Waterless Urinals

A Resource Book

Dr V M Chariar

S Ramesh Sakthivel

Prepared by

Indian Institute of Technology Delhi

The Vigyan Vijay Foundation

Funded by

unicef

SEI STOCKHOLM ENVIRONMENT INSTITUTE

About this Publication

Waterless Urinals do not require water for flushing and can be promoted at homes, institutions and public places to save water, energy and to harvest urine as a resource. Reduction in infrastructure required for water supply and waste water treatment is also a spinoff arising from installing waterless urinals. The concept, founded on the principles of ecological sanitation helps in preventing environmental damage caused by conventional flush sanitation systems.

In recent years, Human Urine has been identified as a potential resource that can be beneficially used for agriculture and industrial purposes. Human urine contains significant portion of essential plant nutrients such as nitrogen, phosphate and potassium excreted by human beings. Urine and faeces can also be separated employing systems such as urine diverting toilets. In the light of diminishing world's phosphate and oil reserves which determine availability as well as pricing of mineral fertilisers, harvesting urine for reuse in agriculture assumes significant importance. Akin to the movement for harvesting rain water, urine harvesting is a concept which could have huge implications for resource conservation.

This Resource Book is a guide that seeks to assist individuals, builders, engineers, architects, and policy makers in promoting waterless urinals and the benefits of harvesting urine for reuse through waterless urinals and urine diverting toilets.

Contents

List of Tables and Figures

1. Waterless Urinals

Waterless urinals look very much like conventional urinals in design and these can be used in the same manner. However, waterless urinals do not require water for flushing and thus result in saving anything between 56,800 litres to 1, 70,000 litres of water per urinal per year.

On an average, a person urinates about four to five times a day. Urine, which is usually sterile and contains mostly water, does not require additional water for flushing to make it flow into drainage lines. Therefore, installing waterless urinals can make large reduction in quantity of fresh water used for flushing as also in the corresponding volume of sewage.

Waterless urinals do not need water and expensive plumbing accessories usually required for flushing. Also, the dry operation of waterless urinals and touch free operations reduce spreading of communicable diseases. Odour trap mechanisms using sealant liquid, microbial control, membrane and curtain valve fitted to waterless urinals assist in preventing odour developed inside the drainage lines connected to urinals.

Therefore, installing waterless urinals in homes, institutions and public places can offer several advantages.

1.1 Advantages of Waterless Urinals and Reuse of Urine

- Save enormous quantities of freshwater
- Enhance efficiencies of sewer lines and wastewater treatment plants
- Optimize cost of plumbing accessories at supply & consumption ends
- Conserve electricity used for pumping water & treating wastewater
- Replace chemical fertilizers with urine to grow crops
- Produce fertiliser & other chemicals from urine (industrial feedstock)
- Recover hydrogen for producing energy and fuel
- Reduce emission of green house gases and pollution of water bodies

Figure 1. Waterless urinals for men (Source: Caroma)

1.2 Demerits of Conventional Urinals

- Conventional water flush urinals use approximately 4 litres of water for flushing. This figure goes up to 10-15 litres when a toilet pan with flush is used for urinating.
- Water used for flushing urine (liquid human waste is over 95% liquid) increases the volume of sewage generated in cities.
- Odour control in conventional urinals is only achieved by the use of water and deodorising agents.
- Use of hard water for flushing urine leads to scale formation causing blockages in drainage lines.
- Dampness in the urinals offers favourable environment for growth of microbes and result in air borne infections.
- Hand operated valves used for flushing conventional urinals lead to transmission of communicable diseases.
- Valves and plumbing lines used in conventional urinals require frequent maintenance and expenditure.
- Naphthalene and strong acids used for cleaning conventional urinals contaminate the waste water generated. Some of these are carcinogenic in nature.
- High nitrate and phosphorous levels are found in sewage, which can be reduced substantially if urine is separated from sewage for productive use such as agricultural and industrial purposes.

2. Functioning of Waterless Urinals

Odour associated with urine severely affects the performance of urinals. The enzyme urease hydrolyses the urea present in urine into ammonia and carbonate. The latter decomposes spontaneously to carbonic acid and a second molecule of ammonia. The overall reaction can be written as follows:

$$NH_2\,(CO)\,NH_2 + 2H_2O \longrightarrow NH_3 + NH_4^+ + HCO_3^-$$

Flushing with water is employed to control odour in the conventional urinals whereas waterless urinals utilise odour control mechanisms. Waterless urinals require regular cleaning routines similar to conventional urinals based on the number of users. However, waterless urinals can be cleaned using a moist sponge or brush without the use of water.

