Technology review of urine diversion components

Overview of urine diversion components such as waterless urinals, urine diversion toilets, urine storage and reuse systems

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Foreword

This publication is an important contribution of the GIZ program "Sustainable sanitation – ecosan" as it pulls together scattered knowledge around the topic of urine diversion in a concise manner.

The program is commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ). The ecological sanitation (ecosan) approach is able to address both: child health which needs to be improved through better sanitation, and sustainable management and safe recycling of important resources such as water and nutrients, in particular phosphorus.

It is a positive development that more and more people are now becoming aware of the present worldwide sanitation crisis – which is killing thousands of young children each day. It is also becoming more widely known that phosphorus (in the form of phosphate rock deposits), is a non-renewable, limited resource. High-quality phosphate rock will run out in the future.

The safe use of urine as a fertiliser can enable all farmers to grow more food – not only those who have the means to buy artificial fertilisers. When prices for artificial fertiliser increase again – as in 2008 when prices increased by up to eight times in some countries – farmers relying on urine will be less affected by such fertiliser price hikes.

I am sure this technology review will help and inspire people working on sustainable solutions for excreta management. Feedback about this publication is welcome and should be sent to ecosan@giz.de.

Let us jointly continue to work towards the aim of safe and sustainable sanitation for all!

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1 Summary

The target audience for this publication are people who are new to the topic of urine diversion or new to the topic of ecological sanitation (ecosan), and who:

- need to obtain an overview of the main issues for urine diversion and the main technical components
- want to know which are the main important documents for further reading
- have a particular interest in developing countries, with a pro-poor perspective
- need information on available suppliers worldwide and on costs for waterless urinals and urine diversion toilet pedestals and squatting pans.

This publication explains the purposes of urine diversion, its benefits and challenges, urine precipitation, urine treatment and reuse in agriculture. It provides an overview on design and operational aspects for equipment needed, such as waterless urinals and urine diversion toilets including supplier information and indicative costs. The publication also provides basic design information for urine piping and storage tanks (including tank sizing, odour control and ventilation design issues).

Urine diversion is the term used to describe keeping urine and faeces separate from each other at the point of excretion. The four main purposes of implementing systems with urine diversion (UD) are: to reduce odour, to prevent production of wet faecal sludge, to reduce water consumption and to collect pure urine for use as fertiliser in agriculture.

Further benefits include minimised excreta-related groundwater pollution, the fact that the toilet can be indoors (as opposed to a pit latrine) and better control over micro-pollutants discharged to the environment. The challenges include social acceptance, user cooperation, urine reuse or disposal issues and urine precipitation.

Equipment used in urine diversion systems includes waterless urinals, urine diversion toilets (either with or without flush water), urine piping and urine storage tanks. The most common and cheapest method to treat urine for pathogen removal from faecal cross-contamination is by extended storage.

Urine can safely be used in gardening and agriculture as a nutrient-rich fertiliser, provided relevant reuse guidelines (see WHO, 2006) are followed. If there is no use for the urine, it can be discharged to a sewer or possibly infiltrated in the ground (if local soil and groundwater conditions permit this without adverse impacts on groundwater quality).

Waterless urinals enable the collection of undiluted urine and are already widely used in many industrialised countries (particularly in Germany) in public or communal buildings (not common at household level). But so far, they are usually just connected to the sewer system and the urine is neither collected nor reused. Odour control in waterless urinals is crucial for user acceptance, and is achieved by (i) various designs for an odour blocking mechanism (most notably with a flat rubber tube, silicon curtain valve or sealant liquid), and (ii) by ensuring correct maintenance procedures.

Urine diversion dehydration toilets (UDDTs) collect faeces "*in a dry system*" (i.e. separately from urine, flush water and anal washwater) in vaults or buckets located underneath the UD pedestal or squatting pan. For pro-poor approaches in developing countries, UDDTs are more suitable than UD flush toilets, as the latter still require a sewer system and treatment for brownwater. UDDTs can easily be designed to suit users who use water instead of toilet paper by providing a separate drain hole for anal washwater.

Odour control and pressure equalisation within urine pipes and urine storage tanks need to be included in the design in the case of indoor multi-toilet systems. Waterless urinals and UDDTs are a promising step forward towards implementing water saving, more sustainable sanitation and reduced dependency on costly artificial fertiliser, thus contributing to poverty reduction.

2 Introduction to urine diversion (UD)

2.1 Definition of UD

Urine diversion (UD) devices collect urine separately from faeces and from water (or with minimal flush water). A urine diversion toilet has two outlets with two collection systems: one for urine and one for faeces (and possibly a third one for anal washwater), in order to keep these two (or three) excreta or wastewater fractions separate. UD toilets may, or may not, mix water and faeces, or some water and urine, but they **never mix urine and faeces**. *Section 5.1* provides an overview of the two main types of urine diversion toilets: UD toilets without flush water (these are called urine diversion dehydration toilets or UDDTs) and those with flush water (UD flush toilets).

Urinals – widely used by men at public toilets, restaurants, schools, etc. – work as urine diversion devices because urine is collected separately from faeces. When urinals are of the waterless type, they can collect the urine pure, meaning without dilution with water.

Urine diversion may be used in ecological sanitation (ecosan) concepts, but **not all ecosan projects use urine diversion**. Ecosan is an approach to sanitation which focusses on reuse of nutrients and organic matter contained in excreta and wastewater, and emphasises sustainability in all aspects[1].

1 The definition of "*sustainable sanitation*" is provided in the first vision document of the Sustainable Sanitation Alliance (http://www.susana.org/index.php/lang-en/intro/vision/42-vision/76-vision-document).

2.2 Purposes of UD installations

The purpose of a UD installation is usually one, or several of the following four purposes – which can be split in two categories:

Purposes relevant for all types of UD systems (described in more detail in *Section 2.3.1* below):

1. to reduce water consumption
2. to be able to collect urine pure and undiluted so that it can – after sanitisation by storage – be safely used as fertiliser in agriculture.

Purposes relevant for UDDTs (urine diversion dehydration toilets) compared to pit latrines (described in more detail in *Section 2.3.2* below):

3. to reduce odour
4. to avoid production of wet, odorous faecal sludge, which has to be removed by someone when the pit latrine is full.

2.3 Benefits of UD systems

2.3.1 Benefits of all types of UD toilets and waterless urinals

- **Water savings:** UDDTs and waterless urinals require no flush water, whereas conventional urinals use around 4 L per flush (flush toilets use about 8-12 L per flush; pour flush toilets use 2-3 L per flush). UD flush toilets can also reduce water consumption when compared to conventional water-flushed toilets: this is because the "*urine flush*" uses a low volume to flush away remaining urine drops and used toilet paper (0.5 to 2 L of flush water, depending on the toilet model). If urine-soiled toilet paper is collected in a bin, rather than flushed away, water savings could be even greater.
- The collected urine can be used as **fertiliser**, which can increase crop yields. As explained further in *Section 3*, urine is a liquid fertiliser rich in nitrogen and phosphorus. This is of particular importance for those farmers in developing countries who cannot afford mineral fertilisers.
- **Recycling of phosphorus from urine** may become necessary in the mid-term future and is easier to achieve if urine is collected pure rather than mixed with wastewater. Phosphorus is an essential element for agricultural production. It is either available in the soil or added with fertiliser, and is produced from mined deposits of phosphate rock. High-grade phosphate rock reserves are running out: at current rates of exploitation (increasing at around 3% per year), the economic reserves of phosphorus will last no more than 50 years. The economically viable reserves in the United States for example, will be depleted within 25 to 30 years (Rosemarin et al., 2008; Cordell et al., 2009). In the future, increased efforts to recycle the phosphorus content of human and animal excreta are inevitable (EcoSanRes, 2008).
- If there is concern about **hormones and pharmaceutical residues** entering drinking water sources via household wastewater (sewage), then the separate collection of urine can simplify removal of these substances from the environment. Particularly for industrialised countries, this could be a major driving force in favour of UD systems *(see Section 3.2)*.
- Urine diversion may also create **business opportunities** for the private sector via the sale of UD technology and related services.
- In many cases, **cost savings** can be realised when implementing UD systems especially regarding economic costs when a system-wide analysis is performed (including external costs due to groundwater pollution for example), *see Section 2.8* for details.

2.3.2 Further additional benefits of UDDTs compared to pit latrines

- There is significantly **less odour** when urine and faeces are not mixed – as in a UDDT – compared to the case where urine and faeces are mixed as in a pit latrine.
- Since UDDTs are odour-free when designed and operated correctly and since they do not need contact with the soil to infiltrate liquids, UDDTs can be **indoors**, which leads to improved security, privacy and user comfort. This aspect is very important especially for women and girls, for whom it may be too dangerous to go to the toilet outside in darkness (sexual assaults).
- **No production of wet faecal sludge**: Faeces collected in a dry manner, separately from urine and water, are not offensive, especially after an extended drying period. Hence, it is much easier to empty the faeces vault of a UDDT than the pit of a pit latrine. This is particularly important for hilly or crowded areas where access to pit latrines by conventional trucks is impossible.
- **Minimised toilet-related groundwater pollution with nitrate and pathogens**. Pit latrines and septic tanks are designed to infiltrate liquid into the soil, which can lead to groundwater pollution if the population density is high, the groundwater level is high or there are preferential pathways in the soil to the groundwater. UDDTs on the other hand collect the urine and faeces above-ground and therefore do not pollute the groundwater. Note that onsite greywater disposal can also lead to groundwater pollution and this issue is not addressed by urine diversion toilets.

2.4 Challenges with UD systems

2.4.1 Social acceptance amongst users

Regarding social acceptance, the successful adoption of urine diversion systems is closely linked to:

- Users' motivation and willingness to change existing habits and behaviours, for example:
  - The willingness of men to sit down on pedestal-type UD toilets for urination if no urinals are being provided – this does not apply to squatting-type UD toilets;
  - The willingness to move backwards a little bit so that anal washwater can be collected separately from faeces in the case of UDDTs and "*anal washers*".
- Supportive attitude of all stakeholders involved (users, maintenance staff, planners, farmers, politicians and so on).
- Possible use of urine as a fertiliser (or some other disposal option for collected urine if reuse in agriculture or aquaculture is not possible).
- Cultural obstacles like superstition of the users.

