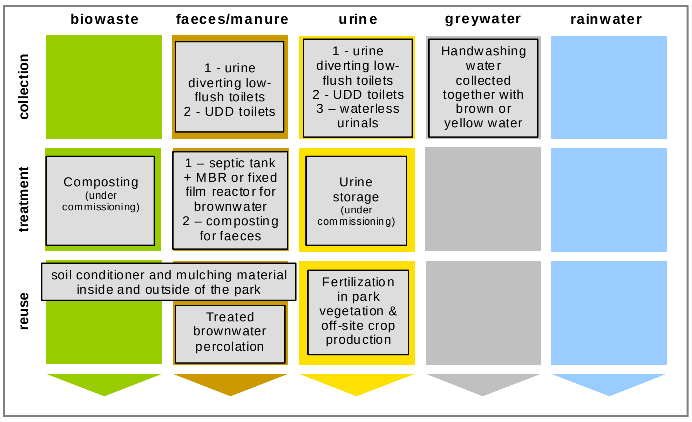

Fig. 2: Applied sanitation components in this project (numbers refer to different flow streams)

1 General data

Type of project:
Urine diversion and nutrient cycling in a large public urban park (demo project)

Project period:
Start of planning: August 2007
Start of construction: December 2007
Start of operation: August 2008
Commissioning of treatment processes: still ongoing in April 2009

Project scale:
Total area of 704 ha, planted area of 434 ha
5.3 million expected visitors/year
4,280 staff
38 urine-diversion public toilet blocks, 1 staff restroom
(capital costs not disclosed)

Address of project location:
Olympic Forest Park, Kehui Street, Chaoyang District, Beijing

Planning institution:
Dept. of Landscape Planning & Design (LPD), Planning & Design Institute, Tsinghua University, Beijing;
Dept. of Environmental Science and Engineering (DESE), Tsinghua University, Beijing;
Beijing Zhongyuan Engineering Design & Consulting Co. (ZEDC), Beijing

Executing institution:
EnviroSystems Engineering & Technology Co. Ltd., Beijing

Supporting agency:
None

Note: at the time of last update of this document, we were still trying to obtain some missing information from colleagues in China. As soon as these details are available, an update to this case study will be prepared.

2 Objective and motivation of the project

The main project objective was to supply the Olympic Forest Park with sanitary installations for visitors and staff. By governmental directive all works related to the Olympic summer games in Beijing in August 2008 were required to observe three principles: ‘Green Olympics, High-tech Olympics and People’s Olympics’. Besides the ‘Green Olympics’ motto, cost savings (figures not disclosed) were an additional incentive for the establishment of an alternative closed-loop sanitation system due to the park’s special topography.

The aim of the system is to interlink the sanitation material flows as a water and nutrient source with the green areas of the park as a water and nutrient sink. Reduced water and energy demand as well as the substitution of fertilizer by urine and faeces-derived manure are expected advantages. A further aim is to convey the idea of alternative sustainable sanitation solutions to decision makers and the wider public.

3 Location and conditions

The Olympic Forest Park lies at the northern end of the historic north-south axis of Beijing. It covers a total area of 704 ha and is one of the world’s biggest inner city parks.

Fig. 3: Public toilet block in the Olympic Forest Park[a]

[a] All pictures without further reference are by Jörn Germer.

The park's topography is characterised by a man-made mountain in the south and an extensive network of waterways, lakes and wetlands expanding over 70 ha. More than 60% of the park is covered by vegetation. An average irrigation water demand of 350 mm is estimated for these areas, which is entirely provided by reclaimed wastewater.

The park area lies inside a planar depression. This does not allow gravity drainage and was the starting point for the planning team at the Department of Environmental Science and Engineering, Tsinghua University (DESE), in charge of sanitation system planning, to consider alternative sanitation solutions.

Fig. 4: Elevation map of the Olympic Forest Park (source: Planning & Design Institute, Tsinghua University)

4 Project history

Starting in 2003 the construction of the Olympic Forest Park lasted five years and was officially completed on 3rd July 2008.

Detailed planning of the sanitation installations and the associated treatment systems began in August 2007. DESE in cooperation with the Beijing Zhongyuan Engineering Design & Consulting Company (ZEDC) developed a decentralised treatment system, integrated urine separation and suggested reuse of the sanitation-derived nutrient resources in the park.

