Technology review of urine diversion dehydration toilets (UDDTs)

Design principles, urine and faeces management

Last update 21 October 2011

giz Sustainable sanitation ecosan

On behalf of Federal Ministry for Economic Cooperation and Development

Imprint

Published by:

Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH
Sustainable sanitation - ecosan program
Postfach 5180, 65726 Eschborn, Germany
T +49 61 96 79-4220
F +49 61 96 79-80 4220
E ecosan@giz.de
I www.gtz.de/ecosan

Place and date of publication:
Eschborn, June 2011

Authors:
Christian Rieck, Dr. Elisabeth von Muench

Responsible editor:
Dr. Elisabeth von Muench

Acknowledgements:
We thank all the contributors to the very useful Ecosanres discussion forum, from where we have taken many inputs for this publication (http://www.ecosanres.org/discussion_group.htm)

Contact:
Dr. Elisabeth von Muench, GIZ (ecosan@giz.de)

Design:
Christian Rieck (GIZ)

Photos:
Cover: Heike Hoffmann, xxxx
Back: Stefanie Lorenz, Kathrin Windolf, xxx

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1 Summary

This publication deals in detail with one particular dry excreta management system which has only recently become more widely known as the urine diversion dehydration toilet (UDDT). A complete overview is given on functions, designs, operation and maintenance issues, and costs of UDDTs.

A standard UDDT has two vaults for the collection of faeces, usually placed above the ground. The alternate use of the two vaults enables the "resting" of the faecal matter over several months thus promoting the drying out / dehydration which is key for safe handling. This treatment does however not lead to a complete sanitisation and pathogen die-off in the faecal matter. Therefore during handling and disposal or reuse of urine and faeces additional safety measures like wearing protection gear and hand washing must be strictly followed.

Single vault systems with urine diversion are not considered to belong to UDDT systems as they do not provide the dehydration of faecal matter.

The separation of urine and faecal matter in a UDDT provide the option of reuse as fertiliser and soil conditioner for crop production, however reuse is not a must. There are plenty of examples where other benefits are more relevant for the choice of a UDDT than reuse. In this case urine and faeces can be safely disposed on- or offsite by the users themselves or adequate service providers.

The benefits of a UDDT are manifold like.

- The odour and fly free performance makes it suitable for indoor installations.
- The dry conditions of faecal matter prevent possible leaching of pathogens into the environment and above all the groundwater.
- Emptying of faecal matter from dehydration vaults is not offensive and due to above ground construction user-friendly thus resulting in long life spans and favourable conditions for urban faecal matter / sludge management.
- UDDTs are suitable in challenging environments where conventional pit latrines are problematic such as areas with rocky and instable underground, high groundwater levels and heavy rains which cause light flooding.
- Providing valuable resources for crop production in areas with subsistence agriculture.

In terms of design all kinds of user needs have been satisfactorily catered for in various UDDT installations around the world as case studies and pictures demonstrate. For example the recently more popular bench design requires less or no stairs at all which offers advantages for access by physically disadvantaged persons and for indoor installations. The different designs offer at the same time a wide range of costs which make them also affordable for the poorer segments of population.

When UDDTs are implemented the users must be aware about and willing to execute or outsource the necessary operation and maintenance requirements. It is in general a simple system, but requires more attention from the user as compared to simple pit latrines.

2 Introduction

2.1 Target audience

The target audience for this publication are project planners and implementers, engineers, architects, teachers, trainers, lecturers, or generally people with some basic technical background who:

- want to obtain an overview of UDDTs, their designs and maintenance requirements;
- want to understand whether UDDTs could be a possible option for a given context;
- work with organisations who are building UDDTs and thus need to be able to ask the right questions to consultants and suppliers;
- have an interest in sustainable sanitation solutions for developing countries and countries in transition.

2.2 Scope of this document

This publication focuses on the function and design of urine diversion dehydration toilets with a double vault system for developing countries and countries in transition. The single vault system is also described here, however more in a sense of a secondary design option which requires a more complex management of faecal matter.

This document does not go into detail regarding: construction of UDDTs, reuse of urine and faeces from UDDTs, secondary treatment options of faeces (outside of the faeces vault) and urine treatment methods (other than storage). Helpful links are given in the relating sections.