Odour nuisance (be it only perceived or actual) is a further potential obstacle to social acceptance, but with the correct design and operation, odours from waterless urinals and UD toilets are the same or less than conventional urinals and toilets. Also, UDDTs have significantly less odour and flies than pit latrines, and can therefore be placed indoors which may prove to be a significant driver for social acceptance.

Social acceptance also depends to a high degree on:

- The current sanitation situation (are people used to "*flying toilets*" (plastic bags), pit latrines or flush toilets?) and the users' expectation for the future.
- The prevailing norms regarding reuse of human excreta and related taboos.
- Available service providers who can offer a collection and maintenance service.

Hence, careful planning with stakeholder participation is crucial.

2.4.2 User cooperation

There are three main issues to be kept in mind regarding user cooperation:

1. Users have to "*think a bit*" when they use UD toilets for the first time (this point does not apply to waterless urinals, which are used in the same way as water-flushed urinals). Thus, urine diversion toilets need some upfront awareness raising to ensure correct usage and social acceptance.
2. If users do not cooperate, toilet misuse can result in odour (e.g. if users urinate in the faeces compartment of a UDDT) or in a "*messed-up*" toilet (e.g. if users defecate into the urine compartment of a UD toilet) – although this is not dissimilar from pit latrines and flush toilets.
3. Cleaning of UD toilets is a little more time consuming than cleaning of conventional toilets, due to the separate urine section in the toilet bowl.

2.4.3 Urine reuse/disposal issues

The following issues regarding urine reuse or disposal are important:

- Urine needs to be transported to the reuse areas which leads to increased traffic, and is problematic if the distances are large (noise, air pollution and CO_2 emissions).
- When urine is used in agriculture, the farmers need to be trained on the correct methods *(see Section 3.1)*.
- If urine cannot be reused, it is sometimes infiltrated in the ground. In some circumstances, this has no adverse environmental impacts. In other cases, this can lead to groundwater pollution with nitrate (depending on the amount of urine infiltrated per area, soil properties, groundwater table) – just like with pit latrines (but with pit latrines there is the added problem of pathogen transport to groundwater).

2.4.4 Urine precipitation

The information given in this section was mainly taken from Larsen and Lienert (2007). In fresh urine, the main nitrogen compound is urea. During storage, urea is hydrolysed to ammonia/ammonium and hydrocarbonate by urease enzymes present in the urine storage container, soil and in aquatic systems *(see also Table 1)*. This process is accompanied by an increase in the pH value. The increased pH value results in precipitation of struvite ($MgNH_4PO_4$) and calcium phosphate ($Ca_{10}(PO_4)_6(OH)_2$) crystals. Those crystals can form incrustations, also called *"urine stone"*.

Precipitation in urine pipes and storage tanks occurs in both water-flushed and waterless systems. In addition skin cells, hair and excreted organic complexes will also settle.

The end result may be hard precipitates (incrustations) or soft, viscous, paste-like precipitates (deposits). Incrustations tend to occur on the inner walls of pipes and pipe bends. Soft deposits occur in storage tanks (where they form a sludge at the bottom of the tank) and in near-horizontal urine pipes.

The following design parameters reduce the extent of precipitation:

- **Short retention time:** precipitation often occurs at locations where the urine flow velocity is low or even stagnant (such as siphons, horizontal pipes, U-bends of the toilet). Such arrangements should therefore be avoided.
- **Smooth surfaces and hydrophobic materials** should be used. Scratching of surfaces by mechanical cleaning should be avoided. Plastic PVC pipes are commonly used for urine pipes.
- If flushing with water: **Flushing with soft water,** such as rainwater, is preferred to flushing with hard water (soft water has less calcium and magnesium which can precipitate with the urine's ammonium and phosphate).
- **Pipes with a relatively large diameter** (at least 2.5 cm) are less likely to get clogged.

Using no flush water at all (as in waterless urinals) does not eliminate the problem, since urine also contains calcium and magnesium which can precipitate with ammonium and phosphate to form struvite. In waterless UD systems, more soft deposits tend to occur than hard incrustations, whereas for water-flushed UD systems it is the other way around. Information about maintenance tasks to prevent or remove blockages in urine pipes is provided in *Section 6.4*.

2.5 Quantity of urine

The quantity of urine produced by an adult is around 0.8 to 1.5 L per adult per day (WHO, 2006, Volume 4) – it mainly depends on the amount a person drinks and his or her transpiration. Children produce approx. half as much urine as adults. A widely used design figure, based on Swedish data, is **1.5 L/cap/d (or 550 L/cap/year)**[2].

2.6 Quality of urine

2.6.1 Source considerations

The description of urine quality in this section applies to urine collected *without* cross-contamination with faeces. Such cross-contamination is dealt with via urine treatment methods *(see Section 2.7)*.

Additionally, it should be highlighted that the quality of the collected urine is related to the health and life style of the people excreting it and to the urine collection system. For example, if urine is collected from a hospital or an old-age home it will most likely contain more pharmaceutical residues than urine from healthy and young people. And if urine is led through copper pipes it may have a high copper concentration. This has to be kept in mind during the design phase, especially when reuse is planned.

2.6.2 Pathogens

There are four types of pathogens relevant for sanitation: bacteria, viruses, parasitic protozoa and intestinal helminths. It is important to know that urine in the bladder of a healthy person is sterile (meaning it contains no pathogens). Only very few diseases are transmitted via pathogens in urine. The only disease which needs to be considered from a risk perspective when urine is reused in agriculture is *Schistosoma haematobium* – and only in areas where this disease is endemic (WHO, 2006, Volume 4). In contrast, the amount of pathogens in faeces can be very high, depending on the prevalence of diseases in the population.

2.6.3 Nutrients

Macro-nutrients in excreta include N, P, K and S (nitrogen, phosphorus, potassium and sulphur) of which N and P are the most important.

With regards to the nutrients contained in urine, the following design figures are used (derived mainly from Swedish data but considered to be quite universal, see Jönsson et al., 2004):

- Mass of nutrients excreted with urine: 4 kgN/cap/yr, 0.36 kgP/cap/yr and 1.0 kgK/cap/yr.
- Concentrations of macro-nutrients in urine (design figure): 7300 mg/L N; 670 mg/L P; 1800 mg/L K.
- Concentration figures are based on a person's diet and should preferably be verified onsite.
- 80% of the nitrogen excreted by a person is excreted with the urine, and the rest with the faeces. Hence, in terms of nitrogen fertiliser, urine is more important than faeces. For phosphorus, 55% is excreted with the urine, the rest with the faeces.
- Adults excrete the same mass of nutrients as taken up in their diet, as there is no retention of nitrogen and phosphorus in the human body, except for children where a small amount is retained for bone growth.

The chemical composition of fresh and stored[3] urine is summarised in *Table 1 (see next page)* and the following observations are highlighted:

- Fresh urine contains nitrogen mainly in the form of urea; stored urine contains nitrogen mainly in the form of ammonium/ammonia (the transformation process is described in *Section 2.7.2*).
- The lower phosphate, magnesium and calcium concentrations in stored urine compared to fresh urine are due to precipitation processes during storage.

2 Cap = capita = person

3 Stored urine means urine which is completely hydrolysed (Udert et al., 2003), and this typically occurs within 2-4 weeks depending on the amount of urease present (Maurer, 2007).

Table 1. Average chemical composition of fresh urine (literature values) and stored urine (simulated values, see Udert et al. (2006))[4]. Significant changes during storage are indicated in bold.

Parameter	Fresh urine	Stored urine
pH	**6.2**	**9.1**
Total nitrogen, TN (mg/L)	8830	9200
Ammonium/ammonia-N, NH_4^+ and NH_3 (mgN/L)	**460**	**8100**
Nitrate/nitrite NO_3 + NO_2 (mgN/L)	0.06	0
Chemical oxygen demand, COD (mg/L)*	6,000	10,000
Total phosphorus, TP (mg/L)	800 – 2000	540
Potassium, K (mg/L)	2740	2200
Sulphate, SO_4 (mgSO_4/L)	1500	1500
Sodium, Na (mg/L)	3450	2600
Magnesium, Mg (mg/L)	120	0
Chloride, Cl (mg/L)	4970	3800
Calcium, Ca (mg/L)	230	0

* COD is a measure of the organic components.

2.6.4 Micro-pollutants

Micro-pollutants in urine could include the following categories of substances:

1. Natural hormones
2. Pharmaceutical residues, including hormones from contraceptive pill
3. Heavy metals
4. Persistent organic pollutants (POPs)

The last two categories of micro-pollutants – heavy metals and POPs – are virtually non-existent in urine as they would originate from the food a person has eaten. Urine is an important pathway for the body to eliminate organic degradation products which are toxic to the human body, but these substances are easily biodegradable by soil microorganisms after excretion. The first two categories of micro-pollutants – the natural hormones and pharmaceutical residues – do occur in urine and can be managed *(see Section 2.7.3 and 3.2)*.

2.7 Urine treatment

2.7.1 Treatment objectives

Urine treatment has the following objectives:

- **Pathogen kill** (this is the main objective): Collected urine may be contaminated with faecal pathogens if careless users deposit faeces in the urine compartment of a UD toilet (this is termed "*cross-contamination*" of urine with faecal material). As mentioned above, pure urine is virtually pathogen-free.
- Other possible treatment objectives may include:
  - Volume reduction by evaporation or by conversion into solid form (struvite) to reduce transport costs.
  - Extraction (further concentration) of nutrients.
  - Elimination of micro-pollutants.

2.7.2 Treatment by storage

The simplest, cheapest and most common method to treat urine with the aim of pathogen kill, is extended storage in storage tanks.