The great amounts of nutrients involved required a careful nutrient mass balance for the park to avoid any adverse impact such as over-fertilization of the green areas or eutrophication of the waterbodies. In December 2007 in cooperation with the German Technical Cooperation (GTZ) ecosan team, material use strategies were identified and a model was developed that allows identification of nutrient flows in the park (see Section 6).

It is anticipated that the fertilization with treated urine and compost will start in the second quarter of 2010.

5 Technologies applied

A total of 38 public toilet blocks plus one staff restroom in a service building are located in the park. Each block contains on average five toilets in the female section and four toilets plus three urinals in the male section.

The restrooms initially planned for the park were supposed to be equipped with conventional flush toilets and urinals. Wastewater disposal to the public sewer system was planned. Due to the size and topography of the park, this would have required a very complex and costly network of pipes and pump stations. In order to reduce the length of the network, decentralised treatment was considered. Membrane as well as granular biological reactors were chosen for on-site wastewater treatment.

Further, the flush toilets in some public toilet blocks were substituted by waterless toilets. The parallel implementation of these three systems was selected to enable comparisons at a later stage. Urine separation was integrated due to the advantage of a lower nitrogen content in the wastewater for the treatment reactors and high dry matter content in the collection chambers of the dry toilet system.

The anticipated quantities of urine led to the question if nutrient cycling in the park was possible. To enable urine sanitisation by extended storage, a large-scale urine treatment unit was added to the design. Additionally, the composting unit for the treatment of gardening debris was redesigned to allow co-composting of faecal matter from UDD (urine diversion dehydration) toilets and sludge from septic tanks.

Extensive man-made wetlands covering over 6 ha (Fig. 5) are integrated into the park for the purpose of beautification and to control the nutrient status of the open water-bodies. The lake water is continuously reticulated through these wetlands. It is expected that the vegetation will take up significant amounts of nutrients, thus avoiding eutrophication of the open water-bodies.

Fig. 5: Vertical flow constructed wetland in the Olympic Forest Park

6 Design information

Low flush, urine diversion, sitting or squatting toilets are used in **33 public toilet blocks** (Fig. 6B/C) and in one staff office building. The average flush volume for faeces is approximately 6 litres and for urine 0.1-0.3 litres. The brownwater (mixture of faeces plus flush and hand wash water) is flushed by gravity into a two chamber septic tank system.

Each of the flush toilet blocks has an individual tank system with an average volume of 75 m^3 (50-100 m^3). The brownwater undergoes a liquid/solid separation in the tanks and afterwards passes through a biological reactor. The reactor effluent flows through open drains towards the wetlands and water-bodies. It is anticipated that a large part of the effluent infiltrates and evaporates on the way. Scum and sludge that floats and settles in the septic tanks is removed via a vacuum truck.

Fig. 6: Different toilet models and a waterless urinal used in the public toilet blocks. A Urine-diverting dehydration toilet (UDDT), B Urine-diverting, low flush sitting toilet, C Urine-diverting, low flush squatting pan and D Waterless urinal. (Source: B - EnviroSystems Engineering & Technology Co. Ltd., China)

Five public toilet blocks are equipped with UDDT also called no-flush (waterless), separating, sitting and squatting toilets (Fig. 6A)[b]. The faecal matter is collected in containers below the toilet. Mechanical addition of sawdust and automatic stirring of the faeces vaults controls odours and contributes to hygienisation of faeces. Every 6 months, the accumulated faecal matter mixture is conveyed to the composting plant for secondary treatment.

In all blocks, only waterless urinals without any flushing water are installed. The urine from these and yellow water (mixture of urine plus water) from the separating toilets is collected in underground tanks of an average volume of 15 m^2 (5-30 m^3) at each block. At the blocks equipped with UDDTs, the water from the hand wash basins is collected together with the yellow water.

Additionally, there are four blocks equipped with conventional flush toilets. These blocks are connected to the public sewer system.

The treatment process for the materials (excreta) collected with sustainable sanitation technology comprises three functional units which are either in operation or currently being commissioned. These are:

1. A urine storage tank complex that sanitises urine by storage. With a total capacity of **2,000 m^3**, the potential storage time is over 180 days (tank not yet full – awaiting further feedback from China).
2. A solid-liquid separation that receives the scum and sludge from the septic tanks. The liquid fraction is treated in an MBR and the solid fraction composted (not yet in operation).
3. A composting plant with an annual treatment capacity of about 2,000 t of fresh organic matter. The plant treats gardening debris, including grass clippings, leaves and other biomass. Faecal matter from the dry toilets as well as solid material from the solid-liquid separation plant is co-composted together with the gardening debris[c].