Moreover this document also does not cover the main "software" topics such as project implementation, awareness creation, behaviour change, hygiene education etc., even though these issues are very important for successful implementation of UDDTs. For information on these issues please refer to the links given in the Section 12.2 "Further resources for UDDTs".

2.3 Definition and terminology

Urine diversion dehydration toilets (UDDTs) are dry toilets that separately collect urine and faeces with a special toilet seat or pan. The faeces are collected in two collection vaults for extended storage in order to dehydrate the faeces for treatment and safe handling.

Several different terms are being used around the world to denote UDDTs. These include:

- *Ecosan toilet* – a widely used term, which is very easy to communicate at grass-roots level and can also easily be translated into other languages. But the disadvantage is that it implies that all ecosan concepts use this particular technology which is not the case. For this reason GIZ does not recommend to use the term "ecosan toilet".
- *Composting latrine* – For example in India, "composting latrine" is a socially more acceptable term than UDDT. Strictly speaking a UDDT does not include any composting, as the faeces chambers are dry and the

moisture content is too low for composting[1]. A certain amount of aerobic decomposition of faeces does occur though.
- *Double vault urine diversion latrine (DVUD latrine)* – a term used by researchers from the US, which describes a standard UDDT with two faeces vaults.
- *Skyloo* – a term coined by Peter Morgan in Zimbabwe (Morgan, 2004), but not used much outside of Zimbabwe.

The recommended translation of the term UDDT in other languages is: *Inodoros secos con separación de orina* (Spanish), *toilette sèche avec séparation d'urine* (French). Also other names exist in parallel.

2.4 Background

More than 2.6 billion people do not use improved sanitation facilities according to the GLASS report 2010 (WHO, 2010)[2] and an estimated 1.2 billion people are still defecating in the open[3]. Crucial hygiene behaviours such as hand-washing after toilet use are also widely lacking. The consequences are severe. The pollution of drinking water resources, food and the direct faecal-oral transmission cause a massive amount of disease and preventable deaths, especially of young children. For instance, the GLASS report indicates that the impact of diarrhoeal disease on children is greater than the combined impact of HIV/AIDS, tuberculosis and malaria together. The same report states that the provision of improved sanitation and drinking water could reduce diarrhoeal diseases by nearly 90%.

The majority of people in developing countries and countries in transition choose pit latrines with a relatively deep pit as their toilet and excreta disposal system. The reasons are that pit latrines are relatively cheap to build, simple and easy to use and do not require water for their operation. However, pit latrines cause challenges due to costly removal of sludge or rebuilding of the pit latrine when pit emptying is not an option, and occurrence of water pollution in certain environments (such as during flooding or in areas with high groundwater tables). Other dry toilet options exist, but lack of awareness about options and assumed higher costs are generally the overriding factors in the planners' and household's decision making.

Sanitation systems are always context dependent. People have various expectations and conceptions about sanitation. In general they aim for improved standards to their current sanitation solution with are in majority pit latrines or no latrines. This entails for example attribute such as less odour, flies, privacy and more "prestige". In order to achieve sustainable sanitation systems they should be based on the five sustainability criteria defined by the Sustainable Sanitation Alliance (these are health & hygiene, environment, technology & operation, financial, socio-cultural and institutional, see SuSanA (2008) for more details).

An excellent publication to explain all the different sanitation systems is the Compendium of Sanitation systems and technologies (Tilley et al., 2008) as well as the technology matrix by GIZ with a one-page overview of available sanitation technologies provided on the GIZ website in four languages[4].

The urine diversion dehydration toilet (UDDT) is one dry excreta management system which has only recently become implemented by donor agencies and NGOs. It is an alternative solution to the widely used pit latrines.

This type of toilet is strongly linked to the ecological sanitation (ecosan) concept which focuses on reuse of water, energy and nutrients. However UDDTs are just *one example* of an ecosan system, but must not necessarily serve the purpose of nutrient recycling as successfully shown in the South African municipality of eThekwini with 75,000 households using UDDT that dispose urine and faeces[5].

2.5 Overview of waterless sanitation systems based on urine separation

A good overview of waterless sanitation systems based on urine separation is given in the Compendium of Sanitation Systems and Technologies (Tilley et al., 2008). In short, it describes a dry toilet that operates without water. It is designed to separate urine and faeces which allow faeces to dehydrate and urine to be recovered for beneficial use or disposal. Such systems can be used anywhere, but it is especially appropriate for rocky areas where digging of pits is difficult, where there is a high groundwater table, or in water-scarce regions.