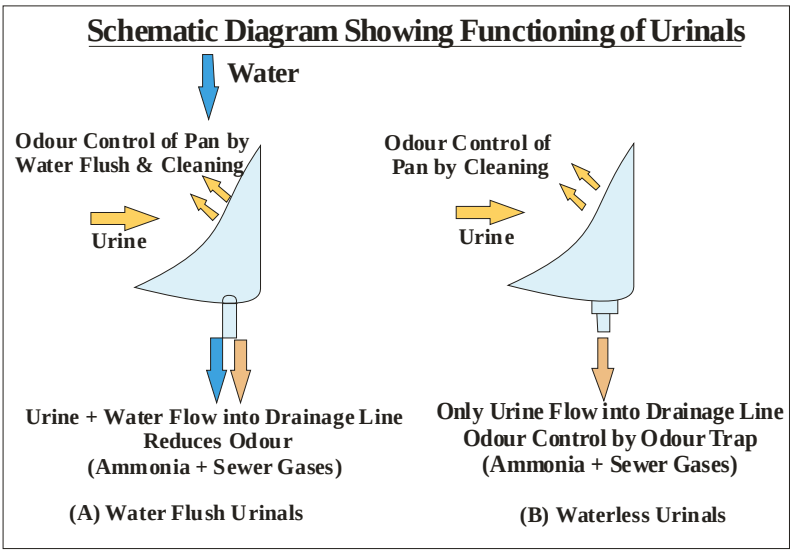

Figure 2. Schematic diagram showing functioning of urinals

Precipitation of salts present in urine and deposits such as hair, dead skin cells and cigarette butts can potentially block urinal drains. Use of hard water for flushing in conventional urinals also aggravates the problem. Both these problems are also eliminated in waterless urinals. Further, installation and maintenance cost of waterless urinals is less on account of absence of expensive flushing valves and fittings.

Odour Traps

Odour trap mechanisms fitted to waterless urinals assist in preventing odour developed inside the drainage lines connected to urinals from entering rest rooms. The first waterless urinal trap using sealant liquid method was patented by Mr. Beetz of Austria in 1894, and was commercially exploited by the company F. Ernst Engineer in Zurich, Switzerland, who was the sole supplier of waterless urinals worldwide for approximately 100 years. Since then, apart from sealant liquid traps, odour prevention methods using microbial control and membrane /curtain valve have been developed across the globe.

The following sections describe some of the common odour prevention traps available in the market in detail.

2.1 Sealant Liquid Traps

Odour traps using sealant liquids made of vegetable oils or aliphatic alcohols (see location 1 in Figure 3) are fitted to urinal bowls to prevent odours from reaching the washroom. As sealant liquids have lower specific gravity than urine, these allow passage of urine but prevent odour emitted by drainage lines. The sealant liquid is contained either within a replaceable or built in cartridges provided to the urinal pans.

Figure3. Sealant liquid based odour trap (source: waterwisetech.net)

Figure 4. Urinals with sealant liquid based odour traps (Photo:R.Sakthivel)

Maintenance

- Cartridges need to be replaced or cleaned when precipitates of urine and foreign objects such as cigarette butt get deposited in the trap.
- The sealant liquid also needs refilling as they evaporate and also get washed away owing to the urine flow.

Merits

- Performance of sealant liquid based odour traps has been found to be very good. In countries such as USA, legalisation permits only use of liquid filled traps presently.

Demerits

- To retrofit an existing conventional urinal into sealant liquid type waterless urinal, the old urinal pans have to be replaced.
- Models of waterless urinals working based on the sealant liquid are expensive than other models.
- Regular replacement of cartridges and refilling of sealant liquid increases the maintenance cost.

Availability

- In India, sealant liquid based waterless urinals are being marketed by companies such as Parryware, Hindware, Falcon and Waterless.
- The cost of a waterless urinal pan with sealant liquid trap ranges from Rs 6000/- to Rs 15,000.

2.2 Membrane Traps

Membrane based traps use rubber, silicone or LDPE in the shape of tubes is used for controlling odour. The membrane acts as one way valve allowing urine to flow while blocking odour released from drainage lines. The top portion of the tube is fixed to a holder to keep its mouth open. Rest of the portion deforms into a flat tube due to its flexibility and prevents odour when urinal is not in use.

Figure 5. Flat rubber tube by Keramag and Silicon membranes by Addicom (Source: Elisabeth von

Figure 6. LDPE membrane by Shital Ceramics (Photo: R.Sakthivel)

A design variation of membrane-based trap is one in which, silicone tubes having their bottom portion split into two curtains have been introduced to reduce the requirement of frequent maintenance and to enable ease of cleaning. Urine with grit up to 2 mm is allowed to pass through.

Maintenance

- Precipitates of urine and foreign materials deposited in inner surface of the membranes need to be cleaned regularly.
- The cleaning frequency depends directly on the number of uses per day.
- Membranes need to be replaced between three months to six months depending on quantum of usage.

Merits

- Performance of membrane based odour traps has been found to be very good. Membranes made of rubber manufactured by Keramag and silicone curtain valves manufactured by Addicom are being widely used in Europe and other foreign countries.

