

Case Study of Vacuum Urine-Diverting Sewerage System of SIEEB Tsinghua University

C. Wang*, W. Bao**

* Department of Environmental Science & Engineering, Tsinghua University, Beijing, 100084, P. R. China
(Email: wangcw@mail.tsinghua.edu.cn)

** Department of Environmental Science & Engineering, Tsinghua University, Beijing, 100084, P. R. China
(Email: bwj05@mails.tsinghua.edu.cn)

Abstract

In this paper, a new sewerage system with innovative technology of vacuum urine-diverting toilet is introduced. The sewerage system, first one of its kind in China, is installed in a 9-storey modern building in Beijing, China. In the system, urine is separated and then collected by gravity while feces is transported through sewerage system driven by a vacuum station. The difference between traditional toilet and vacuum-urine-diverting toilet within the same building is studied. Certain technological and economical factors regarding of the design, construction, operation and maintenance are analyzed.

Keyword

Sewage system; squatting pan; vacuum urine-diverting toilet

INTRODUCTION

Conventional sewage system, where the human excreta is diluted with flushing water, mixed with other wastewater and finally treated and disposed in a centralized way, has been under increasing criticism recently. Its high investment in construction, operation & maintenance, and great demand for flush water has rendered it an uneconomical way of sanitation and nearly ruled out its availability in developing countries, esp. in the arid regions.

Gardner (1997) pointed that flush water counts to 20-40% of total municipal water consumption. On the other hand, Otterphol (2000) found that feces & urine contains more than 90% of nitrogen and 60% of phosphorous in conventional municipal wastewater. Since the early 1990s, to minimize the demand of the fresh water and maximize the recycling of nutrients, the research in sewage system has been reoriented into the some economical and ecological alternatives, such as composting toilet, vacuum toilet, flushing urine-diverting toilet, etc. All these approaches share the common merits: (1) Natural or low-energy-demanding treatment and disposal of human excreta; (2) Complete reclamation of nutrients from human excreta; (3) Efficient and safe treatment and reuse of possible discharged wastewater.

Moreover, the know-how and expertise has been applied and proven in practice with a great amount of pilot projects launched around the world.

C. K. Choi Building, located in Vancouver Canada, is a perfect example of biological composting toilet. Human excreta is collected in a biological tank in basement, where the biological degradation takes place. With vacuum technology, the toilets with 0.5-1.5 flush capacity have been available in market. Gulbrandsen (1999) pointed out that the vacuum toilet generates 5-7 L black water per day per capita, roughly 1/10 of that of conventional toilet. In Lübeck-Flintenbreite Germany (2000), vacuum-composting toilet has been developed and applied in double and terrace houses.

In a test on fecal separation & urine diversion in Swedish household sewage system, Vinnerås et al (2002) have proven the technology as a promising alternative in the future. More simple and practical urine-diverting systems have been applied in developing nations, i.e. Linjiang and Dongsheng, China, Garla Mare, Romania, India, Mid-east and etc.

In 2006, a vacuum urine-diverting sewage system, a combined technology of vacuum toilet & urine-diverting toilet, has been developed and practiced in a nine-storey modern office building in Tsinghua University, Beijing, China. The case study on this system is to give a clear picture of its design, construction and operation.

METHODS AND RESULTS

Building

Sino-Italy Environment & Energy Building (SIEEB) is an intelligent, ecological and energy-efficient building: a model for a new generation of sustainable buildings. It is a 20,000 m² building, 40 m high, located in the campus of Tsinghua University in Beijing, and hosts a Sino-Italy education, training and research centre for environment protection and energy conservation.

The SIEEB, mainly financed by Italy (Ministry for the Environment and Territory, in the framework of the Sino Italian Cooperation Program for Environmental Protection) and co-financed by Tsinghua University, is also regarded as a platform to develop the bilateral long-term cooperation in the environment and energy fields, and a model case for showing the reduction potential of CO₂ emission in the building sector in China.

