Case study of sustainable sanitation projects
Urine and brownwater separation at GTZ main office building
Eschborn, Germany

Fig. 1: Project location

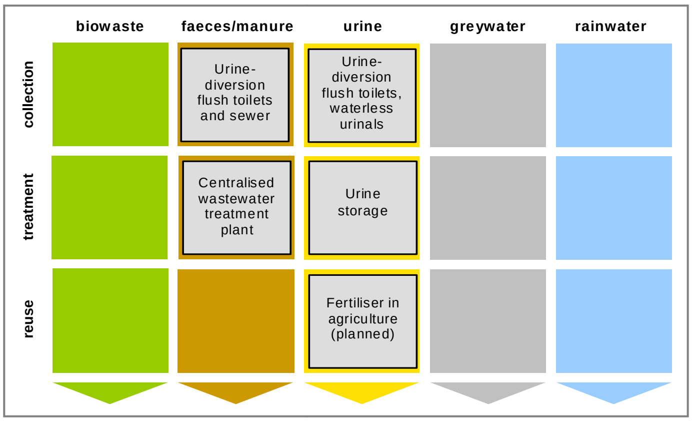

Fig. 2: Applied sanitation components in this project (for Phase 1 only)

1 General data

Type of project:

Demonstration project in an urban office building

Project period:

Phase 1: Start of construction: 2005
Start of operation: end of 2006 (ongoing)

Phase 2: Research project (treatment and reuse): planned to start mid 2009

Project scale:

Approx. 400 employees and visitors served by the urine separation system: 50 urine-diversion flush toilets, 23 waterless urinals, 10 m³ urine storage tank. Investment cost: EUR 125,800.

Address of project location:

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH,
Dag-Hammerskjöld-Weg 1-5
65760 Eschborn, Germany

Planning institution:

Pettersson & Ahrens Ingenieur-Planung GmbH, Germany and GTZ ecosan program.

Executing institution:

Maßalsky GmbH, Germany.

Supporting agencies:

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH.

Hessen State Ministry for Environment (HMULV). Subsidy for Phase 1 by Investitionsbank Hessen (IBH) of € 43,070.

German Federal Ministry of Education and Research (BMBF) for Phase 2.

2 Objectives and motivation of the project

Objectives of the project:

1. To demonstrate the implementation of an ecological sanitation (ecosan) concept (here with urine-diversion flush toilets, urine storage and reuse) in an urban context (this is just one possible ecosan technology; many others exist too). Ultimatively, if this technology was used widely in Germany, it could also prevent pharmaceutical residues contained in urine from entering into groundwater and surface water (as these substances are only partially removed in conventional wastewater treatment plants).
2. To reduce the amount of water used in the GTZ House 1 building.
3. To research important aspects of ecosan systems in Germany (social acceptance, reuse of urine in agriculture); this is planned for Phase 2.

The GTZ headquarters in Eschborn is frequently visited by international GTZ staff and decision makers, making this a good location for the demonstration of innovative ecological sanitation concepts.

Fig. 3: The main building ("House 1") at the GTZ headquarters in Eschborn near Frankfurt, where this project is implemented (source: GTZ).

3 Location and conditions

The GTZ headquarters consists of four multi-storey buildings and is located in Eschborn, a city of 21,000 inhabitants, 10 km northwest of Frankfurt am Main, the financial capital of Germany.

Approximately 1,450 people work in the GTZ headquarters(in 2009), of which the main building ("House 1") provides space on 10 floors for about 650 employees, the canteen and one large auditorium (capacity for about 250 people). House 1 has a double-Y shaped floor plan with a central section and two wings at either end. The urine diversion system is installed only in the central section of the building. The total number of persons using the urine separating toilets is difficult to estimate but may be around 400 people per working day.

4 Project history

The GTZ main building ("House 1") was constructed in 1976. When it was 30 years old it was completely renovated during 2004 to 2006 because the environmental performance and the technological standards of the building were not satisfying anymore, creating high operation and maintenance costs.

On behalf of the German Ministry for Economic Cooperation and Development (BMZ), GTZ is running an ecosan program since 2001 to mainstream ecosan concepts around the world.

When House 1 had to be renovated, the GTZ ecosan team promoted the implementation of an ecosan demonstration and research project. This project in House 1 was planned to be implemented in two phases:

Phase 1: The construction of the urine separation, collection and storage system along with the renovation works, was financed by GTZ and subsidized by the HMULV (Hessen State Ministry for Environment). The construction of phase 1 was completed in late 2006 and the installations are being used since then.