Demerits

- To retrofit an existing conventional urinal into rubber membrane type waterless urinal, the old urinal pans have to be replaced. However, silicone curtain valves can be fitted to existing urinal pans.
- Models of waterless urinals working based on the membrane traps are expensive than other models.
- Regular replacement of membrane traps increases the maintenance cost.

Availability

- Membranes traps manufactured by Keramag and Addicom have to be imported.

- In India, a low-cost variant is being manufactured by Shital Ceramics, Gujarat. The trap costing Rs.100/- is suitable for low end urinal pans. The current trap design fits only to low cost basins from the bottom.

2.3 Biological Blocks

Biological blocks used for making urinals into waterless contain a number of active ingredients, including microbial spores and surfactants. These blocks are placed either in the urinal pans or housed within a dome inserted into the urinal waste outlet to gain contact with the urine flow.

Figure7. Biological blocks (Source: www.restormate.co.uk)

Upon interaction of urine with the block, the spores become active 'good' bacteria that 'feed' upon the urine and then multiply. By breaking down the urine into components, the build-up of sludge and crystals which cause blockages are prevented. They also generate an environment

hostile to odour causing bacteria. A busy urinal seat requires replacement of blocks which cost Rs.20/-each at an interval of 2-3days.

Maintenance

- Apart from regular cleaning of urinal pans, there is no maintenance required for water urinals functioning using biological blocks.
- Biological blocks need to be replaced approximately 2-3 days based on the usage.

Merits

- Biological blocks are found to be effective in making urinals water free. In India, few corporate offices and malls have started using Biological blocks.
- Any existing conventional urinal can be converted into a waterless urinal by providing biological blocks to urinal pans.

Demerits

- Regular use of biological blocks increases the maintenance cost.

Availability

- Biological blocks are being marketed by few suppliers in India.
- At present, the biological blocks are priced around Rs.20/-per block.

2.4 Comparative Analysis of Popular Odour Traps

Description	Membrane Traps	Sealant Liquid	Biological Blocks
Odour Control	Good	Good	Good
Cost of the system	Trap can be fitted to existing urinal pans costing around Rs.500-1750/-. Cost of a trap is Rs.1200/- (Silicone Curtain Valve of Addicom).	New Urinal Pan with cartridge has to be procured. A single urinal costs Rs.6,500-14,000	Any urinal can be made waterless using bio-blocks. A bio-block costs Rs.20/- (Lasts for 2-3 days depending on no. of users)
Retrofitting of Existing Urinals	Traps can be fitted to existing urinals	New sealant liquid based urinal pans to be installed	Bio-blocks can be placed in existing urinal pans
Replacement of Parts	Membrane needs to be replaced once in a year.	Sealant Liquid (approx. 1000 uses) & cartridge replacement (approx. once in a year).	Bio-blocks need to be replaced once 2-3 days based on usage.
Clogging Frequency	High (Silcone curtain valves require low maintenance)	Medium	Low

Maintenance of Pan & Trap	High	Medium	Low (only pan)
Flow of Particles through Trap	< 2mm size particles	Particles accumulate in trap cartridge	Same as in normal urinals
Dependence on Suppliers	Supply of membranes	Supply of cartridge and sealant liquid	Supply of bio-blocks

Table 1. Comparative analysis of popular odour traps based on literature review and observation

2.5 Other Types of odour Traps

A trap using **hydrostatic float barrier** which is magnetically activated to allow passage of urine to pass through an overflow chamber was introduced by Urimat to replace the sealant liquid traps. However, due to higher complexities of the system it has not been widely promoted.

Air enclosing trap using an adsorbing membrane sheath and a spring controlled tray to facilitate passage of urine by gravity has been introduced by Sunming in India recently. The model does not require replacement of cartridge.

An odour trap **Zerodor** which does not require replaceable parts or consumables resulting in low maintenance costs has been developed at IIT Delhi. This model is in final test stage yet to be made commercially available.

Other than the commercially available odour traps, few **simple and low-cost techniques** are being utilised to create waterless urinals.

- Urine pipes transferring urine to a collection tank from urinals can be extended up to the bottom of collection tanks so as to allow the stored urine to acts as liquid seal.
- Pouring some amount of oil in the tank also helps in creating a seal over the collected urine.
- Surgical gloves and condoms with a small hole at their closed end are fitted to urinal pans to act as an odour trap.

2.6 Installation and Maintenance of Waterless Urinals

The following steps should be considered while installing waterless urinals :

Waterless Urinal System

- An appropriate type of waterless urinal odour trap can be chosen based on the location to be installed, investment cost, maintenance costs and easy availability of spares.
- Maintenance instructions of the manufacturer to optimise the performance of the odour traps must be followed.
- Cleaning staff must wear gloves and face masks while attending maintenance works.
- Users of urinal must be educated to avoid spitting and throwing of cigarette butts and chewing gum in the urinal pans.

