Experiences and Suggestions for Collection Systems for Source separated Urine and Faeces

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Abstract
The objective of this study was to collect experiences from existing systems with urine diversion and dry handling of faecal matter and to develop design recommendations for improved function of new systems.
Urine collection and piping systems were studied in four larger housing districts, in Scandinavia and South Africa where urine had been collected separately for 5-9 years, the dry faecal collection systems investigated had been in use from 4 to more than 15 years. Our recommendation is that larger (> 1 bathroom) urine collection systems should have odour locks. Blockages in u-bend odour locks can be efficiently prevented by cleaning the u-bend 1-4 times per year using a sewage auger, caustic soda solution or strong acetic acid. A urine pipe diameter 75 mm and a slope of at least 1% is recommended. In small systems, without a u-bend, a diameter of 25 mm can be used in combination with a slope of at least 4%. For faecal collection, the most important factors for good function and high acceptability of the system are that they diverte the urine, have small collection bins (high emptying frequency) and have easy access for emptying of the bin.

INTRODUCTION

Sanitation systems using urine diverting toilets makes separate collection of the urine in a fraction of small volume, high concentration and low pollution possible. Collecting the urine without any faeces, minimizes its hygiene risk as most of the pathogens are excreted with the faeces.
Separate collection of urine might seem simple as it is a liquid excreted in small volume, 1-1.5 litres per person and day (Vinnerås et al. 2006. However, many systems for separate collection of urine have problems. More knowledge in needed on how to construct well functioning collection systems for urine diverted at source, i.e. in the toilet.

Collection systems for source diverted urine can be divided into small systems, collecting urine only from a toilet plus possibly a urinal in one bathroom, and larger collection systems, collecting from more than one bathroom. Urine collection systems can also be classified into flushed, where flush water normally is used after each urination, and unflushed, without use of any flush waster.

At excretion, urine normally has a pH of 4.8-7.5, is low in odour and of its nitrogen, some 75-90% is in the form of urea, the remainder mainly being ammonium and kreatenine (Diem & Lentner, 1970). Upon excretion, and in the contact with bacteria enzymes, these compounds are rapidly degraded to ammonium and other nitrogen containing compounds, many of them odorous, raising the pH, usually to about 9.0-9.3 (Jönsson et al., 1997). At this elevated pH, the solubility of magnesiumammoniumphosphate (MAP) and calciumphosphate is several powers of 10 lower than at pH 7 (Lindquist et al., 2003). The urine becomes supersaturated and the compounds are quickly precipitated together with organic material (Udert et al., 2003; Vinnerås & Jönsson, 2007). It is this combination of odour and precipitation caused by the raised pH that gives the main challenge in the construction of urine diverting systems.
Several solutions are used handle the odour, all of them with the main purpose of eliminating contact between the degraded urine and the air in the bathroom. Flushed toilets with u-bend stench

traps are used, as are flushed toilets without any trap. With some waterless toilets, stench traps based on rubber lips are sometimes used. However, waterless toilets without any stench trap are by far most common. Many waterless urinals use u-bend stench trap with a vegetable oil seal floating on the liquid surface. Irrespective of the type of solution used, many systems suffer from insufficient function of the stench trap regarding blockages, odours and blockages. More knowledge is thus needed on how to construct and maintain well functioning source diverting systems for urine and faeces.

Collecting the faecal matter dry is an attractive solution for on site sanitation as the faecal volume is small compared to the other wastewater fractions. Generally, 100-200 gram of faeces are excreted per person and day in wet weight and this material holds a dry matter content of approximately 20-25 % (Vinnerås et al., 2006). Not polluting the wastewater with the faecal matter reduces the risk of transmitting diseases via the wastewater as most of the pathogens are excreted via the faecal matter.

House-owners in Sweden installing dry sanitation in their permanent house usually motivate this by the environmental advantages of this system. This was shown also our study. Old dry sanitation systems, constructed more than 15 years ago, were mainly of the mixed type, handling the urine and the faecal matter mixed, as latrine or latrine compost, while most of the systems constructed during the last ten years were urine diverting.. For a larger implementation of dry sanitation systems, evaluation of the current systems is needed, and important aspects are the technical function and the design.

Thus, one objective of this study was to collect experiences from existing urine diverting systems and to develop design and maintenance recommendations for improved function of new systems. Another objective was to collect experiences from existing faecal collection systems and to develop design recommendations for improved function of new systems.

METHODS

Data on the urine collection and piping were collected by structured investigations in four larger housing districts, where the urine diversion had been used long: Understenshöjden, Sweden, 44 apartments with urine diversion system used about 9 years; Palsternackan, Sweden, 51 apartments with urine diversion used about 9 years; Hyldespælet, Denmark, 10 apartments with urine diversion used about 5 years and Moshoeshoe, South Africa, 11 apartments urine diversion used about 4.5 years. Understenshöjden, Palsternackan and Hyldespælet all used water flushed urine diverting toilets with a stench trap for the urine pipe in the form of a u-bend. Moshoeshoe used unflushed urine diverting toilets, with dry faecal handling and without any stench trap on the toilets. In addition, experiences were collected in an unstructured manner from small (one bathroom) urine diversion systems around the world.

