HUYS ADVIES

Urine Diversion Toilet (UDT)
Urine Diversion Dry (Dehydration) Toilet (UDDT)

Ecological Sustainable Sanitation in Himalayan Conditions

Technical Working Paper ~ Number 13

HUYS ADVIES

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Abstract

Practical examples of ecosan urine diversion toilet systems for Himalayan and similar high altitude conditions with long frost periods above 1500 m (5,000 ft). Reasons and benefits for ecosan-biogas linked urine diversion toilet (UDT) and urine diversion dry (dehydration) toilet (UDDT) systems. Basic elements required for good operation of the UDT and UDDT. Variations in the design of the base structure housing the composting chambers (vaults), biogas and urine diversion. Design of UDDT pan. Insulating plasterwork. Progressive building. Building in the winter. Possible design options for the upper structure and thermal insulated bathroom walls. Poster support material in awareness development. Handling and annual use of the compost. Urine collection, filtering, dilution, Struvite production and plant fertilization.

Photo Front Page

Poster on hardboard upper structure of new UDDT in Tajikistan. The construction can be gradually improved when more funds become available and the house owner wants increased comfort.

INTRODUCTION

The Technical Working Papers incorporate knowledge gained from more than 30 years experience in project development and implementation in several development countries. Much time has been dedicated to providing practical information on how to realise beneficial, low-cost solutions for the inhabitants of the mountain regions of the Himalayas.

Technologies need to be adapted to local circumstances because of socio-economic circumstances. Existing, proven technical solutions have been modified taking into consideration local customs; technical skills of local craftsmen; ease of transport; availability of materials in the local markets of the mountain regions; as well as the acceptability and affordability by the village people.

Making existing or traditional buildings more comfortable with better kitchens and sanitation is necessary for the tens of thousands of houses and other constructions in the Himalayas. When undertaking these renovation projects, the high altitude climate conditions need to be taken into consideration.

> For low-income people, it is important to find appropriate technical solutions taking into consideration the local economy of the people. Also the possibilities of the local entrepreneurs, such as skills, tools, materials and other resources, need to be considered to create affordable products for improving living conditions and livelihood.

This Technical Working Paper #13 gives a resume of the most sanitary and cost-efficient options for sustainable sanitation in frost areas. Hygiene and durability of the sanitation systems are essential and very important factors. The renovated sanitation unit has the highest cost per square meter in modern buildings, while in the past the sanitation unit had the lowest cost per square meter as it was an outdoor shack or sometimes open defecation. Excellent hygiene and odour control are essential for full acceptance of the UDT and UDDT systems by the villagers.

The document is based on field experience from the author and information which can be found on the Internet.[1] The paper does not elaborate on the technical biogas design and operational details as this is a subject by itself with more specialized technology. The paper can serve for capacity building for local artisans and decision making for house owners on the subject when they do not have access to other information sources. It remains, however, a working document and should be extended when additional information becomes available.[2]

Capacity building of technical staff, local building contractors and entrepreneurs is realised by a combination of theoretical education and practical implementation. Analysing existing examples is a good training method, as well as further study of material available from the Internet.[3]

The document can also be used for awareness development, training and as part or basis of curriculum development and vocational training. National training institutes need to develop and expand on the subject with additional practical examples of sanitation solutions, the advantages and disadvantages and comparison to the local situation.

Terminology

Human sanitary needs are several times per day, but rarely discussed in public. To explain the advantages or disadvantages of a sanitation system, not only do the technical details of the construction need to be discussed, but people's habits and behaviour as well, using precise wording. The wording in this paper has been chosen carefully. The translation into local language also needs a correct local terminology to explain precisely the sanitation process and to avoid misunderstanding.

[1] Internet search: ecosan, UDT, UDDT, composting, sanitation, urine diversion, fertilizer, Struvite, water saving.
[2] Readers are invited to comment by email: Ecosan@nienhuys.info
[3] Regularly new information material is coming forward on the Internet, such as on www.susana.org

1. DEFINITION OF WASTE SOURCES

When different types of wastes are mixed, the resulting mixture has the quality of the least pure ingredient and accordingly needs to be additionally processed for purification. The following definitions are part of the waste sources. Both faeces and urine are excreta.

***Urine*:** Rather pure (bacteriological clean) element, but smells of ammonia when fresh. Can be used as plant fertilizer, either pure, diluted with water or crystallized (Struvite[4]).

The dilution of urine for agricultural purpose depends on the growing phase of the plant, the temperature and humidity of the environment, and the soil structure.[5] Discarding the urine into a biogas reactor is not recommended. Storage of urine during the non-growing frost period has cost implications.

Picture from www.ecosanres.org on urine research.

Faeces: Bodily waste matter with high bacteria levels, including possible parasites. Inside the body is an anaerobic environment (non-air/oxygen). When mixed with humid material (water, urine) and exposed to air (oxygen), it will cause different bacteriological fermentation, decomposition and strong offensive smells. The exposure to air, moisture and warmth also allows other bacteria to grow and harmful parasites to develop.

Fresh human faeces should NOT be used as fertilizer in open land because when exposed to air, it attracts insects (such as flies) that transmit the bacteria and germs which cause diseases. However, faeces can be processed through a biogas reactor producing cooking gas and pathogen-free effluent, which can be used directly as fertilizer or further sun-dried for compost. Faeces can also be composted in a urine diversion dry toilet (UDDT).

Kitchen Solid Waste: Remains from cleaning vegetables/fruits and food leftovers. These can be easily composted when they do not have a high content of fat, used cooking oil, meat or fish waste (high protein). Shredded and soft kitchen waste can be discarded into a UDDT or a biogas reactor where it contributes to the gas production.

Wash Water from Kitchen, Shower and Laundry: This is called “grey water”. Although it may contain some soap and small food remains, it is rather harmless and can be used for agricultural irrigation or, after filtering (various membrane techniques), for flushing toilets. Storing “grey water” or filtered water during the winter period requires large frost-free tanks.

Anal Wash Water: As this is contaminated with faeces, it should be treated as faeces or “black water” and general sewage. “Black water” is sometimes called “brown water”.

Anal Dry Cleaning (Paper): In water-closet sanitation systems, the toilet paper is flushed away along with the faeces. Therefore, the paper must dissolve (disintegrate) easily into the water where it further decomposes. Wood fibre based dissolvable paper (high carbon content) can also be discarded into a biogas reactor system where it contributes to the gas production or into the UDDT where it assists in keeping the waste dry.

Rainwater: When the roof has a clean surface[6], collected rainwater can be used filtered and for showering and laundry, or further purified for drinking water. Storing rainwater in high-frost areas needs to be underground to avoid freezing. As the volume of rainwater in many high mountain areas can be low, this element is not further elaborated in this document.

> *Mixing different types of waste results in downgrading.*

[4] See Annexe II, page 45.
[5] In several countries, research is ongoing to determine the best composition per plant type and climate zone.
[6] Asbestos cement roofs are unsuitable for capturing drinking water. After a long dry period, many roofs become dirty.

2. MANY TOILET SYSTEMS

A whole separate document can be devoted to the various types of toilet systems in use.[7] The introduction of UDT or UDDT systems is an environmental and economic necessity as the water used in the flush toilet systems more than doubles the overall operational cost and, if the sewage is not cleaned, leads to an increase in environmental hazard and health costs for the population.

Sanitation is a wide terminology covering measurements for a clean environment and avoiding diseases that affect human health.

- Clean and safe management of human excrements (faeces and urine), including methods of anal cleaning, hand washing and hand drying.
- Other human waste management, such as solid kitchen and food waste.
- Management of liquid household wastages from shower, washing and laundry ("grey water"). This includes house/car cleaning water.
- Management of rainwater, including catchment, filtering, re-utilization and drainage.
- Safe management and disposal of cattle dung and urine.

Open defecation becomes highly contaminating in an increasingly populated rural area and is outright an environmental and health hazard in villages and more urbanized areas. Insects and animals spread the germs and pathogens into the environment, affecting the health of all the inhabitants living in the area.

An advantage of open defecation is that urine and faeces are not mixed, but deposited separately, causing less environmental problems than many toilet systems where these two are mixed and thereafter need to be sanitized.

The chamber pot is/was a common solution, especially in cold climates where going outside into the dark in freezing weather is uncomfortable. When urine and faeces are mixed in the chamber pot, it is going to smell badly. A cover and cabinet will reduce this. A problem with the chamber pot is that its contents need to be deposited, for example, in a deep pit.


Single open pot under bed

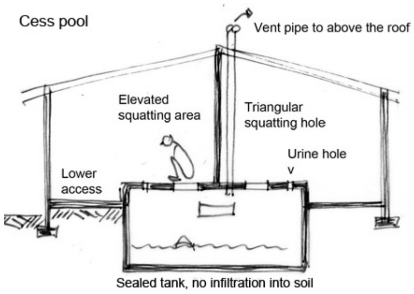

High pot with wide seat


Chamber pot with lid


Cabinet with cover

A pit latrine should be deep enough to allow continued functioning during the winter when natural composting does not occur. The main problem with the pit latrine is that it needs good ventilation because the urine and faeces together cause a stinking ammonia-loaded environment. The mix does not compost in cold weather and only slowly in warm weather. Leaking liquids from the pit will contaminate the subsoil and possible drinking water sources. For these reasons, the pit latrine or the Ventilated Improved Pit Latrine needs to be located far away from any water wells.

The cesspool is used with communal toilets in some urban locations, but some designs have no pipe going down into the liquid. The result is an excessive amount of bad smells. When the design of the squatting pan is without proper footsteps or urine catchment, the floor area becomes very dirty and unhygienic. The full tank needs to be emptied, but because of the poor design and dirty environment, in many cases the entire building is closed down and a new unit is constructed. This is an additional cost for the population.



[7] See: www.sandec.ch – free download area with 50 different sanitation technologies.

The sewer-based flush toilet system has become popular in areas with good access to low-cost water and the possibility to dump the sewage into open water. That open water, however, is water used by people downstream for irrigation and sometimes for converting to drinking water as well. Raw sewage from toilets can partly be treated through the use of septic tanks; this has become compulsory in many villages. The sewer-based system in cities receives not only the human excreta (toilet) waste, but also many other types of waste materials, especially from small and large enterprises and industries. This causes strong contamination. Purifying contaminated water is very expensive, costs that eventually will need to be paid for by the population.

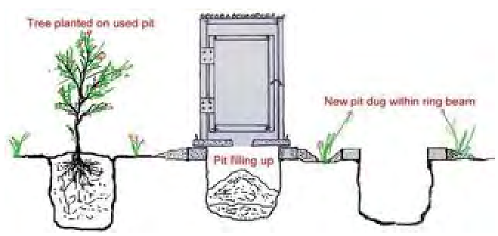
All of the above systems generate methane gas (CH_4), which is a highly insulating environmental greenhouse gas (GHG) contributing 21 times as much to global warming as CO_2.

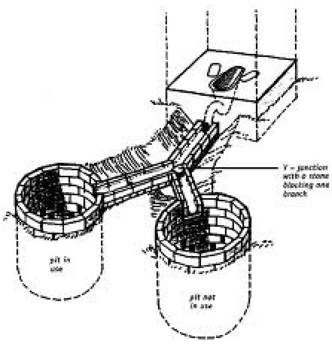
Ecosan is an abbreviation of “Ecological Sanitation”; a sanitation system which is environmentally less damaging than other toilet systems. Ecological sanitation systems recycle part or all of the inputs and can have the following features:

- Uses less (drinking) water for toilet flushing.
- Composting of the faeces with UDDT.
- Separation of urine and re-utilisation as plant fertilizer; direct, diluted or processed (Struvite)
- Compost contributes to environment improvements; fertilization of soil for better crops, improved growth of trees for better water retention of the soil and reduced land slides, etc.
- Toilet system can be connected to a biogas reactor with the advantages of biogas for cooking (reduces consumption of firewood/charcoal and thereby reducing deforestation); effluent as plant fertilizer; and reduces emission of greenhouse gasses (GHG) into the atmosphere.
- UDDT (dry) and the UDT-biogas (wet) systems allow the disposition of soft or shredded kitchen and food waste into their systems, which reduces fly and rodent populations.
- Less sewage, such as the vacuum toilet systems, using small bore piping.

Ecosan toilets is a collective name for all toilets that are an environmental improvement on the high water consumption “Flush and Forget” toilets requiring a complete city sewerage system. Because the terminology is applicable to several toilet designs, it is better to mention the specific toilet system rather than just ecosan toilet. One can use the following terminologies for clarity:

- ◊ Ecosan-UDT for on-site recycling of all inputs.
- ◊ Ecosan-biogas for UDT connected to a biogas reactor on-site or in a housing cluster.
- ◊ Ecosan-UDDT for the “dehydration or dry” systems producing compost and separate urine.
- ◊ Ecosan-Arborloo. When the pit-latrine is full, a tree is planted into the hole.[8]
- ◊ Ecosan-double soak pit. Pour-flush system with the alternate use of a deep soak pit. When one soak pit is full, the junction box is modified and the other soak pit is used, while the full pit is composting for a period. The clean compost is used for soil improvement.[9]
- ◊ Ecosan-flush toilet, as long as disposal and processing is done in an environmentally responsible way by which the nutrients and water are properly recycled.





Ecosan-Arborloo and Ecosan-double soak pit[10]

[8] Some pictures on: http://conference2005.ecosan.org/presentations/morgan.pdf
[9] See also: http://hesperian.org/wp-content/uploads/pdf/en_cgeh_2012/en_cgeh_2012-07.pdf
[10] Internet drawings.

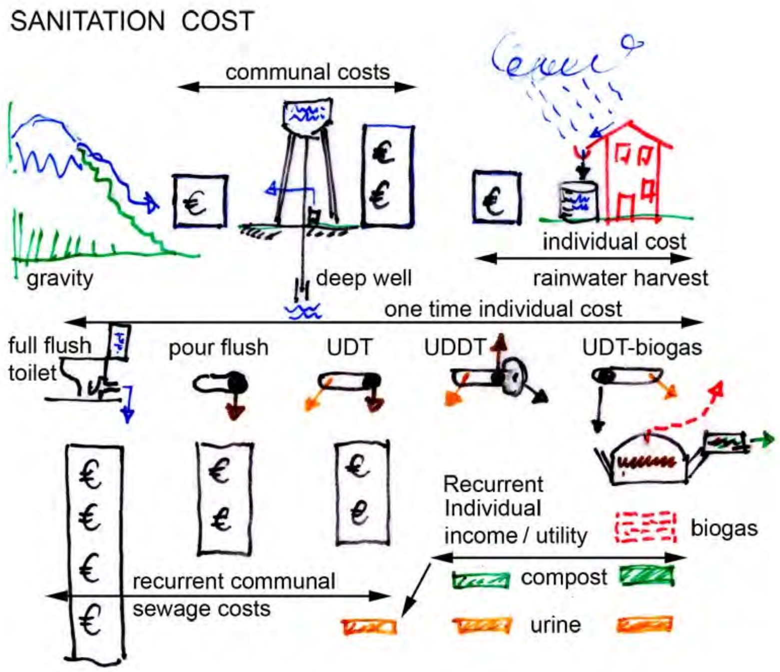
3. DIFFERENT SANITATION MODELS

In looking at the best sanitation option, the entire cycle from food intake, toilet design and waste processing for re-utilisation needs to be reviewed up to the point of growing food again. In some capitalized societies, sanitation consists of a “Flush and Forget” model. This model is unaffordable for low-income people and certainly not sustainable in high mountain areas.

Sanitation systems based on large amounts of good quality drinking water being used for flushing faeces mixed with urine into a communal sewerage system have high costs.
(a) Very large amounts of drinking water need to be purified and piped to the residents.
(b) Water supply and sanitation systems need to be kept frost-free at all times.
(c) Costly residential connected sewerage system needs to be installed and maintained.
(d) Highly diluted sewage water needs to be purified before discharging into open water.

The system becomes even more expensive when the sewerage system also receives rainwater, which further dilutes the mixture. Therefore, in many countries, the rainwater diluted raw sewage is discharged into open water causing bacterial pollution and general health risks for the entire population, in particular people living downstream.

The cost of a sewerage system and cleaning the raw sewage is twice as high as the production and transport of clean drinking water (from wells). Hence, the more water used, the higher becomes the cost of the sewage treatment. Although municipalities organise the water supply and finance these sewerage costs, the funding is through taxation of the population.



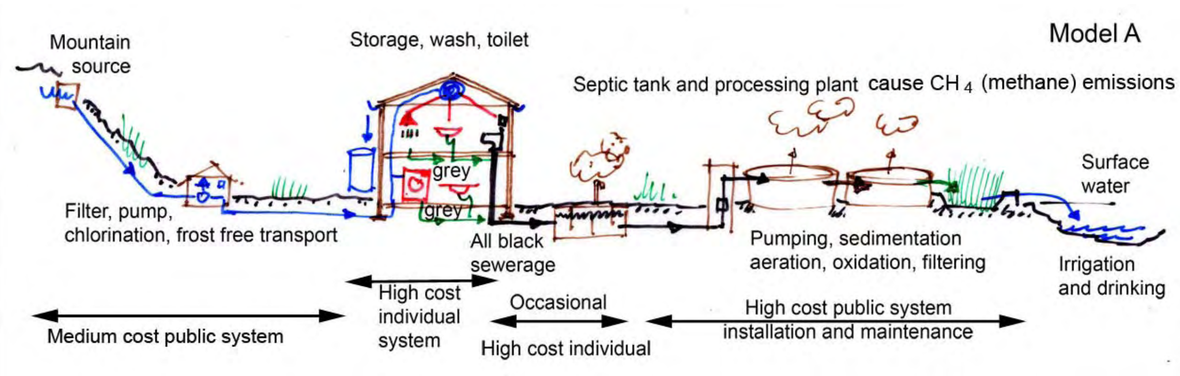
- ❖ The cost of a sanitation system is divided into water supply, individual house installation and the waste process.
- ❖ Each sanitation system has investment, maintenance and operational costs.
- ❖ Each system has a lifetime and eventually needs to be replaced.
- ❖ Every sanitation system has a public health cost.