Drainage Pipes and Fittings

- There should be no sharp 90° bends in the pipes carrying urine to prevent accumulation of deposits.

- Pipes carrying urine should be at least 2 in in diameter (except the connector lines below the urinal pans) and they must be laid with a slope of at least 1:100.
- Pipes carrying urine can be of polyethylene (PE) or polyvinyl chloride (PVC).
- Length of urine pipes should be short to prevent clogging. Flushing of pipes can be taken up based on the clogging of pipes.
- No vent pipe should be provided to prevent loss of nitrogen in the form of ammonia gas. If necessary, a one way air admittance valve be provided to equalise gas pressure in the pipeline.
- Loose and open connections in the urine pipes and urinal pans must be avoided to prevent release of odour.

Storage of Urine and Pumping

- Storage tanks made of plastic materials, inflatable rubber and high quality masonry can be used when reuse of urine is intended. These can be over ground or below ground, but adequate precautions for structural safety must be followed.
- The urine inlet pipe to the tank can be up to floor level of the storage tank to prevent turbulence in the tank.
- The tank cover can be kept slightly loose or pipe of very small diameter can be fixed to the storage tanks to equalise the gas pressure.
- Use of gloves and face mask is a must for inspection and urine emptying routines.

- Storage tanks be designed so that they are away from homes or habitats.
- For large storage tanks, pumps which can handle some amount of precipitates in the tank must be chosen. For small storages, small submersible pumps used in household air coolers can be used.

3. Innovative Urinal Designs

Public toilets that are badly designed, badly maintained, and poorly located generate a sense of neglect, attracting vandalism, anti-social behaviour and social disorder. Poor quality of construction and inappropriate designs of urinals lead to improper use of facilities in most cases. As a result, most urinals suffer from the vicious cycle of bad use and improper construction or maintenance.

Waterless urinals are a good option to be considered while promoting public urinals because they overcome the need for water as well as infrastructure required for conventional urinals.

The unmanned public urinals usually constructed on streets and less density areas can be improved to provide better aesthetic and environment to the user. Quality of construction is an issue in most of such stand alone urinals constructed in less crowded areas.

Innovative waterless urinal models, which are inexpensive and offer aesthetic surroundings, can provide sound solution to the problem being faced in the public urinal front. The following innovative urinal designs can be promoted as per the feasibility and budget available;

- Waterless Public Urinal Kiosks
- Green Waterless Urinals
- Homemade Urinals (Eco Lilly)

3.1 Waterless Public Urinal Kiosk

Waterless Public Urinal Kiosk (WPUK) is a stand-alone concrete reinforced pre-fabricated urinal kiosk which can be installed in public places and institutions. Although pre-fabricated urinal kiosks made of steel and FRP have existed in the past, the kiosks made of concrete can be cheaper and robust.

Urine collected can be diverted to a storage tank for recovery of nutrients from urine or to normal sewer lines/soak pit. The surrounding area of the urinal kiosk covered with a planted hedge to offer privacy to

the users. In place of the planted hedge, billboards can also be erected at public places to generate revenue for maintenance of the urinals.

Figure8. Formwork used for fabrication of public urinal kiosk (Photo:

Figure9. Reinforced concrete public urinal kiosk (Photo: R.Sakthivel)

This approach of using pre-fabricated concrete structures will ensure higher standards of urinals unlike the current onsite construction of urinals which results in poor quality. Prefabricated FRP urinal kiosks are being used very recently in some parts of the country, however these are expensive and prone to vandalism.

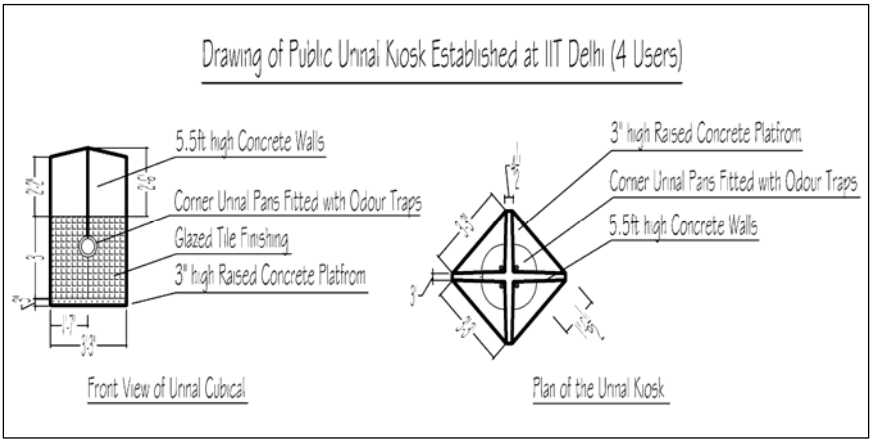

Figure10. Drawing of public urinal kiosk established at IIT Delhi (Photo:R.Sakthivel)

The prefabricated concrete structure can fabricated in an industry or onsite, and transported to a desired site of a city and institution for creating urinals for men. A public urinal kiosk can offer a pleasant atmosphere to the users due to its open and attractive surrounding. Cost of the pre-fabricated urinal is very low compared to FRP or other

materials. The public urinal kiosk can be constructed between Rs. 10,000 to Rs. 30,000/- as per the design adopted.