For the study of faecal collection systems, interviews were performed with 75 users in Sweden of source separation system that collected faecal matter dry, i.e. without any flush water. The answers covered nine housing areas and in addition 15 separate households. The questions can be divided into three categories technical description, experiences of the system and the degree of user satisfaction with the system.

Of the systems investigated 30 systems had urine-diverting toilets with dry faecal collection, 4 systems had urine diversion by use of a separate toilet for urine collection combined with a non-urine diverting toilet for the faeces and 41 systems collected the toilet waste mixed, as latrine or latrine compost. Of the mixed systems, three systems collected the faecal material in a bucket direct below the toilet, and these treated the collected material in a separate location, and 34 systems had the compost direct below the toilet in the collection chamber, while this question was left unanswered for four systems. The collection bins in the different systems varied in size from approximately 20 litres up to more than one cubic metre.

RESULTS AND DISCUSSION

Odours in urine systems

The odour level in bathrooms with urine diverting toilets equipped with u-bends on the urine pipe was by the users considered almost similar to that with ordinary, non-diverting water flushed toilets (Lindgren, 1999), while 7 out of the 11 households in Moshoeshoe with urine diverting toilets without any odour lock on the urine pipe had experienced odour problems from the urine system. On the other hand, many small (1 bathroom) urine diverting systems without any stench trap are in use around the world without any odour problem. This is probably because the urine in well designed small urine diverting systems without a strench trap flows rapidly and thus a long way, usually to the tank, before it is significantly degraded. The odours from the degraded urine only slowly diffuse back to the bathroom, provided that there is now gas flow in the urine pipe to the bathroom. In small urine diversion systems, this can be ensured by having the incoming pipe to the tank go down to close to the bottom of the tank, as is recommended (Kvarnström et al., 2006). The diffused odours are rapidly diluted and eliminated by an efficient bathroom ventilation. However, in large systems, like that at Moshoeshoe, air will flow in the urine pipe from bathrooms with higher air pressure to bathrooms with lower air pressure. A gentle wind or a difference in temperature is enough to give a difference in air pressure between different bathrooms. Our conclusion therefore is that stench traps should always be used in large (>1 bathroom) urine diverting systems.

Blockages in urine system

In systems with u-bend, by far most blockages occurred in this (Jönsson et al, 2000). However, 5-9 years of experience from Understenshöjden and Palsternackan showed that these blockages could efficiently be managed by cleaning with a sewage auger and/or with a caustic soda solution (1 part soda dissolved in 2 parts of water), which is poured into the u-bend and allowed to sit over night, before being flushed away by 2-5 litres of water vigorously poured into the urine pipe in the morning. At Hyldespælet, the recommendation was to do the preventive cleaning once a month using strong (32%) acetic acid and completing this with a thorough cleaning with a sewage auger. Our experiments have shown that caustic soda is far more efficient in cleansing urine precipitates than citric acid (Jönsson et al, 2000). Therefore, our conclusion is that blockages in the urine u-bend can be eliminated by preventive cleaning 1-4 times per year using a sewage auger, caustic soda solution (1:2; soda:water). The effect from the caustic soda is removal of the matrix of organics, which is hydrolysed by the high pH. This enables simple removal, flushing away, of the precipitated phosphate compounds. The caustic soda solution can, up to every second time, be replaced by strong (>32%) acetic acid. Using an acid will instead attack the mineral part of the structure. Thus, alternating alkaline and acid treatment targets both the organic and the mineral part of the build-up.

In Understenshöjden, Hyldespældet and Moshoeshoe, blockages had occurred also in the urine pipes further down in the system. In Understenshöjden, one blockage had occurred in a 75 mm pipe with a negative slope, in Hyldespældet blockages had occurred in the 40 – 50 mm pipes behind the toilet in the 7-8 of the 10 apartments. These blockages normally occurred in the 90° bend immediately behind the toilet. The 35 mm pipes in Moshoeshoe were also joined by many 90° bends, and also here blockages occurred. In Palsternackan, no documented blockage of the pipes had occurred, and the pipes were inspected visually through 14 inspections openings after 9 years of operation. This inspection showed normally a thick, syrup-like sludge layer at the bottom with a thin liquid layer on top. As long as the slope of the pipe was enough (≥1%) and the bends not too sharp, the sludge slowly flowed along the pipe without blocking it, even in 50 mm pipes after and also after 9 years. However, when the slope was too small, sludge accumulated risking eventual pipe blockage. In small systems without any u-bend and with short pipes of good slope, blockages due to precipitation seems unheard of, while they rapidly occurred whenever the slope of the urine pipe is too small. In small systems, precipitation and blockage seems to be prevented by the urine flowing so rapidly through the pipes, that there is not enough time for degradation and pH increase, even if this occurs rapidly (Udert et al., 2003). Thus, no sludge is precipitated and therefore the pipe can be thinner, down to 25 mm, provided that its slope is good and the pipe is not too long. Our tentative recommendation is that the slope should be ≥4% and the pipe length ≤10 m to ensure this.

