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**WATER, SANITATION AND HYGIENE:
SUSTAINABLE DEVELOPMENT AND MULTISECTORAL APPROACHES**

**Waterless urinals: a proposal to save water and recover
urine nutrients in Africa**

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Waterless urinals have two important advantages compared to conventional water-flushed urinals: They save water and they allow the collection of undiluted urine, which – because of its nitrogen and phosphorus content - is a valuable resource as fertiliser in agriculture. In the context of African developing countries, costs and maintenance requirements of waterless urinals need to be as low as possible. Despite the fact that hundreds of thousands of waterless (and odourless) urinals are now already in use worldwide, many municipalities are not yet aware of their existence or are reluctant to accept them as a viable option. This paper aims to reduce this knowledge gap by describing available models, odour control methods in waterless urinals (flat rubber tube, silicon curtain valve or sealant liquid), and the aspects to be considered regarding maintenance requirements and costs. Waterless urinals are a promising step towards achieving water saving, more sustainable sanitation and reduced dependency on costly artificial fertilisers, thus contributing to poverty reduction.

Introduction to urine diversion and waterless urinals

The major difference between urine diversion (UD) and other sanitation systems is that a urine-diverting toilet has two outlets and two collection systems: one for urine and one for faeces, in order to keep these excreta fractions separate. UD toilets may, or may not, mix water and faeces, or water and urine, but they never mix urine and faeces. Urinals – widely used by men at public toilets, restaurants, schools, etc. – act *per se* as a urine-diversion device because faeces are collected separately from urine. When urinals are of the waterless version, they can collect the urine pure, i.e. without dilution with water.

The purpose of UD installations (as opposed to conventional, non-UD systems) is usually one, or several of the following:

1. to reduce **odour** (in dry toilets): when urine and faeces are not mixed, the odour from a dry (or waterless) UD toilet is much, much less than when urine and faeces are mixed together (as in a pit latrine). Therefore, a dry toilet with UD can even be placed indoors without causing odour problems.
2. to **avoid production of wet, odorous faecal sludge**, which has to be removed by someone when the pit latrine is full (faeces collected dry, separately from urine and water, have less offensive properties, especially after an extended drying period in a faeces vault); this is particularly relevant for hilly areas with difficult access for vacuum trucks to empty pit latrines (example: e-Thekwini / Durban (South Africa) peri-urban areas).
3. to **reduce water consumption** – in the case where UD devices are of the waterless type (i.e. waterless urinals; UD toilets without flush water) or of the water-saving type (UD toilets where the urine is flushed with a smaller amount than the faeces).
4. to be able to **collect urine pure** so that it can – after sanitisation by storage – be safely used as fertiliser in agriculture. This is particularly important for small-scale African farmers who cannot afford costly artificial fertilisers (for details on this aspect refer to SuSanA (2008), Morgan (2007) and WHO (2006)).

Another issue which is likely to become more important in the future is the fact that recycling of phosphorus from urine is easier if urine is collected pure, rather than diluted with flushing water. The element

phosphorus is a finite resource, which will eventually run out - and up to that point, it will become increasingly expensive to produce phosphorus from phosphate rock. Phosphorus is an essential element in fertilisers. But at current rates of exploitation (increasing over 3% per year), the economic reserves of phosphorus will last only another 50 years (Rosemarin et al., 2008). Hence, in the future increased efforts to recycle the phosphorus content in human excreta are in fact unavoidable (EcoSanRes, 2008).

Technology needed for urine diversion

To achieve urine diversion, the following technical components are used: waterless urinals and urine diversion (UD) toilets, urine piping to a urine storage tank and a reuse system for the urine. UD toilets do not mix urine and faeces at the point of collection in the toilet. There are two main variants of UD toilets (described in detail in GTZ (2008)): UDD toilets (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).

In this paper, our focus is solely on waterless urinals. Where a urine reuse concept is not possible or not desired (yet), these urinals can simply be connected to a sewer system. As has been pointed out previously, urine diversion can be a first step towards ecological sanitation (Kvarnström et al., 2006). And waterless urinals are the *first and easiest step* towards urine diversion.

Purposes of waterless urinals

A urinal is a specialized toilet for urinating only, which is used while standing up, and is designed for male users. Urinals are widely used around the world, primarily in public facilities being frequented by a large number of people, 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.

Some urinals for females (to be used while standing up, rather than squatting) are also on the market but they are not so popular for various reasons, e.g. females have greater need for privacy as they have to partially undress. Squatting-type urinals (i.e. squatting pans with a small hole for urine but no hole for faeces) are sometimes used for girls in e.g. 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 use no water at all. The main motivation for using waterless urinals is to:

1. Save water (and energy) and hence costs – these urinals are simply connected to the sewer system; or
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.