Phase 2:

- In mid 2006 an application for funding for a research project on urine and brownwater[1] treatment was submitted to BMBF (German Federal Ministry for Education and Research).
- The research project was proposed by GTZ, universities (University of Bonn, RWTH Aachen University and Giessen University of Applied Sciences) and industrial partners (Hans Huber AG and Roediger Vacuum GmbH).
- Approval by BMBF was granted in May 2009 and the research project is due to start in August 2009.

The planned research project, will focus on the development of treatment technologies and reuse practices, user acceptance, environmental and health issues (particularly with regards to micropollutants), legal and economic aspects, and the applicability of the system in industrialised, emerging and developing countries.

[1] mixture of flushing water and faeces

5 Technologies applied

Phase 1:

The urine separation and storage system which was installed in Phase 1 consists of:

- 23 waterless urinals
- 50 urine-diversion flush toilets for the waterless collection of urine
- A separate piping system for undiluted urine collection
- Urine storage tanks in the basement of the building

Fig. 4: Left: waterless urinal (Keramag). Right: urine-diversion flush toilet (Roediger) at GTZ main building; note the two buttons for flushing: the small one is for the urine flush, the larger one for the faeces flush (source: L. Ulrich, January 2009).

Fig. 5: Left: Plastic urine storage tanks in the basement of House 1 with connected urine pipework. Right: urine tanks with level indicating plastic pipes (source: L. Ulrich, April 2009).

Phase 2 (planned):

Two urine treatment options will be investigated in Phase 2:

- Treatment by prolonged storage for direct application of urine to fields (this treatment is already carried out in Phase 1).
- Precipitation of phosphorus and nitrogen from urine by the addition of magnesium oxide. This process produces the crystal magnesium-ammonium-phosphate (MAP) or struvite.

Brownwater treatment will be implemented by using a membrane bioreactor(MBR).

6 Design information

House 1 has a central section and two wings. The urine diversion sanitation system is implemented only in the central section, on all 10 floors.

Waterless urinals (23 are installed)

The Keramag waterless urinals (model Centaurus), which are made of sanitary porcelain, are equipped with a flat rubber tube as odour seal and a sieve made of high-grade steel (see Fig. 6). The flat tube opens when urine flows through it. The sieve traps pubic hair which could otherwise stop the flat rubber tube from closing properly.

Fig. 6: Urinal inlet sieve with flat rubber tube as odour seal (Keramag). Left: old model (mostly replaced, see Section 11). Right: optimised new model (source: L. Ulrich, April 2009).

Urine-diversion flush toilets (50 are installed)

The toilets by Roediger (model NoMix) have two separate bowls for urine and brownwater collection and two pipe connections for the separated wastewater fractions. They are made of sanitary porcelain. The urine is collected undiluted (without flush water) by means of a valve located below the urinal bowl: the valve is opened when the user sits down (see Fig. 7).

There are two buttons for toilet flushing (see Fig. 4): the smaller button is for the urine flush, which releases about 1-3 L of water, and with the larger button the faeces are flushed using 6 L of water[2].

Pipework

Two separate piping systems are implemented for separate urine and brownwater collection.

The urine flows from the toilets to the storage tanks in cast iron pipes with enamel (epoxide) coating. The pipe diameters are 100 mm (for the main collectors), 80 mm and 50 mm. A connection to the conventional sewer is installed as well, which enables bypassing of the urine tanks.

This Pipe material was chosen to minimise urine stone formation(encrustations). Plastic pipes would also be possible and are cheaper.