Fig. 7: Type of vacuum trucks to be used for the transport of scum and sludge from the septic tanks at the public toilet blocks with low flush, urine diverting toilets in the Olympic Forest Park. This picture was taken at an MBR wastewater treatment in metropolitan Beijing.

The sanitation system design and the number of park visitors plus staff determine the nutrient influx via urine and faeces as well as the production of yellow water, brown water and faecal matter. Currently, 5.3 million visitors are estimated per year and assumed to urinate once during their visit. Nutrient and mass flows are calculated on basis of the following assumptions:

- On average, each visitor urinates once during their park visit (18% of daily total excretion) and 15 % of visitors defecate during their visit to the park
- Excretion of 1.6 L urine and 150 g faeces per 24 hours and person (fresh weight)
- Nutrient content of 6.5 g nitrogen (N), 0.7 g phosphorus (P) and 2.0 g potassium (K) per litre of urine
- Moisture content of approximately 75% and dry matter nutrient content of 18 g N, 4 g P, 3.6 g K per kg of faeces

Accordingly, a production of 2,500 m^3 urine, resulting in **4,000 m^3 yellow water, is expected per year**. The annually harnessed yellow water contains 6.4 t N, 0.8 t P and 2.2 t K. Further, the developed flow model indicates a yearly (waterless) collection of 15 t of faecal matter containing 71 kg N, 19 kg P and 17 kg K.

At the same time, the flush toilet facilities are expected to produce about 20,000 m^3 brown water. It is expected that from the septic tanks, 225 m^3 of scum and sludge, containing 0.4 t N, 0.1 t P and 0.1 t K per year, will be conveyed to the treatment site.

[b] In Beijing sitting toilets are more common in public toilets, while squatting toilets are usually used in homes and restaurants.

[c] We have requested more information and are awaiting a response.

Co-composting of faecal matter and dehydrated scum and sludge, together with 2,000 m³ of gardening debris, produces 1,400 m³ of compost, providing 7 t N, 1 t P and 4 t K annually.

While yellow water (urine plus some flush water) and compost alone supply a great load of nutrients, additionally significant amounts of nutrients are added to the park's ecosystem through irrigation with reclaimed wastewater (see Section 8). The nutrient flow model highlights that on the 'sources side', only the use of fertilizers can be reduced, which is already minimal. On the 'sink side', organic matter (e.g. plant cuttings, grass clippings, leaves), compost and urine can be exported to maintain the nutrient balance.

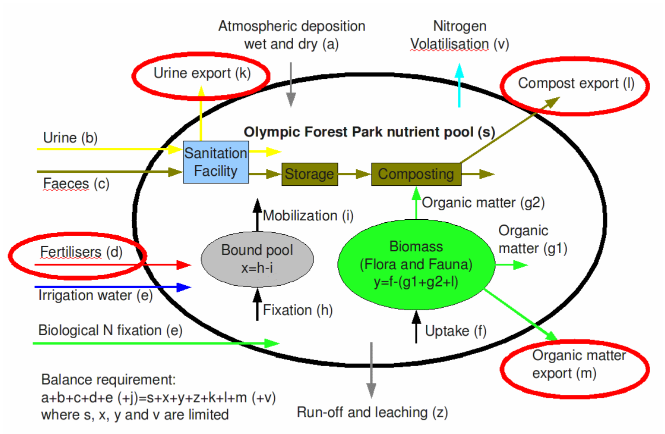

Fig. 8: Simplified nutrient flow model (mass balance) for a sustainable sanitation nutrient cycling in the Olympic Forest Park (source: Germer, 2008)

7 Type and level of reuse

So far no urine has been reused, as the urine treatment system is still being commissioned (the tank is being used, but it is not yet full – awaiting further details from China).

Application of treated yellow water will be based on current irrigation practises. Yellow water will be applied for fertigation (fertilization plus irrigation) with trucks or mobile application units (Fig. 9A). This reuse scheme allows a high degree of flexibility throughout the park until robust monitoring data is available. The estimated dilution ratio of the stored urine with water is 1:1. Whether and for what plants a further dilution is necessary is to be assessed. The co-compost will be used in the same manner as plain plant material compost or other commonly used mulch material (Fig. 9D).

As soon as the actual mass and nutrient flows are known, suitable, permanently installed fertigation systems will be implemented. Underground pipes with several outlets/taps for the attachment of hoses are a convenient option. This dispersion system is already widely used for irrigation in Beijing's parks (Fig. 9B/C).