These systems have a special toilet seat or pan with a divider that drains the urine separately away from the faeces. It takes advantage of the anatomy of the human body which is excreting urine and faeces separately thus both substances can be collected separately. The urine is drained via a small hole at the front area of the toilet seat or pan, while faeces fall through a larger hole in the back section into a vault or container.

In addition to the given overview by Tilley et al. (2008) it has to be pointed out that urine diversion and the absence of flushing water effectively reduces odour that originates from the faeces since they are kept dry. Moreover the dry condition makes the handling of faeces less offensive and safer and lastly it prevents the leaching of pathogens and other pollutants into the groundwater.

Apart from the collection of faeces in above ground vaults for purpose of dehydration there are also well working systems using shallow and unlined pits for source separated faeces collection. Here the faeces undergo a composting process. Both processes of dehydration and composting similarly encourage the hygienisation of faeces and provide an odourless operation as well as a relatively safe end-product that enables a simple and offenseless removal, transport and use or disposal of faeces

[1] For more information on composting toilets see Berger (2010).
[2] http://www.unwater.org/downloads/UN-Water_GLAAS_2010_Report.pdf
[3] http://www.communityledtotalsanitation.org
[4] http://www.gtz.de/en/themen/umwelt-infrastruktur/wasser/26250.htm
[5] http://www.susana.org/docs_ccbk/susana_download/2-791-en-susana-cs-south-africa-ethekwini-durban-uddts-2010-ver95x.pdf

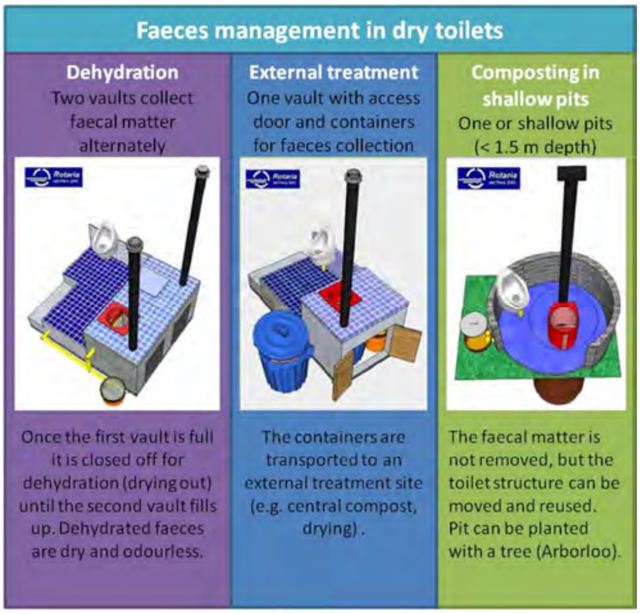

Figure 1: Overview of faeces management in dry toilets (composting is not displayed here) (adapted from Rotaria del Peru 2011 – internal document).

Additionally there are sanitation systems that collect the faeces and require an external composting or drying set up for treatment.

Therefore there are the following types of waterless sanitation systems based on urine diversion that vary on the way how faeces are managed:

- **Faeces dehydration systems**
  - UDDTs with double vault (alternating double pit)
- **Faeces composting or dehydration systems in external locations**
  - Single vault systems (transferable containers)
- **Faeces composting systems in shallow pit latrines**
  - Arborloos (single pit with tree planted after filling)
  - Fossa Alterna (alternating double pit)
- **Faeces composting is chambers**
  - Composting toilets with leachate collection system

In UDDTs, Arborloos and Fossa Alterna a cup of **dry covering material** such as wood ash, lime, sand, dry soil or similar is added to fresh faeces after each defecation event. This covering material soaks up moisture and controls initial odour, provides a barrier between faeces and vectors e.g. keeps flies away and gets the faeces "out of sight". It is also to some extent beneficial for the composting process.

All sanitation systems should provide a **ventilation** of the faeces vault or pit by means of a vent pipe which reduces odour and moisture (see Section 4.6). This makes urine diversion systems also suitable for indoor installations apart from shallow pit latrines that require an outdoor location.