Making a decision for a water-based flush toilet system will have life-time cost and environmental consequences for water supply and sewage treatment. Providing a water-based sanitation facility in an individual house not only has a construction cost (materials, labour), but health, operational, maintenance and public taxation costs as well. With increasing population density and the need to keep the open water clean, the public maintenance and taxation costs will increase over time.

To keep the surface water clean, sewage needs to be completely cleaned.[11] Municipalities can oblige the installation of septic tanks before sewage is drained into a soak away (rural) or the urban sewer. When sewage is drained directly into the sewer, the cleaning costs increase, which in turn increases the cost of the public connection to the sewerage system. Discharging raw sewage into open water should be prohibited in all housing situations, even at the remote village level.

3.1 Model A – Flush Toilet

Model A sanitation system is the most costly option of “Flush and Forget”. In the 19th century, flush toilets (water closets) typically used 10-15 litres of drinking water to flush. Nearly 80% of the good quality drinking water in a household is used to flush away the faeces.



Improvements to the above model A are the following:

- Use the “grey water” from the shower and laundry for flushing and complement this with collected rainwater. This reduces the amount of drinking water wasted, but will require a “grey water” storage tank with filter and piping to the toilet. Water storage tanks have to be protected from frost and are therefore more costly in cold areas.
- Use a “dual-flush” toilet design, using less water for flushing urine and full flush for faeces. This reduces the amount of sewage.



Different types of push buttons and systems for “dual-flush toilets”, reducing the amount of flush water.

- Place a plastic bottle filled with water inside the existing toilet cistern, thereby reducing the amount of flush water.
- Use pour-flush toilets, requiring substantially less water than the full-flush toilet. This concentrates the amount of sewage.

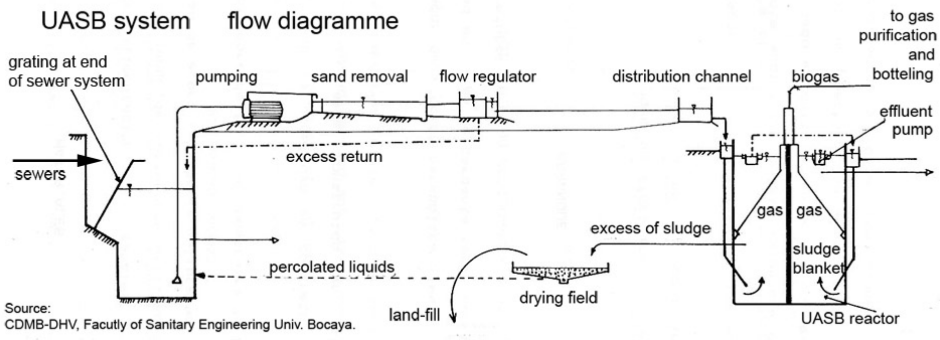
Pour-flush toilets use only a few litres of water for each flush and therefore produce less sewage. Urine, anal wash water and anal cleaning paper can also be flushed in this system.

In model A, rainwater (even occasional) should not drain into the same sewer system because it will excessively dilute the sewage and with that increase the treatment cost.

[11] Unfortunately, in many places, dirty wastewater from villages, factories and towns is still dumped into rivers and the sea.

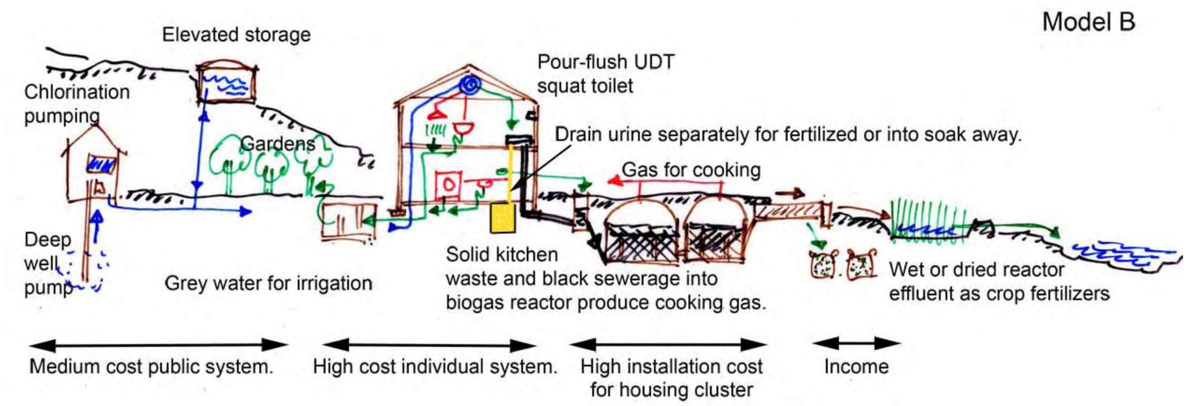
The large amount of diluted faeces and urine need to be processed in large installations. The construction and maintenance of sewage water treatment and purification plants is very costly and can only be financed by large organisations.

It is possible to extract biogas from the central sewage purification plant by means of an Upflow Anearobic Sludge Blanket (UASB) system. The amount of methane gas that would otherwise leak into the atmosphere will be reduced. The biogas resulting from this system needs to be purified (sulphur removed). The purified gas can be bottled and sold for cooking purposes. The income from the bottled gas, however, does not cover the exploitation cost of the UASB installation.



3.2 Model B – Pour-Flush UDT Toilet

Model B is an optimization of on-site recycling through the use of a biogas reactor system and the lack of a municipal sewerage system for the connected households. In this sketch, the option of a deep-well water supply system has been presented, which is more costly than a gravity supply from a clean high mountain source.



Model B has a pour-flush toilet, preferably with a urine diversion toilet (UDT) where only the faeces and anal wash water goes into the "black water" sewer, while the urine goes into a separate draining system. The "grey water" from the house is collected in a tank and used for flushing the toilet, irrigation or drained through a soak away.

A UDT pan has a drop hole for the faeces and a forward positioned receptacle for the urine.

In a squat position (left photo) the urine is projected more forward than in a sitting toilet (right photo), but the principle is the same.

The toilet sewage and shredded soft kitchen waste are fed into a biogas reactor, which produces biogas and slurry (effluent); the later can be used for plant fertilizer.[12] Cattle dung can be fed into the biogas reactor as well to increase the gas production.

The domestic production of biogas reduces the large methane emissions of raw sewage and produces efficient fuel for cooking.

Advantages and Disadvantages

The biogas reactor model requires the input of minimal 20 kg human faeces per day (100 persons) and about 10 kg shredded kitchen and food waste per day to produce sufficient cooking gas for one or two families only. This means that the installation is feasible for 20-30 families or a small housing cluster.[13]

- The installation costs are to be shared between the several families. The few families operating the system can use the gas. Income from fertilizer is shared by the group. This requires good group organisation and finance control.
- There will be municipal cost for the water supply, but no cost for sewage connection to municipal treatment plants.
- The amount of solid kitchen and food waste to dispose of will be minimal. An immediate result is a smaller fly, insect and rat population living from kitchen waste.
- In areas with a very long and cold winter, the biogas model B will be more costly in construction due to thermal insulation needed for the biogas reactor to ensure it continuously produces cooking gas and has good elimination of pathogens.
- Using separate urinals or non-flush urinals will reduce the amount of sewage a little and improves the functioning of the biogas reactor, but requires the installation of such urinals. It also allows the separate capture of the urine for fertilizer purposes.



Left: Squatting urinal for men and women.

Centre: Wall-fixed urinal with water-flush or waterless models.

Right: Different systems of waterless urinals exist. This is a holder with an inside flexible nylon tube that allows the urine to pass and closes.

Storage of urine will be problematic in very cold areas, since the (minimum) one litre per person per day needs to be stored until it can be gradually used during the planting season. For 100 persons (5 households) times 100 days (winter period), this is a (minimum) 10 m^3 tank.

The biogas model B has a special long-term environmental advantage because it captures CH_4 (methane) and avoids emission into the atmosphere. National government entities may be able to co-finance the construction of the biogas installation to a large extent from Carbon Emission Reduction (CERs).

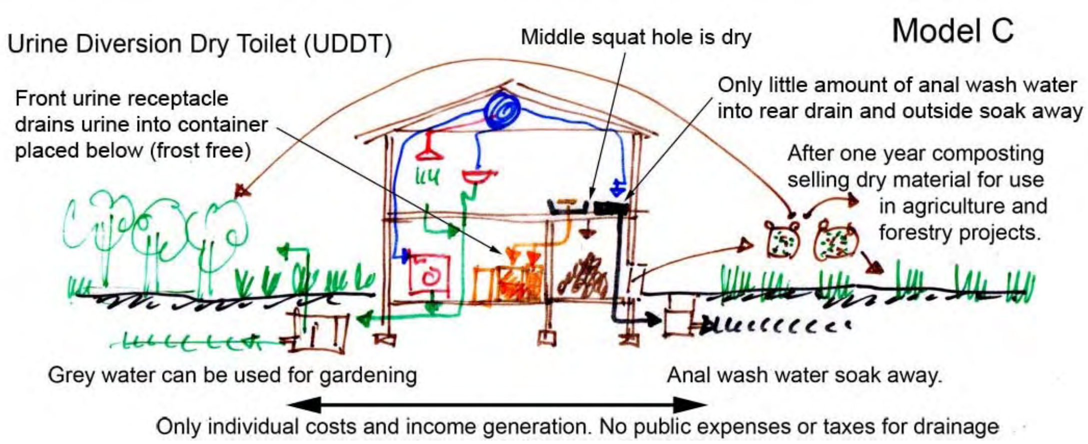
There are various biogas reactor designs, which can be constructed from locally available building materials. To ensure the dome is gas-tight, good detailing, workmanship and quality control will be required by experienced people.

[12] A difference with the city UASB plant is that the slurry from city sewage can contain many other waste products, such as heavy metals, medicine remains and chemicals, which are undesirable in compost.

[13] For adding dung from horses, donkeys, cows, buffalo and pigs, the situation changes. The quantities need to be calculated and well managed. Changing the type and size of the population will affect the retention time and gas output.

3.3 Model C – Urine Diversion Dry Toilet (UDDT)

In model C, the UDDT substantially reduces the amount of "black water" and clean compost is produced. In addition, "grey water" can be recycled on site. The "black and grey" waste water is managed on site in two separate soak aways. The household, however, needs to have sufficient land for a durable soak away for the "black water" from anal washing. The sketch below does not show the water supply or the connection to a municipal sewerage system.



The only "black water" is from anal washing after toilet use. This water needs to be captured and drained separately from the main squatting hole and the urine receptacle. For this purpose, a special squatting pan has been designed having three holes.

Left: *Two section ceramic three-hole UDDT squatting pan that allows anal washing with water over the wider section (left), which goes separate into the "black water" drain. The drain on the right-hand side is for urine only, allowing the squat hole to remain dry.*
Middle: *Same principle, but a single plastic (or glass fibre polyester) unit.*
Right: *Plastic two-hole UDDT unit with on the side a cement-masoned anal wash area, draining separately.*

The UDDT system has a double-vault design (one closed for one year for composting of the faeces, one in use). By keeping the contents of the vaults dry and ventilated, no odour will be emitted from the system. Unpleasant smells are caused by an anaerobic and wet environment. Therefore, the toilet does not need to be built at a distance and can be built inside or attached to the house. For practical reasons, the best location is on the first floor. For houses on small slopes, this is not a problem.

The ventilation pipe is clearly visible in this timber-constructed ecosan toilet with UDDT pedestal.

The contents of the vaults are kept dry by diverting urine and anal wash water and by adding sawdust, wood ashes or pure dry clay soil.[14] A container with these materials needs to be available inside the toilet room.

[14] Dry sand is not good as it does not absorb humidity; it only fills up the vault and does not decompose. Pure clay additionally binds the nitrogen, increasing the compost value.

When the UDDT room is not internally linked to the house, it will be difficult to keep the unit frost free. Especially the required hand-washing facility should be functional at all times.

UDDT toilet separate from the house with a separate urinal and outside hand-washing facility in a warm climate having no frost risk.

When anal cleaning is done with dry, compostable paper, the "black water" soak away for anal wash water is not required, but the toilet paper usually has a higher recurrent cost than washing with water. No plastic or other non-compostable materials should be added to the dry toilet. Sanitary napkins need to be disposed of separately.

After one-year closure of the vault, the dry compost can be used on the house owner's farm or sold as agricultural fertilizer for direct application in grain and maize agriculture or forestry projects. Contracts can be made with farmers.

The same compost material can be further reduced through vermicomposting (using earthworms)[15], thus obtaining a higher grade purified compost suitable for decorative house plants, kitchen vegetable gardens and hydroponics. Vermicompost has a much reduced volume as compared to the compost from the vault and is easy to transport.

The urine is collected separately and should be stored in a frost-free location. It can be used for agriculture, converted to Struvite or drained with the "black water". When the urine is drained along with the anal wash water, the capacity of the soak away needs to be increased.

To eliminate the ammonia smell from the urine, it is drained through a 10-litre sand and 10-litre carbon filter. This will also remove the colour. When the toilet room is on the first floor of the building, the filters and storage tanks can be located below. For practical reasons, access to the urine storage and piping should be from the outside, NOT through the vault in use.

The urine, however, needs to be stored for at least half a year before it can be used in the field. Several containers are required and sufficient storage capacity. A household of six members requires 6 x 100 days x >1 litre per day = >600 litre tank to cover the winter. To extract the liquid, either a pump or a bucket system is then required.

A separate soak away or reuse of the "grey water" in agriculture is needed. During the cold winter period without agriculture, this water is to be drained away.

The system, however, does not capture biogas. The aerated ventilation process allows the methane gas to escape into the environment. Methane gas is 21 times more insulating in the earth's atmosphere than CO_2.

When drainage on site is not possible, such as in a highly urbanised area, the anal wash water, "grey water" and urine are all passed as "black water" into the public sewerage system. The diameter of the sewer pipe can remain small and the needed level of sewage treatment is greatly reduced, leading to lower public expenses (small bore system[16]). The municipality can apply different sewage rates for people having on-site dry composting of faeces.

Compost from a one-year closed vault is clean and can be easily handled without risk of diseases. In cold climates, the drainage piping should be inside the building to keep them frost free. The door of the vault needs to be insulating.

[15] See: Small Scale Vermicomposting by Cooperative Extension Service, Home Garden, August 2005, HG-45 and http://journeytoforever.org/compost_wormlink.html and www.wormdigest.org.
[16] See: TAG 14, The Design of Small Bore Sewer Systems, World Bank Technical Note No.14. Project INT/81/047.

4. Models A-B-C, UDT or UDDT?

The choice between the three models A, B and C depends on many factors, but for each of them a top quality and sophisticated sanitation solution can be developed. The overall quality of the sanitation option depends largely on the materials and precision of the workmanship, not on the chosen system.

The choice between the systems, however, has implication on the amount of work needed to maintain the system at the house, or the operation and maintenance costs. The periodic collection of the dry compost and urine can be subcontracted to interested farmers.

The following options are possible:

#	Description of the Design Elements or Variations Possible	Model A City Sewer		Model B Biogas	Model C	
		1 Hole Toilet	UDT 2 Holes	UDT 2 Holes	UDT 2 Holes	UDDT 3 Holes
1	High water consumption of 10-15 litre per flush	x	x			
2	Reduced flush system with 4-5 litre per large flush and small flush	x	x			
3	Pour-flush toilet with 2-3 litre per flush	x	x	x		
4	No septic tank on-site with high municipal connection cost	x	x	x		
5	Septic tank on-site with sewage to municipality (medium connection cost)	x	x	x		
6	Septic tank on-site with on-site soak away (large capacity) without sewer connection cost	x	x	x		
7	Soak away for little black water: anal wash water				x	x
8	Soak away for urine (in winter)	x	x	x	x	x
9	Collection system for urine and possible income generation	x	x	x	x	x
10	Anal cleaning with cold/warm water (low recurrent cost)	x	x	x	x	x
11	Anal cleaning with toilet paper (high recurrent cost)	x	x	x	x	x
12	Large storage of urine during winter	x	x	x	x	x
13	Shredded soft kitchen/food waste No oil, no proteins (meat-fish)			x	x	x
14	Production of cooking gas			x		
15	Increase gas production with additional cattle dung			x		
16	Methane emissions into air	x	x	none	x	x
17	Production of liquid or dried compost from biogas slurry and income			x		
18	Production of dry compost and possible income generation			x	x	x
19	Possibility of tiled flooring/walls	x	x	x	x	x
20	All in house construction possible	x	x	x	x	x
21	Possible subsidies from CERs			x		

For any of the combinations, the house owner needs to decide whether he/she likes the option. After selecting an option or combination, the cost of the system needs to be estimated depending on the level of luxury required. New construction costs of each design depend very much on material choice and labour costs. The choice of the system also depends on the quantity of "grey water" produced and what can be done on-site with it: irrigation, soak-away or sewer.