Another possibility system is subsurface drip irrigation. This system is highly water efficient, but may require adjustment and development to avoid blockage if it is to be used for fertigation with yellow water. Subsurface drip irrigation would significantly reduce handling, limit nitrogen volatilisation and inhibit odour development, and the covering soil layer would act as a physical barrier between the yellow water and park visitors. Both of the permanent systems require either several smaller storage tanks or an extensive pipe distribution system.

The potential nutrient reuse in the Olympic Forest Park is 'sink limited' (the amount of ecosan products that can be used in the park is limited by the area available). To enable environmentally sound and sustainable use of the resources, a comprehensive monitoring program for hygienic safety and nutrient flow should be carried out. Nutrient flow monitoring is essential for the determination of whether, when and to what magnitude nutrient export will become necessary.

Fig. 9: Suggested application systems for the fertigation with yellow water (A via truck, B, C Pipe and hose system) and compost use (D Mulching) [A,B,C Beijing Botanical Garden, D Chaoyang Park, Beijing]

8 Further project components

The nearby Qinghe Wastewater Treatment Plant uses 1,000 ultrafiltration membranes for the tertiary treatment (filtration and phosphorus removal) of secondary effluent, to reclaim the wastewater. Per day 60,000 m³ of reclaimed wastewater are pumped into the park to ensure a sufficiently high water level in the Olympic Forest Park lake and to be used for irrigation and maintenance work. This contributes to the sustainability of Beijing's water supply as it reduces potable water demand.

Fig. 10: Nearby Qinghe Wastewater Treatment Plant supplying irrigation water and feeding the Olympic Forest Park's waterbodies (source: Germer, 2008).

In order to raise awareness in the wider public of sustainable sanitation solutions, an ecosan education area is under discussion, enabling the visitor to follow the nutrient flow as it passes from the toilet to the collection and treatment system, and ultimately to its reuse for crop production.

9 Costs and economics

A comprehensive cost analysis of establishing and running the Olympic Forest Park sanitation system is not yet available.

The theoretical nutrient value of the reused excreta can be expressed as urea (for N), monoammonium phosphate (for P) and muriate (for K) of potash fertilizer equivalents. By recycling urine and faeces, € 12,650 per year (or 0.23 cent per visitor per year) worth of these fertilizers are substituted (based on currently subsidised fertilizer prices in China).

Apart from the nutrients, the economic value of running the sustainable sanitation system includes the opportunity cost of using less water and reducing the load to wastewater treatment plants.

10 Operation and maintenance

Chaoyang's district government was put in charge of the entire construction phase of the park by the government of Beijing. The Olympic Forest Park Management Co. Ltd., has been set up for the supervision of operation and maintenance works during the park's establishment. Final task allocation is expected when all operational units are fully functional.

11 Practical experience and lessons learnt

The public toilet blocks were built and equipped by different contractors, using materials of numerous suppliers. The overall acceptance of all toilet blocks by the public is good. Some of the toilets were, however, not installed as designed and the urine treatment centre is not yet finished (April 2009). Since the Beijing Olympic Games took place in Aug. 2008, the park has so far predominantly been operated under winter conditions and the system is not yet fully operational. Therefore, not enough data is available to formulate robust statements from practical experience.

A comparative assessment of the different sanitation installations will be conducted by ZEDC (Beijing Zhongyuan Engineering Design & Consulting Co.) as soon as the necessary data are available. - Operational results are not yet available.

A preliminary assessment shows that the urine tanks are currently *about* half full[d]. This means that approx. 1000 m³ of yellow water (urine plus some flush water) has been collected in the period Sept. 2008 to April 2009. This is significantly less than the amount predicted from the model for an 8-month period (see Section 6 - 4,000 m³ yellow water was expected per year, or 2670 m³ for an 8-month period). Reasons for the lower collected amount could be that the park did not receive as many visitors as assumed in the calculations because of restrictive access, the delayed opening of one of the wings of the park and the harsh winter.

12 Sustainability assessment and long-term impacts

A basic assessment (Table 1) was carried out to indicate in which of the five sustainability criteria for sanitation (according to the SuSanA Vision Document 1) this project has its strengths and which aspects were not emphasised (weaknesses).

Regarding long-term impacts, it can be concluded that:

1. The Olympic Forest Park sanitation solution is contributing to the sustainability of fresh water and nutrient resource use by reducing water consumption, substituting artificial fertilizers and lowering the volume as well as the nutrient content of wastewater treatment effluent into natural water bodies.
2. This project demonstrates the feasibility of urine and brownwater separation in an urban context to visitors from China and all over the world. In this way it contributes to awareness raising for a promising approach for the future. Other cities in China may be inspired to set up a similar closed-loop sanitation system.