It must be kept in mind that a total destruction of all pathogens is rather unrealistic in such systems. In theory it is possible to achieve total pathogen die-off, but there is first and foremost the human factor and as well other uncertainties like unexpected weather conditions. Therefore it is strongly recommended to handle faeces and urine which have been collected in such systems with caution and to apply simple safety measures (see Section 2.7). Guidelines for the safe use of excreta, faecal sludge and urine have been published by the World Health Organization (WHO, 2006).

All toilets should provide a **hand washing facility** at or near the toilet. Simple facilities without piped water supply can be installed like tippy taps, hand washers with cans, plastic bottles or tanks with taps. If a water connection is available a piped hand wash stations is advisable (see links in Section 12.2.5).

Moreover for user convenience and to reduce the risk of misuse, i.e. male users urinating into the faeces compartment it is a good idea to provide **waterless urinals** for the convenience of men. Urinals for females are not yet common although for example girls' urinals in schools can be a good option (von Muench and Dahm, 2009)).

2.6 UDDT concept

You can find a good overview of UDDTs and in particular dehydration vaults in the Compendium of Sanitation Systems and Technologies (Tilley et al., 2008). In general a standard UDDT has two vaults for the collection of faeces placed above the ground. The vaults are used alternately. Only one vault is used at a time until the vault is full, so that the other vault can "rest" to dehydrate. The period to fill one vault generally ranges from 6 to more than 12 months – this is the same time that the other vault is resting and the faeces are drying out (dehydrating) and become partly treated.

Urine diversion toilets with only one vault, also called single vault, are not considered as UDDTs since they do not provide for a dehydration of faeces inside the toilet. It is however partly described in this paper as modified design for mobile and indoor toilets.

The unique characteristic of UDDTs in comparison to other dry sanitation technologies with urine diversion as described in the previous section is the collection and storage of faeces in above ground vaults over a certain period of time. This has the advantage of easy access to the vaults making empting of faecal material practical thus enabling a long life cycle of UDDTs. Moreover it creates a crumbly, powdery, odourless and thus inoffensive end product that can be safely removed.

Moreover the vaults are set up in a way that provides a good protection from rain and light flooding which is paramount for the continuous drying process of faeces. This also leads to an effective prevention of pollution of groundwater since the faeces are dry and do not cause any seepage of pathogens and other pollutants into the soil.

UDDTs facilitate the treatment of urine and faeces (pathogen removal) mainly through storage, gradual drying out (dehydration) and a pH increase (see Section 7.5 for details). The aim of the treatment is to decrease the pathogen load to acceptable levels for the handling person but not a complete removal which is hardly achievable (see Section 7.5). If safety measures are followed dehydrated faeces and stored urine can be safely reused for productive purposes in agriculture or disposed (see Section 2.7 on safe reuse and disposal).

A UDDT consists of six basic functional elements:

1. Urine separating toilet seat or squatting pan
2. Two separate vaults (chambers)
3. Urine piping leading from the user interface to a urine collection container, tank or infiltration system
4. Ventilation pipe(s) from the faeces vault
5. Bucket with dry covering material such as wood ash, sand, lime, leaves, compost, earth, saw dust, rice hulls. A second bucket for general waste should also be provided
6. Anal cleansing area if practiced
7. Toilet superstructure

Figure 2 UDDT outhouse in Burkina frontview and rearview with faeces vault doors (photo by A. Fall and S. Tapsoba)6

UDDTs can often be recognised by the stairs that lead to the toilet cubicle above the vaults, although this does not apply to the bench designs, the indoor UDDTs nor those UDDTs whose vaults are partially underground when built on a slope (see Section 11.1).

2.7 Safe reuse and disposal of urine and faeces from UDDTs

Reuse of urine and faeces from UDDTs for crop production is an option, not a must. The advantage of reuse is the increased crop production and the sustained fertility of the arable land. On the other hand disposal is often easier in terms of user acceptance and practicability. Reuse may also come an optional second step after user have come accustomed and show interest in extra benefit of reuse..

Safe reuse of human excreta focuses on limiting the risk of pathogens transmission to humans and into their living environment. Since pathogens are predominantly contained in faeces and in some cases also in urine, when faecal cross-contamination has occurred, it is crucial to treat and handle excreta in such a way that the health risk of disease transmission is minimised. Treatment options for excreta are explained later in Section 7 and 8.

