sustainable sanitation alliance

Case study of sustainable sanitation projects

Urine-diverting vacuum sanitation system Beijing, China

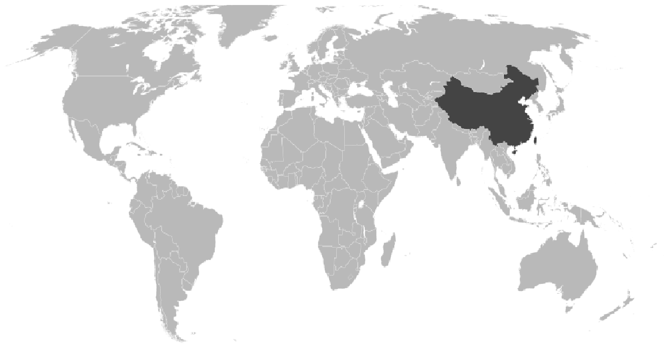

Fig. 1: Project location

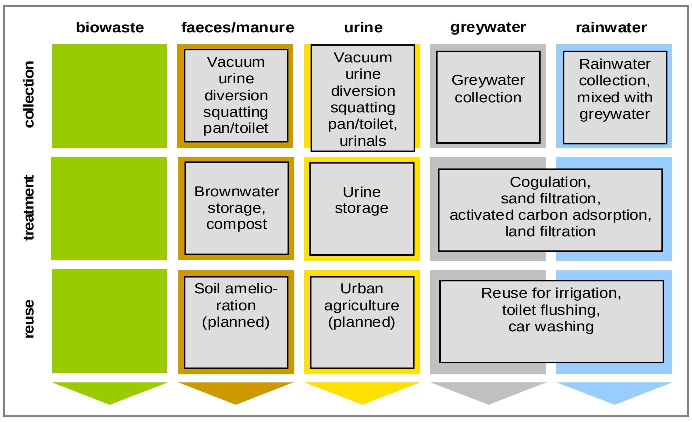

Fig. 2: Applied sanitation components in this project

1 General data

Type of project:

Vacuum urine-diverting sewerage system at a university building

Project period:

Planning: January 2003 – November 2004
Construction: December 2004 – May 2006
Start of operation: February 2007

Project scale:

9 storey building with total area of 20,000 m², capacity of 50 persons per floor
26 squatting and 2 sitting toilets, 14 urinals
total project budget € 20 million, € 27,000 for the vacuum sanitation system

Address of project location:

Sino-Italian Environment & Energy Building (SIEEB), Tsinghua University, Beijing 100084, P. R. China

Planning institution:

China Construction Research & Design Institute, P. R. China

Executing institution:

EnviroSystems Engineering & Technology, P. R. China

Supporting agency:

None

2 Objectives and motivation of the project

The main objective of the project is to demonstrate and evaluate the functionality of an alternative sanitation system for urban buildings. The vacuum urine-diverting sewerage system is used to reduce potable water consumption and to reduce wastewater production.

3 Location and conditions

The Sino-Italian Environment & Energy Building (SIEEB) is located on the campus of the Tsinghua University in north-western Beijing and is financed by the Italian Ministry for the Enviromental and Territory and the Tsinghua University, in the framework of the Sino Italian Cooperation Programme for Enviromental Protection. Its design integrates ecological and energy-efficient technologies and shows the reduction potential of CO_2-emissions in China's building sector. On nine stories, plus the ground floor and two stories below ground SIEEB provides a total floor space of 20,000 m². The west wing of the symmetrical building is equipped with conventional water flush toilets, while the east wing is equipped with a vacuum urine diverting sanitation.

Fig. 3: Sino-Italian Environment & Energy Building at Tsinghua University, Beijing (source: EnviroSystems)

last updated: 26 August 2009

4 Project history

Reclamation of greywater for the flushing of conventional toilets was originally planned in 2003/2004. In the course of the detailed design phase, vacuum toilets were adopted as a very water efficient flush system. Urine diversion was integrated; further reducing water and electricity demand. The implementation of the source separation of urine and faeces provides an additional option to reduce the environmental footprint of SIEEB due the reuse of urine and faeces as a fertiliser for landscaping and agriculture. Currently, suitable pathways for urban-rural nutrient cycling are being investigated. The system has been in operation since February 2007.

5 Technologies applied

Urine collected in the source-separation sitting and squatting toilets as well as the waterless urinals[1] is drained by gravity. Faeces are withdrawn by vacuum suction. Both evacuation systems are made of PVC pipes. Transport of both fractions is carried out with minimal volumes of flush water. Greywater from the hand washing basins is also collected separately and transferred to a compact water treatment facility, where it undergoes coagulation, sand filtration and activated carbon adsorption processes.

Fig. 4: Urine-diversion vacuum squatting toilet in the Sino-Italian Environment & Energy Building (source: EnviroSystems)

6 Design information

From the 2nd to the 7th floor, two vacuum urine diverting squatting pans are installed in men's and women's restrooms, while on the 1st floor, one vacuum urine diverting squatting pan and one vacuum toilet are used in both restrooms. On all floors, the men's restrooms are equipped with two waterless urinals.

