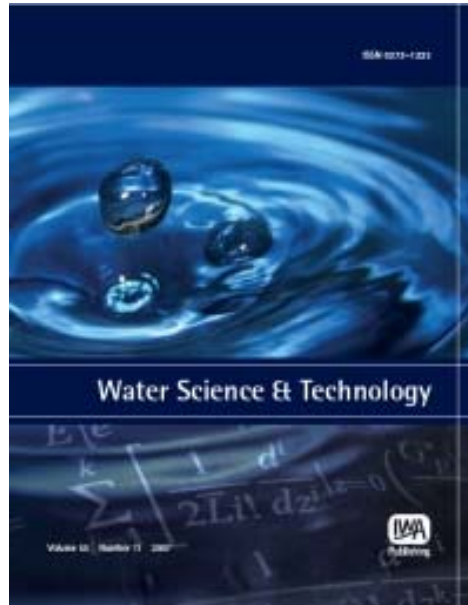


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Three years of operation of the urine diversion system at GTZ headquarters in Germany: user opinions and maintenance challenges

S. Blume and M. Winker

ABSTRACT

In the main office building of GTZ in Eschborn, Germany a resource-oriented sanitation system containing urine diversion (UD) toilets and waterless urinals has been in operation since 2006. After 2.5 years of operating the system, a first overall evaluation of the system in terms of its acceptance amongst the users and the cleaning staff was conducted by carrying out two surveys and many interviews. The overall result is that most of the users appreciate the sanitation concept in theory but have problems with the technical design of the particular type of UD flush toilets installed here. The survey results also gave some directions towards which hygiene devices the users would appreciate in order to overcome their reluctance to sit down on the toilet seat in public buildings (the sitting being necessary for correct operation of the urine valve to separate urine from flush water). Also, it is difficult to convince the cleaning and facility maintenance staff of the necessity of special cleaning and preventative maintenance routines. Hence, before such systems can be widely used, clear cleaning routines and maintenance instruction are required as well as certain technical modifications of this type of UD flush toilets to optimise the urine/water separation and the flushing properties of the toilet.

Key words | acceptance, resource oriented sanitation system, source control, UD flush toilet, urine diversion, waterless urinal

S. Blume

M. Winker (corresponding author)
German International Cooperation (GIZ) GmbH,
Sustainable sanitation – ecosan program,
Postfach 5180,
65726 Eschborn,
Germany
E-mail: martina.winker@giz.de

INTRODUCTION

Urine diversion (UD) systems are an innovative concept towards a resource-oriented and water saving sanitation system. Nevertheless, the success and failure of such systems are strongly influenced by the acceptance of users and the maintenance requirements (Lienert & Larsen 2010). If acceptance is lacking, it can even lead to reconstruction of the sanitation infrastructure back to a conventional system (Jurga 2009).

In Europe the installation of UD toilets started in Swedish ecological housing projects (Kvarnström *et al.* 2006), where inhabitants tend to have a higher environmental consciousness and therefore a positive perception towards such resource-oriented and water saving systems. From there the technology spread to Central Europe and was installed in some buildings where the users did not have a specific 'environmental' motivation but the installation was driven by wishes of developers (e.g. SolarCity in Linz, Austria (Oldenburg *et al.* 2009), office building of the Swiss Federal Institute of Aquatic Science and Technology (Larsen & Lienert 2007)).

UD technology is also seen as an approach with good prospects for developing countries (von Münch & Winker 2009). In order to 'lead by example' the German Technical Cooperation (GTZ) GmbH (since January 2011 German International Cooperation (GIZ) GmbH) decided to install such a system in its headquarters located in Eschborn near Frankfurt, Germany (Winker & Hartmann 2010). The main building ('Building 1') was being renovated and as part of this renovation, technologies for reducing water and energy consumption were included. This included a UD and collection system.

The purposes of installing this UD system were to demonstrate the implementation of such a resource-oriented sanitation system, to reduce the amount of water used in the GTZ building, and to be able to conduct research on reuse of urine in agriculture and on social acceptance in Germany (the activities to achieve this last objective began in mid 2009 within the project SANIRESCH (SanitaryRecycling Eschborn), an accompanying research project funded by

the German Federal Ministry of Education and Research (www.saniresch.de). See also Winker & Hartmann (2010) for further details on the installation and the research project.