Figure 3 and 4 Comparison of onion with and without fertiliser in Niger on the left and urine application in Bonn, Germany in a research project on the right (photo by Linus Dagerskog[7] and Ute Arnold[8])

In practice, however, the treatment of faeces in a UDDT cannot provide for a complete removal of all contained pathogens especially with regard to worm eggs which are more resistant to treatment (see Section 7.5). In the case of urine a complete pathogen removal can be achieved. Nonetheless misuse of UDDTs and poorly operated secondary treatment processes can reduce the efficiency of the sanitisation process of both urine and faeces. Thus additional health protection measures should be deployed to reduce the risks during reuse of excreta to an acceptable level via the multi-barrier approach.

Safe disposal of urine can be done through infiltration into the ground via soak pits if the groundwater is not negatively affected or not used for drinking purposes (see Section 8.8). Faeces can be safely buried in shallow pits or trenches as long as it is well protected from re-exposure by erosion, human and animal activities. The groundwater should be protected as described above for urine (see Section 7.9). Also the handling during disposal should be done careful according to the multi-barrier approach. It is especially important to not accidentally spread excreta on the surface around the disposal site.

2.7.1 Multi-barrier approach

The World Health Organisation has issued in 2006 the “Guidelines for the safe use of wastewater, excreta and greywater in agriculture” containing guidelines for managing the health risks associated with the use of excreta in agriculture (WHO, 2006). These guidelines promote a flexible **multi-barrier approach** that comprises a series of measures and barriers from “toilet to table” that reduce health risks to a reasonable level for field workers, households or consumers (Richert et al, 2010). This means in general that for all types of treated excreta in reuse systems, these additional safety measures apply.

Important barriers in connection with UDDTs are:

6 http://www.flickr.com/photos/gtzecosan/collections/72157624907659995/

7 http://www.flickr.com/photos/gtzecosan/sets/72157627175906041/with/5983908931/

8 http://www.flickr.com/photos/gtzecosan/sets/72157624540490811/with/4461921719/

1. Source separation (urine not contaminated with faeces, and faeces are kept dry from liquids) (Section 3)
2. Dehydration of faeces during storage in the UDDT vaults and possibly secondary treatment of faecal matter outside of the UDDT vaults. See guiding values in Section 7.4 and 8.5.
3. Farming-related barriers: Application techniques, crop restriction, withholding period (Sections 8.7 and 7.7)
4. Protective equipment and hand-washing (Section 9.2.1)
5. Food handling and cooking
6. Health and hygiene promotion

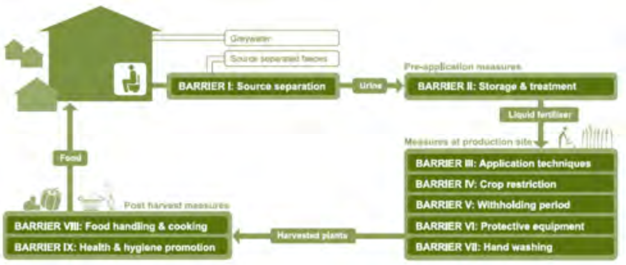

Figure 5: Barrier concept for safe use of urine as a fertiliser (Source: Richert et al, 2010)

2.7.2 The pro and contra of reuse

Reuse can be a welcome benefit if the specific local context provides that the costs of recycling excreta including costs for collection, treatment and transport are favourable, the users accept consuming products fertilised by excreta and the legal framework supports reuse. The fact that phosphorous is a limited mineral resource for agriculture and other dependent industries also supports the demand for more recycling of excreta (http://phosphorusfutures.net/index.php).

On the other hand there are several health risks when using urine and faeces in agriculture. It is often observed that farmers use excreta in an unsafe manner thereby putting themselves, traders and consumers at risk in large scale systems. The reuse and own consumption at household level is however relatively safe since a single family will most probably transmit diseases more easily between each other through direct routes (such as by handshakes, hugs and coughing) than reuse of urine and faeces.

Over the past decades it has been observed that reuse is not necessarily the main driver and incentive for people to acquire an UDDT. One of the main benefits of these latrines from a user perspective is more often the reduced odour compared to conventional pit latrines or other advantages of not digging in rocky or flood prone areas as described in Section 2.8 on suitability.