Advantages of Waterless Public Urinal Kiosk

- Open and green surrounding provides good aesthetic environment.
- Low cost of construction and easy to maintain.
- Quality of construction is assured due to centralised production.
- Any concrete fabrication industry can produce it.
- Strong RCC structure can withstand any act of vandalism.
- Low odour due to open surroundings and requires lesser space.
- Suitable for parks, road side sites, schools and institutions.

3.2 Green Waterless Urinal

A Green Waterless Urinal (GWU) is low-cost onsite urine application model suitable for sites where adequate space is available and the number of users are limited. Urine collected is diverted to a plant bed of Canna Indica and Ficus planted around the urinal. For enabling uniform distribution of urine to the plant bed, a perforated pipe connected to the urinal is laid along the plant bed. As urine contains essential plant nutrients such as nitrogen, phosphate and potassium, these are utilized by the plants for their growth. The plantation also doubles as a hedge around the urinal offering privacy to the users.

Figure11. Green urinal established at IIT Delhi (Photo: R.Sakthivel)

Figure12. Plant bed of green urinal with perforated pipe (Photo: R.Sakthivel)

The bed must be surrounded by earthen bunds to prevent flow of urine to nearby areas during rainy seasons. At periodic intervals, watering and emptying of the phosphate deposits is carried out to maintain the system. Treatment for reducing salinity of the soil must be taken up at regular intervals.

This model of onsite utilization of the urine through GWUs can be adopted in public places, gardens and institutions where there is open space. The initial and maintenance cost of GWUs is also very low compared to the normal urinals. GWUs can be established at a cost of Rs.500/- to Rs.10,000/- based on the design adopted.

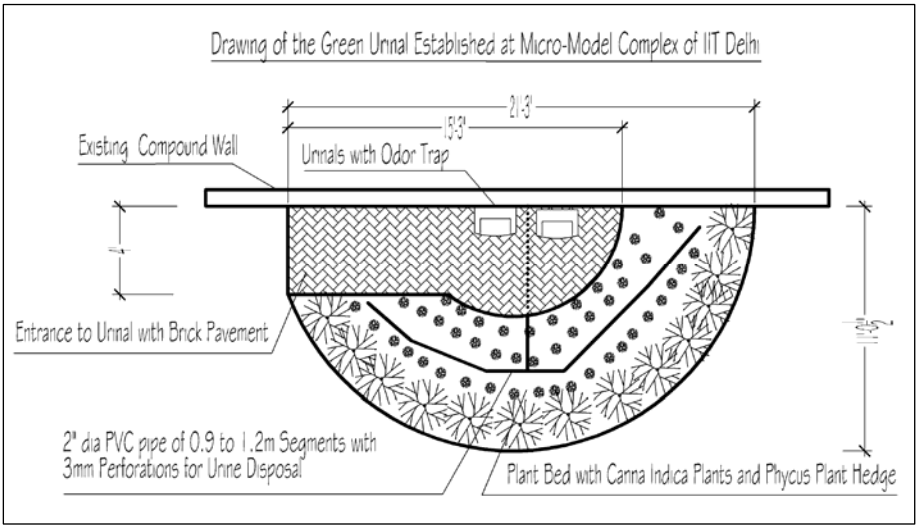

Figure13. Drawing of public urinal kiosk established at IIT Delhi
(Photo: R.Sakthivel)

Advantages of Green Waterless Urinal

- Open and green surroundings provide very good aesthetic environment to users.
- No waste is generated as urine is led to plant bed.
- Low cost of construction (existing compound walls can be used).
- Suitable for parks, road side sites, schools, institutions and individual houses.
- Requires lesser space and easy to install anywhere.
- Lower level of ammonia smell due to open environment.

3.3 Self Constructed Urinal

Self Constructed urinal is a simple option of creating waterless urinals in rural areas. “Eco-lily” is one such model promoted in some parts of Africa. A plastic funnel can be inserted to the opening of a plastic jerry can and an old light bulb or a table tennis ball is placed into the funnel. The bulb or ball act as an odour seal while it floats when urine enters the funnel and releases urine into the jerry can. Connecting a short hose in the bottom of the funnel for directing urine to bottom of the jerry can prevent emission of gas due to turbulence.

Special designs of funnels which offer convenience to both men and women can be fabricated at low cost using locally available materials such as tin sheets. Regular cleaning of the bulb or float and the funnel is necessary for removal of the deposits. However, use of bulb may contaminate urine as solder and metal cap of the bulb contains heavy metals.