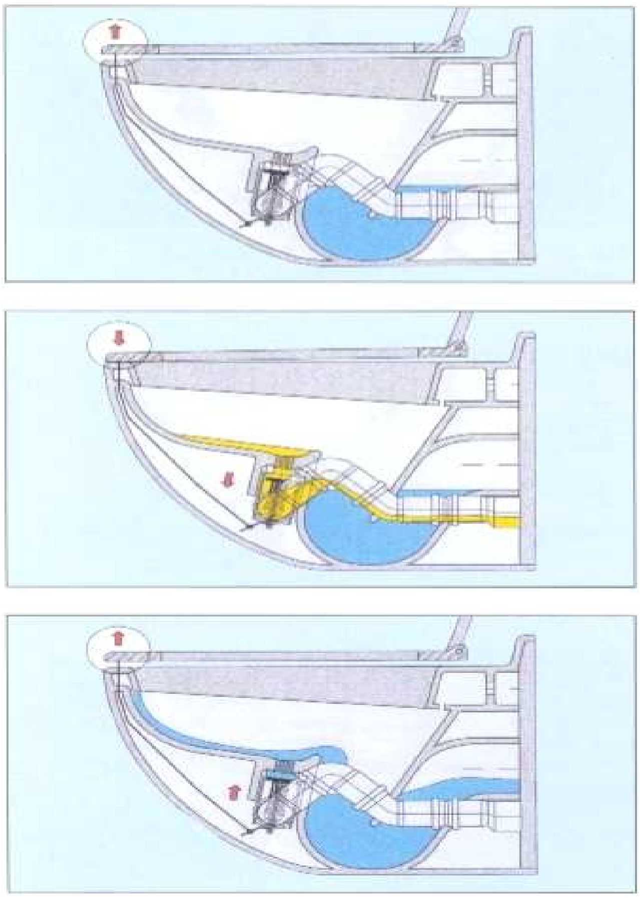

Fig. 7: Functional diagram of a urine-diversion flush toilet (source: Roediger). Top picture: closed valve before user sits down (idle state). Middle picture: toilet in use; bottom picture: during flushing(user no longer sitting).

Urine storage tanks

A total volume of 10 m³ is provided for urine collection and storage. The four polyethylene (PE) tanks of 2.5 m³ each are located in the basement of the building in a room in the car park area, and are equipped with sampling and level measuring devices. The pipework design allows filling each tank separately.

Measurements in 2008 showed that it takes about 3 months to fill the 4 tanks (corresponding to a storage time of 3 months). When the tanks are full, the urine overflows to a sewer. Therefore, about 40m^3 of urine are collected per year.

7 Type and level of reuse

Up to now urine has only been reused for demonstration purposes in pot plants in the offices of the GTZ ecosan team. Several times urine was transported to universities for research purposes: one entire tank load of 10 m³ was taken to the University of Aachen for MAP precipitation tests, and several batches of the urine were taken to the Universities of Giessen and Bonn for chemical analyses.

Reuse of treated urine will be realised in Phase 2. Under German fertiliser law, urine reuse in agriculture is not yet possible without special permits. In the upcoming BMBF funded research project, the GTZ ecosan team will try to establish such

[2] Exact volume for the urine flush is yet to be measured on-site.

a permit for the application of stored urine as fertiliser on local agricultural fields.

When brownwater treatment is installed in Phase 2, the treated brownwater may be suitable for irrigation or toilet flushing – depending on the technology applied.

8 Further project components

The GTZ ecosan team regularly conducts guided tours through the facilities. A demonstration room with various urine-diversion toilet models from all over the world is adjacent to the urine storage tanks.

Due to the complete renovation of the buildings facade and the use of energy efficient heating systems and boilers the energy consumption of House 1 was substantially reduced.

The new ground design and a green roof (about 50 % of the total surface) enhance a positive microclimate and reduce rainwater runoff.

The building has won several awards including the "CSR Mobility Award" for sustainable travel management in 2008 from DMM, B.A.U.M. and VCD, and the "Bike + Business Award" in 2009 from the "Planungsverband Ballungsraum Frankfurt Rhein/Main (PVFRM)" and the "ADFC Hessen".

Water saving

During 2004-2006 all four GTZ buildings in Eschborn were equipped with water efficient fittings. Two of the four buildings, including the main building, are equipped with a separate service water system for toilet flushing, hand washing and cleaning, using the groundwater that has to be pumped up in order to lower the high groundwater level for the underground carpark in the building.

The groundwater which has to be pumped anyway is used as service water in preference to the more expensive municipal drinking water. Because of this groundwater pumping, greywater recycling was not a cost-effective option for the GTZ main building and has therefore not been implemented. Greywater is instead discharged into the sewer system leading to the central wastewater treatment plant located in Frankfurt-Niederrad.

9 Costs and economics

Table 1 shows a cost comparison between the present prototype installation and a conventional system.

These costs are based on a prior cost estimate from the year 2004 (for scenario 1) and actual costs from the year 2006 (for scenario 2).

Table 1: Investment costs (in EUR) for the collection system for scenario 1 (conventional system, based on cost estimate) and scenario 2 (ecological system installed at GTZ building, based on actual costs) for Phase 1.