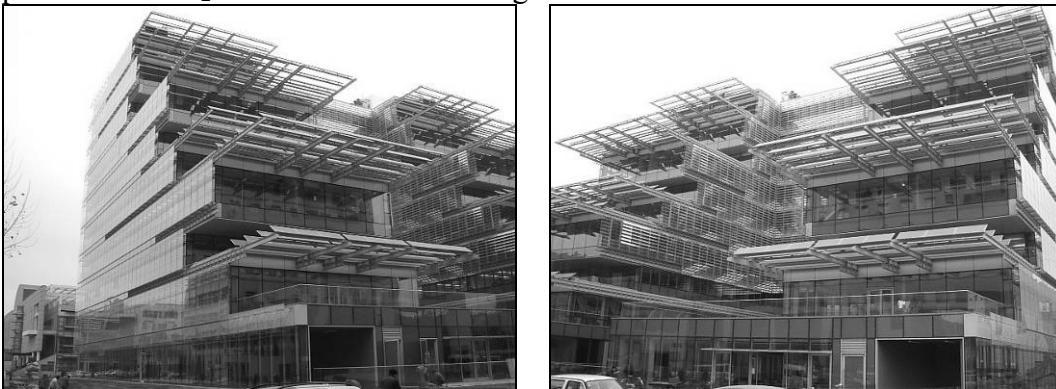


Fig 1 Sino-Italy Environment & Energy Building

Ecological Water Management (Greywater, Rain, Landscaping water)

In SIEEB, a closed loop water system, several water-saving and energy-efficient approaches have been applied in the treatment and reuse of greywater, rain, and landscaping water.

Greywater (washing water) is collected separately and transferred to a compact water treatment facility, which consists of coagulation, sand filtration and activated carbon adsorption processes. After treatment, greywater is reused for toilet-flushing, car-washing, and irrigation for the greens?. Rain is collected in the terraces of each floor, mixed with greywater, and finally becomes another water source.

The internal garden & landscaping consists of water falls and pools of a water capacity of more than 150 m³. The landscaping water is treated and recycled by land filtration in lawn nearby.

Sewage System Outline (urine, feces)

SIEEB, with 9 storeys above ground and 2 storeys underground, is a symmetrical two-wing building. The sewage system on the west wing of the building is the conventional water flush system meanwhile the east side uses the new vacuum urine-diverting sewerage system. (shown in Fig 2)

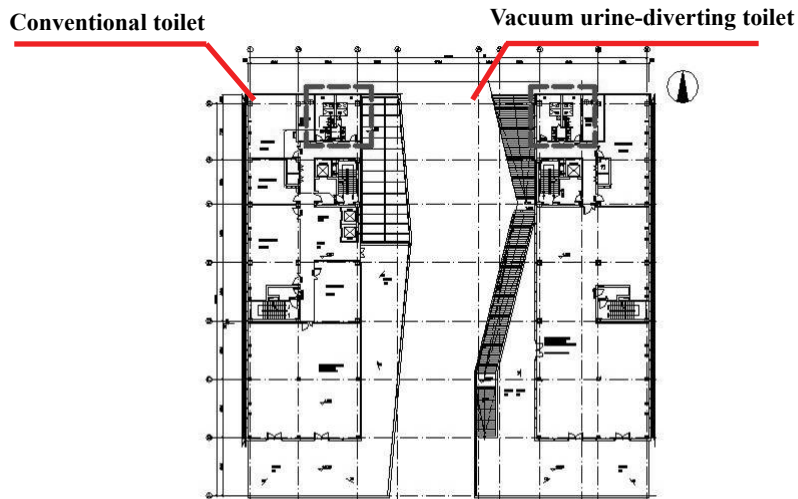


Fig 2 layout of SIEEB (2nd floor)

In the vacuum urine-diverting system, urine is collected gravitationally from the man's urine collectors and urine-diverted squatting pans, and then transferred to the storage tank in the basement while feces is separated from the squatting pans and transferred through vacuum pipelines driven by the vacuum station also in the basement (Fig 3).