Figure14. Self constructed urinal “Eco-lily” (Source: GTZ)

Advantages

- Self constructed urinals can be created at any desired location such as farms, out houses and temporary camping sites.
- Construction of these urinals is very low cost.
- In rural areas, the jerry cans can be transported to agricultural plots for fertilisation of crops when they are full.

4. Urine Diverting Toilets

Like waterless urinals, urine diverting toilets can also be employed to harvest urine for reuse in agriculture. Urine diverting toilets facilitate separation of urine from faeces and wash-water. A variant in which urine, faeces and wash-water are separated are called Urine Diverting Dry Toilets (UDDT). In many parts of the world, including India, such toilets are being promoted to recover resources present in urine and faeces for productive purposes, mainly agriculture.

Urine diverting toilets facilitate;

- harvesting of nutrients present in urine and faeces
- saving of water used for flushing
- saving of energy required for water and waste water treatment
- to minimise ground water pollution

In urine diverting dry toilets, chambers provided below the toilet seat is designed to collect faeces, while urine and wash water is diverted to containers and a plant bed respectively. After every use of the toilet, small quantities of ash or earth or dry leaves stored in a container in the toilet is spread over the faeces collected in the chamber. A household toilet unit usually has two chambers which are used in rotation. When a chamber gets filled-up, it is sealed and the contents are allowed to decompose over a period of approximately nine months. Upon dehydration, the content is collected and used as manure for agricultural crops. Urine collected regularly is stored in containers and applied as liquid fertiliser to crops as and when required.

Figure15. Squatting type urine diverting dry toilet with two chambers (Photo: Dr. Lucas Dengel)

Figure16. Urine diverting no mix toilet (Source: www.washjeff.edu)

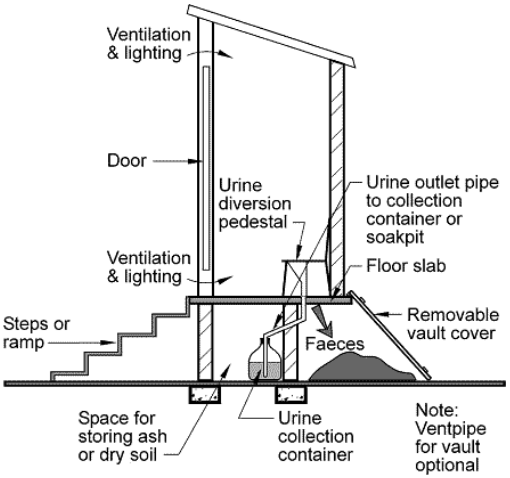

Figure17. Sectional view of a urine diverting dry toilet (Source: www.training.gpa.unep.org)

5. Urine Harvesting for Agriculture

Urine harvested by constructing waterless urinals and urine diverting toilets can be utilised as a resource in agriculture. Human urine contains 80% of Nitrogen and 50% of Phosphorous excreted by human beings.

As urine in liquid form contains macro-nutrients such as nitrogen, phosphorus, potassium and sulphur, among others, it can be termed as quick acting multi-component fertiliser. Therefore, urine can reduce the demand for mineral fertilizers used for growing agricultural crops.

A person urinates about 550 litres in a year, at an average of 1.5 litres per day. The quantity of urine urinated by a person in a year contains sufficient nutrients to grow 250 kg of cereal required for a person per year. Therefore, harvesting urine for reuse in agriculture offers tremendous potential for replacing mineral fertilisers and minimising environmental contamination. Table 2 provides characteristics of fresh and stored urine.

Quality of Urine

- Urine is usually sterile, unless it is cross contaminated by faeces which contain pathogens.
- Only notable risk of reusing urine in agriculture is the use of urine collected from endemic areas with Schistosoma Haematobium disease.

Table 2. Average chemical composition of fresh urine (literature values) and stored urine (simulated values, see Udert et al. (2006)

Parameter	*Fresh urine*	*Stored urine*
pH	6.2	9.1
Total nitrogen, TN (mg/L)	8830	9200
Ammonium/ammonia-N, NH4 + and NH3 (mgN/L)	460	8100
Nitrate/nitrite NO3 + NO2 (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, SO4 (mg/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.

- Urine contains low levels of heavy metals than conventional fertilisers which is a desired characteristic.
- Presence of pharmaceutical residues in urine is an issue being debated, a topic where substantial research has not been carried out so far. However, the risks posed by pesticide residues from agriculture and the use of sewage and animal manure which also contain high level of pharmaceutical residues for agriculture and also release of them in water bodies are of much higher concerns to be noted.