	Scenario 1 (conventional)	**Scenario 2** (installed Phase 1)
Conventional urinals (23 units, 392 EUR each)	9,016	-
Waterless urinals (23 units, 315 EUR each)	-	7,245
Conventional toilets (50 units, 272 EUR each)	13,600	-
UD toilets (50 units, 1347 EUR each)	-	67,350
Blackwater pipe system	17,500	-
Urine, brownwater and greywater pipe system	-	12,422
Urine collection tank, pumps	-	38,800
Total investment costs	**40,116**	**125,817**
Difference	**0**	**+ 85,701**

Compared to scenario 1, the additional costs of scenario 2 are 85,700 EUR (see Table). The relatively high costs for scenario 2 are due to the following factors:

- Some components are currently only being manufactured in small numbers (e.g. the urine-diversion flush toilets). This has lead to unit costs for urine diversion toilets that were in 2005 about 5 times higher than the unit costs of conventional toilets[3].
- The urine tanks had to be manufactured specifically to fit into an existing room.
- Some units were designed with an extra safety factor (e.g. the urine pipe with enamel coating)
- The separated wastewater fractions can not yet be reused(onsite) thus still requiring a sewer connection. If no sewer connection was necessary, this could lead to cost savings in the case of a new building.

The use of the urine-diversion flush toilets and the waterless urinals reduce the water consumption for toilet and urinal flushing by approx. 1,200 m^3 per year compared to flush urinals and conventional toilets depending on the assumptions made.[4] This amount however cannot exactly be quantified because separate water meters measuring the water consumption before and after the installation of the new sanitary equipment were not installed.

Resulting from the water savings mentioned above, the calculated costs savings of scenario 2 compared to scenario 1 amount to approx. 4,800 EUR/year (see Table).

[3] In 2009 the unit costs for Roediger NoMix toilets were EUR 780 and for Keramag Centaurus waterless urinals EUR 505(discounts possible for larger orders).

[4] Assumptions for this calculation: 200 men and 200 women (staff and guests), 220 working days per year. Men using the urinals 3 times/day at 3 L/flush (scenario 1) and 0 L/flush (scenario 2) and using the toilet 0.5 times/day at 8 L/flush(scenario 1) and 6 L/flush(scenario 2). Women activating the urine flush 3 times/day at 8 L/flush(scenario 1) and 3 L/flush(scenario 2) respectively and the faeces flush 0.5 times/day at 8 L/flush(scenario 1) and 6 L/flush(scenario 2).

Table 2: Estimated water-related operating costs (in EUR/year) of the two scenarios[5].

	Scenario 1 (conventional)	Scenario 2 (installed Phase 1)
Urinal flushing	2,200	0
Toilet flushing	9,600	7,000
Kitchenettes, sanitary sinks	3,200	3,200
Total water operating costs	**15,000**	**10,200**
Difference	**0**	**- 4,800**

10 Operation and maintenance

The installations which convey undiluted urine need special care because they are prone to the formation of urine scale(e.g. struvite).

Waterless urinals

Every evening the waterless urinals are cleaned(wiped down manually). On the highly frequented ground floor they are additionally cleaned every hour between 9:00h and 13:30h with a wet cloth and subsequently sprayed with a special odour removing cleaning agent for waterless urinals[6].

At least fortnightly the sieves and rubber tube seals should be removed from the urinals and regular toilet cleaner should be used to clean the sieves and to remove urine scale. The rubber tube seals are rinsed with water. They are replaced about once per year when the sealing mechanism does not work properly any more (not on a regular basis). The cost of one rubber tube(see Fig 6) is EUR 17.

Urine-diversion flush toilets

The daily cleaning routine is the same as for conventional toilets. For precipitation prevention the urine valve (in open position) needs to be soaked overnight with urine scale removing chemicals[7] every 2-3 months and soaked over night. This is done on two consecutive days by filling 200ml of this chemical into the open valve(seat pressed down to open the valve). Annually, the functionality of the valves is controlled and defective valves should be cleaned or replaced. If this maintenance routine is not followed problems will occur, see below.

Compared to conventional toilets this maintenance work is slightly more time consuming. Other than that the cleaning routine does not differ to normal toilet maintenance.

11 Practical experience and lessons learnt

The toilets and urinals have been in use since the end of 2006. Since that time valuable experience has been gained with the operation of the source separating collection system.

The users' opinion on the project and on ecosan in general

In September 2008 a GTZ internal survey about the acceptance of the waterless urinals and urine-diversion toilets as well as ecological sanitation in general was carried out. The following facts were revealed by the survey (217 participants):

- 90% of the participants pointed out that they like the idea of separately collecting urine and faeces for the application as fertiliser in agriculture.
- 71% would buy products fertilised with human excreta, whereas only 6% would not.
- 46% say urine should be permitted as fertiliser in organic agriculture, 12% think not.
- 48% would move into an apartment with urine-diversion toilets, 25% would not.
- The majority of users likes the modern design of the toilets and appreciates the installation of the novel watersaving sanitation system in the GTZ main building. However, only 5% of the users say the cleanliness of the toilet is better compared to conventional toilets, and 51% say it is worse.
- Many people complained about the higher demand for toilet cleaning after defecation and insufficient flushing strength for brownwater if a lot of toilet paper is used. 61% of the users flush the toilet more than once after usage.