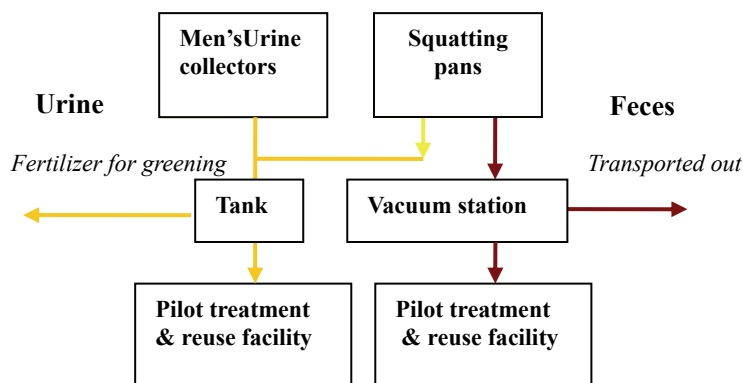


Fig 3 Vacuum urine-diverting system diagram

System design

The average water flowrate for design is shown in the table 1, which indicates how much flush water is needed and how much wastewater is generated for each day.

Table 1 average flowrate of wastewater for design

	Number of persons per floor (east wing)	Number of floor (east wing)	Flush per day per capita	Water per flush (L)	Water demand (L/d)
Feces	25	7	1	0.8	140
Urine	25	7	5	0.1	87.5

On the east wing of SIEEB, from the 2nd to 7th floor, two vacuum urine-diverting squatting pans are installed in both man and woman's room (Fig 4 left). On the 1st floor, since there is a small chamber for disabled people in each washroom, one vacuum urine-diverting squatting pan and one vacuum toilet are used in both man and woman's room (Fig 4 right).

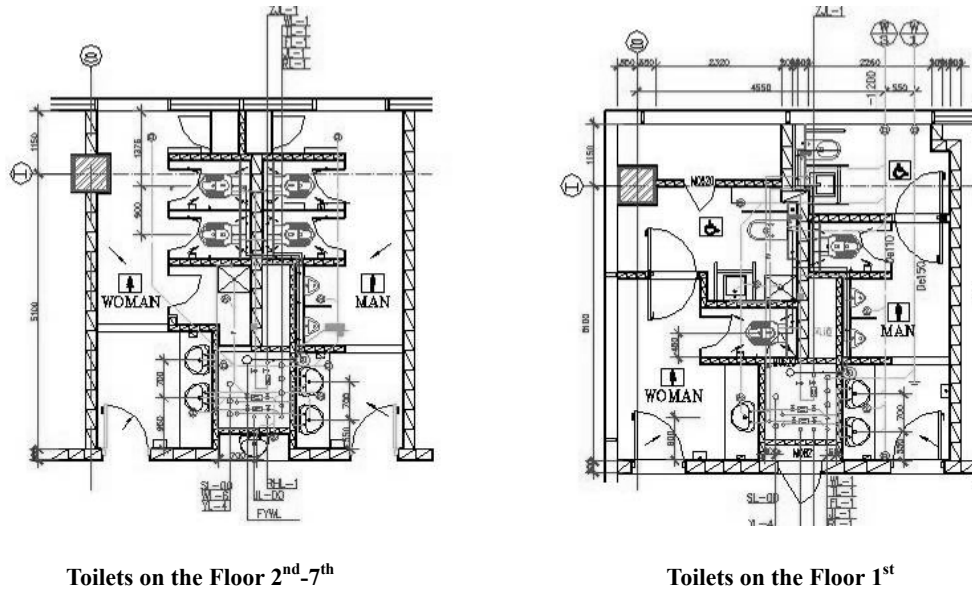


Fig 4 Layout of toilets on the east side of SIEEB

Squatting pan design

The vacuum urine-diverting sewage system on the east wing of SIEEB consists of 26 squatting pan and 2 vacuum toilets. (shown in Fig 5).

As the profile of urine-diverting squatting pan, urine is collected in the front part of the pan and transferred through a thin pipe down to the storage tank by gravity. Unlike the conventional flush toilet, which is driven by the level difference of water (10 cm high, 1 kpa), the vacuum toilet is driven by a vacuum force (20-60 kpa) to the transfer feces with less water and higher efficiency and reliability.