Figure 1. Waterless urinal of Keramag, Germany (model Centaurus). Photo: E. v. Münch.



Figure 2. Flat rubber tube (in Keramag Centaurus model shown in Figure 1). Photo: E. v. Münch

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 later in this paper). 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 waterless urinal manufacturers 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 today used in waterless urinals and marketed by various sanitary ware companies, for example Keramag (model Centaurus).

In 2002, a Swiss engineer (co-author of this paper) 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). Even the 100-year old company F. Ernst Ingenieur AG is since October 2006 using the ESS unit instead of its sealant liquid system.

At present (in 2008), Germany is probably the country with the highest number of waterless urinals per capita, as the price of municipal tap water in Germany is arguably the highest in the world, and Germans are consequently very interested in all water-saving opportunities. Waterless urinals are commonly used for public toilets which are not connected to the sewer (e.g. rest stops along highways). – There is now an opportunity for this technology – in a low-cost version – to also be used more widely African cities.

Odour control methods for waterless urinals

Overview

To guarantee a success, 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 or urine storage tank, for example (discussed in detail in the sections below):
 - rubber tube seal
 - curtain valve seal
 - sealant liquid (blocking fluid)
 - old light bulb placed in a funnel which is inserted in the opening of a jerrican; or place urinal in a well ventilated area (located outside of houses), and put up with some odour (may be possible for peri-urban areas).
2. Appropriate surface of the urinal bowl (smooth, non-stick, 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 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 by the urinal supplier (see below).

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 directly on the number of uses per day (e.g. cleaning once per month under average circumstances may be sufficient). The rubber tube needs to be replaced approx. once per year. The rubber material is sensitive to solvents, acids, and deodorising tablets often used in urinals. The use of acids or aggressive cleaning agents must therefore be avoided. This system is used by the German company Keramag in their Centaurus model (e.g. 1200 waterless urinals of this type are in use in the public toilets of Hamburg in Germany).

Curtain valve seal

The curtain valve seal is similar to the rubber tube seal, but was designed to reduce maintenance requirements. It was designed to hydrodynamic laws quantified by Bernoulli (relation between flow speed of a medium and its pressure). 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 curtain is made of Liquid Silicon Rubber. The liquid material of relatively high viscosity is injected (in a cooled piping system) into a mould permanently heated to 180 - 240°C. The process is "high tech" 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 and light-weight).

The silicon curtain element is integrated into a plastic casing (Figure 3). The placing of the EcoSmellstop (ESS) element into a plastic sleeve has a twin purpose, firstly to guarantee that no odour from the sewer or urine storage tanks escapes into the room, and secondly to allow easy removal of the ESS unit for maintenance purposes. For replacement of the curtain, the entire plastic casing is removed with a small plastic extractor tool (Figure 4), then discarded and replaced with a new ESS. This replacement process takes only a few seconds and can be performed without having to touch the ESS element by hand.

The production of the ESS element is fully automated using industrial robots. At the end of the assembly line 100% of the ESS units are tested aerodynamically. A pre-set airflow is channelled through the ESS element causing a sound. A frequency measuring device set to a narrow tolerance will eliminate sub-standard units. This patented ESS unit is used by the companies Addicom, Kellerinvent AG and F. Ernst Ingenieur AG (see Table 1) since 2006.



Figure 3. Transparent EcoSmellstop (ESS) unit showing the blue silicon curtain one-way valve inside. Photo: P. Dahm.



Figure 4. EcoSmellstop (ESS) unit with plastic casing (left) and extractor tool (top right). Photo: P. Dahm.

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 the cartridge (e.g. for Falcon Waterfree urinals) or inner cylinder of the trap (e.g. for Uridan urinals).

The maintenance program of waterless urinals with a sealant liquid calls for the cleaning of the urinal bowl and the regular exchange of the cartridge (or the sealant liquid). Again, the required exchange frequency depends on the number of uses. 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 replaced. Should the trap commence 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 type of waterless urinal is currently the most common type, as under current legislation only liquid filled traps are approved, but not waterless urinals that use the rubber tube or silicon curtain system.

As mentioned above, one of the market leaders for waterless urinals which had the sealant liquid system (F. Ernst Ingenieur AG), changed over to the EcoSmellstop curtain 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). The reason for this change-over is the lower maintenance requirement of the ESS unit.