Low nitrogen content of the collected urine

With 2.8 g/l[8] the measured nitrogen concentration for the stored urine is two thirds less than literature values for stored urine (7-9 g/l). The main reason for this is probably that nitrogen loss occurs in the form of ammonia gases being emitted through the tank's ventilation system. This could be reduced in the future by reducing the ventilation rate so that only pressure equalisation takes place. It is also possible that the urine may be diluted with some flush water.

Experience with the waterless urinals

The cleaning staff changes relatively often at the GTZ facilities. It has been found that thorough instruction of the staff which is responsible for the maintenance of the urinals is sometimes lacking. These problems are slightly reduced by replacing sieves and rubber tube seals with a new, optimised model (see Fig. 6) but if maintenance is neglected, then these will also cause odour problems.

As a result, the urinal sieves, and rubber tube seals were in some instances not cleaned for many weeks or months. This led to the accumulation of urinestone on the sieve(Fig. 8) as well as pubic hair and slime deposits which then cause odour problems.

[5] Costs for water supply and wastewater disposal are calculated with 2 EUR/m³ each. Maintenance costs are not included in this calculation.

[6] URIMAT MB-AktivReiniger with Kalkex

[7] 200 ml of "MELLERUD Urin- und Kalkstein-Entferner" (urine and calcium stone remover) per toilet

[8] The total nitrogen concentration in the stored urine was measured on about five occasions.

Fig. 8: Urine scale deposition on a waterless urinal's outlet sieve (old model). With the new model of the sieve and rubber tube seal (see Fig. 6 right), such urine scale formation and internal pubic hair accumulation is reduced (source: L. Ulrich, December 2008).

Experience with the urine-diversion flush toilets

The main problem with these toilets is that the urine pipe valve is susceptible to slimy struvite precipitations(see Fig. 9) this causes clogging of the valve, causing the urine to discharge through the brownwater pipe. Therefore it is crucial to apply an adequate maintenance routine, (see Section 10)[9]. As this maintenance has been neglected in this project, all valves stopped working after about two years of use and now need to be replaced(June 2009)[10].

The trade-off between sufficient flushing strength and water saving, should also be adressed in further development of the toilet bowl design. It was found that the urine flush is often not strong enough to flush away urine-soiled toilet paper. When users the flush twice, water savings are negated.

About two third of female users do not sit down on these or any other toilets in public places[11].The urine of these females is therefore not collected. This problem could be reduced by providing disinfection sprays for the seats.

Fig. 9: Soft urine precipitations inside a urine valve of a Roediger urine-diversion toilet. This valve was disassembled and cleaned after clogging (source: L. Ulrich, December 2008). One valve costs EUR 118 and requires a bowden cable costing EUR 51(location of valve in Fig. 7).

12 Sustainability assessment and long-term impacts

In Table 3 a basic assessment 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).

Table 3: Qualitative sustainability assessment of the system. The crosses indicate the relative sustainability for each project component (column) and sustainability criterion (row). (+): strong point of project, (o): average strength for this aspect, (-): no emphasis on this aspect in the project.

	collection and transport			treatment[a]			transport and reuse[a]		
Sustainability criteria:	+	o	-	+	o	-	+	o	-
• health and hygiene				X					
• environmental and natural resources	X			X					
• technology and operation			X						
• finance and economics			X						
• sociocultural and institutional		X							

[a] Not implemented yet.

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).

The following impacts of this project can be highlighted:

1. This project demonstrates the feasibility of urine and brownwater separation in an urban context to visitors from all over the world and thus helps to disseminate the ecosan concept.
2. By introducing an innovative sanitation system at its own main office building, GTZ shows its commitment to the ecosan approach.
3. The waterless urinals save water compared to conventional urinals.
4. This project has raised the visibility of the ecosan program within GTZ.

13 Available documents and references

Detailed design information and drawings are available on request from the GTZ ecosan programme. A presentation on this project is available here:

http://www2.gtz.de/dokumente/oe44/ecosan/en-presentation-gtz-eschborn-haus1-2009.pdf

[9] Pictures showing clogged and then cleaned valves can be seen here: http://www.flickr.com/photos/gtzecosan/sets/72157611453079661/
[10] The valves could be cleaned but are very difficult to put back into place
[11] A very small sample size consisting of fifteen females was used.

14 Institutions, organisations and contact persons

Project owner and project champion

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SuSanA 2009

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