Historical development

The information in this section is mainly taken from Winblad and Simpson (2004). Perhaps the oldest type of a dry toilet with urine diversion existed in **Yemen** until the last decade. They were used for hundreds of years in traditional multi-storey buildings in the old centres of Yemeni towns.

UDDTs in a sense of a double vault system as we know them today originated from the model of the **Vietnamese** dry toilet, consisting of two chambers built above the ground. This type of toilet was developed in the 1960s to increase hygienic safety of the traditional use of excreta in agriculture.

Modifications of this design have been promoted in pioneer countries like Mexico, Guatemala, El Salvador and Sweden. Vent pipes were introduced to reduce odour and facilitate dry conditions, and toilets were installed inside of houses. At the same time prefabricated squatting pans and toilet seats for dry toilet systems with urine diversion emerged which increased the durability and prestige status of the system.

In India and other countries the design was further adapted around 2001 for anal cleansing with water, thus having a separate anal cleansing area that drains the washwater to a disposal system or separate treatment (often combined with the remaining greywater).

In 2008 the bench UDDT, a sitting type, was developed and promoted in Peru by Rotaria del Peru. This type of UDDT is often fitted indoors as it can be easily fit in existing structures on the strength of not relying on stairs (see 6.4).

Very popular versions of UDDTs are commercially produced in Sweden and the Scandinavian countries in general since the mid 1990s where many summer houses are not connected to a sewer thus requiring alternative solutions. For example, the Swedish company Separett has sold tens of thousands of plastic urine diversion dry toilets[9] (single vault) with built-in electrical fans.

In 2001, the EcosanRes 1 program started at Stockholm Environment Institute, Sweden. Together with the ecosan program of GIZ (which also began in 2001), these two government funded programs have helped to promote the knowledge about UDDTs which has lead to more widespread uptake of this technology.

The number of current users of UDDTs around the world is impossible to determine exactly, but a rough estimate puts the number in 2011 at 2 million users within *documented* projects in about 100 countries in the world[10]. Currently the highest numbers of UDDTs in use are located in China and South Africa[11].

2.8 Suitability of technology

2.8.1 In which situations do UDDTs have competitive advantages?

The main application for UDDTs is for situations where the conventional sanitation systems, i.e. *pit latrines*, *flush toilets with septic tanks* or *sewer systems*, are less suitable. This can be the case for the following circumstances:

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[9] Units sold: around 200,000 units of separating toilets from the cheapest to the most exclusive toilets (from 1994 to 2010), source: http://www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=1148

[10] See worldwide ecosan project list maintained by GIZ: http://www.gtz.de/en/themen/umwelt-infrastruktur/wasser/30631.htm

[11] 75,000 UDDTs have been installed in the eThekwini (Durban) area since 2003 (Roma et al, 2011)

- *High groundwater table*, where groundwater is used for drinking purposes but is vulnerable to contamination by pit latrines or overflowing septic tanks. UDDTs help to protect groundwater from pollution with faecal pathogens since excreta are safely contained in the vaults. The infiltration of urine can be critical to the groundwater quality if larger quantities (e.g. from schools) are infiltrated and the risk of faecal cross-contamination of urine is high. Alternatively urine should be productively used in agriculture.
- *Instable soil conditions* making digging of pit latrines difficult and dangerous unless lining is provided which is however expensive.

Figure 6 A collapsed pit latrine after rains in Narok, Kenya on the left and a UDDT withstanding a flooding in Bangladesh (photo by P. Mboya, 2008 and A. Delepiere, 2009)

- *Rocky soils* where digging of pit latrines and other underground sanitation systems like septic tanks are difficult to implement and expensive.
- *Frequent flooding or inundation* caused by heavy rains making pits prone to overflow which leads to contamination of surface water with faecal material. This is a common cause for cholera outbreaks and other water-related diseases, which tend to "peak" in the rainy season in many developing countries.
- *Lack of water or high costs for water supply* make the installation of flush toilets less reasonable or even impossible.
- Settings where pit latrines are not commonly emptied and *the space* for continuous construction of new latrines *is limited*[12]. In practice many schools have "graveyards of full and abandoned pit latrines" that slowly cover the entire school compound. A long lasting solution like UDDTs is more adequate.
- Settings where a better *proximity* of toilets to housing is desirable as compared to pit latrines which are mostly located far away from houses because of smell. This is a common desire of women and people with disabilities. UDDTs can be built attached to the house or inside of houses or schools as compared to pit latrines due to the fact that they are free of odour and flies if constructed and operated properly.
- Settings where there is a *lack of financial and institutional capacity* for centralised wastewater treatment or faecal sludge management.
- Settings where there is a *demand for cheap fertiliser* close to the location of the toilets.