Fig 5 urine-diverting squatting pan and vacuum toilet

Collection and storage station

The collection and storage station in the basement (shown in Fig 6) consists of a urine storage tank (D=600mm, H=2m), a feces storage tank (D=600mm, H=2m), a buffer tank for pressure compensation (D=600mm, H=2m), many vacuum pumps and automation & control system.

The vacuum in system is generated by 2 vacuum pumps in automatically alternate operation. The water level monitoring device in storage tank will turn on the discharge valve and the discharging pumps. The vacuum system is controlled by an on-site PLC, which allows both the automatic and manual operation.

For the easy analysis of separated urine and feces, two storage tanks (ca.500L) in atmospheric pressure are installed. Since the feces is transferred by vacuum force, another pressure compensation tank is required.



Fig 6 collection and storage station.

Construction

The vacuum system has posed stricter requirement for construction. For example, the pipeline system should be absolutely sealed while the electronic valves and control system for each toilet made the construction much more complicated.

However, the pipes in the system have relatively small diameter (i.e. DN 40 for feces and DN 10 for urine, compared with DN 1000 for conventional toilet). Since the feces is transferred by vacuum, the layout of the PVC pipe could be more flexible as well. These merits, on the other side, facilitate the construction to some extent.

Operation and maintenance

The toilets are easy to use. Every toilet has two buttons for urine and feces flush respectively. When user pushes the urine button, 0-0.1L flush water is needed to flush the urine area of the pan within 1 second.

When feces button is pushed, two electronic valves open simultaneously and 0.5-0.8L water flushes the feces area while 0-0.1L water flushes the urine area. The whole process takes 1.5 second.

The collection and storage station in the basement is automatically-controlled. No dedicated staff is needed for the routine operation except periodical maintenance. There is a small lab next to the station, where water quality is monitored and analyzed

Economical analysis

The project has cost about 300,000 RMB (\$40,000) including construction expense. Compared with the conventional toilet system on the west side of the building, about 5~10 Kw.h / day energy cost is need for the system operation, while 2.5~4 m³/d fresh water is saved. Taking into account the reuse of urine, compost of feces, greatly decreasing loading of wastewater esp. the nutrients, the vacuum urine-diverting system, as a new method of ecological sanitation, is not only technologically feasible in modern buildings but also environmentally friendly and economically reasonable.

CONCLUSIONS

The vacuum urine-diverting sewage system is a newly-developed system, which has its first presence in China.

Its practice in SIEEB, a modern multi-storey building, has proven the vacuum urine-diverting sewage system as a potential alternative in modern city, which is technologically-feasible and economically-reasonable system.

The valuable data of design, construction and operation in this case might provide important experience for its wider application in the future.

Vacuum urine-diverting system can greatly save the fresh water resource, reduce the loading of nutrient substances and exert a significant effect on municipal wastewater treatment. With advanced on-site treatment and reclamation technology, vacuum urine-diverting system may give an answer to closing-loop of water and wastewater in modern cities.

REFERENCES

- Calvert, P. (2000). The Practise and Potential of Ecological Sanitation in India and the sub-continent based on current research and demonstration of compost toilets in India. Proceedings of the Eco-san International Symposium, 30-31 October 2000, p129, Bonn, Germany.
- Gardner, G. (1997). Recycling organic waste: From urban pollutant to farm resource. Worldwatch Institute, paper 135, 58 p. 1997
- Gulbrandsen, A.(1999). A water saving vacuum system for transport of blackwaterand onsite treatment of greywater in a constructed wetland. M.Sc. Thesis. Dept. of Engineering, Agr. Univ Norway. 1999.
- Oldenburg, M. (2000). Experiences with Ecosan Projects in Germany and Austria. Proceedings of the Eco-san International Symposium, 30-31 October 2000, p191-p197, Bonn, Germany.
- Otterphol, R. (2000). New Developments of EcoSan in Germany and Europe, Proceedings of the Eco-san International Symposium, 64-38 October 2000, p191-p197, Bonn, Germany.
- Vinnerås, B., Jönsson, H (2002). The performance and potential of faecal separation and urine diversion to recycle plant nutrients in household wastewater Bioresource Technology 84 (2002) 275–282