The collection and storage station in the basement consists of a urine storage tank, a brownwater (faeces + water) storage tank and a buffer tank for pressure compensation of the vacuum system. All three tanks have a diameter of 0.6 m and a height of 2.0 m (volume 565 L). Two pumps with an installed power of 1.1 kW each generate a vacuum force of 0.4 to 0.6 bar. The vacuum in the air tight system is consistently maintained.

Fig. 5: Collection and storage station for the urine and brownwater (source: EnviroSystems)

The pipes in the system have a relatively small diameter (i.e. 40/50 mm for faeces and 50 mm for urine, compared to 100 mm for conventional toilets).

The flush system of the toilets is operated with two buttons. Flushing urine requires only about 0.1 L of water. The button for faeces simultaneously opens two electronic valves and 0.8-1.5 L of water flushes the faeces area while 0.1 L rinses the urine area. There is no separate collection of toilet paper and used paper is evacuated together with the faeces.

The calculation of the average flowrates for designing the system were based on the following figures:

- Number of persons using the system per floors: 25
- Number of floors: 7
- Number of flushes per day per capita for faeces: 1
- Number of flushes per day per capita for urine: 5
- Water volume per flush for faeces: 0.8 – 1.5 L
- Water volume per flush for urine: 0.1 L
- Water demand for faeces flushing per day: 140 – 263 L/d
- Water demand for urine flushing per day: 87.5 L/d

7 Type of reuse

Rainwater, mixed with reclaimed greywater is used for toilet flushing, car washing and landscaping. Especially the internal garden, consisting of water falls and pools with a capacity of more than 150 m³, requires much water. The landscaping water is treated by land filtration integrated in a lawn nearby and recycled.

There is currently no reuse of urine and brownwater, but they flow to the sewer.

[1] We have requested more information on the type of the waterless urinal and are awaiting a response.

8 Further project components

- Rainwater is drained from the terraces of each floor and collected together with the greywater.
- A small lab next to the collection and storage station is used for water quality monitoring and analysing.
- The difference between the conventional water flush system in the west side of the building and the vacuum urine diverting system in the east side of the building are being studied.
- The SIEEB building is equipped with a variety of additional ecological and environmentally sound technologies that focus primarily on the energy efficiency of the building.

9 Costs and economics

The construction cost of the vacuum urine diverting system (pipe, pump and storage installations) was about € 27,000. A detailed cost break-down is not available. O&M (Operation and maintenance) costs are also not available.

10 Operation and maintenance

The collection and storage station in the basement is automatically controlled. No dedicated staff is required for the routine operation except periodical maintenance, carried out by a contracted service company. The service staff was trained by the system supplier for several months.

Until now, no chemical or mechanical cleaning of the pipe systems has been necessary as there have been no blackages, neither due to precipitation of urine salts nor due to toilet paper. The collected urine and brownwater (faeces plus flush water) is used for research purposes, before disposal in the public sewer system. No routine reuse has been established.

11 Practical experience and lessons learnt

The vacuum urine diverting sanitation system has been newly developed for SIEEB and is the first of its kind in China. Its successful use in a modern multi-storey building demonstrates that the system is a potential alternative to more water-demanding gravitation flush systems in urban areas.

Based on the knowledge gathered during planning and in later phases, it was found that the system represents a technologically feasible and economically reasonable system. Accumulated data on the design, construction and operation are expected to provide important information for optimisation of the technology and its dissemination.

Low dilution with flush water yields concentrated yellow- and brownwater. Due to the concentration, the volume to be treated and transported is quite low per nutrient unit. This is a valuable advantage if these materials are to be used as plant fertilisers. The mass flows as well as their chemical and hygienic properties are being currently monitored to study such reuse options. Thus, vacuum urine diverting systems contribute to limiting the water requirements of modern cities and may help to close the nutrient loop between rural and urban areas.[2]

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 emphasized (weaknesses).
The vacuum urine diverting system in combination with greywater reclamation reduces greatly the fresh water demand. Accordingly, the system lowers significantly the amount of wastewater discharged to the municipal wastewater treatment plant. Further, the on-site treatment of greywater lessens the absolute load of organic and mineral compounds in the wastewater stream.

Table 1: Relative sustainability of system components
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			Treat-ment*			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	
• sociocultural and institutional	X				X			X	

*Currently applies to greywater reclamation only

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.
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).

[2] We have requested more information on the experiences and are awaiting a response.

13 Available documents and references

Wang, C. and Bao, W. (2007) Case Study of Vacuum Urine-Diverting Sewerage System of SIEEB Tsinghua University, Gewässerschutz, Wasser, Abwasser, 206, 22/1-22/6. Editor: Institut für Siedlungswasserwirtschaft, University RWTH Aachen, Germany (http://www.isa.rwth-aachen.de/). Also available: http://www2.gtz.de/Dokumente/oe44/ecosan/en-case-study-of-vacuum-urine-diverting-sewerage-system-2007.pdf

Zhang, J. (2008) Application of vacuum toilets and collection systems for water saving and source separation, China Water & Wastewater Engineering, 34(2), 96-99 (in Chinese, available on request by J. Zhang)

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

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