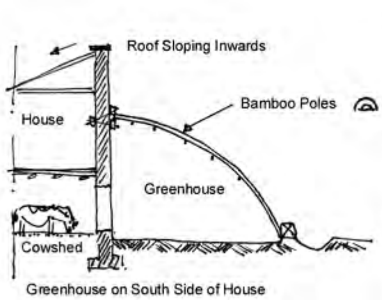
4.1 Biogas

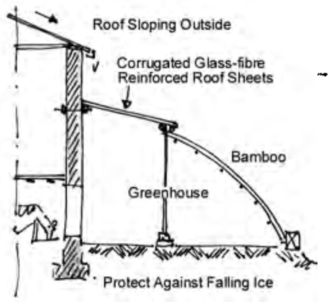
The biogas option is environmentally the most beneficial option since both urine and slurry can be used, respectively as fertilizer or compost, and the biogas for cooking. Because the biogas is burned, it avoids that the methane gas component (65% of the biogas) enters into the atmosphere and adds to global warming.

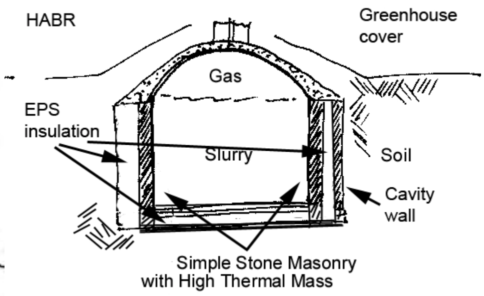
When several cattle (4-5 cows or pigs) or at least two large buffalos are <u>permanently</u> on stable, a biogas system is an interesting option. Emphasis needs to be on permanent because when the dung is not collected and fed into the system on a daily basis both summer and winter, the system will not produce gas and the relatively costly unit will not be economical.

Because the reactor needs to remain warm, the option is less costly at altitudes of 1000 to 1500 m where the amount of thermal insulation needed for the reactor is limited.

An average family requires about two hours cooking gas per day for food preparation, tea and some water heating. A minimum amount of cattle dung to produce these two hours of cooking gas is 30 kg/day (4-5 small cows). A family of five members only contributes 1 kg faeces per day and 200 grams food waste.







To keep the cattle warm in the winter, a large (house attached) greenhouse design can be considered. The greenhouse would extend the growing period of cattle food by at least two months. Milk and gas amount depends on the feed quality of the cattle. For thermal insulation of the High Altitude Biogas Reactor (HABR), a thick layer of expanded polystyrene (EPS) insulation of the construction is required. For every 250 m in altitude, 1 cm EPS is needed.

"Grey water" and rainwater cannot be drained into the biogas reactor as it will cause too much dilution. Anal wash water should preferably be lukewarm.[17]

Urine from the cattle and people can be collected separately and stored. Urine has a higher fertilizing quality than the biogas reactor effluent, but the dried effluent has good soil improvement properties, such as better retention of moisture.

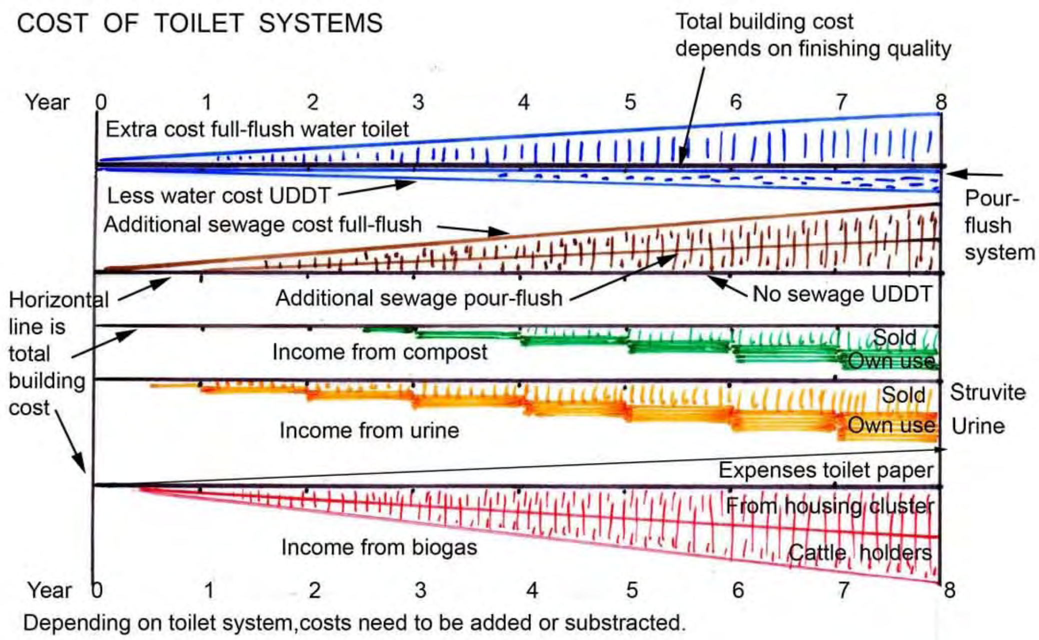
When the retention period of the slurry in the biogas reactor is minimum two months, the effluent can be used directly on the land. It can also be sun-dried for packing in bags for easy transport to forestry projects or bamboo production sites. Bamboo is highly productive, a versatile building material and grows above 1000 m altitude.

[17] To assure supply of warm water, a solar water heater is recommended.

4.2 Overview Costing

The costing of the toilet system after the construction has been realised becomes more important with an increasing number of years. The construction cost of the toilet facility itself will vary greatly with the quality and durability of the materials and the level of thermal insulation of the building.[18] Only for the communal or individual biogas system, are the building costs substantially higher because of an increased cost for higher altitudes due to the thermal insulation.

Every year, one system will cost money for operation or sewage, while another system may have annually incomes. These expenses or incomes vary depending on the choice of system, the municipal responsibility to clean the sewage and the possibility to sell the fertilizer outputs or use these fertilizers on one's own land. The increased agricultural output or/and the savings on chemical fertilizer are counted as income. Adding and subtracting these costs will give an impression of the economy of each system.



During the operation, each system will also have maintenance costs, but when built with durable materials, these maintenance costs can be lower than when periodic repairs are needed.

It depends on the local (municipal) situation whether the water supply and sewage costs are high. It depends on the farming situation or market whether income can be generated from the supply of the fertilizers and better crops. Generally speaking, when the fertilizer is used on one's own land, the increased farm produce will generate more income than when the urine or compost is sold to a trader or service provider.

In the decision-making process, the expected durability of the system needs to be taken into consideration. If a new toilet system lasts only three years before a new toilet needs to be built, the possible income will be very low. The more durable the system, the more operational costs or income generated over time, and less building maintenance costs incurred.

In the above chart, the possible negative health expenses caused by diseases or loss of the ability to work are not included. As with the level of comfort, health will be a major decision-making point.

[18] The construction of a UDDT can be realized in different phases, thus lowering the initial investment cost.

5. UDDT PAN DESIGN

The UDDT option can be applied in houses where there is a city sewage connection, but most people would not easily change their existing toilet design unless a good commercial market exists for urine collection and sales. The UDDT option cannot be used with a flush toilet; it is a dehydration or dry system.

The success of a UDDT depends largely on the quality of the toilet pan or pedestal seating toilet. Various designs exist already, depending on the local availability of materials and skills.[19] In many countries, readymade good quality toilet pans are now available. The UDDT should comply with the following conditions:

Seating Toilet

- Seating height must suit the users. For schools with small children, the floor should be raised or the toilet height lowered. The height should be no more than 40 cm in most situations.
- The seating surface should be very easy to clean. Hard, smooth plastic types, such as PVC or polyester resin, are most suitable. Varnished hardwood is an option.

UDDT with locally manufactured hardwood seat. The pot contains wood ash and sits on the closed vault.

- The fitting should be from stainless steel[20] and easy to remove for cleaning.
- The urine receptacle should be deep enough and shaped to minimize backward splashing.
- The urine drain needs to be cleaned once a year as deposits can clog the small tube. These deposits occur through evaporation of the urine. Therefore, the urine drain should be easy to remove for maintenance.
- When the pedestal is made from fibre cement or concrete, the inside and outside finishing must be very smooth, impregnated, coated with layers of two component filler, smoothened and finished with durable paint. Periodic paint repair will be necessary.

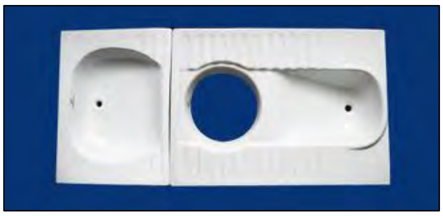
Half finished units of toilet pedestals made from fibre cement.

Squatting Toilet

◊ Squatting pans need to have a hole of approximately 18-20 cm (7-8”). Smaller holes will create difficulties of correct positioning over the hole, while larger holes will have the risk of small children falling into the pit. The hole can be narrowing downwards to 15 cm. Because the sides will get soiled, a sturdy cleaning brush for the toilet is essential.

In this UDDT squatting pan, the bridge between the squatting hole and the urine receptacle is rather wide and there is no elevation around the squatting hole. When washing the floor, water will flow into the squatting hole.

◊ There needs to be a small elevation around the squatting hole of the UDDT to avoid that wash water from the floor (or shower) flows into the large hole. If the urine is to remain concentrated without shower or wash water, then there should be an elevated border around the deeper urine receptacle as well.



This two section ceramic UDDT design can be kept very clean. There is a good distinction between the urine side and the washing side. However, the right-hand side must be elevated from the floor. The rear side with the wider receptacle can be level with the floor. This way floor wash water will only flow into the rear section.

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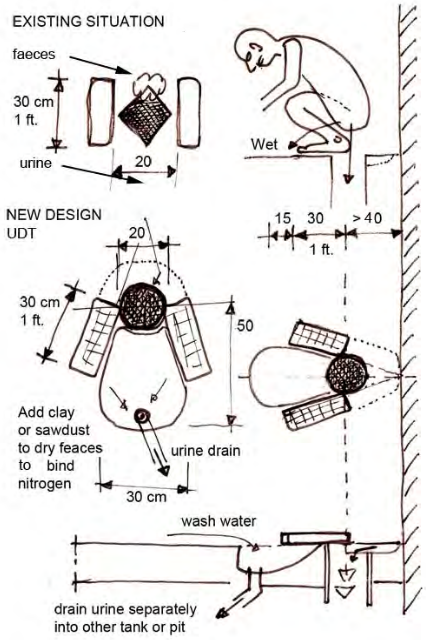
[19] For photos and posters type in an Internet search engine: “UDDT Toilet + images”.
[20] Copper will rust and plastic or nylon will break, while chrome covered copper may peel off.

◊ The possibility should be assessed whether the toilet room can be used as a shower area as well. In this case, the squatting hole should be closed and have an elevated rim.

When used as a shower room, some water will drain through the urine outlet. Shower and floor washing water need to be drained through another outlet in the floor.

◊ The position of the footsteps should stimulate proper defecation into the hole. Human anatomy indicates that the centre of the squatting hole should be in line with the rear side of the heels. There should be sufficient room at the rear side for anal cleaning.

The sketch shows the basic dimensions of the UDT unit with the correct positioning of the elevated foot steps.



◊ The footsteps should be slightly elevated from the floor and have an anti-slip profile. The surface, however, should be easy to clean and automatically drain the cleaning water away.

Left: The UDT is installed over a vinyl covered floor without footsteps. The lack of footsteps allows missing the squat hole. Water can go into the joint in the vinyl floor.

Middle: A well tiled floor, but the footsteps extend far too much towards the rear. Anal washing is separate along the side.

Right: Correct position of footsteps, nice tiles. Anal washing on the side with own anti-slip footsteps.

◊ The toilet room needs sufficient area for water (bucket and scoop or tap) in case anal cleaning is done with water, a container with a drying agent (sawdust, wood ash, dry clay soil, etc.) and cleaning equipment (toilet brush).

The toilet brush is an essential and integral part of the toilet. Different shapes and models exist. Brushes that will dry after use are preferred over brushes that remain wet or sit in a detergent (most right picture).

In addition to the toilet brush, a small container should be available to deposit sanitary napkins as these should not be dropped into the UDT or UDDT.

◊ The UDDT can be made as a single unit or two units to cover the two vaults, which are used alternating for one year. Two units mean that one is closed and one in use. One unit with two holes means that one side must be securely closed for one year.

Left: A single squatting pan which is exchanged from one side to the other with the black cover when the vault is emptied. This saves some of the cost, especially if the plastic squatting unit is far more expensive than the cover.

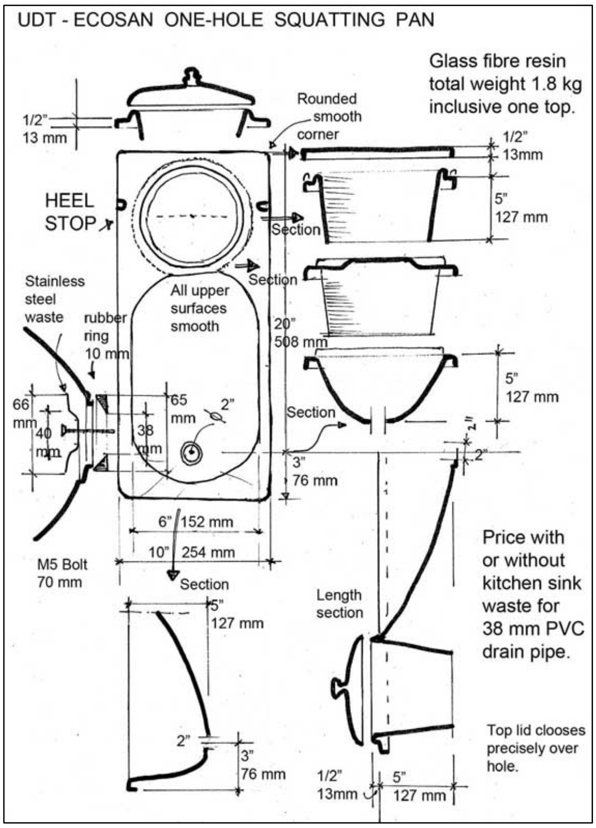
Right: Three fixed ceramic units over two vaults, one being in use (handle) and one closed. The central section for urine and anal washing water with its outlet over the dividing wall between the vaults below. The ceramic unit had a high cost and was difficult to transport to remote areas; it made this unit uneconomical.

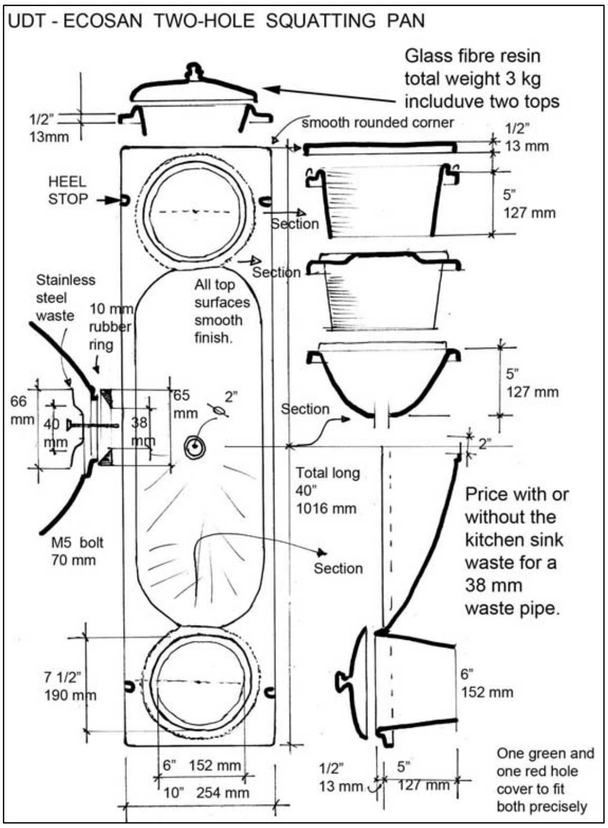
◊ Other models exist in which the one hole squatting pan is turned around when the vault is full. The disadvantage is that the fitting has to be done over the open/full vault with fresh faeces.

Left: Two complete UDDT units over two vaults below. The left vault below is closed for one year with a sheet of plywood on which the ash bucket is placed. Because the toilet is regularly washed, the plywood deteriorates and needs to be replaced periodically. A more durable water-resistant closing method is recommended.

Right: Show model of a two-sided UDDT (without footsteps), central urine receptacle over the dividing wall of the vaults below and two rear washing areas. One squat hole should be visually well closed with a sealing cover.

◊ When the cost of the plastic squatting pan is high, a single unit can be made which covers the two vaults. In that case, the urine and anal wash water is not separated and drained together into a single “black water” soak away. The following two designs are also possible. Squatting pans can be locally manufactured using a mould and glass fibre reinforced polyester resin.