These impacts remain to be confirmed when the system is in full operation.

Table 1: Qualitative indication of sustainability of the system. A cross in the respective column shows assessment of the relative sustainability of project (+ means: strong point of project; o means: average strength for this aspect and – means: no emphasis on this aspect for this project)

	collection and transport			treatment			transport and reuse		
Sustainability criteria:	+	o	-	+	o	-	+	o	-
• health and hygiene	X			X				X	
• environmental and natural resources	X			X			X		
• technology and operation	X				X		X		
• finance and economics			X			X			X
• socio-cultural and institutional		X				X			X

Sustainability criteria for sanitation:

Health and hygiene include the risk of exposure to pathogens and hazardous substances and improvement of livelihood achieved by the application of a certain sanitation system.

Environment and natural resources involve the resources needed in the project as well as the degree of recycling and reuse practiced and the effects of these.

Technology and operation relate to the functionality and ease of constructing, operating and monitoring the entire system as well as its robustness and adaptability to existing systems.

Financial and economic issues include the capacity of households and communities to cover the costs for sanitation as well as the benefit, e.g. from fertilizer and the external impact on the economy.

[d] Exact level in urine storage tanks has been requested; awaiting information.

Sustainability criteria for sanitation (cont.):
Socio-cultural and institutional aspects refer to the socio-cultural acceptance and appropriateness of the system, perceptions, gender issues and compliance with legal and institutional frameworks.

For details on these criteria, please see the SuSanA Vision document "Towards more sustainable solutions" (www.susana.org).

13 Available documents and references

Germer, J. (2008) Ecological sanitation nutrient cycling in the Olympic Forest Park: From nutrient flow planning to cycle implementation. Consultancy report for GTZ Eschborn, Germany. Available at: http://www2.gtz.de/dokumente/oe44/ecosan/en-ecological-sanitation-nutrient-cycling-2008.pdf.

Kangning Xu, Chengwen Wang (2008) Sustainable treatment of green waste and wastewater based on urine-diverting: a case study of Beijing Olympic Forest Park in China. Proceeding of the 15th seminar of JSPS-MOE core university program on urban environment, Sept. 2-3, 2008, Toyohashi, Japan.

An Excel spreadsheet program for this case as a nutrient flow decision management tool is available either from j.germer@sanergy–net.de or ecosan@gtz.de.

14 Institutions, organisations and contact persons

Planning & Design Institute, Tsinghua University, Beijing, China (landscape planning & design)
Prof. Dr. Jie Hu
T: +86-10-62785857-811
E: hujie02467@126.com
I: www.tupdi.com

Department of Environmental Science and Engineering, Tsinghua University, Beijing, China (sanitation system planning)
Prof. Dr. Chengwen Wang
Kangning Xu (PhD student with Prof. Wang)
E: wangcw@mail.tsinghua.edu.cn
I: www.env.tsinghua.edu.cn

Beijing Zhongyuan Engineering Design & Consulting Co., Beijing, China (sanitation system design)
He, Weijia
E: Sheji666@126.com

EnviroSystems Engineering & Technology Co. Ltd., Beijing, China (waterless urinals, UD flush squatting pans and sanitation technology supplier)
Dr.-Ing. Zhang, Jian
E: j.zhang@envi8.com
I: http://www.envi8.com/ (in Chinese)

Beijing Zhongke Longtai Biotechnology Co. Ltd., Beijing, China (UDD squatting pans supplier)
E: sales@zhongkelongtai.com
I: http://www.zhongkelongtai.com/

Sanergy - Engineering Office for Urban Sanitation and Energy Crop Cultivation in the Tropics and Subtropics, Ostfildern, Germany (sanitation mass flow & use consultancy)
Dr. Jörn Germer
E: j.germer@sanergy-net.de
I: www.sanergy-net.de

Note: we are currently still waiting for information about the Chinese suppliers of the urine diversion toilets and waterless urinals.

Case study of SuSanA projects
Urine diversion sanitation in Olympic Forest Park, Beijing, China
SuSanA 2009
Authors: Jörn Germer (Sanergy), Kangning Xu (Tsinghua University)
Editing and reviewing: Carola Israel, Steffen Blume, Elisabeth v. Münch (GTZ ecosan programme - ecosan@gtz.de)

This document is available from:
www.susana.org