2.8.2 Are UDDTs applicable for dense urban areas?

In dense urban areas there is a general lack of agricultural area to productively use the excreta from UDDTs. Also, urban dwellers are less likely to be engaged in farming or gardening. Therefore, services that remove and safely dispose or reuse the faeces and urine are a must for urban areas.

These sanitation services cause costs and must be paid for thus require a willingness to pay by users. Urban agriculture can absorb certain quantities of fertiliser so that overall transport cost can be lowered. Food supply of cities in developing countries and countries in transition are especially depending on urban and close by peri-urban food production.

Similarly the safe *disposal* of excreta in dense urban areas is limited to available and suitable space. The urine can be infiltrated and faecal matter buried in the ground only where groundwater is protected or not utilised for drinking purposes. Otherwise appropriate disposal sites outside the city need to be identified thereby leading to transport expenses. This aspect however also applies to all other onsite and decentralised sanitation systems such as pit latrines or septic tanks.

UDDTs offer the advantage of safer and easier handling of faecal matter as compared to pit latrines and wet sanitation systems with regard to emptying and treatment requirements. Additionally they can be theoretically integrated in multi-storey houses, which however has not yet been proven to work in the longer term outside of Sweden (see Section 11.2).

2.8.3 Why have some UDDT projects failed?

Failures of UDDT projects are not uncommon, just like failed projects with sewer systems, septic tanks or pit latrines. The lessons learnt of such failed UDDT projects have been documented in various SuSanA case studies[13]. Common reasons have been the lack of ownership in many subsidy-driven programs that lead to the negligence of facilities.

Furthermore the UDDT is not intuitive or immediately obvious to some users who are used to one drop hole only. At first, users may be hesitant about using it and mistakes (e.g. faeces in the urine bowl) can easily lead to malfunction and odour which may deter others from accepting this type of toilet. Other aspects can be for example higher construction costs as compared to simple and unlined pit latrines as well as lack of awareness and training on construction, operation and maintenance.

[12] Lack of space can be a driver for UDDTs when compared to pit latrines. It is not a driver when compared to flush toilets with centralised off-site treatment plants.

[13] www.susana.org/library?search=abandoned

3 Design of the urine diversion toilet bowl, squatting pan and toilet cubicle

3.1 Who squats and who sits?

Users have preferences for either sitting or squatting when going to the toilet based on what they are used to. Some people prefer sitting toilets at home, but squatting toilets in public places, as they are thought to be more hygienic (no need to have skin contact with the toilet). Sitting toilets are often called “western toilets” and are sometimes perceived as the more modern toilet. An indication for this is that the luxury hotels in capital cities of developing countries tend to have sitting toilets.

On the other hand, people from countries where sitting is the norm (most of Europe, USA, Australia etc.) find the thought of having to squat over a toilet hole quite unattractive and difficult.

Detailed lists of worldwide suppliers and prices of UD squatting pans and seats (pedestals and bench) are being maintained by GIZ[14].

3.2 Urine diversion function of the urine diversion toilet bowl or pan

The core element of a UDDT is the urine diversion squatting pan or toilet seat (sometimes called “user interface”) that can be designed according to sitting or squatting cultures (see Figure 7).

Figure 7: Overview of general types of user interface.

Urine diversion takes advantage of the anatomy of the human body which is excreting urine and faeces separately thus both substances can be collected independently. The urine is drained via a small hole at the front area of the toilet seat or pan, while faeces fall through a larger hole or chute in the back section into a vault or container. This separate collection is also called “source-separation”. Accordingly the user does not need to change position for a separate collection, although he or she does need to position themselves right.

In the beginning and the end of the urination some urine may fall vertically down and end up in the faeces collection vault. This is a relatively small amount which does not have a negative influence on the dehydration of faeces.