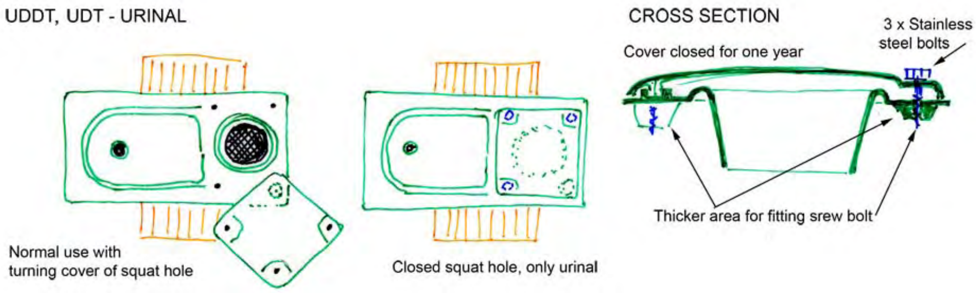
Single UDDT or UDT Unit
Two units are required, one above each vault.

Double UDDT or UDT Unit
The separation wall between the vaults goes through the middle and contains the urine drain.

◊ Tile floors in the toilet should be anti-slip and well draining. Tiling the room not only gives it a more luxury appearance, but tiles are easy to clean. The tiles should be as large as possible. Small tiles or mosaics have many cement joints and therefore are less slippery, but it is difficult to keep the joints clean. Many joints may easily cause fungus or mould development when the walls and floor are not well insulated.

Larger ceramic tiles are more expensive than small tiles, but require less cleaning of the joints and have less possibility of mould growth.

◊ A cover can be screwed down over the squatting hole closed for composting so that the squatting pan can still serve as a urinal for girls (or boys). This way the efficiency of the (public) toilet is greatly increased.



The squat hole cover should be designed so it can be securely closed with 2-4 stainless steel screw bolts. When the squat hole is in use the screw hole needs to sealed.

◊ Urinals for boys can be made in many ways. A gutter on the ground causes substantial splash over the legs of the users and is not recommended. A higher gutter is best made from a plastic rainwater gutter, rather than masoned and plastered (middle picture below). To reduce splash, a stainless steel or plastic wire mesh can be placed at the bottom of the urinal.

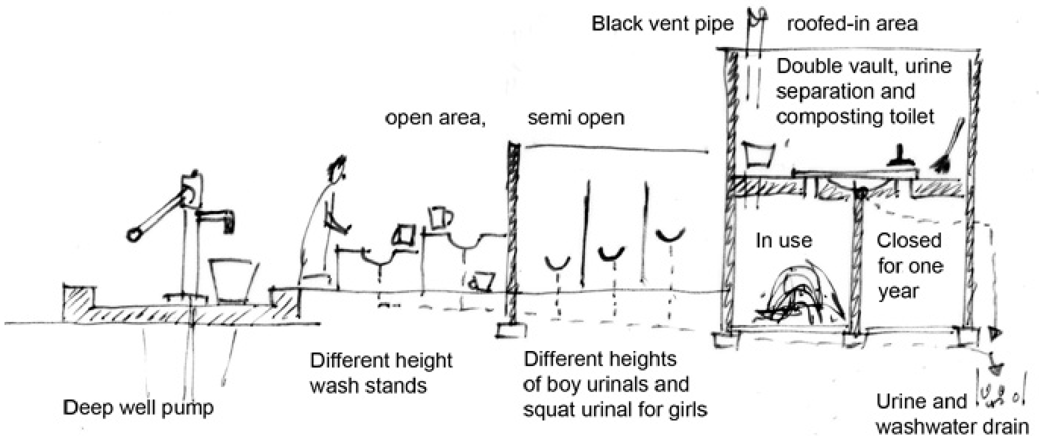
Left: This urinal wall design is not recommended as urine will splash on the legs. The gutter must be minimal 30 cm deep and the painted wall section minimal 90 cm high

Right: This low-cost series of urinals is made from plastic buckets and placed at different heights in a nursery home in Nakuru, London.

◊ A squatting pan which does not have a distinctive difference between the urinal side and the anal washing side should be avoided. In the design pictured right, both sides can be used. In this case, both sides are to be drained as "black water" and the urine should not be collected for agricultural purpose.

◊ Hand-washing with soap and drying should be an integral design of any toilet system. Thoroughly drying the hands after washing will avoid rapid re-growth of bacteria. Bacteria reproduce very fast in a warm (hands) and wet environment.

◊ In frost areas, the hand-washing facility in public (school) toilets can be located in the centre to reduce the risk of freezing or drawn from a frost-free deep well pump directly outside the toilet. A number of containers for anal washing should be available at the wash stand.



6. Construction of Vaults

The construction of the vaults under the UDT or UDDT can be done in many ways and would depend on the available building materials, local skills and the desires of the house owner.

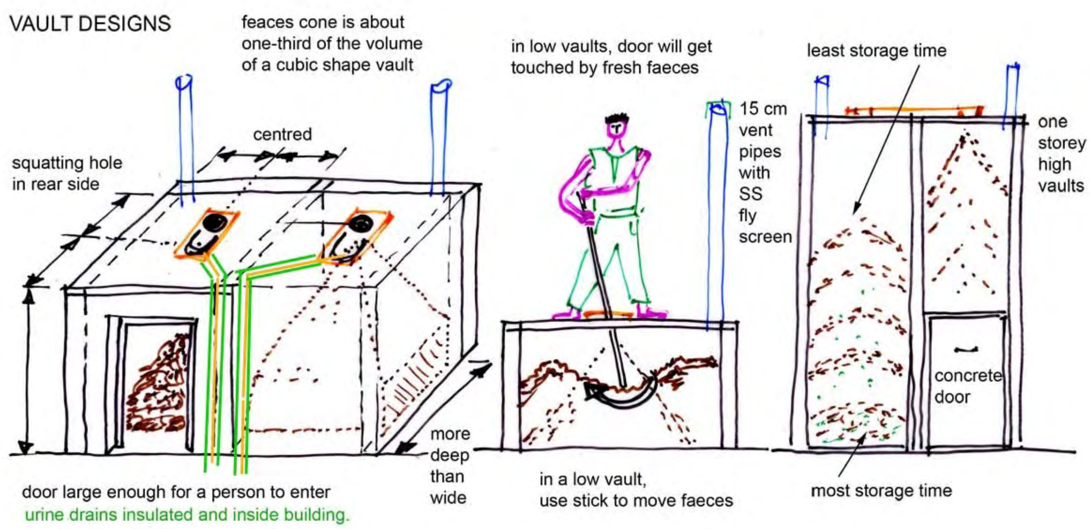
- The size of each vault depends on the number of users and the retention period. The recommended minimum retention period of the sealed vault is one year in climates with a cold period. The volume also depends on the height of the toilet floor above the land. With a high vault, the horizontal section of the room can be smaller than with a low vault (see Annexe I). A higher vault, however, requires an increasing construction height and extra stairs for a separate building.

- When the vault has approximately a cubical shape, the available volume for the faeces and drying agent is about one third of that cube. The faeces will reduce in warm weather to less than half of its original volume because of bacterial digestion, but not in cold or freezing weather.

  Per 5 persons, a volume of about 1.8 litres per day (including 50% drying agent) should be estimated. For one year and considering some reduction in the warm period, a volume of 350 days x 1.8 ℓ/day ≈ 0.6 m^3. The cubic vault volume therefore is minimum 3 x 0.6 m^3 = 1.8 m^3. This means a rectangular space with a floor plan of 1.0 m x 1.8 m and 1 m high. A floor height of 1 m requires 5 steps of 20 cm.

- The construction design should consider the thickness of the walls. In the picture right, natural stone was used for masoning the walls, requiring a lot of space. The toilet floor is 8 steps high. Since heavy separation walls are not required in the upper toilets, ample room is available for the squatting pans.

- To better utilize the volume of a low vault, the fresh excrements can be pushed away from the middle by using a stick through the squatting hole. High vaults with the toilet on the first floor makes this unnecessary.

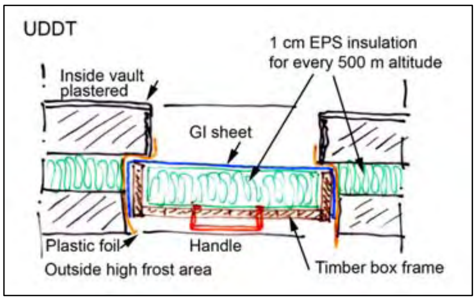


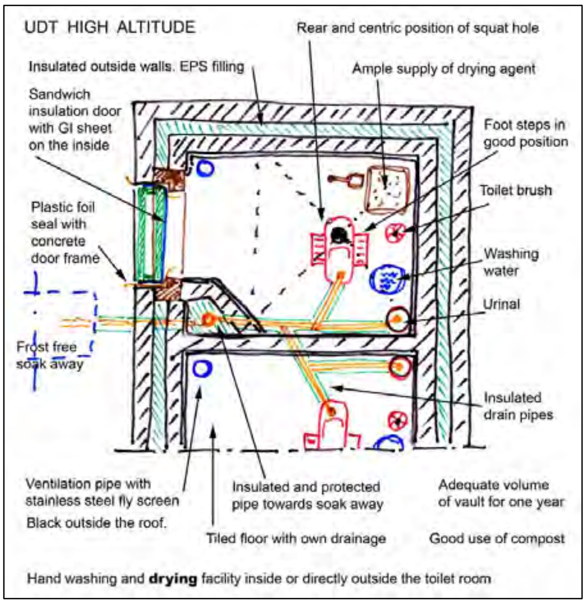
- Urine drains need to be thermally insulated down to the soak away. Inside the vault corner, a protective wall can be masoned around the pipe insulation. The connection to the toilet pan must be serviceable from below.

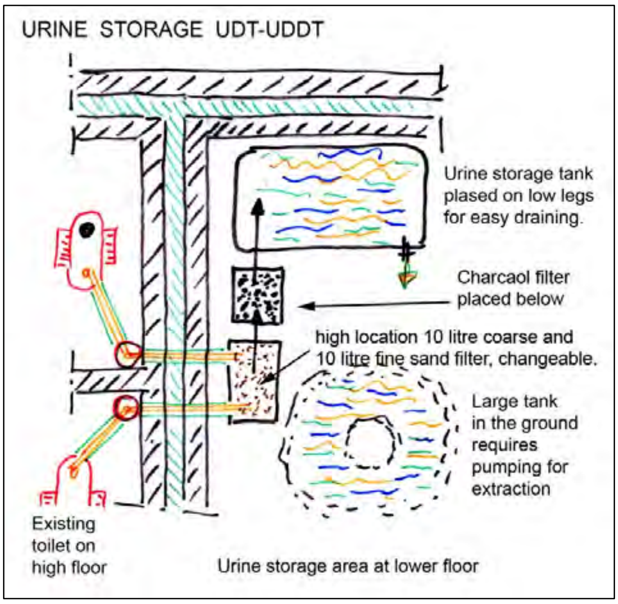
- In frost regions, the urine needs to be stored in a place where it will not freeze, such as inside (below) the house if this area remains frost-free. Alternatively, the urine (and anal wash water) should drain sufficiently deep underground to avoid freezing. This means that the soak away needs to be below the frost level and the piping towards the soak away needs to be inside the building and insulated.

- An insulating timber door can be made with the inner side lined with galvanised sheeting to protect the wood from the faeces. A timber doorframe, however, is still vulnerable to rot at the bottom part due to small amounts of moisture from the faeces. It is more economical to cast thin concrete slabs on site and fit them directly into the masonry.

To allow easy opening of the door in the future, plastic can be placed in the joint between the door and the masonry. Then the 2 cm joint is filled in with mortar. The urine pipe needs to be insulated and protected from the sun.

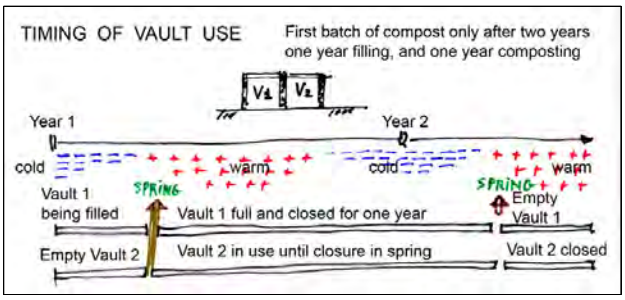






With a newly built UDDT, the economic benefit of the compost starts only after about two and a half years. The urine can be applied in half a year. In outhouse buildings, the composting process will stop during the winter. In areas with a very long winter, the actual composting period is only half a year.

During the first year, vault 1 is being filled and is closed at the start of the spring time. During the summer period, composting takes place in vault 1 while vault 2 is in use. The next spring vault 1 is emptied and the compost used on the fields. Vault 2 is then closed for composting. A half year later, the crops are harvested. The economic benefit is from a better harvest due to the use of soil improvement compost and the urine fertilizer.



Ventilation

To avoid the UDDT develops bad smells, the content needs to remain dry and the two composting vaults ventilated. There are several options for ventilation. In all options, the toilet cover or squatting pan cover should close well over the squatting hole.

(a) Natural Draft

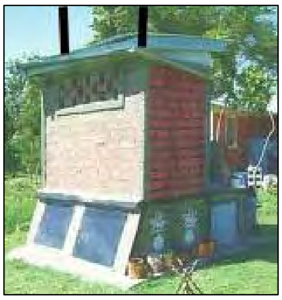
Each vault requires a ventilation pipe with an inside diameter of minimum 15 cm. The ventilation pipe should be black high density polyethylene (HDPE) and extend minimum one meter above the roof. When the sun warms up the black pipe, a vertical airflow will occur inside the pipe and cause an under pressure in the toilet room. This way no air or smell will enter the toilet room from below. In addition, when in a heated and insulated bathroom the inside air is warmer than the outside air, the room temperature will heat the air inside the ventilation pipe and a natural up draft will occur, evacuating any odours.

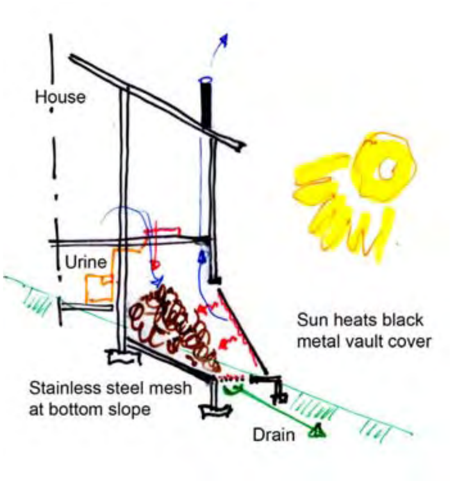
The top of the pipe should be covered with a stainless steel or aluminium fly screen.[21] Flies that develop inside the vault will fly to the light and die in the ventilation pipe when they cannot escape.

A further improvement is the installation of a rotor that creates suction with a little wind (picture).

(b) Extra Dehydration by Solar Heating

The (black metal) doors of the two vaults below the toilet need to be facing the sun, preferably inclined for increased heat absorption and not insulated.





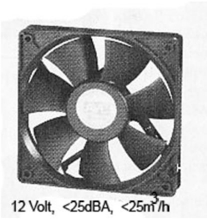
In the sketch, the vault floor is inclined 30°, allowing some liquids to drain down into a gutter through a stainless steel mesh.

The warm air disappears through the black chimney pipe (covered by a stainless steel or aluminium fly screen).

(c) Electrical Ventilation

Electrical ventilation requires a small electric fan, such as is used in computers.[22] These are 12 Volt, while some can be wired for only 7 Volt. The lower volt wiring will reduce the volume of air extracted per hour. A 12 Volt transformer needs to reduce the 220V AC into 12V DC.

The small ventilators come in a wide range of capacities in the number of m^3/hr or air displacement per hour and all of them produce some sound (decibel = dBA). More than 20-25 m^3/hr is not needed when operating continuously. <25 dBA is a low sound level and <15 dBA is hardly noticeable, but these are more expensive.



12 Volt, <25dBA, <25m³/h

The small fan depicted right has an outside diameter of 6 cm x 6 cm and needs to be fitted on a plate with a hole and in the ventilation pipe. Even when the power is off, if the sun shines, it will heat up the black 15 cm diameter ventilation pipe and the rotor of the fan will be moved by the air movement.