Storage of urine in a closed tank or container (not necessarily gas tight) is an efficient treatment method for reducing pathogens in urine: The decomposition of urea into ammonia/ammonium and hydrocarbonate – which is facilitated by the natural enzyme urease – leads to an **increased pH value** (pH around 9) which has a sanitising effect (meaning it kills pathogens), so that bacteria, parasitic protozoa, viruses and intestinal helminths die off over time. An environment with a high temperature and low dilution with water enhances this effect. Time itself also leads to pathogen kill.

Safe reuse of urine in agriculture can be ensured if the following recommended storage times are used (for details see WHO, 2006, Volume 4):

- Urine originating from larger systems (community level) – where cross-contamination with faeces cannot be ruled out – should be stored for at least one month if it is used on food or fodder crops which are processed. For a higher safety margin, 6 months of storage can be used (in which case the urine can be used on all crops). But if the ammonia level in the urine is greater than 2 mgN/L (which it should be for undiluted urine) then shorter storage times will suffice (Winker et al., 2008).
- No storage is needed when urine from own production (or from systems where cross-contamination with faeces is definitely not occurring[5]) is used for crops grown for own consumption. This is because disease transmission within the household via the urine-oral route is much less likely compared to day-to-day contact of the household members.

2.7.3 Other urine treatment technologies

Advanced urine treatment technologies can include biological processes (nitrification), chemical processes (struvite precipitation; ozonation) or physical processes (membrane-based). Some of these high-tech methods (such as ozonation

4 Source: Maurer (2007)

5 For example when urine is collected from waterless urinals.

and membrane-based processes) can remove micro-pollutants from urine (see Larsen and Lienert (2007); Tettenborn (2007)). This is useful to know if there is concern about micro-pollutants in urine *(see Section 3.2)*.

2.8 Are UD systems more cost effective?

Possible cost savings of urine diversion systems may be related to the following aspects (in each case, one needs to consider which systems are being compared):

- If a centralised sewer system and wastewater treatment plant can be avoided by using UD toilets, then cost savings will be significant. However, the collection and treatment of **greywater, industrial wastewater and rainwater** still requires a sewer system of some sort (separate, decentralised systems may often be preferable). Note that the remaining greywater in UD systems contains a far lower concentration of pathogens and nutrients compared to conventional domestic wastewater.
- In regions where water is scarce and expensive, water savings from UD toilets (in particular UDDTs) can lead to overall cost savings compared to flush toilets.
- In regions where soil fertility is poor and fertiliser expensive, farmers may have production cost savings or higher yields when using urine as a fertiliser instead of mineral fertiliser or no fertiliser at all.

Regarding potential **energy** savings, this needs to be analysed on a case by case basis. Energy savings may be possible with UD systems in three areas:

1. If the system is set up to use less water, energy savings are possible with respect to pumping, processing and distribution of the tap water.
2. Energy savings may be possible at the wastewater treatment plant, which receives a lower load of nitrogen in the sewage if urine is collected separately (hence less oxygen required for nitrification process).
3. If urine replaces artificial mineral fertiliser, then energy savings are possible for fertiliser production as well as for fertiliser transport (most African countries have no local mineral fertiliser production facilities).

A life cycle analysis, comparing the energy demand for nutrient removal and mineral fertiliser production versus nutrient recovery identified a considerable energy saving potential with urine diversion nutrient recovery (Maurer et al., 2003).

On the other hand, the following aspects can lead to UD systems having higher costs than conventional systems:

- In comparison with conventional sewer-based sanitation systems, urine diversion systems using UD flush toilets tend to have a higher initial investment cost as they require additional components for the separate collection, transport and treatment of the urine and faeces.
- A UDDT usually has a slightly higher capital cost than a simple pit latrine or – of course – the do-nothing option of open defecation.

Adequate financing and operating schemes have to be found that ensure financial sustainability and make the system affordable for the users. Further information is available in the fact sheet of the SuSanA working group on "*costs and economics*" (http://susana.org/lang-en/library/rm-susana-publications?view=ccbktypeitem&type=2&id=609).

2.9 Technical components used for achieving UD

To achieve urine diversion, the following technical components are used: waterless urinals, urine diversion toilets, urine piping to a urine storage tank (or to a sewer) and a reuse system for the urine. Further information is provided in *Sections 4 to 6*.

There are two main variants of UD toilets: UDDTs (urine-diversion dehydration toilets - no flush water is used at all) and UD flush toilets (water is used to flush the faeces away and to rinse the urine compartment).

3 Reuse of urine as fertiliser in agriculture

3.1 How to use urine as a fertiliser

When sanitation projects are set up where collected urine is to be used as fertiliser, consultation with farmers and soil fertility experts is essential, as the engineers setting up the sanitation projects usually lack the necessary agricultural expertise.

3.1.1 Basic guidelines

The benefits of urine as a fertiliser and its application methods have been well documented, for example in Gensch et al. (2011), Richert et al. (2010), SuSanA (2008), Morgan (2007), WHO (2006) and Jonsson et al. (2004). Some highlights from these documents are summarised below.

Urine is a quick acting fertiliser that can be used for any crops which require the macro-nutrients N, P, K or S (nitrogen, phosphorus, potassium or sulphur[6]). The fertilising effects of these nutrients in urine are the same as those of artificial mineral fertiliser if the same amount of nutriens is applied. Hence, reuse of urine in agriculture has the potential to reduce demand for artificial mineral fertiliser.

6 Sulphur is an important macro-nutrient, needed in approximately the same amount as phosphorus, and often lacking.

Below are some rules of thumb for the use of urine as a fertiliser with respect to its nutrient content (taken from Jönsson et al. (2004) and others):

- Urine is a nitrogen-rich complete fertiliser, containing also sodium and chloride. This makes it well suited as fertiliser for crops thriving on nitrogen (such as maize) and especially for crops also enjoying sodium, such as chard (similar to spinach). Care should be taken when applying it for crops sensitive to chloride (such as potatoes and tomatoes), although yields of these crops can also be much improved by appropriate urine application.
- If all urine from one person is collected, it will suffice to fertilise about **300-400 m²** of crop per person per year, e.g. producing for example 250 kg of maize (roughly equal to the food intake of one person per year).
- Apply the amount of urine that one person excretes in one day on **one square metre** per cropping season (this means approx. 1.5 L undiluted urine per square metre). If we assume that there is 7 gN/L in urine (typical value for Swedish conditions), then 1.5 L urine/m² will correspond to 105 kg N/ha, which is a low to normal dose for cereals (depending on the country, soil and expected harvest from the field).
- The crop yield also depends very much on the soil, and urine will always work better in "*living soils*" compared to barren, sandy soils. The nitrogen converting bacteria must be present and compost helps enormously[7].

Some recommendations for the methods on how urine should be applied as a fertiliser are:

- Between last fertilisation and harvest a period of at least one month should always be applied (for both large and small scale systems).
- The person applying the urine to the fields should follow good personal hygiene practices (thorough hand washing after applying the urine, and if possible also wearing gloves and boots).
- The best nitrogen fertilising effect is obtained when urine is applied close to the ground and directly incorporated or watered into the soil in order to minimise ammonia losses to the air. In order to avoid leaching, and for climates with heavy rainfall or very sandy soils, frequent application of small amounts of urine is favourable but not essential. It is necessary to balance maximum crop yield with what is practical in real life.
- Urine should always be applied to the soil **next to the plant** (in furrows) but **not onto** the plant. Otherwise it might lead to "*burning*" of the leaves.

  Note: "*We fertilise the soil, not the plant!*".

3.1.2 Specific advantages of urine compared to other mineral fertilisers

As pointed out by Elisabeth Kvarnström (Stockholm Environment Institute), one of the great advantages of urine is that "*the content of heavy metals and organic compounds is very low, as these only come from the food which you have once considered having a high enough quality to ingest. Artificial mineral fertilisers can have a relatively high content of heavy metals.*"

Secondly, when farmers are able to use the urine from their families and neighbours in their own fields, this fertiliser is essentially for free (but if urine has to be transported over a distance from production to use, there are transport costs).

Urine fertiliser is also independent from the availability and price of mineral fertiliser on the world market. Furthermore, urine contains micro-nutrients which the soil may need for higher soil fertility.

3.1.3 Disadvantages of urine compared to other mineral fertilisers

Whilst urine is a proven fertiliser, it has some drawbacks compared to artificially manufactured chemical fertilisers:

- Urine is, compared to artificial fertilisers, a **diluted fertiliser:** The N, P, K and S concentration in urine is much lower than in artificially manufactured fertiliser. Urine's nutrient content – expressed with the international fertiliser convention of $N:P_2O_5:K_2O$[8] – is approximately 0.7:0.15:0.22 – compared to for example di-ammonium-phosphate (DAP) or $(NH_4)_2HPO_4$ with the composition $N:P_2O_5:K_2O$ of 21:46:0. This means that a huge volume of water is transported whenever urine fertiliser is transported.
- Urine contains traces of pharmaceutical residues and hormones, and potential buyers of crops fertilised with urine may be put off even if the actual health risks are extremely low *(see Section 3.2)*.
- Urine is a multi-component fertiliser, containing N, P, K and S in a slightly variable ratio, which may or may not be the right fertiliser for a given soil and crop. The macro-nutrient concentrations in urine may vary somewhat (although in relatively narrow ranges), depending on people's diet and whether toilet users add flush water to the toilet.
- Urine is a liquid fertiliser, whilst some farmers may prefer a solid fertiliser if this is what they are used to (unless urine is converted to struvite, by addition of magnesium and raising pH, which is also a proven process).