Other methods for the odour seal

Other methods for odour control have been invented and used. One example is the system introduced to the market by Urimat where the sealant liquid was replaced by a float (hydrostatic float barrier) which is magnetically activated thus opening the channel to the overflow chamber. This system has a higher complexity compared to the other two systems described before.

Design information

The space requirement of a urinal is less than that of a toilet, which makes them popular for venues where many people need to urinate (soccer stadiums, restaurants, schools, etc.). Waterless urinals are usually wall hung and do not require piping for fresh 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 would further reduce maintenance costs). Waterless urinals have the additional advantage that they need not necessarily be connected to a sewer but can also 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 of course still required in ablution facilities.

The following procurement options exist for waterless urinals in Africa:

1. Imported waterless urinals with patented odour control mechanism (most expensive option)
2. Plastic waterless urinals manufactured locally (mould for urinal bowl could be imported if needed), and imported ESS element inserted for odour control
3. Self-constructed waterless urinals made from plastic containers with cut-off condom for odour control

Urinal bowls are typically made of acrylic, ceramics, stainless steel or glass-fibre reinforced polyester, but can also be made of low-cost plastic or concrete, 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 among 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. These plastic urinal bowls 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.

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. However, it is very important to get a snug fit of the ESS into the urinal drain, according to the suppliers' specifications.

Urine piping and storage

The urine which is collected by means of a waterless urinal (or by a urine-diversion toilet), can be collected undiluted in a urine storage tank (Figure 5 and Figure 6). These 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 if desired).

A comprehensive description of the technical details for urine pipes and tanks is available in Kvarnström et al. (2006). As urine generates a considerable amount of urine precipitates or sludge, special attention has to be given to the design (diameter and slope) and maintenance of the urine pipes (Larsen and Lienert, 2007). Urine pipes flushed with water are more likely to be blocked by hard incrustations over time than pipes carrying urine only, where soft blockages would be the more common type of blockage.



Figure 5. Plastic urine storage tank in Ouagadougou, Burkina Faso installed as part of EU-funded project ECOSAN_UE, Sept. 2008 (Photo: S. Rüd).



Figure 6. Urine storage tank made of a PVC bladder (3 x 150 m³) at Lake Bornsjön near Stockholm (Sweden), Aug. 2007. Photo: E. v. Münch

Use and maintenance of waterless urinals

The urinal bowl should be cleaned daily, just like any other (water-flushed) urinal. There are 100% organic cleaning solutions on the market that are simply sprayed onto the urinal bowl, and not wiped off. For the waterless urinals in the GTZ headquarters in Eschborn, Germany, URIMAT MB-AktivReiniger with anionic and non-ionic tensides is used – this is a biologically active and biodegradable cleaning agent.

Any type of odour seal (be it flat rubber tube, curtain seal or sealant liquid) needs to be cleaned (and ultimately replaced) in regular intervals to keep it fully functional for odour control. The frequency of cleaning or replacement of the odour seal system depends on the number of uses per day, user and cleaning staff behaviour (e.g. in terms of foreign objects discarded in urinal), etc. It can therefore vary widely, e.g. ranging from once per week to once per month or once every six months. The flat rubber tube and ESS units can be cleaned many times before having to be replaced, whereas the sealant liquid cartridges cannot be cleaned and instead need to be replaced when they fail.

To give an example: According to information given by Addicom, the expected 16-month life time of an ESS element can be achieved with careful maintenance, e.g. spraying the urinal bowl regularly with the cleaning agent “DestroySmell” and removing the ESS element and immersing 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 (e.g. public parks and taxi ranks in Johannesburg) since 2004 seems to suggest that the curtain seal (ESS system) can perform its functionality with *less maintenance* than the flat rubber tube. In regions where diligent maintenance of urinals cannot be guaranteed (e.g. public toilets in informal settlements in Africa), the ESS system may therefore be a suitable choice.

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.

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 change required in behaviour (many users do not even notice that they are using a waterless urinal). - For those men who are shy and do not like using open urinals (for lack of privacy), it makes no difference whether the urinal is waterless or water-flushed.

When planning the use of urinals in cultures where anal washing with water is practiced, each urinal needs to be installed in a cubicle to guarantee privacy. Many Muslims wash their body with water also after urinating, which requires water supply and separate drainage facilities. Prior to providing waterless ablutions, one has to establish whether the community in question is willing to accept such facilities.

In some instances, there may be a theoretical 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 important. Today's waterless urinals are designed to be odourless and simple to maintain.

As waterless urinals are a novelty for many communities, 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 longstanding odorous history. It is a fact that any type of urinal (water-flushed or waterless) will in fact 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).