Our recommendation for pipes from toilets with a u-bend or with a slope <4% is that the diameter of the urine pipe should be at least 75 mm (110 mm for underground pipes), their slope should be at least 1% and they should be supplied with ample openings for inspection and cleaning. A diameter as small as 50 mm can be allowed, if the pipe has a slope of at least 1%, has no sharp bends and is easy to inspect, clean and disassemble, as more maintenance and cleaning might be needed. To minimize the risk of odour and of blockage in vertical urine pipes, it is recommended that the pipes are not ventilated, just pressure equalised (Jönsson et al., 2000; Kvarnström et al, 2006).

Dry faecal collection systems

The interviews showed that three factors were especially important for the satisfaction with the dry faecal collection system:

1. combination with urine diversion
2. placement and design of the collection bin
3. size of the collection bin

The 34 users of systems with urine diversion were far more satisfied than the 41 users of composting toilet systems collecting latrine, i.e. urine and the faeces mixed. This was shown e.g. by the fact that 15 of the 41 latrine systems had been changed to another system, either to a urine diverting dry system or to a regular flushed toilet system. In addition, some users of latrine systems and some users of systems with separate toilets for urine and faeces indicating an interest of changing the system in near future. The main complaints on the mixed system concerned insects, non-functioning or too wet compost, un-clean toilet and collection chamber being over-filled.

The fraction of users that had experienced problems with flies was similar between the systems, 93-96%. The major difference was found in the frequency of the fly incidents. The frequency of flies in the toilet system was much higher for the latrine system compared to the urine diverting system. In the latter, the incidents were mainly described as single events. The most successful method of decreasing the frequency of fly events was to decrease the size of the collection vessel and thereby increase the frequency of emptying.

The complaints about smell from the faecal matter, 40-42%, were similar between the systems and correlated to ventilation failures due to power cuts, but the general comment is that none of the systems do smell. The frequency of complaints on un-clean toilets was similar between the investigated systems. Improved cleaning techniques have to be developed for dry toilets, as stains can not be removed by just brushing and flushing as in flushed sewage systems.

The problem with non- functioning and/or too wet composts was experienced often in the mixed latrine system but hardly at all in the urine diverting systems. This is explained by the volume of urine, 1-1.5 litre of urine per person and day, being very large compared to the small amount of faecal matter, 0.02-0.04 kg of faecal dry matter per person and day (Vinnerås et al., 2006). The wet material has in several cases also been linked to the high frequency of flies in the toilet. The easiest way to manage this is installation of a urine diverting system or some kind of drainage system.

Some cases of overfilled bins were also reported. This was mainly due to improper maintenance of the system as the volume collected was not monitored. The problems with overfilled bins correlated to bins with a volume of more than 100 litres, i.e. bins with a low emptying frequency. The frequency of this was higher in mixed systems, 44%, than in urine diverting systems, 28%.

Many users complained about the placement of the faecal collection bin and how to empty it. One common problem was that the opening to be used for emptying the collection bin was hard to reach, resulting in strained working postures. Additionally, the transport route of the bin itself or of the emptied material often included high lifts and steep ladders. Of the users with a mixed system, 85% experienced the emptying as difficult while the corresponding fraction was 33% for the users with urine diversion. One common comment was an uncertainty regarding how to manage to empty the bin when getting older. The users of small collection bins were generally more positive about the emptying compared to users with large bins. For design of systems for handing human excreta one of the main factors to include is the placement of the bin and how the access for emptying is planned. This is even more important when planning larger systems with centralised emptying of the bins.

When asked whether the user recommended the system to others, so did 20% of the users with mixed systems, while 71% and 62% of the users with urine-diverting toilets and separate urine and faecal toilets, respectively did this.

CONCLUSIONS

Based on this study, we recommend two types of designs: 1) Toilets with a u-bend stench trap. These are recommended both for large and small systems. The urine pipe should have a diameter of at least 75 mm and it is extremely important that its slope is at least 1% and that frequent openings for inspection and cleaning are provided. Preventive cleaning of the u-bend and the pipe immediately behind it by use of caustic soda, acetic acid and/or a drain auger 1-4 times per year is recommended. 2) Toilets without a stench trap. This design is at present only recommended for small, one bathroom, urine collection systems. In this case, precipitation is prevented by minimizing the time the urine stays in the pipe. In these systems, a thin pipe (diameter ≥ 25 mm) can be used, but it is essential that its slope is good (≥4%) all the way and that all obstacles that slows down the flow of the urine are avoided and that the pipe is short, preferably <10 m. It is recommended that urine pipes are pressure equalized but not ventilated. Normally the urine pipe should go down to close to the bottom of the urine tank.

The main factors for achieving high acceptance of a dry toilet system proved to be whether it had any problems with flies and how difficult the user experienced that emptying of the collected faecal material. To avoid these two functional problems the design of dry faecal collection systems needs to be combined with urine diversion and the emptying interval should be short, preferably just a fortnight. For long term acceptance the collected material has to be easy to remove and transport away.

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