7 Source: Peter Morgan, Aquamor, Zimbabwe in 2008

8 This means 0.15% by weight of P_2O_5, or 1500 mg/L P_2O_5 (multiply % value by 10,000).

The following disadvantages are not specific to urine as a fertiliser but still need to be kept in mind:

- Like other fertilisers, urine can cause plant fertiliser burn (also called leaf scorch) if not applied correctly. Fertiliser burn is the visible symptom of insufficient water in a plant associated with an over application of fertiliser salts (salts dissolved in urine)[9].
- Urine adds salinity to the soil and therefore its use as fertiliser to pot plants is only recommended when the soil can easily be exchanged.
- Also like other fertilisers, urine can lead to groundwater pollution (with nitrate) and nutrient run-off (resulting in eutrophication in water bodies) if excess amounts are applied.
- Urine is a multi-component fertiliser (with a fixed ratio of N, P, K and S) which should only be applied until the first nutrient reaches its optimum for the soil (probably nitrogen or sulphur). Otherwise (if applied until phosphorus is sufficiently supplied) it can cause over-fertilisation of nitrogen and sulphur.

3.1.4 Should urine be applied undiluted or diluted with water?

Urine can be applied either undiluted or diluted with water, depending on the soil and the gardener's or farmer's preferences. Some gardeners dilute urine with water in a ratio of 1:3, 1:5 or even up to 1:15, and this dilution has the following advantages:

1. Reduces risk of plant "*fertiliser burn*" *(see previous section)*.
2. Enables irrigation and fertilisation in one step (also called "*fertigation*") and with one piece of equipment. But nozzles of drip irrigation may clog when a urine-water mixture is used for fertigation.
3. Reduces odour during application, especially if a high dilution ratio is used (1:5 or greater).
4. Minimises the risk of applying too much fertiliser to potted plants, as the pot will overflow before too much nitrogen is applied.

On the other hand, applying urine undiluted has the advantage that a smaller volume of an odorous liquid has to be handled.

When applying urine undiluted, fertiliser burn of the roots is avoided by adding urine in furrows, somewhat to the side of the plants (approx. 15 cm). Odour nuisance is minimised by immediately covering the urine with soil after the urine has been added to the furrows. Usually, irrigation water is added directly after the urine application.

3.2 Are hormones and pharmaceutical residues in urine problematic for reuse?

The information in this section is based on Winker (2009) and the input from Arno Rosemarin (Stockholm Environment Institute). The publication of Larsen and Lienert (2007) is also recommended in this context.

Hormones and pharmaceutical residues are two types of micro-pollutants which occur in urine (concentration levels are available in Winker (2009)), as humans excrete them with their urine and faeces (as a rule of thumb: two thirds of pharmaceutical residue substances are excreted with the urine, one third with faeces, although the figures can vary widely for individual substances[10]).

If urine is reused in agriculture, some of these micro-pollutants can be taken up by plants and thereby enter the human food chain. This is a risk, but a small one. A full evaluation of the potential toxic effects of pharmaceuticals ingested by humans via urine-fertilised crops is very difficult and has not yet been done. The potential risks from consuming crops fertilised with urine need to be compared with the risks related to pesticide use on crops, as well as antiobiotics and hormones given to farm animals (poultry and cattle) which can be traced for example in milk and eggs. At the end of the day, it comes down to a risk analysis and risk management strategy.

Animal manures and sewage sludge containing pharmaceutical residues and hormones are already now being used on fields. It was shown that the load of hormones and antibiotics in human urine is in fact much lower than in animal manure (however not all groups of substances can be compared in this way as they are not all present in animal manure). With sewer-based sanitation systems, these types of micro-pollutants are not removed in conventional sewage treatment plants and are thus discharged into surface water bodies and can reach the groundwater (detected concentrations of pharmaceutial residues in groundwater are in the order of 50 ng/L in several locations in Germany).

When comparing the two approaches (discharging urine with treated wastewater to surface water versus urine application to soil), it is likely to be safer to discharge urine to soil rather than water. The micro-pollutants can be degraded better in the aerobic, biologically active soil layers (high concentration of micro-organisms per cubic centimetre) with longer residence times than in water bodies whose ecosystems are much more sensitive. This has previously been proven in the case of hormones[11], and more research is needed to prove it for other types of micro-pollutants as well.

9 Root cells actively absorb fertiliser salts from soil solution, and under normal conditions maintain a higher osmotic pressure. If excess fertiliser salts are applied (i.e. concentrated urine which is not diluted), the osmotic pressure of the soil solution is raised. This means water cannot enter the cell and may actively move out of it. The resulting injury is known as fertiliser burn or physiological drought (Robert Holmer, Ecosanres discussion forum, 2008).

10 To be more precise: around 70% of pharmaceutical substances are excreted via urine accounting for 50% of the overall ecotoxicological risk (Larsen and Lienert, 2007). The ecotoxicological risk of the fraction of pharmaceutical residues contained in urine and in faeces is the same regardless of the higher number of substances excreted via urine.

11 This finding is of particular relevance regarding the artificial hormones which are excreted in urine from women taking the contraceptive pill.

Terrestial systems (soil) are more suitable for natural degradation of pharmaceuticals than aquatic systems because:

- The oxygen levels are around 50,000 times higher in soil than in water.
- Exposure to UV light helps to degrade pharmaceuticals, although this only applies to the surface (1-2 cm soil depth) and crops can shade the ground.
- The high specific surface of soil particles maximises the exposure of adsorbed chemicals, maximising the kinetics of degradation.
- The wide biodiversity of the fungal and bacterial flora of soil is adapted to degrade various types of organic molecules, both complex and simple.

Finally: "*Drug residues in sustainable sanitation products used to supply plant nutrients can hardly be a serious issue in regions where malnutrition, groundwater and surface water pollution due to inappropriate sanitation and irrigation with untreated wastewater is a reality*" [12].

3.3 Is urine an "organic fertiliser" and can it be used in organic farming?

The definition of "*organic fertiliser*" may be according to two different categories:

1. Organic in the **analytical chemistry sense** (a compound which contains carbon and may contain other elements such as hydrogen, oxygen, nitrogen).
2. Organic in a ***"green", "eco"*** or ***"natural"*** sense.

Fresh urine contains urea and is thus an organic fertiliser in the analytical chemistry sense. Stored urine contains ammonia and no urea *(see Section 2.6.3)*, and is therefore not organic but rather a "*mineral fertiliser*" in the analytical chemistry sense. In other words: Urine is both a natural mineralised or mineral fertiliser, and an organic, ecological or natural fertiliser [13].

The "*organic farming*" [14] regulations differ between countries with regards to which type of fertiliser is allowed (and is in this context called "*organic fertiliser*"). For example, countries in the European Union are subject to the EU organic farming legislation, where urine is **not** considered an allowed fertiliser. In China on the other hand, urine is considered a natural fertiliser and thus allowed in organic farming. Making urine allowed for organic farming in the EU remains an important challenge. It should be possible as urine is a natural fertiliser with a similar composition as for example pig urine.

4 Waterless urinals

This chapter draws on the publication by v. Münch and Dahm (2009). Note: "*waterless*" means "*without water*" in English. Some people also use the term "*waterfree*". We do not recommend any particular urinal model in this publication.

4.1 Definition and purpose

A urinal is a specialised toilet for urinating only, which is used while standing up, and is designed primarily for male users. Urinals are widely used around the world, especially in public facilities being frequented by a large number of boys and men, because they save space and costs compared to toilets (simpler design; no separate cubicles needed, although in many cases separation panels are installed). Urinals are not commonly used in private households due to their additional space requirements.

A limited number of urinals for females (to be used while standing or squatting) are on the market but they are not widely accepted for various reasons, such as females having greater needs for privacy as they have to partially undress. Squatting-type urinals (squatting pans without an outlet for faeces) are sometimes used for girls in African or Asian primary schools to save on space and costs compared to toilets.

Conventional urinals are flushed with approx. 4 L of water either after each use or based on a timer, whereas waterless urinals *(see Figure 1)* use no water for flushing.

The main motivation for using waterless urinals is to:

1. Save water and hence costs – these urinals are connected to a sewer system.
2. Allow collection of pure, undiluted urine for use in agriculture as a nitrogen and phosphorus-rich fertiliser – these urinals are connected to a urine storage tank.

Waterless urinals are the first and easiest step towards urine diversion and, possibly, ecological sanitation (ecosan).

Figure 1. Waterless urinals for men. Left: Centaurus model of Keramag company. Right: Plastic urinal from Addicom, South Africa, with EcoSmell-stop device (sources: (left) E. v. Münch, Delft, 2006; right: Addicom).

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12 Source: Jörn Germer on Ecosanres discussion forum, April 2009.

13 Source: Håkan Jönsson (on Ecosanres Discussion Forum, December 2008, http://www.ecosanres.org/discussion_group.htm)

14 A possible definition of "*organic farming/agriculture*": Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved (source: International Federation of Organic Farming Movement, http://www.ifoam.org/).

4.2 Historical development of waterless urinals

In 1894, Mr. Beetz from Austria patented a drainage device (trap) which allowed urinals to be made "*flushless*". The trap used a sealant liquid (the mechanism is explained in *section 4.4.3*). This patent was then commercially exploited by the company F. Ernst Engineer in Zürich, Switzerland who was the sole supplier of waterless urinals worldwide for approximately 100 years.

In the early 1990s, water saving came into fashion and several companies appeared on the market using derivatives of the Beetz patent. At more or less the same time Hepworth, a UK plumbing manufacturer, patented a drainage device (one way valve) which was in fact a flat tube. A similar device is used in small boats to drain spray water from the bilge. Derivative patents of the flat tube elements are used today in waterless urinals and marketed by various sanitary ware companies, for example Keramag (model Centaurus).

In 2002, a Swiss engineer living in South Africa (Peter Dahm) patented a one way valve similar to the flat tube design but using a "*curtain*" mechanism in order to reduce maintenance requirements. This unit, which is now used in waterless urinals of several suppliers, is sold under the name of EcoSmellstop (ESS).

At present, Germany is probably the country with the highest number of waterless urinals per capita, as the price of municipal tap water in Germany is one of the highest in the world, and Germans are consequently very interested in all water-saving opportunities (1,200 waterless urinals of Keramag are in use in the public toilets of Hamburg in Germany).

Waterless urinals are commonly used in industrialised countries for public toilets which are not connected to the sewer (such as rest stops along highways). It would be beneficial if they became widely used in developing countries as well.