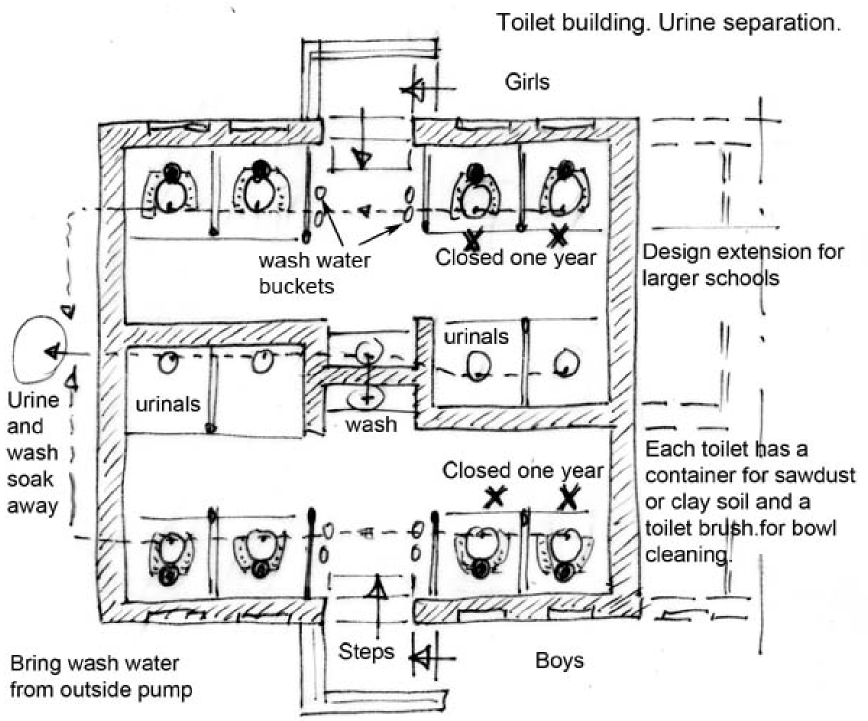
Such electrical fans are used in apartment complexes.

[21] A nylon or plastic fly screen will soon deteriorate because of the UV radiation of the sun. Galvanize will rust.

[22] Price ranging from USD 10 to 30, depending on size, power and noise level.

Communal Toilet Buildings

The design for communal toilet buildings (such as for schools) should be compact to minimise floor and roof area. The urinal options should be double the number of faecal drop areas.[23] A quality closing design of the UDDT reduces the amount of building construction.



In situations where elderly and invalid people are using the UDT or UDDT, steep stairs should be avoided. A slightly inclined ramp can lead to the door. The ramp, the entrance door and the toilet itself should be wide enough for wheelchair users, as well as providing assistance to invalid people. Inside requires a pedestal toilet type and support railing.

Since the toilet for invalid persons has a very low floor and composting chamber, it should only be used for the intended target group. Having a clear painting on the outside of the unit will help selective use of the facility.

In both of these designs, the ramp and the door to the toilet do not allow wheelchair access. The user needs to park below and to hold onto the railing bar to climb the rather steep ramp. The railing should continue inside.

[23] Some standards recommend a minimum of 1 toilet for every 20 students. Thus, for every 60 students, there should be minimum one squatting toilet and two urinals.

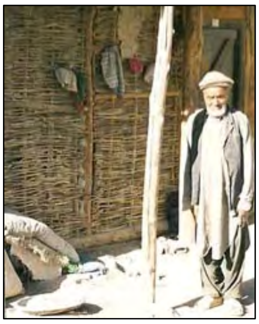
7. INSULATING INSIDE PLASTER WORK

The acceptability of the new toilet facility depends on three issues.

(1) There are no bad smells.
(2) It looks good, preferably with ceramic tiles.
(3) The bathroom is warm in the winter.

Available in most markets is water-resistant (green) gypsum plaster board, which can be tiled. The gypsum board, however, is difficult to transport in whole sheets, especially to remote villages. The high cost of transport added to the high cost of the material makes it unaffordable for many villagers.

A very effective low-cost option is plastered willow (wattle) panels. This technique exists already for several hundreds of years, but the making of the willow panels for this purpose has been reduced due to the low status of soil plastered willow walls.

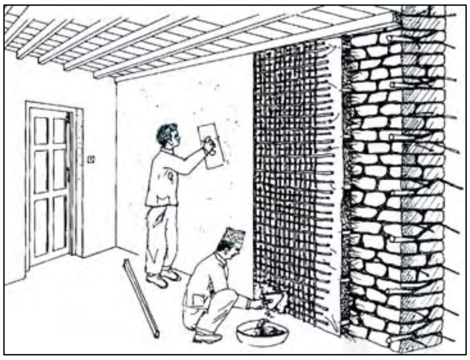


200 years old

Commercially manufactured

Demonstration with cement plaster

The use of wattle wall construction is environmentally sustainable, as well as durable when properly executed. When the ancient technology of clay-loam plaster is replaced with a lime-cement plaster, the surface becomes more durable and is less subject to damage or erosion.



Painted pegs with anchor nails are masoned into the cement block or stone wall during the construction or long pegs are hammered in between the stones of an existing wall.
Behind the wattle wall (or wire-mesh), a plastic sheet and straw filling, glass wool or EPS can be applied. Straw needs to be dusted with lime to minimise insect infestation.
Pre-producing plastic bags with straw is an effective working method.

The wattle panels need to be manufactured in the village directly after harvesting the thin, fresh willow branches. Either full wall or half wall height panels can be made, the latter being easier to transport. The panels can be fixed directly on the wall, while fixing the panels onto pegs or horizontal strips will create an air cavity providing additional thermal insulation.

Willow plantations and growth can be stimulated with the use of "grey water", urine application and compost.

Photo Right: 300-year-old house.

<u>Expanded Wire-Mesh (Lathing)</u>

When willow mat panels are not easily available, metal wire mesh or glass fibre can be used. Metal thickness galvanised openings horizontal <3 cm x vertical <1 cm. Gauge 20-22.

In the Pakistan programme, natural stone walls and cement block walls of houses have been insulated on the inside by a cavity using a thin suspended plaster cover to create a durable surface as follows:

(1) Horizontal timber support strips of minimum 2 cm x 2 cm are fixed into the existing wall by means of plastic screw plugs. The 2 cm air is an insulating cavity, while the horizontal strips minimise vertical air flow through that cavity. The plastic screw plugs are needed when the wall can become moist. As an alternative, galvanized 2 mm anchor wires can be masoned into the wall to which the horizontal strips are tied. The timbers need to have a protective paint coat on the wall side.

(2) Plastic foil (0.15 mm – 0.2 mm)[24] is stapled over the strips to create a moisture barrier. This plastic foil can be substituted with a 5 mm (or thicker) PE foam sheet, which provides a little more insulation. Still better insulation is achieved with 3-5 mm PE-backed reflective foil. In this case, the reflective side faces the wall to avoid that the cement touches the reflective surface. For thermal resistance, it does not make much difference which side the reflective surface is facing.[25]

The plastic foil is required because the humidity from inside the (bath)room should not go deeper into the wall than the (warmed up) plaster work. Otherwise, it would condensate inside the cold wall and can freeze in the winter. Increased humidity inside the wall will also reduce its thermal resistance and the bathroom will become extra cold. Moreover, freezing of moisture inside the wall will destroy the cement masoned joints or blocks.

(3) Over the plastic (or PE or PE + reflective foil), **expanded wire mesh** is stretched and stapled to the horizontal support strips or pegs. The expanded metal mesh has a fine maze (about 2 holes per cm in one direction). The fine maze expanded metal is preferably galvanized to avoid rust forming when some parts are not fully covered with cement plaster. It is also possible to use **fibre glass mesh**, but this material is not easily available.

(4) The expanded metal mesh is lightly sprayed with a cement water mix. This process is called "burning" or "priming" and improves the adherence of the cement plaster to the expanded metal.

(5) The next day the cement plaster paste is pushed partly through the mesh and will remain in place. The surface will not be totally smooth. It should be allowed to set for one night.

(6) When the plastered wall needs to be strong, such as the lower wall section in schools, a second expanded metal mesh is applied with the cement plaster.

[24] This can be recycled plastic. The plastic inside the cavity is protected from damaging UV radiation.

[25] Additional information on wall insulation techniques, basics, calculation of the insulation values and wall, roof and floor insulation is available on website: www.nienhuys.info, page: "Thermal Insulation".

The use of the (½ in.) expanded metal mesh and plaster over a plastic foil and cavity has proven to be a successful wall insulation technology, which can be learned in one day by any mason.

(7) The third day, a second (finer) plaster coating is applied to smoothen or straighten the surface. As an alternative, the first plaster coating can also be tiled, provided the plaster is straight to create flat tile work.

(8) Bathrooms and showers can be finished with tiles or waterproof paints. An impregnating primer will be required before the application of paint. It is recommended to use large tiles to minimise the number of joints. Joints can develop mould in cold humid circumstances.

(9) The right angle joints between the floor and walls can be left partly open and sealed afterwards with sanitary silicon mastic (do not use butyl mastic).

Galvanised Smooth Wire

In Tajikistan, the fine maze galvanized expanded metal was not readily available in the market and a galvanized smooth steel mesh (2-2.5 cm square) was tried instead (Gauge 20). Two overlapping wire mesh were applied to create holes of about 1 cm. Because of the large holes and very smooth wire, the plaster did not adhere and fell through.

The technology needed was to place moisture absorbing cardboard paper directly behind the (galvanised) wire mesh. This will hold the plaster in place. A single mesh can then be larger. Behind the cardboard paper, plastic foil should be placed to stop humidity transport into the outside wall and assist in curing the plaster work.

Carton/Cardboard Paper

The technology of a thin free hanging cement plaster coat can be realised by using wire mesh (maze 5 cm) backed by thin cardboard paper, followed by plastic foil. The cardboard paper can be smooth or single-sided corrugated packing paper. The cardboard paper needs to be (slightly) moistened to avoid that the dry cardboard paper sucks all the moisture out of the thin plaster layer. Some experience is required to obtain the right moisture level as this depends on the absorption capacity of the used cardboard paper. When the pasty plaster coat is applied over the thin wire mesh, the cardboard paper will absorb some of the moisture and the plaster will stay nicely in its place and harden. Corrugated cardboard paper will absorb more moisture. The plastic behind the cardboard improves the curing and creates the humidity barrier. The next day, an additional plaster coating or eventual tile work can be applied.

The tri-ply product (plastic + cardboard paper + wire mesh) is available in the market in Europe. A stainless steel wire mesh is also available for sea-side climate conditions. Stainless steel will not corrode in the salty sea air environment, but is far more expensive than galvanised wire.

The advantage of the plastic + cardboard paper + wire mesh construction is that less metal is used and therefore the combined product will have a lower purchase cost. The second advantage is that the combination comes on ready-made rolls and saves on labour for the application.

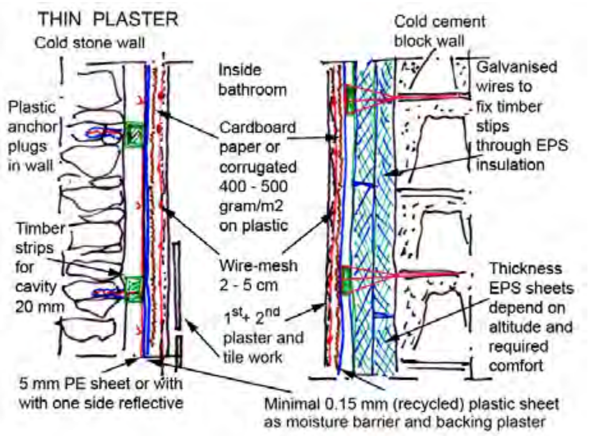
Based on the above product information, it is suggested that suitable cardboard paper (400-500 grams/m^2) is sourced in the market and some tests are realised to find the best combination and the largest wire mesh openings. When a good combination has been field-tested, the rolls can be locally assembled for house insulation.

Several combinations can be marketed:

(1) Plastic + cardboard paper + wire mesh
(2) 5 mm PE foam + cardboard paper + wire mesh
(3) PE/reflective foil + cardboard paper + wire mesh

The sketch gives an impression of the construction. The thermal insulation of the left-hand sketch can be further improved with additional cavities, glass wool, etc.

An option with the right-hand sketch is to apply EPS sheets and a cavity. Glass fibre mesh can be used as an alternative to metal for the exterior wall application.

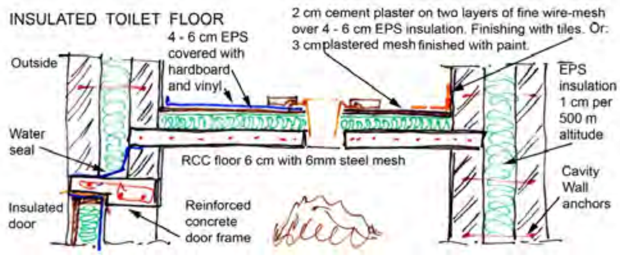


Thermal Insulation

The amount of thermal insulation is a comfort issue. The building can be insulated from the outside using a cavity wall and filling the cavity with insulation material, such as expanded polystyrene (EPS) or straw. Four every 500 m above sea level, 1 cm EPS or 2 cm straw is required as total insulation material inside and outside.

Floor Insulation

The level of comfort of the toilet room is greatly influenced by the floor temperature. When the space is only slightly heated (frost free), poor floor insulation will cause the floor to feel cold. To cover the small width over the vaults, only a thin reinforced concrete floor is required with a 6-8 mm steel bar mesh (square 10-15 cm).



Over a layer of medium density EPS, two options are possible:

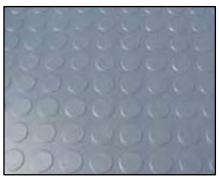
(1) A hardboard or plywood sheet over which a vinyl floor is laid. It is important that water does not get under the vinyl when the floor is washed. Optional linoleum flooring is possible; the linoleum can be hot sealed to make a waterproof floor.

(2) Over the EPS insulation a sheet of fine maze wire mesh is laid and plastered. A second wire mesh is placed and plastered again. This way a stiff and thin cement floor is created. This floor can be tiled as finishing and is strong enough for heavy people. When the cement floor is only to be finished with a coat of paint, a third thin and dense cement plaster is applied as finishing.

Bathroom with two UDDT plastic squatting pans, sawdust/wood ash bucket, toilet paper, toilet brush and posters. The cement floor is covered with vinyl and synthetic carpets for warm feet. A wash basin and soap is visible on the left. The added footsteps next to the squatting pan are from EPS. EPS is insulating and provides warm feet when using the toilet, but it is a weak material.

In cold areas, keeping feet warm is very important. The currently produced plastic squatting pan has no footsteps incorporated. EPS is very warm on the feet, but will easily break, become dirty and will need to be replaced regularly.

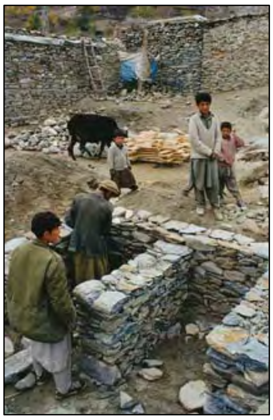
In this situation, it is recommended to make separate timber footsteps that fit precisely on the plastic pan and the floor, and cover these on the top and sides with linoleum or flooring rubber. The covered plank can be pasted onto the plastic squatting pan and vinyl floor with sanitary silicon mastic. This way a durable and cleanable footstep is created.



Linoleum or rubber flooring material comes in a variety of colours and profiles. With an anti-slip profile, the surface must be easy to clean.

8. PROGRESSIVE DEVELOPMENT

The construction of a new and more sophisticated toilet system, when in the past only an outside open pit or a bad quality communal latrine was available, usually requires a substantial financial and labour investment for the house owner.



The basement of a double vault composting toilet being constructed in dry-stone masonry by the house owner and a mason. The existing pit latrine is visible in the rear of the yard.
The main reason for building a new toilet system is to obtain an improved situation. However, this can be realised in phases as long as the basis is well made and modifications can be easily made.

While it is argued in this paper that the introduction of a new toilet system should be better than the current system, the new toilet system can be realised in phases in order to spread the expenses. Essential in such a phase development is that the new elements realized should not prevent further upgrading.

When the double vault construction and the squatting pan with urine/wash water drain is made correctly, the plaster work, painting or ceramic tiles can be realised in a later phase when funding or time becomes available. When there is a market for urine, the outlet can then be modified.

The following are some examples of different upper structures of UDDTs being realised in the project areas. In these examples, thermal insulation is not yet included.



Left: *Stone vaults and cement block upper structure with GI sheet roof. This wall allows easy plastering and future tiling which can be a suitable solution at 1500 m altitude.*
Middle: *Stone vaults with upper structure from a timber frame with corrugated fibre cement sheets. Because the toilet area is spacious, in a later phase this durable outside wall can be insulated on the inside with glass wool or EPS with a finishing plaster layer or tiles.*
Right: *Vaults made from baked bricks, upper section already plastered and painted. Because the building is new, the second vault door has not been placed yet.*


Left: *The vaults are stone masonry with a concrete floor. The floor can be tiled or insulated later when funds are available. The upper building is a temporary hardboard construction.*
Right: *The narrow vaults are covered with a plank floor and then vinyl, which is warm to the feet. The walls are nicely plastered. As long as the contents of the vault remain dry, a timber construction can be a durable solution.*

9. BUILDING IN THE WINTER

In higher altitude areas, the winter period with night frost is long. It is not recommended to build with cement mortar during this period, as the hardening of the mortar will be negatively affected and poor quality concrete or masonry joints and plaster will be the result.[26]

Nevertheless, in the rural areas of the higher altitudes (above 1500 m), the main building period is after the harvest and before the land defrosts in the spring. Utilizing this period, when no agricultural labour is undertaken, for house construction is therefore desirable.

The minimum temperature for cement mortar to harden is about 5°C. The reaction between the cement and water is minimal and thus the setting time of cement mortar at 5°C is about 10 hours. The long setting time will cause what little water there is in the mortar to evaporate and prevent chemical bonding. When the water : cement factor is larger than 0.5, the water will absorb any soluble salts and cause efflorescence in the masonry. Mortar that dries out before hardening will be porous and cause leaking masonry or concrete.