Benefits

- Urine in liquid form is a quick acting fertiliser. Studies shows higher nutrient uptake by plants when urine is applied in the liquid form than solid mineral fertilisers.
- Small farmers of rural areas can benefit from the use of urine as fertiliser due to prohibitively increasing cost of commercial fertilisers.
- Crop trials in India and various parts of the world have shown that crops fertilised with urine have shown better crop yield and plant characteristics. Better sweetness of the fruits like banana and orange has been reported in the blind tests conducted.

Disadvantages

- Some farmers may have reservation in handling liquid urine in the agricultural fields.
- Increase of soil salinity in the agricultural lands due to application of urine as fertiliser needs to be monitored and managed.
- Large volume of urine has to be transported to meet the needs of agricultural lands increases the cost of transportation.

5.1 Safe Application of Urine in Agriculture

The following precautions must be taken care of while using urine as a fertilizer;

- If urine is collected from urine diverting toilets where there are possibilities of cross contamination with faeces, then urine must be stored for at least one month before it is applied to food and fodder crops. Increase in the pH levels of urine over a period causes destruction of pathogens.
- Application of urine to edible crops must be stopped for a period of one month before the harvest of crops.
- Urine can be applied to crops either diluted or undiluted. Urine can be diluted with water in the ratio from 1:3 to 1:15. Dilution with water reduces fertiliser burn, clogging of drip nozzles and odour problem. Applying undiluted urine has few advantages like handling of low volume of liquid and it can also be easily covered with soil after urine application in furrows. However, irrigation with water should be carried out after urine application.
- Urine should be applied to the soil around the plants not onto the plant as it can cause “burning” of leaves.
- Urine also contains chloride; therefore care must be taken when it is applied to chloride sensitive crops such as potatoes and tomatoes.
- As urine is rich in nitrogen, balancing other nutrients required by crop has to be supplemented with mineral fertiliser.
- Caution should be exercised while applying urine in sandy areas with shallow aquifers to prevent leaching.

- Increase in the salinity of agricultural lands over a period of urine application must be taken into account. Treatment with gypsum, crop rotation with salt tolerant crops and use of smaller pots where soil can be exchanged are some measures which can be adhered to.
- Loss of ammonia must be controlled during storage and application process. Keeping the storage containers closed using a lid and covering the furrows with soil after the urine application can reduce loss of ammonia.
- Persons involved in application of urine must take precautions like wearing of gloves, boots and face mask. Hand washing with soap after urine application is also important.

Crop	**Recommended dose of fertilizer**	**Human urine litre/ha**	**Urine required per plant (litre)**	**SSP required Kg/ha**	**MOP required kg/ha**
Maize	150:75:40	50,000	0.9	-63	-67
Finger millet	100:50:50	33,333	0.6	-42	-47
Jowar	100:75:40	33,333	0.13	115	-22
Pearl millet	100:65:25	33,333	0.15	52	-47
Wheat	100:75:50	33,333	0.06	115	-6
Paddy	100:50:50	33,333	0.29	-42	-6
Chilli	150:75:75	50,000	1.69	-63	-8
Tomato	250:250:250	38,333	3.38	218	-2
Brinjal	125:100:50	41,667	1.13	182	-28
Radish	75:38:38	25,000	0.11	-28	-3
Banana	405:245:507	135,000	53.33	115	36
Sugarcane	250;100:125	83,333	2.25	97	478

Table 3. Recommended dose of urine for various crops in the Indian condition (Source: Dr C A Srinivasamurthy, GKVK, Bengaluru)

5.2 Methods of Urine Application

Urine can be used for agricultural and industrial purposes using the following methods :

Direct Application

- Urine can be directly applied to agricultural lands during land preparation and to fertilise crops after plantation.
- Urine must be applied to soil around the plants by creating furrows. The furrows should be covered with soil after application of urine to prevent loss of nitrogen through ammonia gas.
- Use of watering cans which are commonly used in home gardens can be ideal for application of urine.

Deep Injection

- Deep injection of urine up to 6 inches below the ground surface considerably reduces the ammonia loss. This method is more suited for horticultural plantations where plant density is lower than the traditional crops in a given area.
- Using subsoil injectors and pot irrigation method (use of PET bottles having small holes at bottom can be handy) deep injection of urine can be achieved at low cost.
- For large scale application, custom made mechanised agricultural tools can be designed for deep injection of urine.

Figure18. Deep injection of urine using soil injector (Photo: R.Sakthivel)

Figure19. Deep injection of urine using perforated pet bottles (Photo: R.Sakthivel)

Drip Irrigation

- Urine applied along with irrigation water and applied through drip irrigation.
- Fertilisation tank filled with urine to be applied to crops is connected to water mains carrying water for drip irrigation.
- Regular maintenance of emitters and tubes is necessary to prevent clogging.

Figure20. Use of fertilisation tank for applying urine through drip irrigation (Photo: Prakash Kumar)

Struvite

- Struvite is a fertiliser in solid form containing magnesium ammonium phosphate and is obtained by adding magnesium chloride to urine.
- This process is carried out after pH of urine stored in a closed container increases substantially over time. Addition of magnesium and slow stirring for 10 minutes leads to precipitation of struvite which can be filtered and used as fertiliser.