Operation of the system started in mid 2006. It was clear from the beginning that acceptance by the users and a good maintenance system are crucial for the success. In order to obtain a profound picture on user behaviour and acceptance of the new technology, two user surveys were conducted. These surveys also investigated how the user interface (the toilet itself) and the performance of the cleaning staff affected user acceptance. This paper reports on the results of these user surveys and on the cleaning and maintenance challenges with the waterless urinals and UD flush toilets.

MATERIALS AND METHODS

Implemented UD technologies in Building 1 of GTZ headquarters

The urine separation system in Building 1 is used by approximately 400 people (those with offices in the centre part of the building plus visitors to the canteen and auditorium) and consists of:

- 50 UD flush toilets for the waterless collection of urine (model 'NoMix toilet' of the German company Roediger Vacuum GmbH). The toilet bowls have two compartments: one for urine at the front and one for faeces, toilet paper and flush water at the back (Figure 1). The urine is collected undiluted by means of a valve located under the toilet seat which is triggered when the user sits down. This toilet consumes about 1–2 L for the urine flush and 4–6 L for the solids flush. For further information on this type of toilet see Roediger Vacuum GmbH (2006). Other types of UD flush toilets (most do

not contain a valve for separation) are explained in von Münch and Winker (2009).

- 25 waterless urinals equipped with a patented 'flat rubber tube' smell stop system of the type 'Centaurus' by the German company Keramag AG (Figure 1). For further details on the odour control mechanism see von Münch & Dahm (2009).
- $4 \times 2.5 \text{ m}^3$ polyethylen urine storage tanks located in the underground car park of Building 1.

The toilets and urinals described above are located in the middle part of the 10-storey building in the restrooms closest to the canteen and the auditorium (Figure 2). In the four wings of each floor are restrooms equipped with conventional toilets and urinals (since the UD flush toilets and waterless urinals were still relatively unknown and untested in 2005, it was decided to only equip part of Building 1 with this hardware in order to minimise the risks and costs (a full account of the costs is available in Lazo Paéz (2010)). Therefore, the employees who work in Building 1 have the choice between the two different toilet types.

User surveys with questionnaires

Two user surveys were carried out so far. The first one took place in September 2008 to evaluate the general acceptance of the toilets by the users. The second survey was conducted in May 2009 and had a more specific focus on toilet hygiene and cleanliness issues as a result of the first survey. Both surveys were conducted online (using the survey tools 'Surveygizmo' and 'Surveymonkey'). As the questions needed to be tailored to the specific situation of this office building, the survey questions were developed from scratch but with consideration of other similar surveys like Muskolus (2008) and Lienert (2007).

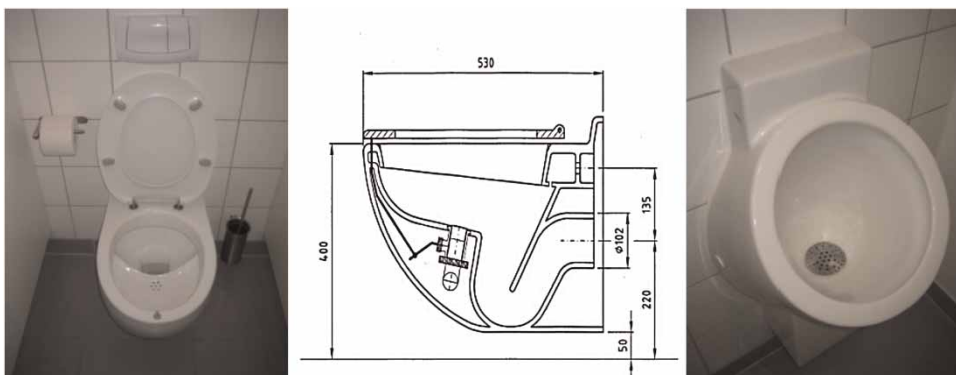


Figure 1 | Left and middle: UD flush toilet and its schematic side view (showing the urine valve); right: waterless urinal in GTZ Building 1 in Eschborn.