A solution is to build a greenhouse construction over the masonry work. This way the sun warms up the building materials on the inside, as well as the already constructed walls. When the sun disappears, the greenhouse needs to be covered with a tarpaulin to create an insulating air layer. In addition, the masonry work and building materials for the next day need to be covered with thick straw-filled blankets to reduce cooling down at night.

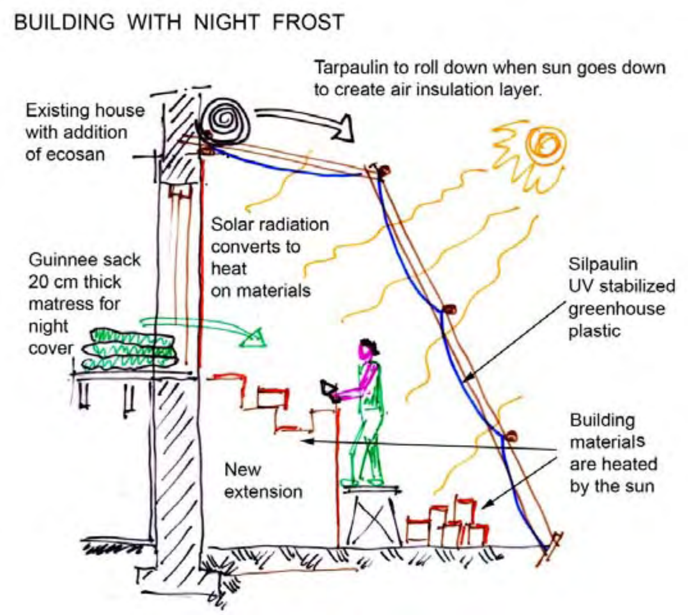
The insulation straw blankets (1.5 m x 3 m) are low cost and easy to make from tarpaulin on one side and jute on the other. Placing the blankets with the tarpaulin side on the masonry reduces evaporation.

The greenhouse must completely surround the new construction and be closed on the upper side to avoid air leaks.

Most heat gain is obtained from the eastern morning sun, south midday sun and western evening sun.

The greenhouse also avoids cooling of the construction by wind.

When dry cement blocks are used, watering them with warm water will increase the heat storage.



If there is no built wall on the non-sunny side, a double tarpaulin should remain at all times for thermal insulation.

Fresh masonry work and concrete generates a little warmth during the hardening process. By insulating the masonry work, the warmth from the building materials and the hardening process are retained and the hardening process will continue.

[26] It is possible to use additives in the cement mortar, but for small quantities and without good experience, this gives poor to very poor quality concrete. Reinforcement bars can corrode as well.

In a school building project in Gilgit, Pakistan (1500 m altitude), a greenhouse tent was used for 4 m high stone masoned walls. It became so warm inside the greenhouse that the masons worked dressed in thin clothes and bare arms. They loved it, not only because it was nice and warm, but also because they had a job while other masons had to stop working as soon as the night frost period started.

In the above Gilgit example, locally available crystal clear PVC was used, allowing vision through the plastic. The material, however, was not UV resistant and became brittle with strong night frost. Therefore, it could not be stored and used again the next winter. Silpaulin or other UV-resistant, translucent UV greenhouse foil should be used.

When the durable UV-resistant Silpaulin is used, all the material can be re-used the next season. The economic benefit is substantial as at nearly all altitudes the construction work can be extended for two months, while the strength of the concrete and masonry work will be improved.

Road construction companies use blankets and tarpaulin covers to protect freshly masoned retention walls from cold wind, night frost and evaporation.

On the shaded side of the mountains, the greenhouse and insulation will extend the building period without the need of chemical additives.

When the toilet is entirely built from cement blocks or stone masonry, all the cement mortar related work, including concrete and tiles, have to be realised before the night frost period. When the upper part uses a non-cement mortar construction technique, this can be done during frost.

Because the inside of the vaults or the finished building is a little protected from wind and night frost, plastering can still be done. Outside plaster and paint finishing should wait until the nigh temperature is above 5°C.

Resume

During the winter period, the daytime temperature can be very comfortable in the sun. However, due to clear skies, the night temperature can drop very low. The greenhouse allows all the building materials to be warmed up by the sun, while the extra night insulation of the greenhouse prevents cooling off at night. The construction company can store the transportable greenhouse in the summer for re-use the following winter.

10. Sanitary Napkin Incinerator

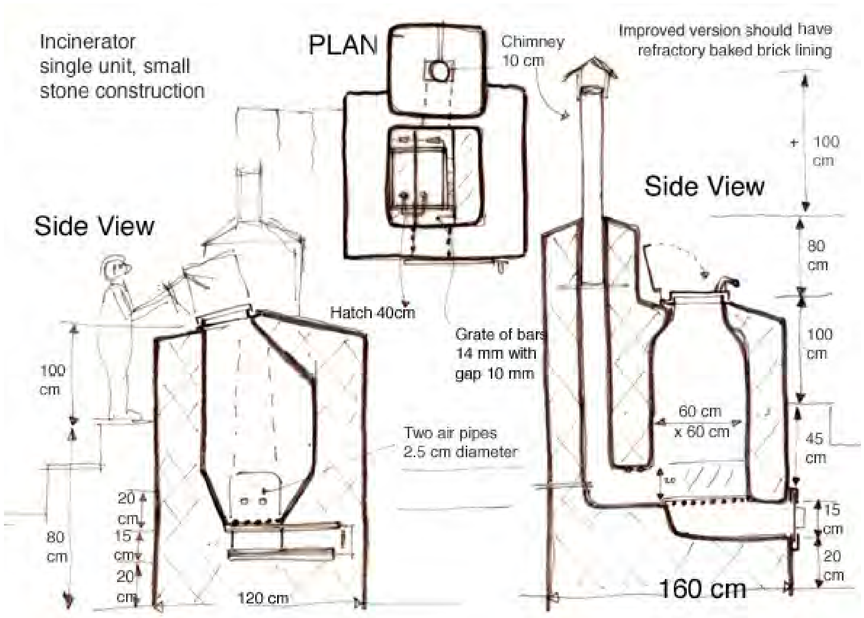
Sanitary napkins, cloth, plastic and other non-compostable materials should not be thrown into the UDT or UDDT. In addition, materials that do not compost rapidly (such as maize cobs or fruit seeds) should not be deposited into the UDDT unless totally shredded or pulverized.

Women who use the toilet need a place to deposit their sanitary napkins. At home this would be a container, but the content of the container needs to be emptied safely. Burning the content of the container is often done, sometimes in combination with used toilet paper. This, however, causes large amounts of smoke, especially when extra fuel is not added to the burning oven; the oven is poorly constructed without aeration from below or lacks thermal insulation; or when there is no chimney.

It is uneconomical for every household to have its own incinerator.

Drop hole for sanitary napkins in the UDDT of a public toilet (above left) with an external incinerator next to the toilet building (above right). This is only fired when full. Women expressed interest in having a low-cost incinerator in the village.

A good quality incinerator like the Montfort Hospital Waste Incinerator can be constructed at public buildings (schools and clinics). When the upper area is filled completely, the incinerator is fired with the aid of additional fuel to ensure a high burning temperature and complete combustion.



Sketch of a small stone-built incinerator for sanitary napkins and small amounts of waste from clinics. The hatch needs to be completely closed and remain closed when the incinerator is fired. Starting the fire is done with some kerosene and dry firewood from below. For Mark 1-9 designs, see the reference in Annexe III.

11. Contamination

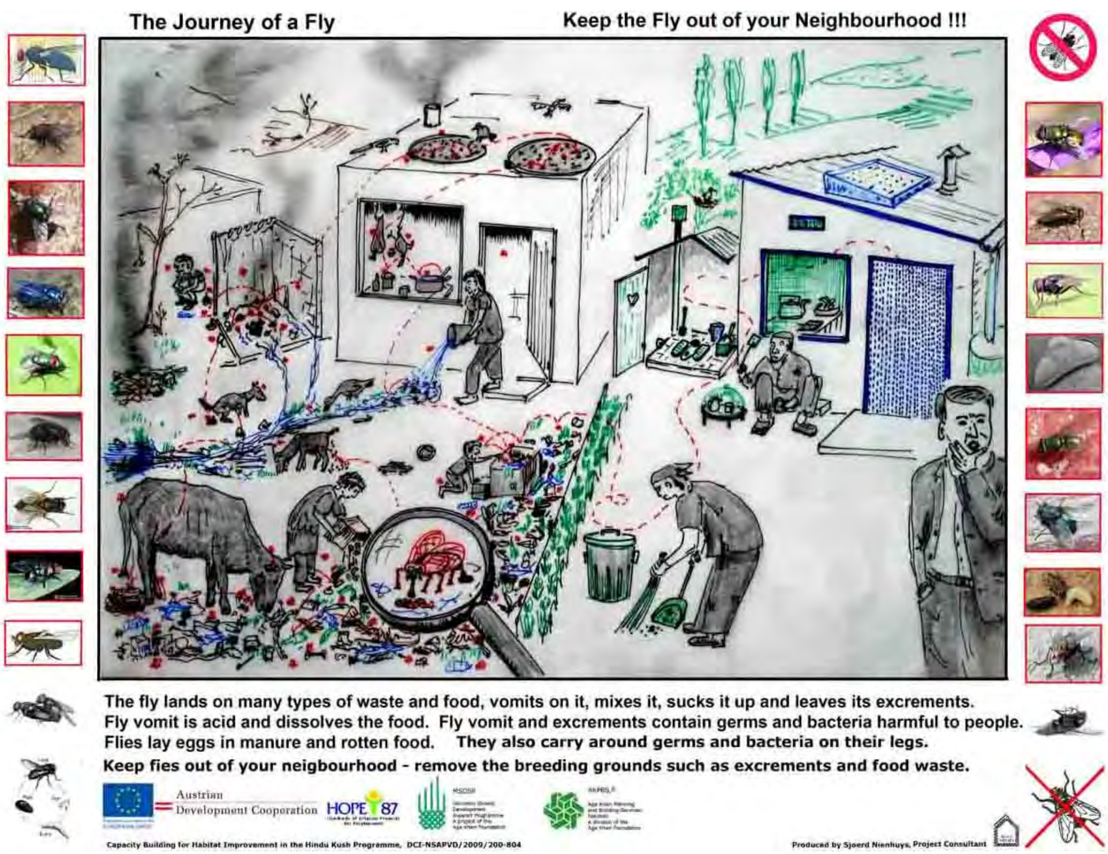
Open defecation, poor toilet habits, not keeping toilets clean and not adequately washing and drying hands immediately after using the toilet can spread diseases, which lead to diarrhoea, intestinal worms (helminths, amoebiasis, giardiasis, ascariasis) and other parasites and diseases. Such diseases can cause chronic weakness, fatigue, weight loss and even death.

Although people are very conscious regarding the construction cost of a new toilet or bathroom, they seldom calculate the cost of disease in terms of discomfort, lack of energy, lost working time, medicine and hospital bills.

After clean drinking water, careful toilet habits are vital to avoid contamination from fresh faecal matter. Urine is clean, but people's faeces contain a very large number of different bacteria and can contain parasites and worm eggs. Long-time storage (2 months) in an anaerobic environment, such as a biogas reactor, will destroy most of the bacteria and parasites, while aerobic or aerated composting (one year) will equally destroy them.

Bacteria and viruses are all around us and our body constantly fights those that enter by inhalation and through our drink and food. However, some bacteria, such as E-Coli that come from faeces, are very strong and only a few germs are needed to make a person sick. Flies are actively spreading several of these bacteria by their habits.

Open defecation attracts flies and spreads diseases.
Keep the flies out of your house and neighbourhood.



Read the text !!

The **UDT biogas system** and **UDDT composting** are good sanitation methods with good fly control and minimising possible contact with fresh faeces. Once the one-year closed vault of the UDDT is opened, the resulting compost can be handled without any risk. Effluent of a long retention biogas reactor is safe, although it may look bad.

Further hygienisation of the one-year UDDT compost can also be done in a separate black container which is placed in the sun. When the additional composting process reaches 50°C for one week, the additional purification is adequate. To ensure that all the content of the black container is treated, turning the matter over at least once is necessary (rotating containers).

Do not use or handle fresh human faeces. This does not mean that all excreta cannot be handled. Urine is also human excreta, but can be handled without sanitary problems. Excreta from cows and buffalo (eating normal vegetation food, without power food) can be handled without serious risk of diseases as well.

City sewage is a dangerous substance. It contains fresh human and dog excreta and the wet and warm environment is a breeding ground for many bacteria; it can also have other chemical or medicine wastages and poisons from households and factories. Therefore, in Germany the application of sewage sludge is prohibited on horticultural grounds, fruit orchards and pastures as it can contain heavy metals and medicine (pharmaceutical) residues. Manure (fresh from cattle which receive power feed) is also not used for horticulture or vegetable growing.

Well-composted UDDT material and urine do not have E-Coli[27] and can be used in the field for growing food crops. The nutrients from the compost and urine are absorbed by the plant by which the plant converts the chemical components from the compost (nitrogen, phosphor, calcium and potassium) into plant tissue. However, dust from the compost on the soil can still contain some dried worm eggs and thus contaminate the crop. For stalk food crops, such as maize and wheat, the risk of this contamination is negligible because these also have a secondary processing.

Food for Sale

When a farmer produces for personal consumption, using urine (diluted) or compost is no problem at all, but consumers buying fresh vegetable from gardens or greenhouses may not want those products when made with UDDT compost or urine. Several measurements are possible to reduce buyers' concern:

A. Explain that the food has been grown bio-organic and not from human excreta or sewage. UDDT and UDT compost or biogas effluent are no longer excreta.

B. Distinguish between food eaten raw or cooked and keep them separate. Food eaten raw can be grown with vermicompost, Struvite or other chemical fertilizers.

C. The application of urine or UDDT compost can stop one month before harvesting. Continued irrigation and sunshine will eliminate possible contamination. Continued fertilization of the plants in the last phase of the growing season may not be necessary to obtain a good crop.

D. Further processing of the UDDT compost can be done through worm composting or vermicomposting producing "wormcast" (Internet picture right). The earthworms fully digest the UDDT compost and produce a concentrated type of fertilizer that is totally free from pathogens, parasites and intestinal worm eggs. The concentrated "wormcast" material (without the worms) is **high value fertilizer and can be safely used for many purposes.**

[27] Living E-Coli bacteria from <u>fresh faeces</u> spread in the field can pass through the roots into the plants (endocytocis), but after some time these bacteria will die. This time period differs per plant type. Plants actually consume microbes as food source, totally converting and destroying them. E-Coli is avoided by one-year composting.

E. Root crops such as potatoes, carrots and beetroot can be planted in composted soil and only irrigated with (diluted) urine during the first months. Generally, the nutrients from compost are absorbed slower than those from the urine, but many root crops require several months to mature.

F. Apply the compost or urine only for tree nurseries, (fruit) trees and bamboo forestry. Since high altitude areas still require plenty of firewood and construction timber, but suffer greatly from deforestation, tree planting is extremely necessary. Planting young trees with compost will improve water retention. Bamboo produces quality construction material and for making furniture and household items (photo right).

Fertilizing Fruit Trees

When UDT or UDDT compost, urine or biogas effluent is used as fruit tree fertilizer, the farmer should understand the effect of the fertilizer on certain types of fruit trees. Most fruit trees, such as apple and pear for example, produce their fruit as a survival mechanism and require fertilizer only in the spring. If soil conditions are poor, they will produce plenty of fruit. However, when these trees are given too much fertilizer following the initial spring fertilization, they will grow rapidly, but not produce many fruits. In addition, they will become more vulnerable for lice. Fruit production from apple and pear trees also depends on correct annual trimming during the winter. Some fruit trees should only be fertilized when the fruit starts growing, such as apricot.

Use of Urine as Plant Fertilizer

The air humidity in higher altitude areas is generally low, while lots of sun will further lower the air humidity. In such cases, the urine needs to be diluted with water or "grey water". The urine to water dilution ratio depends on several parameters.

(1) The most important is the general climate condition and air humidity. If it is a dry, hot climate condition, such as can occur in mid-summer in the Himalayas, evaporation will be high and therefore a dilution 1 urine : 5 water and up to 10 water is recommended. In middle India with a very hot dry season, fast growing banana plantations (lots of leaf development) do best with 1 urine to 10 water.

(2) In cooler seasons when evaporation to the air is low, the dilution can be less, but going below 1 urine : 1 water does not seem to be useful.

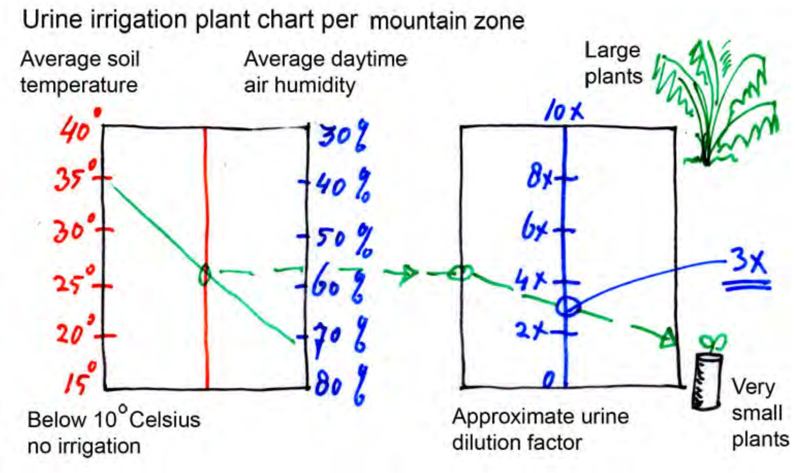
(3) In temperate climates, such as Sweden, sometimes no dilution is done on clay soils as these do not easily absorb water. The distribution should be done very carefully near the plant stems and never onto the leaves of the plants because this may cause burns.