Figure21. Manually operated reactor for recovery of struvite (Source: Eawag)

- This process is ideal when farmers prefer solid fertiliser over liquid urine or where large scale collection of urine is taken up in urban areas to prevent bulk transfer of urine over long distances.

Co-composting

- Urine can be added to compost to enrich its nutrient values and also for quickening the composting process.
- Care should be taken to minimise loss of nitrogen when co-composting is taken up.
- The method is more suitable if farmers have no reservation in handling liquid urine.

6. Other Applications of Urine

- Apart from various pharmaceutical applications which have been carried out in the past, major industrial products like ammonia and hydrogen can also be obtained from urine.
- Urine readily hydrolysis into ammonia under natural conditions. Gas stripping process can be employed to separate ammonia from liquid urine.
- Hydrogen can be obtained using ammonia catalytic electrolyser or using biological routes from urine. Pilot experiments have shown the possibilities of utilising urine for obtaining ammonia and hydrogen in various parts of the world.
- It is hoped that successful application of these processes will lead to use of urine for industrial scale production of mineral fertiliser based on ammonia and clean energy based on hydrogen.

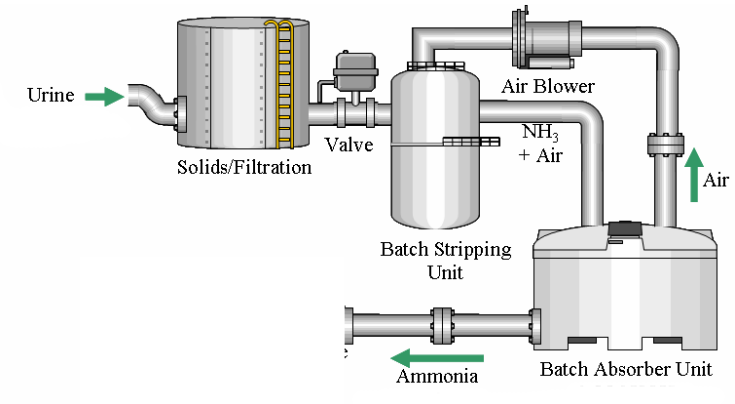

Figure22. Schematic drawing of ammonia stripping from urine (Source: Ohio State University)

7. Challenges and the Way Forward

- **Institutions and Public Places**: Installation of waterless urinals should be made mandatory for institutions and public places. Enforcing proper maintenance routines for the upkeep of waterless urinals in such locations will result in conservation of fresh water and reduce environmental pollution.

- **Building Code for Houses**: Installation of waterless urinals as an integral component of toilets in individual houses should be made mandatory for large houses with several toilets. Provision of a urinal in at least one of the toilets which is often used in the house can minimise the use of conventional toilets for urination. Such a change in the building code can help in preventing wastage of enormous quantities of fresh water and generation of large volumes of sewage in the cities.

- **Female Urinals:** Innovative designs of waterless urinal designs are yet to be developed for meeting the requirements of female population. Currently, toilets double as urinals for the use of female population. In schools, squatting slabs connected to open drains are being used as urinals for girls. As a result, issues like increased cost of construction, excessive odour problems, poor maintenance and inconvenience to the users are being faced. Therefore, further work to address the above issues needs to be taken up.

- **Industrial Application of Urine:** Apart from the use of urine in agriculture, industrial applications using human urine need to be developed to utilise the urine harvested by installing waterless urinals. Diverting and collecting urine separately from sewage can reduce nitrate levels in the effluents discharged to water bodies and ground water. The problem of eutrophication of the water bodies can also be prevented due to lower of levels of nutrients, especially phosphate.

- **Awareness:** Awareness among builders, engineers, architects, town planners and policy makers is essential to promote waterless urinals on a large scale. Efforts to popularise the concept can result in large scale replication of waterless urinals across the country.

- **Maintenance:** Undertaking proper maintenance routines of waterless urinals installed is essential for ensuring their effective functioning. Improper maintenance of the waterless urinals may result in failure of this novel concept. Therefore, sensitising the users, training of maintenance staff and allocation of adequate budget for meeting the maintenance requirements must be ensured after installation of waterless urinals.

8. References and Further Reading

a) http://www.desert.com.au

b) http://www.ecosan.nl

c) http://www.ecosanres.org

d) http://www.eco-solutions.org

e) http://www.eidparry.com

f) http://www.falconwaterfree.com

g) http://groups.yahoo.com/group/ecosanres

h) http://www.gtz.de/ecosan

i) http://www.indiawaterportal.org

j) http://www.iees.ch

k) http://ruralsanitation.net/

l) http://sei-international.org/

m) http://www.susana.org

n) http://www.unicef.org

o) http://www.waterwisetech.net