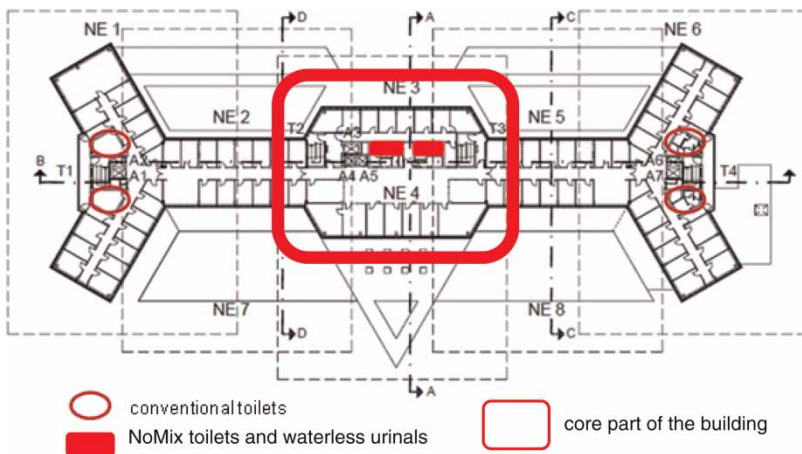


Figure 2 | Schematic design of the restroom locations on one floor of the 10-storey building which is double-Y shaped.

In the first survey, about 900 GTZ employees working in the headquarters were contacted by email independently of their office location within the four GTZ buildings at this site. All contacted employees were employed within the department of Planning and Development, which is GTZ's department for the worldwide technical support of its programs abroad. Filling out the questionnaire online took ~5 min. Apart from statistical parameters about the employees and the general perception of reuse oriented sustainable sanitation systems, the questions covered toilet design, hygiene, odour, ease of use, and acceptance of reuse.

As mentioned earlier, the second questionnaire (in May 2009) focussed on cleanliness aspects and an improvement of the hygienic situation. An invitation to participate in this survey was sent to 50 GTZ employees whose offices are located close to the restrooms in the core of Building 1 (Figure 2). This selection was done to narrow down the focus of the survey on employees who use the UD flush toilets and waterless urinals daily, as their offices are located close to the separation toilets. The survey took ~3 min to complete. Apart from statistical information such as distance to the toilets, frequency of usage, the questions tried to determine what measures could encourage users to sit down on toilets in an office building, which is necessary for proper separation of urine and flush water due to the opening mechanism of the valve of this particular toilet type (see Figure 1).

Training for cleaning and maintenance staff

The cleaning staff (employed by an external service provider) and GTZ facility management staff were shown how to maintain the new urinals and toilets (in 2006). As the

cleaning staff had not cleaned UD flush toilets and waterless urinals before, explanations and demonstrations were necessary to avoid unwanted behaviours such as flushing waterless urinals with water. This was conducted mostly with pictures and demonstrations as many persons of the cleaning personnel were foreigners who did not speak German. Additionally, the foreman and facility manager were kept informed about the cleaning procedures.

The maintenance staff obtained demonstrations by Roediger Vacuum GmbH about the installation and maintenance of the toilets especially how to check the toilet's functionality and to change broken parts. All staff was contacted often in connection with user feedback and technical problems.

RESULTS AND DISCUSSION

Survey 1: Employees' views

In the first survey almost one fourth (24%) of the contacted employees responded (218 of 900 people). Demographic analysis showed that roughly one half (53%) of the people were within the age of 30–50 years, 29% were younger, and 18% were older than 50 years. When comparing the UD flush toilets and the conventional toilets regarding appearance, cleanliness, odour, and ease of use, results showed that the majority of the participants felt that the cleanliness of the UD flush toilets and odour of the urinals were worse than conventional ones (Table 1). The conventional toilets were rated better in almost all parameters (Table 1). About one half (52%) of respondents mentioned that the UD flush toilets had problems with flushing, and

Table 1 | Parameters used for measuring the users' acceptance by comparing the source separating with a conventional system according to Survey 1

Perception compared to conv. system	UD flush toilets			Waterless urinals			Both Ease of use
	Optical appearance	Cleanliness	Odour	Appearance	Cleanliness	Odour	
Better	12	5	7	17	14	8	5
Same	76	45	61	77	52	32	56
Worse	12	50	32	6	34	60	39

Numbers show percentages (%) of total answers (i.e. 218) for toilets and 88 answers for waterless urinals).

39% stated that these toilets needed two flushes after each use (12% stated that even three flushes were needed).