Examples of suppliers and unit costs

Table 1 below summarises relevant information about waterless urinals from four suppliers based in South Africa and Europe. The waterless urinal industry is presently very fragmented, resulting in a multitude of suppliers with relatively small quantities of installations and therefore high costs. Currently, only the first supplier shown in Table 1 has geared his product and price towards the very low-income market bracket.

There are many success stories around the world where highly specialised companies supply components to entire industrial sectors. This allows the manufacturing of large quantities at top quality at relatively low costs for basic components used in different brands e.g. car industry with spark plugs, or IT industry with memory chips. The foundations to introduce a similar concept for the waterless urinal industry are available. This would allow existing brands to take advantage of a proven product at low costs.

For reference installations please either contact the manufactures directly or see the case study descriptions of sustainable sanitation projects on www.susana.org.

Table 1. Examples of waterless urinal manufacturers (this list is non-exhaustive; other important companies are e.g. Uridan, Urimat, Falcon Waterfree Technologies)	
Urinal model name and manufacturer	Materials, costs (in 2008) and other information (costs without freight – for single units bought by individuals (conservative estimate))
SVR-M urinal (with EcoSmellstop (ESS) for odour control) Addicom (Pty) Ltd South Africa www.addicom.co.za	<ul style="list-style-type: none"> • Low density polyethylene urinal bowl without ESS (€35) – <i>Note: the bowl could easily be made locally in any developing country and in various materials</i> • ESS itself: € 15 (to be added to urinal bowl above) – cannot easily be made locally but is small and light, and can easily be imported • Units sold (worldwide): 28,000 (until 2008) - complete working urinals inclusive of ESS fitting. - Urinals sold since 2006 in South Africa alone: 3000 • Units of "stand-alone" ESS units sold: ~ 90,000 as they are being used to convert the 100,000 F Ernst AG waterless urinals on an ongoing basis. • Countries/regions served: Europe, Africa, Mexico, Israel, India
F. Ernst Ingenieur AG, Switzerland: models 5000, 7000, 8000 & 9000 http://www.ernstsystems.com/ (with EcoSmellstop (ESS) odour control since 2006)	<ul style="list-style-type: none"> • Mainly ceramics but also glass fibre • Pre-2006: with liquid sealant (approx. 100,000) • Converting to ESS presently at a rate of around 200 urinals per week • Since end 2006: with silicon curtain ESS system • Approx. cost: €290 to 430 per urinal (depending on number ordered)
Kellerinvent AG www.kellerinvent.com This company has a licence from Addicom to sell the ESS	<ul style="list-style-type: none"> • Ceramics (and new polycarbonate urinals in early to mid 2009) • Units sold: 25,000 units worldwide (since active marketing started in 2006), and since 2008: approx. 10,000 urinals per year. • Similar prices as F. Ernst Ingenieur AG above; countries served: worldwide
Model "Centaurus" Keramag, Germany Ronald.Herkt@Keramag.de http://pro.keramag.com/?id=497&s=22	<ul style="list-style-type: none"> • Ceramics; Cost: €490 per urinal; €20 per rubber tube (for replacement) • Units sold: More than 20,000 from 2004 until Sept. 2008 • Countries served: mainly Central Europe (Germany, Austria, Benelux, France); also some business in Asia and Ghana (pilot project at Valley View University in Accra funded by Germany's federal ministry BMBF)

Conclusions

Waterless urinals are urinals which use no water for flushing, and are designed to emit the same or lower odour compared to conventional water-flushed urinals. The main motivation for using waterless urinals is to save water (urinals connected to a sewer system) and/or to collect urine for the purpose of using the urine's nitrogen and phosphorus as fertiliser in agriculture (urinals connected to a urine storage tank). This would reduce the dependency of small-scale African farmers on costly artificial fertilisers and hence contribute to poverty reduction.

Odour control in waterless urinals is crucial for user acceptance, and is achieved by (i) various designs available 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. In cases where maintenance routines are expected to be neglected, low-maintenance waterless urinals should be selected.

To reduce the capital costs of waterless urinals further, it is proposed to use a standardised, mass-produced unit for odour control, such as the patented EcoSmellstop (ESS) unit, which is already being used by three waterless urinal suppliers. This could allow waterless urinals to become more widespread for low-cost settings in the African context – for water saving and reuse of urine in agriculture. The ESS unit could also be used in urine-diversion toilets, so that a urinal could be integrated into a toilet pedestal or squatting pan, and thus enabling also the collection of urine from female users.

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