(4) Application of fertilizer should be during the main growing period; that is, when the plant grows most and produces many new shoots and leaves. Once the plants are through their main growing period, less fertilizer is required.

(5) Composting urine with plant waste or with other compost is not advised because the aerated composting process will reduce the nitrogen content to about half, while the plant roots will only absorb about half of the remaining nitrogen.

(6) There seems to be no reasons to restrict the use of urine for root crop vegetables (potato, carrots, beetroot, etc.). However, since research is still going on, several farmers have decided to harvest the root crop only after the crop has been watered a few times with plain water.

It would be useful if the local agricultural university or institutes develop test areas for urine application and make recommended dilution charts for each type of crop and its growing season related to the local climate and soil condition. This is important because the values will differ per plant, season and altitude. High altitudes have more evaporation of the water component, but slower plant growth.



Urine Dilution Factors per Plant Type

Altitude ->	**1500 m**	**1500 m in Greenhouse**	**1750 m**
Soil Temperature	5° - 10° - 15° - 20° - 25°	5° - 10° - 15° - 20° - 25°	5° - 10° - 15° - 20° - 25°
Plant A small			
Plant A medium			
Plant A large			
Plant B small			
Plant B medium			
Plant B large			
Crop C small			
Crop C medium			
Crop C large			

For vegetables, other plant definitions can be given, such as the number of weeks.

12. AWARENESS AND ACTION

Three categories of households need to be considered for the installation of a better and more sustainable toilet sanitation system.

A. Households having no toilet sanitation. Some of these people are dependent on public services near their house or practice open defecation. However, the public services are seldom of good hygienic quality, provide insufficient privacy and often poorly maintained so they emit offensive smells.

In the two examples above, the public toilet (left) and the school toilet (right) have the following problems (not the worst examples):

- In some cases, over 100 m away from the houses and not illuminated at night.
- Open cesspool without adequate ventilation. Only a single vent pipe in the corner and no covers over the squatting holes.
- Missing footsteps next to the squat hole, causing dirty feet.
- Footsteps incorrectly placed next to the squat hole, causing faeces and urine to drop on the planking or cemented floor.
- Shape of the hole in combination with the urination area is not well designed.
- Plank floors remain moist with urine and will eventually deteriorate.
- Although a male and female section exists, general lack of privacy.
- The entire construction cannot easily be emptied when full. Commonly a new unit is built when the existing one has been filled up.
- Large fly population spreading bacteria and germs.

B. Households having an open out-house toilet and are looking for improvement of their toilet system, such as increased comfort, less health risks, etc.

In the left example (above), the out-house family toilet is constructed over the cowshed.

◊ The timber beam and branches floor is soil covered which absorbs spilled urine, but is otherwise very dusty.

◊ Human faeces are mixed with cow dung in the shed below and may contain human parasites. When the cow dung is spread over agricultural fields, these human pathogens and parasites are not destroyed.

In the two right-hand cases above, the villagers have their own aerated private toilet outside, but the structure is getting old and it only has one single vault without a urine drain. When collecting the compost in the spring for application on the land, the well composted lower material is mixed with rather fresh excreta from the top, causing possible health hazards.

Cow dung and toilet compost in the field.

C. **Households having a toilet with their existing house**, but are extending their house and want a better looking, more sanitary, easier-to-clean toilet. In some cases, house owners have environmental considerations.

The UDT or UDDT can be constructed on the ground floor with a small elevation of about one meter only, but it is better on the first floor with a whole storey below. In the first storey design, the two vaults can remain narrow, thus limiting the floor space required.[28]

The advantages of building the toilet and vaults <u>attached to or inside</u> the house are:

- ✓ Less construction material is needed when the existing walls of the house can be used as part of the vault and upper toilet construction.
- ✓ The toilet area is heated together with the house and when having adequate thermal insulation creates a comfortable space as compared to an outhouse.
- ✓ The toilet area is directly accessible without going outside.
- ✓ Freezing of water supply for washing purposes can be avoided.
- ✓ The toilet area can be used as a shower or laundry room.
- ✓ For old aged people, the inside toilet at the same level as the living/sleeping area is more convenient than going outside and climbing stairs.

The disadvantage is that when the construction is not properly made or not properly operated (kept dry and ventilated), the system can produce bad odours.

Areas of attention for in-house or outhouse UDT and UDDT are:

- ➢ The system should not leak.
- ➢ The floor should be waterproof.
- ➢ The piping should be accessible for repair and maintenance.
- ➢ The water piping should be insulated to avoid occasional freezing when the building is not heated.
- ➢ The water piping should be easy to drain when the house is not going to be occupied during the cold period.
- ➢ The ventilation must function at all times to assure drying of the vaults.

[28] See Annexe I with a drawing of a 12th century multi-storey building design of a UDDT.

12.1 Four Steps towards Action

The improvement of sanitary systems at the individual household needs to be mainly financed by the home owner. The owner needs to go through the following processes to undertake the action.

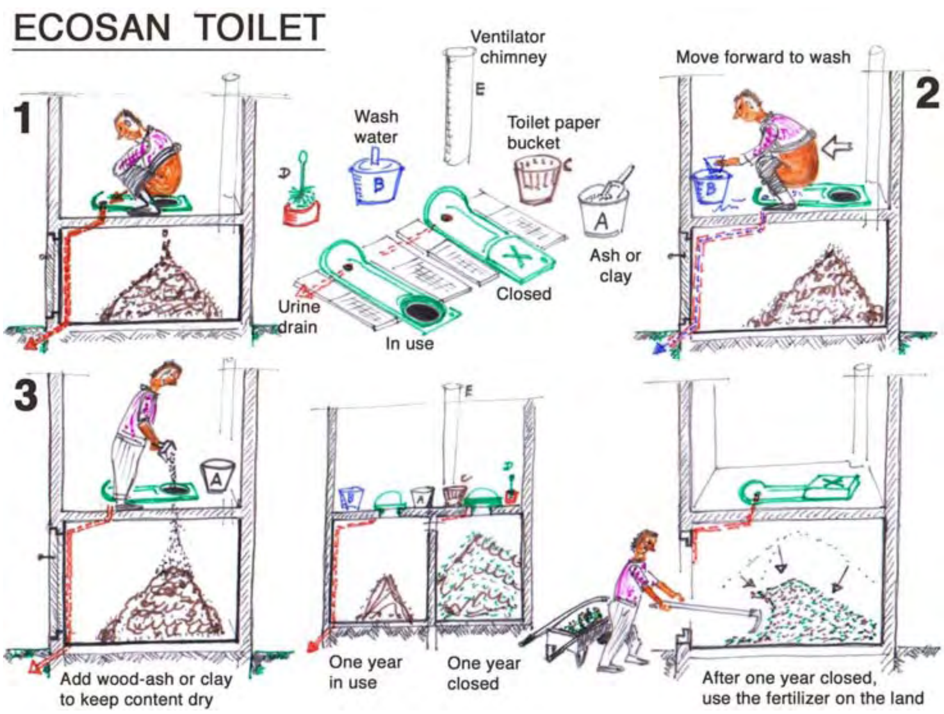
Step 1 – Information and Education about the Various Possibilities

When people travel, they might see and experience other sanitation solutions, such as the "Flush and Forget" toilet with nice tiles, and keep it in mind as improvements. Information provided therefore needs to include all aspects of realising a sanitation system – water supply, sewage processing at the municipal level, installation costs, operation and maintenance. Information is required about other systems like the aforementioned models A, B and C with the advantages and disadvantages of the UDT or UDDT designs.

Many promoters of new systems often present only the advantages, but each change of system or equipment has disadvantages as well; often being the costs involved or the required change of behaviour. Providing only the advantages gives inadequate and sometimes wrong information; leaving out some of the disadvantages is unfair information.

A scale mini model is a low-cost method of providing a visual picture of how a system works, is constructed and finished; and is better to understand than drawings.

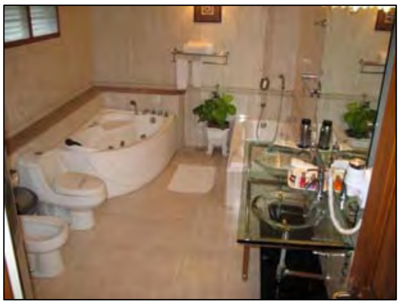
Various methods can be used to provide information. The best is showing operational models and seeing how it works, with peers having the new installation relating their experience and explaining how they realized the construction.



Posters are a good medium for general awareness creation as these can be placed in public areas. Schools, waiting rooms in clinics and municipal buildings are suitable areas for hanging them. The poster should indicate the name and address where additional information can be obtained.

The same picture material can be printed on small low-cost leaflets or triptychs, so people can take the information home and pass it along to family members and neighbours. When new information comes from various sources, it is better retained by the people.

Step 2 – Awareness
It is impossible to create awareness without providing a complete picture, including the installation, operation and maintenance costs. Providing different factsheets with the details allows the house owner to compare systems and evaluate what is most desirable in his/her situation. Talking to users of systems and comparing these with the system at home creates awareness of what is feasible and what is outside the economic scope of the house owner.



Comparing different bathroom designs with their long-term costs, advantages and disadvantages allows the house owner to be realistic about what is achievable.

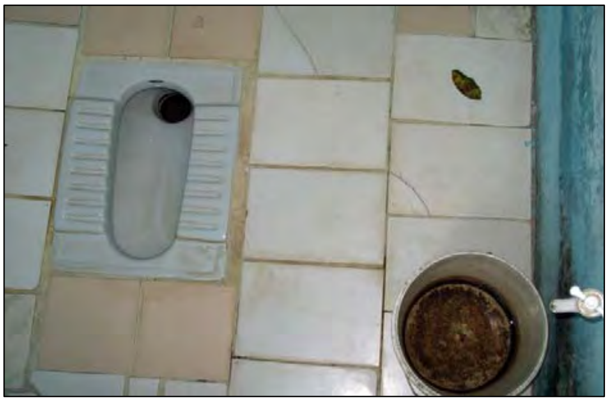
Step 3 – Motivation
The house owner needs to be in a position to change the situation. A person who rents a house will not want to invest his/her own money in someone else's property and if the owner undertakes the improvement, the renter might face an increase in rental fee. Changes are stimulated by dissatisfaction about the current situation, like a cold, smelly outhouse or frequent diarrhoea and health expenses because of contamination.

When only the installation or building costs are compared, the results may be different than when the social costs are included, such as absenteeism from school/work due recurrent diseases or intestinal worms caused by poor sanitation. A person often decides on a purchase or action because of three reasons.

- **Increased comfort** for him/herself and the family members. The comfort of a toilet is the ease of use, low cleaning costs, not too cold in the winter, no offensive smells, etc.

- **Economic benefit.** This includes lower operational and recurrent costs. In the case of UDT and UDDT, income can be generated from biogas and fertilizer. Lower recurrent costs may be possible for the municipal connection to the sewer, etc. In many cases, the high medical cost to cure intestinal diseases is an important decision influencing factor.

- **Status.** A luxury tiled toilet or specious and nice looking bathroom reflects on the owner. In some houses, the guest bathroom is often much nicer than the family bathroom, although seldom used. A problem with status is that a low-cost ecosan toilet often has a simple design and does not appeal as a luxury toilet from which the house owner can derive status.



Left: UDDT with the urine drain on one side of the squatting hole and the wash water drain on the other side. The unit is made by hand from good quality cement plaster and painted.

Right: A pour-flush toilet, tiled, with a water tap.

With the above two toilets, the UDDT is far more economical than the pour-flush toilet as it produces farm fertilizer, while the pour-flush toilet requires large amounts of water, a septic tank and soak away on site. In monsoon areas, the soak away gets flooded, while in high mountain areas there is often limited land for building a soak away.

After the left UDDT was demonstrated, the farmer using it remained happy, but others declined the design as being "not good". Further investigation revealed that the villagers did not mind the design, be it having one, two or three holes in the toilet pan. What they did not like was the cemented/painted floor. They wanted both a sanitary and visual improvement of their toilet, and not another type of cement floor. Without ceramic tiles, they were not prepared to invest in the unit.

This case indicates that people are prepared to change, but the change should lead to a better situation. The definition of "better", however, depends on their perception, while that perception depends on earlier information. These villagers clearly associated a "better" toilet with ceramic tiles and did not care too much about the technology of the UDDT or how many holes they need to use.

Step 4 – Action !!

Only when the first three steps are adequately covered, can the house owner take the right action. The house owner must be fully aware of the consequences that will affect his/her family for the coming 15 years or longer, before the toilet unit is remodelled again. The action consists of:

- ◊ Designating the construction area of the new bathroom.
- ◊ Collecting the necessary building materials and components for the construction.
- ◊ Ensuring frost-free water supply during the winter period.
- ◊ Purchasing the sanitary equipment, piping, tanks, tiles, etc.
- ◊ Contracting a skilled person for building, plumbing and electrical work.
- ◊ Having wood ash or a budget for toilet paper, operation costs and municipal fees.

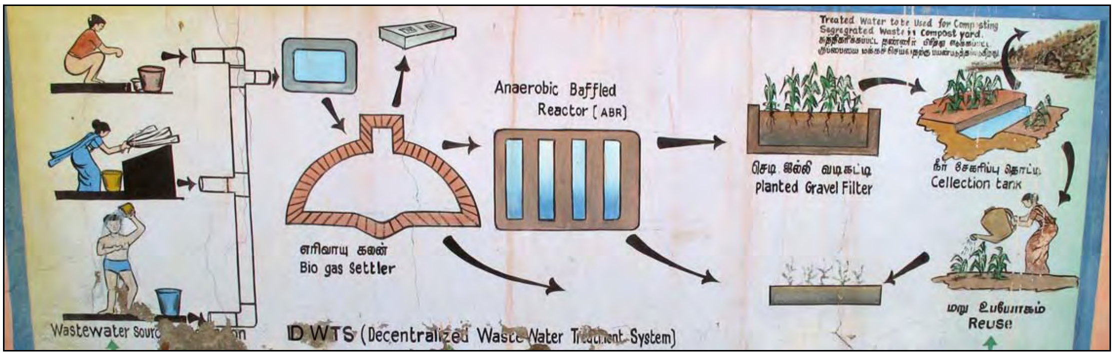
In the above left-hand picture of an UDDT, the owner required anal washing with water, but that should not be done over the UDDT. A separate washing corner was made from bricks and cement plaster. In these cases, the development organisation should develop an easy-to-clean bidet for anal washing.

In the right-hand picture, the house owner contracted two metal vault doors with a local metalworker. A long handle shovel can be used to clean the wide vaults. When the vault is high and narrow, a prefab concrete door is a better solution as it cannot rust when there is contact with the faeces. Both door designs and shovel should be available in the local market with an explanation when to use which design.

A development organisation or municipality can assist the house owners by supplying information about the various sanitation systems, as well as in facilitating the access to the services needed for the action phase. These can include:

- Various toilet designs with different materials.
- Simple calculation of the required design dimensions of vaults, septic tanks, urine storage, biogas reactors, etc.
- Different designs for in-house construction, attached or a separate outhouse.

- Different designs for the upper structure: stone, block, timber, sheds, etc. Insulated or non-insulated, tiled or non-tiled.
- Bills of quantity and cost estimates for material, transport and labour cost.
- Listing of skilled labour who can do the job.
- Providing access to essential elements that are not readily available in local stores, such as UDT or UDDT toilet pans.
- Supplying building equipment for rent for a limited period.
- Providing contract models for builders.
- Simple instruction on how to use a new type of sanitary installation.



Explanatory wall painting on a public toilet and wash area with biogas installation to create general awareness.

Developing the right instruction material to convey a clear message within the people's cultural setting is not simple. Ensuring information material is present in each new toilet design will stimulate proper use and create awareness for new users. Ensuring the material stays in the toilet and remains visible is another necessity.

Left: *An original well designed poster with clear pictures, little text and indicating 6 steps for proper use of the three hole UDDT.*
Middle: *The same poster, plasticized. It is fixed to the wall with three nails. Why not 4 (?) because now the bottom side is loose. Due to the influence of sunlight, it has faded and lost most of its colour. Making poster material should ensure the colour remains under all conditions.*
Right: *In the next toilet, the poster is gone. Making a hard plastic, waterproof plate and securing it with four rust-free screws will increase the lifetime of the instruction.*

Instruction material needs to be field-tested with <u>two control groups</u>, families who have never heard about the ecosan toilet and families who have received basic information about the UDDT. The field-testing should <u>NOT</u> be undertaken by the person(s) who designed the instruction material. Based on the understanding by each family member (males, females and children) of these groups, the instruction material can then be modified for clarity where necessary.

13. REASONS FOR FAILURE

New technologies can easily fail when only a few aspects of the project are adequately attended to or understood by the politicians, building contractors, users, or maintenance people.