When asked for their private decisions, about 48% of respondents stated that they would move to a flat with UD flush toilets whilst 27% were not sure and 25% would not (see Figure 3). A surprising 17% of the respondents would even pay a higher price for buying such an apartment (40% maybe and 43% not). Asked about the waterless urinals, 37% would support other GTZ offices installing waterless urinals, 41% had no opinion and 22% would not support such measures.

Although the technical functionality of the UD flush toilets should be enhanced, a remarkable 90% of the participants were still positive towards the idea to collect urine and faeces separately from each other and to use them as fertilisers in agriculture. It was found that 71% of the respondents would even buy crops which had been fertilised with human excreta according to WHO guidelines (WHO 2006). Even more people (82%) would buy non-edible products which had been fertilised with human urine. When asked about their opinion if urine should be allowed as a fertiliser for organic agriculture, 46% agreed and 42% might

agree while 12% did not support this concept. In their own households, one third of the participants would use and further 39% said they might use urine for their own balcony plants.

The results regarding acceptance of food fertilised with urine are in line with other similar investigations. Muskolus (2008) interviewed inhabitants in Berlin as well as people with an agricultural background or interested in agriculture, and 62% of both groups stated that they would buy food produced with urine as a fertiliser. Also in Switzerland, 72% of people from different user groups (also partially users of UD flush toilets) consider these concepts as a good idea and 86% would even move into a flat equipped with such a technology (Lienert *et al.* 2006; Lienert & Larsen 2006). This is a much higher value (and hence higher potential for social acceptance) than found in Survey 1 undertaken at GTZ and is most likely due to technical and maintenance problems in Building 1 (see below).

Survey 2: User views regarding sitting on toilets

The 2nd survey investigated the potential enhancement of hygiene, and its perception by the users, which would encourage more of them to sit down on the toilet. The sitting is necessary for the undiluted collection of urine. About 40% of the respondents were female and 60% male. As only 25 employees responded (out of 50 approached) the survey results are not necessarily representative but provide a general direction. About 52% of respondents indicated that they used the UD flush toilets on a regular basis.

Many people, especially women avoid sitting on public toilets 'hovering' above the seat instead. The employees were asked which hygienic devices they would prefer to entice them to sit on the toilet seat. Almost 50% of respondents would prefer disinfection spray which is applied with toilet paper to clean the toilet seat, 8% would favour paper covers and 35% other devices (e.g. automatic cleaning of the toilet seat after usage). The respondents stated that

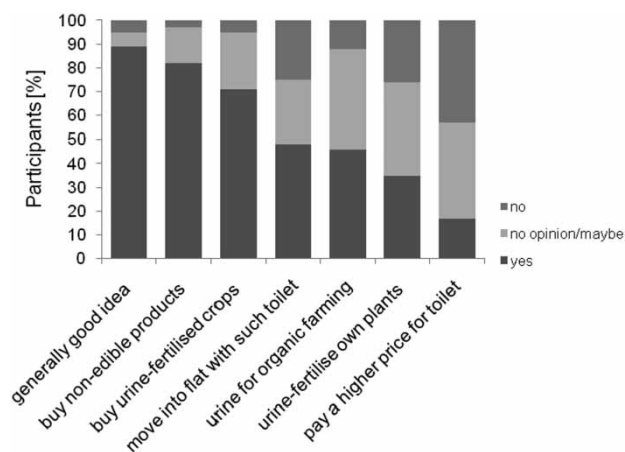


Figure 3 | User opinions regarding the resource oriented sanitation in GTZ Building 1 according to Survey 1 in Sept. 2008 (total of 218 participants).

they would apply these hygienic devices either on a regular basis (26%), only if the toilets were not clean (21%) or not at all (17%).

Further, the participants were asked if they would sit down on the toilet if the above mentioned hygiene devices were available (results are summarised in Figure 4). The question was designed to receive more precise information of users' attitudes towards sitting on a public toilet. The results confirmed that most users would prefer a disinfection spray (52%) or a paper cover (48%), and 35% of users use toilet paper as a cover. A willingness to sit down is indicated by 52% of respondents provided there was a disinfection spray available compared to only 17% of respondents if no hygiene device was available.