4.3 Odour control methods (general)

To gain wide acceptance, waterless urinals must meet the accepted standards applicable for conventional waterborne installations. Their odour emission must be less or at worst equal to the old system. To achieve this odour-free performance four aspects are absolutely crucial for waterless urinals:

1. Suitable mechanism to block the odour coming back from the sewer and urine storage tank, for example (discussed in detail in the *sections below*):
   - rubber tube seal
   - curtain valve seal
   - sealant liquid (blocking fluid)
   - plastic table tennis ball placed in a funnel which is inserted in the opening of a jerrycan; or
   - place urinal in a well ventilated area (located outside of houses), and put up with some odour (may be possible for rural areas).
2. Appropriate surface of the urinal bowl (smooth, non-sticky, e.g. with wax coating).
3. Correctly designed interrelation between urinal bowl and the drain fitting to minimise crevices where urine can accumulate.
4. On an operational level: a thorough maintenance regarding the bowl and the odour blocking device. The surface of the urinal bowl is usually wiped clean once, twice or several times per day with a moist sponge. For the odour blocking device, the maintenance depends on the specifications of the urinal supplier *(see below)*.

4.4 Odour control for connection of urinal to sewer or storage tank

4.4.1 Rubber tube seal

For this method, a flat rubber tube is used *(Figure 2)*. This rubber tube is flat at the bottom when not in use (and hence blocks odour from the sewer or urine storage tank) but opens up when urine is flowing through. This one-way valve allows passage of grit up to 2 mm.

Urine precipitates ("*urine stone*"), which stick to the rubber tube need to be cleaned off with water regularly (otherwise the flat rubber tube does not close properly anymore). The cleaning frequency depends on the number of uses per day (cleaning once per month under average circumstances may be sufficient). The rubber tube needs to be replaced around once a year. The rubber material is sensitive to solvents, acids, and deodorising tablets often used in urinals. Therefore, the use of acids or aggressive cleaning agents must be avoided. This system is used for example by the German company Keramag in their Centaurus model.

4.4.2 Curtain valve seal

The curtain valve seal is similar to the rubber tube seal, but was designed to reduce maintenance requirements. This type of one-way valve has "*self-cleaning properties*" as a small pressure difference forces the urine to wet the whole inner surface between the "*curtains*", therefore flushing them clean. The element is designed in a manner to minimise build-up of urine precipitates or urine sludge and thus keeping the sealing surfaces clean. Like the flat rubber tube seal, this one-way valve also allows passage of grit up to 2 mm.

The silicon curtain element is integrated into a plastic casing *(Figure 2)*. The placing of the EcoSmellstop (ESS) element into a plastic sleeve has two purposes, firstly to guarantee that no odour from the sewer or urine storage tanks escapes into the room, and secondly to allow an easy removal of the ESS unit for maintenance purposes. For replacement of the curtain (if simple cleaning is no longer possible), the entire plastic casing is removed with a small plastic extractor tool *(Figure 3)*, then discarded and replaced with a new ESS. This replacement process may be necessary about once per year and takes only a few seconds. It can be performed without having to touch the ESS element by hand.

The ESS manufacturing process is not simple as the injection moulds are of extreme complexity, and the mixing and injection requires very sophisticated machinery. For this reason, it is not yet possible to manufacture the ESS locally in developing countries, but it can easily be imported as it is small, light-weight and low-cost. This patented ESS unit is used by the companies Addicom, Kellerinvent AG and F. Ernst Ingenieur AG [15] since 2006.

Figure 2. Two types of odour seals for waterless urinals. Left: Flat rubber tube (Keramag Centaurus). Right: (left side) See-through pipe fitting; (right side) see-through EcoSmellstop (ESS) unit showing the blue silicon curtain one-way valve inside (source: (left) E. v. Münch, 2007; (right) Addicom).

Figure 3. EcoSmellstop (ESS) unit with pipe fitting and extractor. Inside the ESS is the silicon curtain valve (source: Addicom).

4.4.3 Sealant liquid (blocking fluid)

This system works with a sealant liquid (also called blocking fluid) which is made of vegetable oils or aliphatic alcohols – they are biodegradable if released to the sewer or urine storage tank. The sealant liquid, with a specific gravity of around 0.8, floats on top of the urine contained in the trap and thus constitutes an effective odour barrier. Urine immediately penetrates the sealant liquid and flows to the drain. Urine precipitates are collected in a cartridge or inner cylinder of the trap. The maintenance program of waterless urinals with a sealant liquid consists of cleaning of the urinal bowl, and the regular exchange of the cartridge (or the sealant liquid, *see Figure 4*). The required exchange frequency depends on the number of users. With each use and in between uses, some urine precipitates accumulate which eventually renders the trap inoperative. Foreign objects, such as cigarette stubs, accelerate the process. At this point the cartridge has to be cleaned or replaced.

If the trap starts to smell, while it is still freely passing urine, merely a refill with the sealant liquid can resolve the problem for some designs. In the USA, this is currently the most common type of waterless urinal, as under current legislation only these liquid-filled traps are approved for waterless urinals.

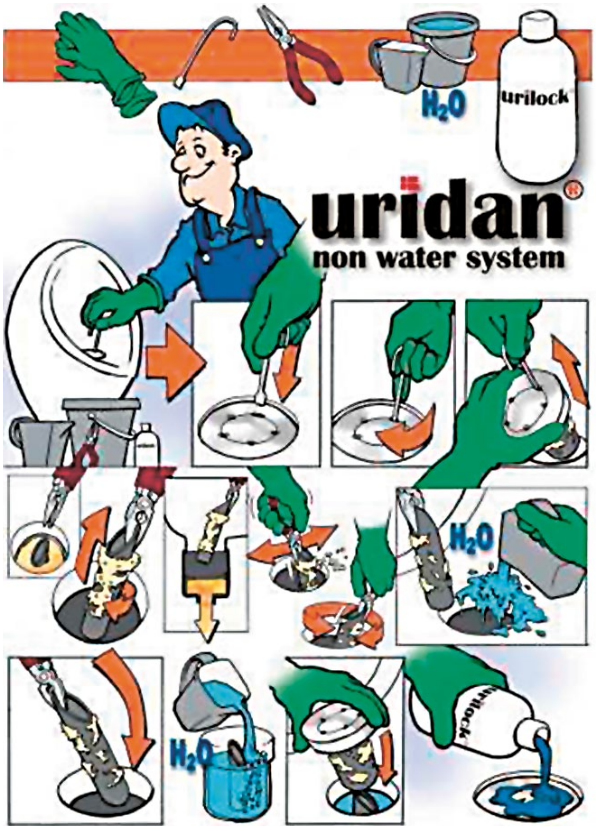

Figure 4. Example instruction sheet, showing replacement of sealant liquid for Uridan urinals (other urinals with sealant liquid have a similar maintenance routine) (source: Uridan).

Possible advantages of sealant liquid systems in the context of developing countries may include:

- No need to be exchanged when full with precipitates, but can be easily cleaned.
- After being cleaned, they can be refilled with some thick cooking oil[16] (this does not last as long as the recommended liquid, but is available almost anywhere).

There is no clear evidence yet which of the three systems discussed above is better for low-cost, low-maintenance applications, and this may depend on the preference of the individuals or companies responsible for the urinals' maintenance.

4.4.4 Other methods for the odour seal

Other methods for odour control are on the market *(see also suppliers listing in Appendix)*. One example is the system by Urimat where the sealant liquid is replaced by a float (hydrostatic float barrier) which is magnetically activated thus opening the channel to the overflow chamber. For low-cost applications in developing countries, this system has the disadvantage of a higher complexity compared to the systems described above[17].

Small-scale simple systems may utilise just a pipe or hose (without any odour trap) connecting the urinal with the tank. Here, the odour can be controlled by having the urine pipe (filling hose) going down to almost the bottom of the collection vessel, thus creating a liquid seal in the collection vessel. Another option is to pour some cooking oil into the collection vessel, thus creating a thin sealant film in the collection vessel itself. A cut-off condom on the urine outlet pipe has also been used.

Another very simple option for a waterless urinal is the "*eco-lily*", where a plastic funnel is inserted into the opening of a plastic jerrycan. An old light bulb or a table tennis ball is placed into the funnel to act as odour seal (it should float up when urine enters the funnel but could end up sticking to the funnel). The disadvantage of the light bulb over the plastic ball is that the solder and metal cap on the light bulb contains heavy metals which can contaminate the urine.

4.5 Further design information

The space requirement of a urinal is less than that of a toilet, which makes them popular for any venue where many men need to urinate (soccer stadiums, restaurants, schools, etc.). Waterless urinals are usually wall hung and do not require piping for flush water nor flushing devices, thus allowing a considerable cost saving. The flushing devices as well as the traditional water traps in the outlet piping (U, P or "bottle" shaped) of conventional urinals tend to attract a considerable amount of vandalism (hence waterless urinals can further reduce maintenance costs). Waterless urinals do not need to be connected to a sewer but can be connected to a urine storage tank instead (important for remote locations not connected to sewers). Obviously, water for hand wash basins and water-flushed toilets (if not replaced by waterless toilets) is still required next to the waterless urinals.

Materials

Urinal bowls are typically made of acrylic, ceramic, stainless steel or glass-fibre reinforced polyester, but can also be made of simple low-cost plastic, provided that it has a smooth surface (for odour control). Self-construction of inexpensive waterless urinals is also possible. When using plastic urinal bowls, one option is to use linear low density polypropylene as it is one of the most inert plastics (non-stick surfaces). The hot production process at 180°C guarantees a smooth, non-porous surface, therefore minimising bacterial biofilm growth.

Converting water-flushed urinals to waterless urinals

It is in principle also possible to convert conventional water-flushed urinals to waterless urinals (depending on the bowl design), for example by using the ESS, which is also sold as a stand alone unit. It is very important to get a snug fit of the ESS into the urinal drain.