> *When in a biogas design the construction leaks gas, condensation freezes, one pours chlorine into the toilet, the content is too wet or too cold, the system stops working.*
>
> *When in a UDDT the content is wet, poorly ventilated, freezes, toilet pan is poorly designed, or the user does not know how to operate the toilet, the system fails.*

This does not mean, however, that the design is bad in principle; it means that somewhere between the first introduction and the practical long-term use something went wrong. The cause needs to be investigated and resolved in coordination with the users, but it will mean a psychological setback for the introduction of the system, even if it is environmentally a good system.

In this double vault UDDT, the project organisation used the outside of the small building to advertise who financed the unit and some minor instructions. Because the unit was placed at a primary school and with the rear side towards the road, anyone passing by could read the information.

The introducing agency can be a local government or a project. Essential is:

(1) Good briefing of the future users on the technology.
(2) Change of toilet procedures and habits.
(3) Availability of posters, brochures and instructions.
(4) Availability of processing the collected urine or compost.
(5) Fixing of durable water-resistant posters with instructions inside each toilet.

For many new technologies, the “software” and proper introduction with explanations are key elements to success.

The users need to accept the technology and be willing to contribute towards the realisation with: (a) planning; (b) organisation; (c) building materials; (d) skilled or unskilled labour; (e) finance, (f) operation; and (g) maintenance.

The motivation of the people depends largely on the type of toilet facility they have before they consider a change. If the current situation is very bad, smelly, far away from the house or without privacy, they are more likely to adopt a new system than people who already have a pour flush or full flush toilet.

If the current situation is unsanitary, the house owner is more likely to change that system for another which promises higher sanitary standards.

If people are extending their house, they may choose for a more environmentally friendly system when they are convinced that it does not smell bad or has other disadvantages.

The technical construction should be adequate in relation to:

(a) Altitude of the house and the amount of frost occurring.
(b) Incorporated, attached or outside location of the UDT or UDDT in relation to the house.
(c) Sufficient vault size allowing only once a year change over.
(d) Availability of contracts or tools to empty the compost from the vault.
(e) Ease of changing the urine containers without opening the vault.
(f) Ease of servicing (cleaning) the urine and wash water drainage on an annual basis when changing over the vault
(g) Availability of skilled service people in case a problem occurs.

In failed UDT and UDDT projects, the main reason (>50%) given why the users did not like the system was that it smelled badly. Proper ventilation, use of adequate amount of drying agent and avoiding that urine and wash water enters the squat hole resolves that problem.

Especially during the cold winter period when natural composting stops, adding sufficient drying agent is important. Wood ash is in the winter readily available. Dry clay (left picture) and saw dust are also excellent. These must be stored before the winter in sufficient quantity.

To avoid smell from the urinal, a swan neck drain and flushing with a little water is a combination of technical and behavioural change.

> *In one primary school project, a neglected, misused, garbage-covered UDT was found. The school teachers were asked why the small children were defecating behind the building rather than in the toilet. The answer was that the smallest children did not know how to use it and made it dirty.*
>
> *The teachers knew that none of the schoolchildren had such a toilet at home, but they never explained to them how to use this new type of toilet. The project had not provided teachers with instructions or posters. In addition, the teachers did not want to clean the toilets.*

Nothing runs by itself. The above illustrates that when a project does not provide good guidelines for parents and teachers, they will not automatically educate the small children what to do and what not to do. There must be a system of frequent cleaning by the users. Only when you have to clean the toilet yourself, will you be more careful in keeping the facility clean.

Posters in plain sight can help people to behave properly in the toilets.

Pictures work better than text. Funny pictures are best.

Posters need to be of durable construction.

Shared responsibility. Toilets that are used by many different people can easily become dirty without a good cleaning protocol. Communal toilets need to be easy to clean and cleaned on a daily or twice daily basis. The user community needs to come up with a solid solution on how to finance such a frequent cleaning service. In one project where only a few families were using the same toilet facility, each family had a key to the toilet.

Monitor implementation and use. When introducing a new technology that requires change of behaviour, the effect needs to be monitored. Only by detecting problem areas with the users, can adjustments be made to avoid complications in future installations. The users therefore need to have an address (telephone number) where they can **complain or ask questions.** This way the implementing organisation gets automatic feedback, but it needs to follow up on all complaints. Often the household having a complaint needs to be re-educated on the proper use of the toilet system.

Availability of washing water. An objective of better toilet systems is to provide better hygiene and reduce intestinal illness, eye infections and general weakness due to parasitical worms living inside the body. Good anal cleaning (dry or wet) is part of the process.

Availability of washing water directly outside the toilet will improve hygiene.

Availability of warm water will further improve the use of water. The owner of the frost-resistant solar water heater financed the new installation from income derived from many more travellers who were looking for increased comfort and good sanitation.

The cycle is not complete. The ecosan toilet is environmentally most beneficial when the entire life cycle of food production, water supply, food consumption and human waste is fully recycled back to food production without contaminating the environment.

Model B with the UDT and biogas reactor is the best option because of the combustion of the methane gas. However, it is economically only suitable for:

(1) Farmers with sufficient cattle producing daily minimal 30 kg dung summer and winter.
(2) A group or condominium of households with at least 200 persons, soft shredded kitchen waste and additional carbon source material to ensure better fermentation and gas production.
(3) At the village level for larger communities, but no chemically hazardous waste thrown into the system. The same applies as well for No. 2.

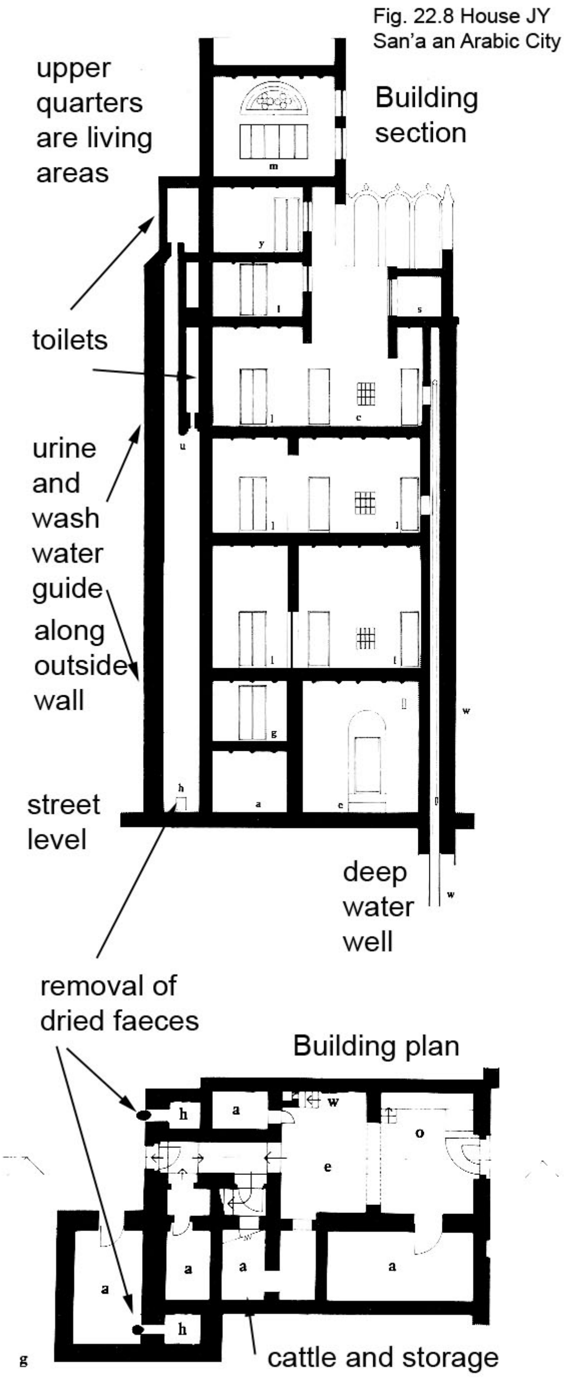
Model C with either the UDT or UDDT can recycle both compost and urine. The environmental disadvantage of model C is that the composting of faeces releases methane gas into the atmosphere. When the urine cannot be used as plant fertilizer due to logistic problems of large volume storage and transport, or because insufficient local experience is available about the best application under the local climate conditions, the urine should be drained away in a soak away.

When the urine is lost for fertilization, the method is less environmentally favourable. The non-use of urine is likely in a climate zone with long cold winters when there is no use for the urine fertilizer and when there is no service to crystallize the urine into Struvite (see Annexe II).

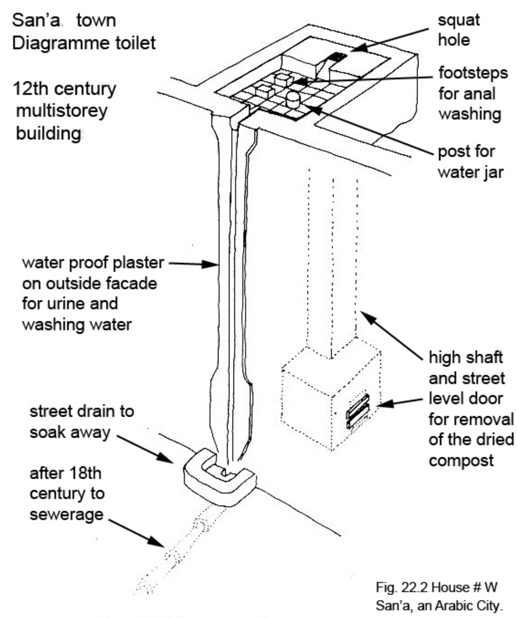
Plant nutrients excreted per person per year in rural India Source: Jonsson et al. (2004)	Nitrogen (N) per person/year	Phosphorous (P) per person/year	Potassium (K) per person/year
Urine	2. 4	0. 3	1.1
Faeces	0. 3	0. 1	0.4
Total	2. 7	0. 4	1.5

ANNEXE I ANCIENT UDDT

In the city of Sana'a of the Yemen Arab Republic, the ancient multi-storey buildings have UDDT units on the upper floors where the living quarters are situated. Due to the dry climate, the faeces dry rapidly inside the shaft. The urine and wash water runs down through an open gutter along the outside of the façade and largely evaporates before reaching the ground. Before the planting season, the compost is excavated at the street side and used in the fields. Since the 19th century, the street drains are often connected to a city sewer.



Yemen Arab Republic
Buildings constructed since the 12th century.



ANNEXE II STRUVITE PRODUCTION

Urine, which contains valuable nutrients like nitrogen and phosphorus, can be directly applied to soil as fertiliser for crops. Though useful in this aspect, urine is sometimes difficult to transport and store, and has an unpleasant odour. To overcome these issues, non-filtered/untreated urine can be processed into Struvite. In addition to the fertilising properties of urine, Struvite has several advantages: reduced volume and weight; compact storage; and easy to handle, transport and apply, especially in a granulated form.

"**Struvite:** (magnesium ammonium phosphate) is a phosphate mineral with formula: $NH_4MgPO_4 \cdot 6H_2O$. Struvite crystallizes in the orthorhombic system as white to yellowish or brownish-white pyramidal crystals or in platy mica-like forms." [29]

"Through a basic *precipitation* reaction, the majority of *phosphorus* in *urine* can be crystallised into a white, odourless powder: *Struvite* ($MgNH_4PO_4 \bullet 6H_2O$), sometimes also called *Magnesium Ammonium Phosphate Hexahydrate* (*M-A-P*). *Struvite* is a bio-available, *slow-release fertiliser*; it is compact and can be stored, transported and applied easily, and does not smell (see the picture below). Through *Struvite* recovery, over 90% of phosphate can easily be removed from *urine*." [30]

> *"Struvite is much easier to carry and transport over long distances than dairy manure," Jactone Arogo says. "We can send the Struvite to areas that are deficient in phosphorus and because Struvite has less volume than the alternative, transportation is cheaper."* [31]

Jactone Arogo's nutrient-removal reactor turns dairy manure into Struvite (pictured here), a salt formed when equal molar concentrations of magnesium, ammonium and phosphate ions in a solution react. The crystals have a variety of uses, including a slow-release fertilizer and a raw material for fire-resistant panels.

The following aspects need to be considered.[28]

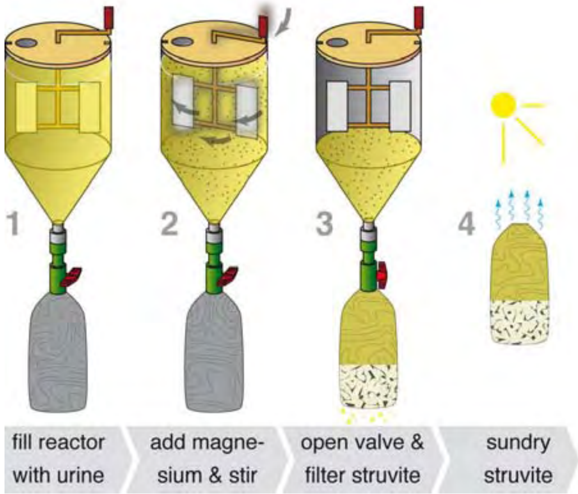
Advantages	Disadvantages
Strongly reduced weight and volume of nutrients compared to urine.	Transport costs of urine (to the Struvite production site) reduces economic viability.
Easy transport, storage and handling.	High volume of urine required.
No bad smell after processing.	Partial recovery of nitrogen and no recovery of potassium.
Simple technology; the installation can be built and operated almost everywhere.	Low yields (approximately 1 kg Struvite from 500 litre urine).
Construction with local materials.	Possible corrosion of metal appliance.
Easy to operate, no electricity required.	Effluent requires treatment or controlled reuse (i.e. fertigation/irrigation).
User friendly fertilizer product.	Requires soluble magnesium source. This may need to be imported.

When there is no communally managed urine collection and Struvite production, it is not recommended for individuals to experiment with their own production.

[29] Copied from: http://en.wikipedia.org/wiki/Struvite
[30] Copied from: http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/processes/struvite
[31] Copied from: http://www.vt.edu/spotlight/impact/2008-09-29_bay/2008-09-29_bay.html

Making Struvite[28]

The reactor consists of a stirring mechanism, which is fitted inside the tank; a nylon cloth filter bag hangs below a valve to allow the main reactor to be drained.



To start the process, the collected urine and soluble magnesium are mixed for 10 minutes in the reaction tank.

The valve is opened and the suspension is then drained into the filter bag. The filter bag retains the Struvite while the effluent passes through.

The filter bag is air/sun dried for one to two days, after which point the Struvite is ready to use.

In field experiments, this type of reactor was able to recover over 90% of the phosphate contained in the urine. Because Struvite also precipitates naturally from urine, any precipitate in the collection system should be incorporated into the final product in order to maximise nutrient recovery.

When the total product line from (A) household collected urine to sand and carbon filter to storage to transport to irrigation, or (B) commercial from urine to storage, transport Struvite production, marketing Struvite and irrigation of effluent is incomplete, the benefits of the process are not obtained and the system becomes less environmentally beneficial. In addition, the economic sustainability can be less.

For the correct use of Struvite, the effluent of Struvite production and other chemical fertilizers, practical information must be available per plant type and per altitude.

Pictures of hand mixer and fertigation (drip irrigation) taken from Internet sources.

ANNEXE III FURTHER STUDY

Of the many websites with information, only a small selection has been presented here.

Typing the various key words in a search engine will provide many links and sometimes the latest information. This paper only provides basic information useful for mountain areas and does not go into detail about the construction of biogas reactors.

www.sandec.ch Free download area with 50 different sanitation technologies.

http://www.fao.org/docrep/003/T0530E/T0530E00.HTM
15 MB. FAO fisheries paper 321.
A technical manual on boat building, including information about making glass fibre polyester.

http://www.slideshare.net/indiawaterportal/ecosan-posters
Good quality training and information poster on Ecosan, UDDT and other resources.

http://who-2009-ecosan-expert-training-course-for-the-introduction-of-ecological-sanitation-in-bhutan-pdf-d331171734 Course material on ecosan.

http://en-logistic-aspects-of-ecological-sanitation-2005-pdf-d84982446
Ecological Sanitation in Urban Areas. Case Study in Low-Income Community in Delhi, India.
4 MB, 200 pages.

http://www.mw-incinerator.info/en/101_welcome.html
Website with document links about the Montfort incinerator for hospital waste.

http://www.susana.org/lang-en/videos-and-photos/videos/158-videos/235-ecosan-udd-toilet-construction-video

http://www.s1366661.fmns.rug.nl/urinedivert.pdf

http://www.allthingsorganic.com/How_To/01.asp Information on worm composting.

http://www.tuhh.de/aww Downloads on practical ecosan research, vermicomposting.

http://www.doku.b.tu-harburg.de/volltexte/2011/1095/
Development of a continuous single chamber vermicomposting toilet with UDT for on-site application.

http://www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=1495
Construction manual with pictures of double vault toilet.

http://www.eawag.ch/vuna Eawag: nitrification of urine, before further treatment.

http://www.eawag.ch/forschung/eng/gruppen/vuna/...trification/index_EN
Eawag information on the process of nitrification and evaporation.

http://www.ecosanres.org/publications.htm
Practical Guidance on the Use of Urine in Crop Production.

http://www.ecosanres.org/pdf_files/ESR2010-1-Pr...nCropProduction.pdf

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