These results on attitudes regarding sitting on public toilets are interesting from a sociological perspective since they relate to users' (partly irrational) fears of 'catching a disease' when sitting on a public toilet. The findings from the small Survey 2 are in contrast to the findings of the Swiss review (Lienert & Larsen 2010). Here 68% of the respondents stated they would sit to urinate. Although there is a major difference between toilets at home (78% stated they would sit) and toilets outside of the home environment (68% stated they would sit in public toilets). A monitoring of the system installed in the Eawag building (Eawag stands for Swiss Federal Institute of Aquatic Science and Technology, located in Zurich, Switzerland) has however not shown discrepancies between the feedback from users as 72% state they would sit (Larsen & Lienert 2007) has been observed so far (Goosse *et al.* 2009).

Challenges with the technology and the maintenance routines

In the following, we describe the main technical and maintenance problems encountered and how we solved them.

Experiences with waterless urinals

To reduce odour problems (see user feedback of the Survey 1 (Table 1)) with the waterless urinals, Keramag AG introduced an improved design for the smell stop in 2007 which has significantly less dirt accumulation and is easier to clean (see Winker & Hartmann (2010) for details).

Unfortunately, urinal sieves and smell stops in some of the restrooms were not cleaned for many weeks or even months during the period 2007–2009 due to unclear maintenance routines and a high turn-over of cleaning staff

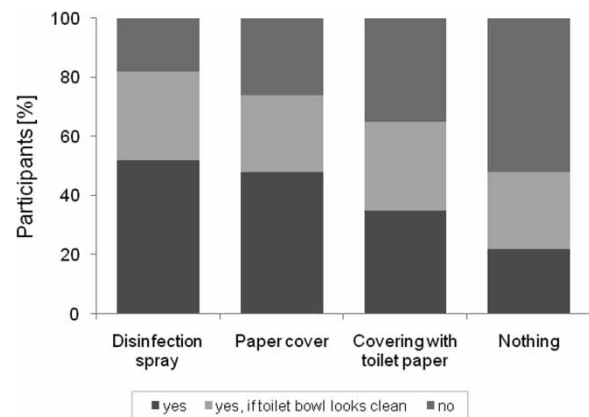


Figure 4 | Survey 2 results: Employees' willingness to sit down on the UD flush toilet's seat if certain hygienic devices were provided (at the moment, none of these are provided). Total number of respondents was 25, with 40% being females.

(employed by an external company who is responsible for the cleaning in the GTZ buildings in Eschborn). This led to the accumulation of urine precipitates, as well as pubic hair and slime deposits which then caused odour problems. This is most likely the main reason for the worse perception in terms of odour for the waterless urinals compared to conventional urinals (stated by 60% of respondents in Survey 1, see Table 1). Hence, even for the (in Germany) quite widely spread waterless urinals, awareness raising and training is still required for the cleaning staff when they are not familiar with such urinals. Thorough cleaning staff instruction and supervision is crucial and has been established since late 2009. With closer supervision and more feedback to the cleaning staff, the smell stops are now in better condition and are generally being cleaned with a sufficiently high frequency (i.e. daily).

Experience with the UD flush toilets

The installed type of UD flush toilet has two main weaknesses:

1. Design of the bowl: Toilet paper thrown into the front part of the bowl (urinal section) is not flushed away with the little amount of flush water for small urine flush (1–2 L) and hence more than one flush becomes necessary – negating the possible water saving effect. The user feedback has shown that even for the faeces sometimes 2–3 flushes are required (6 L per flush). Similar findings were reported for the installations at Eawag: in 17% of all cases a second flush was necessary (Goosse *et al.* 2009).



Figure 5 | Left: Soft urine precipitations inside a urine valve (of 'NoMix toilet' by Roediger Vacuum GmbH). Right: the same valve after cleaning by soaking in citric acid for several days (source: L. Ulrich, 2009).

2. Urine valve: The valve on the urine pipe can get blocked over time (Figure 5). In this case, urine is no longer collected separately but flows to the faeces section of the toilet bowl. Alternatively, valves which are permanently in the open position have been discovered as a result of precipitates in the valve. This leads to odour problems in the restroom and a dilution of the urine with flush water. Therefore, the cleaning staff needs to carry out preventative maintenance on the urine valves which can be done by adding citric acid or organic acids to the valve. In order to gain first experience on the dissolving potential of the organic acid (contained in the toilet detergent the German company Mellerud which is recommended by Roediger Vacuum GmbH for this purpose) organic acid was filled into the urine valve of one toilet and this cabin was then closed for 24 h. As each bathroom had at least two toilets cubicles this did not cause a shortage of available toilets. Some valves had to be removed to ensure proper cleaning. However, when a continuous cleaning procedure is applied we assume this contact time would be sufficient to remove precipitates (struvite and other crystals). Our experience has shown that if this maintenance is neglected, these valves stop working after ~2 years of use (as was the case in our building in about late 2008).