4.6 Use and maintenance of waterless urinals

The instructions given below are not for urinals at households but for installations at institutions or public places[18]. At household level, different maintenance routines apply than those described below due to much lower frequency of use. The urinal bowl should be cleaned daily, just like any other (water-flushed) urinal. There are 100% biodegradable cleaning solutions on the market that are simply sprayed onto the urinal bowl and not wiped off. For example, URIMAT MB-AktivReiniger with tensides is used for the 50 waterless urinals in the GIZ headquarters in Eschborn, Germany.

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15 The company F. Ernst Ingenieur AG used the sealant liquid system (in its waterless urinals installed mostly in Switzerland and Germany), but changed over to the EcoSmellstop system in October 2006, and is now retrofitting all of its approx. 100,000 urinals which were installed prior to that date (F. Ernst AG operates its urinals under a maintenance contract should the client not decide otherwise).

16 Hakan Jönsson: "*the important properties of oil for this use are density lower than water - most oils have a density around 0.7 kg/L - this way it floats on urine; hydrophobic - maintains a lid above the urine and its content; and both of these are shared by cooking oils. Cooking oils are partly unsaturated and will thus oxidise faster and need replacement, but this is secondary to them being generally available*".

17 Hans Keller used to run the company Urimat and has the patents. But he now runs Keller Invent which bought F Ernst AG (hence Mr. Keller moved from hydrostatic float barrier to ESS).

18 In countries with wide-spread sewer systems, urinals are not used at household level. But in countries where onsite sanitation is common, waterless urinals at household level are used together with urine diversion dehydration toilets.

Any type of odour seal (be it flat rubber tube, curtain seal or sealant liquid) needs to be cleaned (or replaced if cleaning is no longer possible) at regular intervals to keep it fully functional. The frequency of cleaning or replacement of the odour seal system depends mainly on the number of uses per day as well as user and cleaning staff behaviour (in terms of foreign objects discarded in urinal). It can therefore vary widely, ranging from once a week to once every six months.

The flat rubber tube and ESS units can be cleaned many times before having to be replaced. Some sealant liquid cartridges cannot be cleaned but need to be replaced when they fail, whilst for example the Uridan system can be cleaned, and the sealant liquid replaced, any number of times. To give an example: According to information given by Addicom, an ESS element can last for 16 months with careful maintenance, such as spraying the urinal bowl regularly with the cleaning agent "*DestroySmell*" (containing tensides and active microorganisms), and removing the ESS element and rinsing with diluted citric acid to slow down the formation of urine precipitates on the curtains.

Empirical evidence gathered in low-income settings in South Africa (such as public parks and taxi ranks in Johannesburg) since 2004 suggests that the curtain seal (ESS system) can perform with *less maintenance* than the flat rubber tube. In regions where diligent maintenance of urinals cannot be guaranteed (such as public toilets in informal settlements in sub-Saharan Africa), the ESS system may therefore be a better choice of the two. More side-by-side comparisons between different waterless urinal types are required, particularly for urban, low-income areas in developing countries with a potentially high level of abuse and neglect.

4.7 User acceptance of waterless urinals

Experience worldwide has shown that waterless urinals enjoy the same level of user acceptance as water-flushed urinals do, since for the male users there is no behaviour change required (many users do not even notice that they are using a waterless urinal). For those men who are shy and do not like using urinals in public places (for lack of privacy), it makes no difference whether the urinal is water-flushed or not.

In cultures where anal washing with water is practiced, each urinal can be installed in a cubicle to guarantee privacy. For example, many Muslim males wash their genitals with water after urinating, which requires water supply and separate drainage facilities. Prior to providing waterless urinals, one has to establish whether the community in question is willing to accept such facilities. Note also that in some cultures men are used to squatting when urinating. Waterless urinals could be placed on the ground instead of being wall-hung.

In some instances, there may be a psychological barrier of users or cleaning staff ("*if a urinal is not flushed it cannot be hygienic*"). The thought that water is always equal to hygiene is an understandable misconception. However, when faced with a well-functioning, odourless waterless urinal, those fears are quickly alleviated, which is why demonstration projects can be useful. Today's waterless urinals are designed to be odourless and simple to maintain.

As waterless urinals are a novelty for many people, any smell emitted from a waterless urinal gets blamed on the new system. However a smelly water-flushed urinal is accepted as normal as they have a long odorous history. It is a fact that any type of urinal (water-flushed or waterless) will not smell if well maintained. The extent of maintenance required for waterless urinals can be higher or lower compared to water-flushed urinals, depending on the type of waterless urinal used (as explained above).

4.8 Suppliers and costs of waterless urinals

The following options exist for buying waterless urinals in developing countries:

- Imported waterless urinals with or without patented odour control devices
- Plastic waterless urinals manufactured locally and imported ESS element or liquid seal inserted for odour control
- Self-constructed waterless urinals made from plastic containers.

For low cost applications, simple plastic urinals may be a good option. These can be produced in a "rotation moulding" process. This is a cheap and simple process to make a single-skin type unit, which can be replicated in any country.

Suppliers lists for waterless urinals are provided in the *Appendix.* For reference installations either contact the manufacturers or see the case study descriptions of sustainable sanitation projects on www.susana.org. Many of these projects incorporate waterless urinals. Photos of waterless urinals are also available here: http://www.flickr.com/photos/gtzecosan/sets/72157613881735035/

4.9 How to choose the right type of waterless urinal

When choosing a waterless urinal from the large range of suppliers and models, the following guide questions can be used (for waterless urinals in institutions and public places[19]):

1. Do the urinals need to be as cheap as possible?
2. Do the users prefer ceramic urinals over plastic urinals?

19 Note: For waterless urinals at households, the maintenance considerations are quite different. Households want to use maintenance materials that can be found in a general store at a minimal cost.

3. Are the urinals available locally (local distributor) or do they have to be imported?
4. Does the supplier offer you to get in contact with the suppliers' existing clients?
5. Does the supplier have reference letters?
6. How many units has the supplier sold already?
7. Do the urinals need spare parts and can they be obtained locally with minimal waiting times?
8. Is there likely to be any vandalism in the location where the urinals will be installed?
9. Who will do the maintenance and will they be diligent or rather unreliable?
10. After how many uses does the odour seal need replacement (or after what time period)?
11. How long does each event of odour seal replacement take?
12. How difficult is the odour seal replacement routine?

5 Urine diversion toilets

5.1 Definition

Urine diversion (UD) toilets are designed to not mix urine and faeces at the point of collection in the toilet. There are two main main types of UD toilets and both types can be built indoors:

1. **Urine diversion dehydration toilets (UDDTs)**
   No flushwater is used. These toilets are often called "*ecosan toilets*" but this would wrongly label one particular toilet type as *the toilet* to be used in ecosan projects.
2. **UD flush toilets**
   Water is used to flush the faeces away and to rinse the urine compartment.

These toilets may be implemented within new sanitation systems or may complement existing systems. In any case, additional pipework such as a pipe from the toilets to the urine storage tanks becomes necessary *(see Section 6)*.

5.2 Basic design information for UD toilets

Careful planning and appropriate design is essential for successful application of UD toilets. They should be designed or chosen based on the needs and the customs of the users. The preferred posture of the user can be:

- **Sitting toilets** (with pedestals): these can be wall-hung or floor mounted; or
- **Squatting toilets** (with squatting pans): many people are used to toilets which are used in a squatting position.

Further design considerations which are important for all types of UD toilets (details are provided in *Section 5.3 and 5.4*):

1. Do the users wash their anal area with water after using the toilets or do they use toilet paper ("*washers*" as opposed to "*wipers*")? This is customary in many Muslim and Buddhist cultures but may also be linked to factors other than religion.
2. Needs of disabled people, elderly, children when using the toilet
3. Specific needs of females (menstrual hygiene; privacy and security needs)
4. Odour control for the urine collection system
5. Will the toilet be an indoor or an outdoor toilet (indoor is likely to become the norm in the future and is possible with UD toilets)?

5.3 Urine diversion dehydration toilets (UDDTs)

This section on UDDTs contains only basic information. For more information on this important technology and its operation and maintenance requirements see:

- Technology review on UDDTs by GIZ (http://www.gtz.de/en/themen/umwelt-infrastruktur/wasser/9397.htm)
- Berger and Lorenz-Ladener (2008); Morgan (2007); Austin (2006); Kvarnström et al. (2006); Winblad and Simpson-Hebert (2004)

The benefits of UDDTs compared to pit latrines were listed in *Section 2.3.2*.

5.3.1 Basic design information

UDDTs do not use water for flushing. They use a very simple system where the urine is captured in a bowl which is integrated in the front of the toilet pedestal or squatting pan. From here, the urine is drained off to a storage container.

For the faeces, a straight drop (or chute if toilets are on several levels in the house) is provided from the toilet pedestal or squatting pan to a collection vault or bin.

A vent pipe is provided to ventilate the faeces chamber, remove odour from the room and to speed up the drying process. UDDTs are **not** designed for composting to take place in the faeces vault but just for drying.

In regions where people practise anal cleansing with water, a third outlet hole is used, to collect and treat the anal washwater separately from urine and faeces *(see Figure 5)*. It is best not to mix anal washwater with urine to keep pathogen levels in the urine at a minimum, if urine is to be used as a fertiliser.

The anal washwater can be infiltrated in a gravel filter or treated together with greywater in a subsurface constructed wetland. UDDTs are especially popular wherever there is water scarcity and a demand for cheap fertiliser. They can be built indoors or outdoors.

Figure 5. left: Indoor UDDT (pedestal type) in Johannesburg, South Africa in the house of Richard Holden (source: E. v. Münch, 2006).
Right: UDDT squatting pan in Bangalore, India, with three holes: the area in the front is for anal washing, middle is for faeces and back is for urine (source: D. Schäfer, 2008).

5.3.2 Odour control for urine collection system

An odour seal may be used on the urine pipe if the toilet is indoors, especially in systems with many toilets (the same types of seals as for waterless urinals can be used, including the ESS *(see Section 4.3)*). Some UDDTs even have an integrated fan (such as the toilet of Separett), which removes odour from both the faeces bucket and the urine pipe. No separate odour blocking device is necessary in this case.