Such maintenance procedures are difficult to accomplish in a public building however: locked toilets are not appreciated and the maintenance is complicated. Other cleaning procedures, such as those reported by Goosse *et al.* (2009) are now being tested within the research project SANIRESCH in cooperation with Roediger Vacuum GmbH.

Low nitrogen content of the collected urine

On average around 200 L of urine is collected per day in Building 1. Low nitrogen concentrations were observed in the urine collection tanks at GTZ: With $2,800 \text{ mg L}^{-1}$ the measured nitrogen concentration for the stored urine is two thirds less than typical literature values for pure urine of $8,000 \text{ mg L}^{-1}$ (Meininger & Oldenburg 2009). Similar values were reported from a pilot project with the same toilet type in Berlin-Stahnsdorf (Peter-Fröhlich *et al.* 2007). The reason for this low concentration is so far still unclear. Probably nitrogen loss occurs in the form of ammonia gas being emitted through the tank's ventilation system, which has also been reported at the Eawag building (Goosse *et al.* 2009). Urine tanks should not be ventilated, only pressure equalised (von Münch & Winker 2009) but in this case, a 10 mm vent pipe from the urine tanks goes all the way to the top of Building 1, causing more ventilation than desired. Another reason could be that the morning urine, which has a higher nitrogen content is not collected here. It is also possible that the urine is diluted with flush water if users flush while being seated as reported by Goosse *et al.* (2009), if the urine valve is broken (permanently open) or if cleaning staff uses water for cleaning the waterless urinals.

The great difficulties with the urine valve have led to the proposal that a UD flush toilet *without* a urine valve may be the better system (even if the nitrogen concentration in the collected urine would then be much lower). Further research will be needed to test this hypothesis.

Recommendations for maintenance of the installed waterless urinals and UD flush toilets

Based on the three years of experience, the following maintenance routines have now been put into place (ensuring that these are really being fully adhered to is still not trivial in our building):

- Every evening the waterless urinals have to be cleaned (wiped down with a wet cloth).
- In the highly frequented restrooms (on the ground floor close to the canteen and meeting rooms) additional cleaning on an hourly base is required using a wet cloth and subsequently spraying a detergent containing microbiologically active ingredients and fragrant substances as well.
- The smell stops (flat rubber tubes) of the waterless urinals have to be taken out once per week and cleaned with detergent and rinsed with water (while one smell stop is being cleaned, a second one is inserted into the drain to stop odour from the open urine pipe).

- As the rubber of the smell stops gets worn out and the sides then stick together, the smell stops have to be replaced about once per year (in accordance with supplier's advice).
- The daily cleaning routine for UD flush toilets is in principle the same as for conventional toilets although it is a bit more time consuming to clean away faeces stains due to the more complicated bowl design.
- For precipitation prevention, the urine valve needs to be soaked once per month with organic acid for a period of 24 h. This is done by filling 200 ml of the organic acid into the open valve (seat pressed down to open the valve).
- Annually, the functionality of the urine valves should be checked and valves which are found to be clogged (despite the preventative maintenance) should be cleaned or replaced.

CONCLUSIONS

The overall result from the user surveys is that the users appreciate the resource oriented sanitation concept (recycling of nutrients and water savings) but are unhappy with the inconveniences caused by the technical design of the type of UD flush toilet installed in this building (whether other UD flush toilets cause fewer inconveniences in an office building is not proven yet). Furthermore, it was shown that many users – in particular female users - do not like to sit on the toilet seats of public toilets due to perceived or actual toilet hygiene. People's willingness to sit down on the toilet could be raised significantly if disinfection devices were available (the sitting activates the urine valve and is hence of importance here). A high turn-over in cleaning staff and communication difficulties due to language problems for the cleaning staff working in Building 1 made it difficult to communicate the necessary cleaning routines. The low performance of the valves responsible for the separation of urine affected the user acceptance additionally. Hence, before such UD flush toilets can be widely spread, clear cleaning and maintenance routines are required and the separation technique needs further development to allow collection of urine without flush water.

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