For outdoor UDDTs with individual urine storage tanks, the connection to the urine storage tank is usually direct, without any odour trapping device. The faeces chamber has a vent pipe to remove odour from the toilet, and dry additives assist in odour control.

5.3.3 Construction methods and materials

Possible materials for the toilet pedestal or squatting pan are: ceramic, concrete, acrylic or glass-fibre reinforced plastic. The toilet can either be self-constructed or prefabricated. Metal components (except for stainless steel) cannot be used since urine is corrosive.

5.3.4 Use and maintenance

The main operational requirement when using UDDTs is that the faeces vault is kept as dry as possible (no addition of urine or water). The urine and faeces containers need to be emptied when full.

Covering material should be added to the faeces vault after each defecation. Covering material can be ash, sand, soil, lime, leaves or compost and should be as dry as possible. The purpose of adding covering material is to:

- reduce odour
- assist in drying of the faeces (to soak up excess moisture)
- prevent access for flies to faeces
- improve aesthetics of the faeces pile (for next user)
- increase pH value (achieved when lime or ash is used).

5.3.5 Project examples

UDDTs are used in many rural and urban sustainable sanitation projects worldwide. They have been installed at households, schools, prisons, universities etc. and for public toilets (see for example SuSanA case studies on: http://www.susana.org/lang-en/case-studies).

5.4 UD flush toilets

5.4.1 Overview on historical development

UD flush toilets were invented in Sweden in the 1990's (Kvarnström et al., 2006). They were first adopted in eco-villages and holiday homes. Today, they are also used in some housing projects and public buildings in several countries in Europe, although still only at a pilot scale. A detailed study (called NOVAQUATIS) on UD flush toilets was conducted by Eawag, Switzerland (Larsen and Lienert, 2007).

5.4.2 Basic design information

The benefits of UD flush toilets compared to flush toilets were listed in *Section 2.3.1*. The UD flush toilet has a partition in the toilet bowl isolating a bowl for urine in the front, and a bowl for faeces in the back. The bowl is similar to bowls used for UDDTs, except that for the UD flush toilet, water is used to flush the faeces away. The flushing mechanism for the urine part is designed in one of two ways:

1. The urine pipe stays open and therefore receives a certain amount of flushing water when the bowl is flushed *(see Figure 6)*; or
2. the urine pipe is closed by a valve and therefore receives no flushing water (this is the case for the Roediger NoMix toilets).

The UD flush toilets can reduce water consumption compared to conventional water-flushed toilets because the water required for the "*urine flush*" is less than the amount for the "*faeces flush*".

UD flush toilets can also be combined with the concept of vacuum toilets (realised for example by the company Roediger for a pilot project in Berlin Stahnsdorf and by the Swedish company Wost Man Ecology, *see Appendix*). This type of toilet collects urine and a small, concentrated amount of brownwater (faeces with about 1 L of flush water).

Figure 6. UD flush toilets. Left: Gustavsberg (in Meppel, the Netherlands); Right: Dubbletten (in Stockholm, Sweden); (sources: E. v. Münch, 2007).

5.4.3 Odour control for the urine collection system

For the urine pipe, several types of odour seals are used by the toilet manufacturers, such as a valve (Roediger NoMix toilets), a urine/water seal (Gustavsberg toilets) or a novel silicon seal (Dubbletten toilets).

Odour locks in the UD toilet's urine pipe are required to prevent back flow of odour into the toilet room; but these are not necessary in the case of short urine pipe systems of up to 3-4 m. For the faeces part, odour control is achieved by a water seal in a U-bend (just like for conventional flush toilets).

5.4.4 Materials

As UD flush toilets have been designed for users in high-income countries, they have been manufactured only in ceramic and have a similar appearance to conventional flush toilets.

5.4.5 Use and maintenance

The faeces section of UD flush toilets is cleaned in the same way as for conventional flush toilets (with a brush). Toilet paper is flushed away together with the faeces.

A particular problem found with the Roediger NoMix toilet is that toilet paper thrown into the urinal bowl is not flushed away with the small urine flush; and hence more than one flush becomes necessary – negating the water saving effect of this type of toilet[20].

Another problem of the Roediger NoMix toilet is that the valve on the urine pipe can get blocked over time. In this case, urine is no longer collected in the storage tank but flows to the faeces section of the toilet, or the valve is not closing anymore causing odour problems in the toilet room. Therefore, the user needs to carry out preventative maintenance by adding diluted citric acid to the valve once per month for a period of 24 hours.

5.4.6 Project examples

UD flush toilets are used in some industrialised countries and they are not a low cost option. So far they are mainly used in Sweden and in some projects in Germany, the Netherlands, Switzerland and Austria.

Two project examples for which detailed descriptions are available are (both on http://www.susana.org/case-studies?showby=default&vbls=2&vbl_2=9&vbl_0=0):

- Urine and brownwater separation at the GIZ main building, Eschborn, Germany
- Urban urine diversion & greywater treatment system, Linz, Austria

5.5 Suppliers and costs for UD toilets

Information on models and suppliers can be found in the *Appendix*. The costs for some of these toilets are relatively high, as the number sold is quite low. If the market for these types of toilets grows and more suppliers enter the market, then the unit costs will decline.

5.6 How to choose between a UDDT and a UD flush toilet

For pro-poor approaches in developing countries, UDDTs are more suitable than UD flush toilets, as the latter still require a reliable 24-hour water supply, a sewer system and a treatment process for the faeces-water mixture (brownwater).

In countries with existing infrastructure for wastewater treatment, the UD flush toilet may become competitive with the conventional flush toilet in the future if the benefits listed in *Section 2.3* are drivers for the required switch.

20 The Roediger NoMix toilet is a first prototype which requires further development of its design.

6 Urine piping and storage tanks

A comprehensive description of the technical details for urine pipes and tanks is available in Kvarnström et al. (2006). Some key considerations are provided below.

6.1 Urine piping

6.1.1 Functional principles

The urine piping system connects waterless urinals or the urine section of a UD toilet to the urine storage tank. As urine generates a considerable amount of urine precipitates and sludge *(see Section 2.4.4 for causes)*, special attention has to be paid to the design and maintenance of the urine piping system.

6.1.2 Materials

Urine pipework is normally made of durable plastics such as polyethylene (PE) or polyvinyl chloride (PVC).

6.1.3 Pipe size and layout

To maximise the flowrate of the urine (and any sediments), the insides of the pipes should be smooth. Flow restrictions, such as sharp 90º bends, should be avoided as much as possible.

The minimum recommended diameter of the pipes is 50 mm, but the optimum range is from 75 mm to 110 mm.

For larger systems (several toilets connected to one urine tank), the slope of the pipe should be at least 1% to minimise urine precipitation. For individual toilet systems, the slope should be at least 4%, but can be built with smaller diameter pipes, down to about 15 mm.

For inspection and cleaning, the pipes should be made accessible (by provision of inspection openings).

As a rule of thumb: keep urine pipes **as short as possible** and with the highest possible slope. Horizontal pipes should not exceed 200 m because of the problems of sludge accumulation in the continuously wetted side of the pipe [21].

Over time crystals and sludge may accumulate in the slow flowing horizontal parts of the pipe system, so periodic flushing may be necessary (once every few years in the best case; more frequent in the worst case) [22].

6.1.4 Odour control

To prevent odours, the piping system should be *only sparingly* ventilated, pressure equalisation is enough *(see Section 6.3 for more details on ventilation)*. Also the pipe opening needs to be immersed into the liquid in the storage tank. This is particularly important in long vent pipes that can act as chimneys with upward flow of air [23].

This means that the incoming pipe to the urine storage tank should go down almost to the bottom, so that a liquid seal is formed preventing undue gas movement through the piping system. But it is not recommend to place a bucket at the base of this pipe, as it might fill with sludge and thus introduce a flow restriction.

6.2 Urine storage tanks

6.2.1 Functional principles

The urine which is collected by means of a waterless urinal or by a urine diversion toilet flows to a urine storage tank. These tanks have a lid and are closed to prevent odour and loss of nitrogen via ammonia gas. The tanks are either emptied by the users themselves (small-scale systems) or emptied by a pump and truck arrangement. The urine is then transported to the point of agricultural reuse or to further storage or treatment.

Urine storage tanks have one or several of the following three main purposes:

1. To bridge the time in between collection/emptying events.
2. To sanitise the urine: over time, pathogens in the urine are killed off (increased pH due to urea conversion to ammonia *(see Section 2.7.2)*.
3. To bridge periods where plants are not fertilised: The plants' need for fertiliser is not constant all year round (except in the tropics). Fertiliser nutrients are generally only needed just before sowing and in the beginning of the growth period *(see Section 3)*.

There are two types of urine tanks: the receptor urine tank at the toilet and the urine storage tank for storage, sanitisation and reuse (these functions can be realised in the same vessel or in separate vessels).

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21 Source: Arno Rosemarin (March 2009)

22 Hakan Jönsson (March 2009): *"My fairly extensive experience is that as long as there is at least a slope of 1% and the diameter is 75 mm or more, then the sludge will flow out at the rate of generation and flushing is not necessary. The reason why extensive pipes should be avoided is that frequently there has been problems with groundwater leaking into the pipes, diluting the urine!"*

23 Source: Arno Rosemarin, March 2009, based on experience with large-scale urine diversion system with indoor UDDTs in Erdos, China.

6.2.2 Locations

The location of the urine storage tanks can be:

1. **At toilet level**: If the urine is to be used in the household garden, a simple plastic jerrycan can be used.
2. **At household/building level** (several toilets together).
3. **At community level** (several houses together) – this is possible if distances between houses are short.

As the urine tanks must be emptied regularly, suitable access for persons or vehicles is required.

The tanks can be located either in the cellar of the building, next to the building or below ground. Urine tanks below ground have the disadvantage that leaks from the urine tank are difficult to detect (a leaking urine storage tank can lead to groundwater pollution with ammonia and nitrate or to the tank being filled with groundwater). Underground tanks have the advantages however that they are usually cheaper to build, have a better insulation in winter (relevant for cold climates) and the access to the manhole is usually also easier. In the case of underground tanks it is important to take the groundwater level into account – to avoid tanks floating in the event of rising groundwater.

Whilst the tanks are closed and designed to minimise odour, some odour could still occur. Hence, the tanks should be in a well-ventilated area and away from kitchens, offices and bedrooms to minimise odour complaints.

A secondary urine storage tank at the farmer's premises may be necessary to enable the farmers to apply the urine when they need it *(Figure 8)*.

6.2.3 Materials

Urine storage tanks need to be completely watertight to avoid loss of urine fertiliser, groundwater contamination and groundwater entering. They are most commonly made of glass fibre reinforced plastic, PE, PP or PVC, but they can also be made of rubber bladders or high-quality reinforced concrete (there are a fair number of concrete urine tanks in Sweden, but they need to be built to a high standard to avoid leakages).

Metal components cannot be used since urine is corrosive (except for stainless steel, which could be used but is expensive).

Plastic tanks which are sold for rainwater harvesting are also suitable as urine storage tanks, and can be a good solution in developing countries.

6.2.4 Urine tank size

The urine tank system may be set up to use one large urine storage tank or several smaller tanks (even down to using a large number of 20 L jerrycans). In either case, the required total storage volume (Vstorage) can be estimated as follows (additional safety factors may be applied):

$$V_{storage} = N_{users} \cdot p_{urine} \cdot t_{storage} \cdot f_{timefraction}$$

with:

N_{users} = number of users
p_{urine} = specific urine production per person (~ 1.5 L/cap/d of urine if the user is at the premises 24 hours per day [24])
$t_{storage}$ = desired storage time [25]
$f_{timefraction}$ = fraction of time that the users stays at the premises where the toilet is.

The required storage time ($t_{storage}$) was already discussed in *Section 2.7.2*). For example, typical design criteria for a storage tank are 360 L of urine per person per year (if they spend 2/3 of their time at the premises) and a storage time of one month.

It is obvious from this equation that if urine is flushed away with water, then a larger urine storage tank is required compared to a toilet where urine is collected undiluted.

When designing the size of the urine storage tank, consideration also needs to be given to the capacity of the emptying vehicle. Details on possible emptying vehicles in the low-cost context are provided in Slob (2006).

If transportation occurs manually, the collection tanks should not be larger than 20 L which equals 20 kg when full (this would already be too heavy for the elderly, females and children).

6.2.5 Number of urine tanks needed

For proper sanitisation (to kill pathogens originating from cross-contamination with faeces) it is important that the urine is stored without fresh urine entering before it is applied in agriculture. Hence, at least two tanks are recommended (a receptor tank and a storage tank).

For large installations, the use of several urine storage tanks is advisable so that one can be taken out of service if necessary.

24 Plus flushing water if UD flush toilets are used, unless they have a valve like the Roediger NoMix toilet model.
25 This could also be the desired time between emptying events if sanitisation by storage is not the aim (for receptor tank with additional storage elsewhere).

6.2.6 Urine overflow pipe

Installation of a urine overflow pipe on the tank is not recommended, as this increases costs and introduces a risk of contamination of the urine when there is an overflow or blockage in the ordinary wastewater system. Also, if there is an overflow arrangement, users may be tempted to just let the urine overflow and not ensure its use. It is better that the urine is pumped to an acceptable disposal point with a portable wastewater pump if the collection tank becomes too full.

6.2.7 Examples

Examples for urine storage tanks of different sizes are shown below.

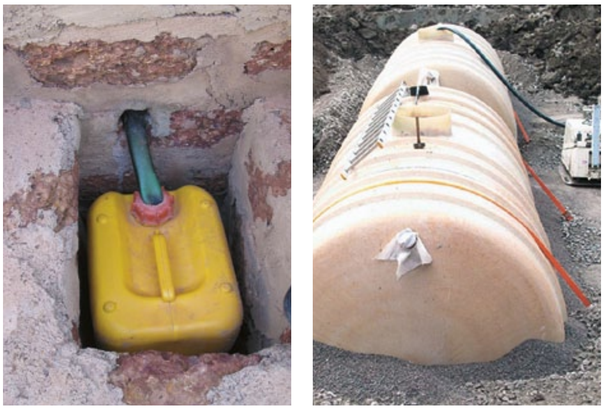

Figure 7. Left: Low-cost solution: 20 L plastic jerrycan for urine storage at individual toilet level in Ouagadougou, Burkina Faso (source: E. v. Münch, 2006). Note: it might be quite difficult to lift up a full jerrycan out of this enclosure. Right: Below-ground plastic urine storage tanks at Kullön, Sweden during the construction process. The tanks will be covered with soil (photo: Mats Johansson, source: Kvarnström et al., 2006).

Figure 8. Urine storage tank made of a 150 m³ plastic bladder at Lake Bornsjön near Stockholm, Sweden (photo comissioned by: E. v. Münch, 2007).

Figure 9. Plastic urine storage tank in Ouagadougou, Burkina Faso as part of the EU-funded project ECOSAN_UE led by CREPA (source: S. Rüd, 2008).

6.3 Ventilation for pressure equalisation of pipes and tanks

The pipe and tank system should only be pressure equalised (not ventilated) which is best done by a small hole in the tank for equalisation with the urine tank pressure. This allows the replacement of headspace air by urine flowing into the tank, and vice versa when emptying the tank.

The reasons why the pipe system should not be ventilated are:

- To eliminate ammonia emissions and odour.
- To reduce risk of sucking the liquid out of any liquid urine seals in the UD toilets.

A one-way valve or air admittance valve placed at the top of the vent pipe can also be a good option. Advantages of such a valve are [26]:

1. that ammonia is not emitted,
2. internal pressure is equalised ensuring proper drainage downwards to the tank (emptied urine pipes mean no standing urine and less precipitation),
3. the installation can be done inside the building just above the top floor in the building so that the top of the vent pipe does not need to penetrate the roof like old-fashioned ventilation pipes,
4. saves on construction costs,
5. eliminates problems caused by condensation ice in cold climates and UV weathering of plastic pipes.

These one-way air valves are popular in Sweden for greywater and urine systems, and many new houses no longer have protruding vent pipes.

The urine tank should not be opened more often than necessary in order to prevent odour development and ammonia-nitrogen losses. Important points concerning the tank's ventilation system are:

26 Posting by Arno Rosemarin (SEI, Sweden) on Ecosanres discussion forum, August 2008.

- Normally no vent pipe is needed, provided that the main opening is not very tightly sealed.
- In places where odour control is essential, a small diameter vent pipe can be used for pressure equalisation of the tank.
- If the tank is emptied by a pump, provisions should be made for sufficient flow of air into the tank. This prevents excessive vacuum in the tank, which can cause tank implosion.

6.4 Maintenance of urine pipes and tanks

It is difficult to predict how frequently pre-emptive maintenance should be carried out as this depends on local circumstances. Trial and error will lead to an optimised cleaning schedule. Experience has shown that correctly installed pipes generally need no cleaning, except for the odour seal or 90° bends (which should be avoided).

Detailed instructions for cleaning and preventing blockages in U-bend odour seals are provided in Kvarnström et al. (2006), from where the following paragraphs are taken:
"*In all installations there is a risk of blockages occurring mainly in the odour seal in the urine pipe. It is a result of fibres and other particles entering the piping system and of chemical precipitation of struvite and calcium phosphates from the urine caused by the increase in pH which occurs when its urea is degraded. The precipitation also forms a viscous sludge, which will slowly flow towards the tank provided that the slope of the pipes is correct.*

Most blockages that occur in urine-diverting toilets are soft blockages caused by precipitation on hair and paper fibre. The other type is hard blockages, caused by precipitation directly on the pipe wall[27]*. The blockages are removed either mechanically by a drain auger or chemically by use of strong solutions of caustic soda (2 parts of water to 1 part of soda) or acetic acid (>24%).*"

It is important that the cleaning is carried out without affecting the quality of the urine in the urine storage tanks is not negatively affected.

If the urine can flow freely and immediately without additions of water directly after urination to the storage tank, then no or very few blockages in the pipe will occur.

At the bottom of the urine storage tank a layer of sludge forms over time (containing precipitates and crystals – see *Section 2.4.4*), with high levels of nitrogen, phosphorus, calcium and magnesium. If the full nutrient value of urine is to be used for fertiliser purposes, then it needs to be ensured that also the bottom sludge layer is emptied and reused. Incomplete emptying would also result in reduced available storage volume.

27 Hard blockages tend to occur when water is mixed with urine, whereas soft blockages tend to occur in pure urine systems.

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7.2 Video clips

Many video clips showing urine diversion technologies are available via video sharing websites (such as Youtube or Vimeo). These can be accessed via:

- SuSanA's Youtube channel: www.youtube.com/susanavideos
- SuSanA website: www.susana.org/videos-and-photos/resource-material-video

7.3 Additional photos

We have uploaded a large number of photos on urine diversion components to the photo sharing website Flickr.com. You find photos of waterless urinals, urine diversion toilets (pedestals or squatting pans, dry or with flushing) in the "technology collection" here: http://www.flickr.com/photos/gtzecosan/collections/72157626218059440/

8 Appendix

Worldwide listing of suppliers for waterless urinals, UD pedestals and squatting pans

The *Appendix* is provided in separate files to keep the file size low and is sorted along the different types of urinals and toilets.

- *Appendix 1*: Worldwide listing of suppliers for waterless urinals
- *Appendix 2*: Worldwide listing of suppliers for urine diversion squatting pans (for UDDTs or for urine diversion flush toilets)
- *Appendix 3*: Worldwide listing of suppliers for urine diversion pedestals/seats (for UDDTs or for UD flush toilets)

All three files are available here: http://www.susana.org/lang-en/library?search=appendix






Notes

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