The toilet seat or pan should be simple to use, easy to clean, durable, pleasant to the eyes and not easily prone to malfunction. The cleaning of the UD bowl or pan is simple: it is done by using a damp cloth and as little water as possible.

Urine diversion is a fairly new and often as yet uncommon function of a toilet which requires appropriate usage in order to assure that most urine is separately collected and faecal cross-contamination of urine is kept low. Therefore it is most important to train new users and to hang up instruction posters.

3.3 Urine diversion seats

3.3.1 Pedestals

Urine diversion (UD) pedestals are like standard toilet seats (often called bowls) with a height between 40 and 50 cm and are installed on top of the vault. They should be installed water tight to the floor to avoid water from floor cleaning entering the vault.

The integration of anal cleansing is usually done through a separate bidet or washing area (squatting) next to the toilet pedestal. More information on anal cleansing is available in Section 3.4.3.

3.3.1 Benches

The bench design uses a flat UD insert which is fitted on the vault whereby the user sits directly on the vault. More information on bench design and its advantages is provided in Section 6.4.

Figure 8 Urine diversion seat (pedestal) and UD insert placed on bench in Peru made from class fibre by Rotaria del Peru SAC (photos by H.Hoffmann, 2010)

3.4 Urine diversion squatting pans

3.4.1 Basic version

The basic version of a UD squatting pan has only two holes, one for urine and one for faeces.

14 http://www.susana.org/lang-en/library?search=appendix

Ideally the squatting pan should be slightly elevated over the floor slab in order to avoid water from entering the faeces vault. In general two identical single drop hole squatting pans are placed in parallel or one mobile pan is placed which can be moved to the active vault. In both cases the user should face the door in order to create a practical toilet cubicle dimension (see Figure 12).

Figure 9. Left: Chinese model installed in Ukraine. Right: Product from Tabor Ceramics in Ethopia.

3.4.2 Twin drop hole version

Squatting pans which are meant to be used for double vault UDDTs can be designed with two faeces drop holes symmetrically arranged at both ends, and the urine hole in the middle whereby the user faces the side walls and not the door. This way, only one squatting pan can be used for both vaults (see Figure 10).

Figure 10 Left: Ecopan from eco-solutions in India. Right: Product from Kentainers in Kenya. Both plastic.

3.4.3 Version with separate outlet for anal cleansing water

Anal cleansing practices differ from region to region with two main types of people. People who use toilet paper for wiping are commonly called 'wipers'. On the other hand, 'washers' are those people who wash the anus after defecation with water[15]. The water is either splashed by hand or by using a hose or a jet like in a bidet. Anal cleansing by hand is a general custom practiced in the majority of Muslim, Buddhist and Hindu cultures. In India for example, also the Christian population tends to wash, so it not strictly linked to religion.

Washwater from anal cleansing must be prevented from entering the faeces vaults at all costs. This is commonly done through a third separate outlet in the squatting pan, also called "3-hole design", located behind the faeces hole as shown in Figure 11 (i.e. further away from the urine drain hole to avoid faecal cross-contamination).

Alternatively, the washwater could be collected together with the urine, but this is only the second best option - if urine is to be used as fertiliser - as it dilutes and contaminates the urine. In any case it is recommended to use lids to cover the faeces hole before the user starts washing.

In practice it means for the user that he or she has to move from the faeces hole of the pan to the anal cleansing section, which is only centimetres away. More details on anal cleansing water management are provided in Section 6.2.

Figure 11: Left: Model from Shital Ceramics (India) installed in Afghanistan. Right: Reversible pan from Systems in N-Fibro in Rajajinagar, India

3.4.4 Footsteps for squatting pans

It is useful to indicate footsteps in order to guide on how to place this feet and body for an ideal squatting position over the defecation drop hole. The footsteps are either indicated on the pan (see Figure 9 right side or Figure 11 left side) or raised as it is often done in conventional pit latrines. The footstep size should be sufficient for adults. In school settings the footsteps should be reduced for smaller children that also need very clear indications. The footstep can also be useful to prevent water from entering the faeces vault as shown in the picture from Kenya in Figure 11.

3.5 Urinals

The easiest way of urine diversion is a urinal. It often makes perfect sense to also install a urinal together with a UDDT as it reduces the risk of misuse by men who like to stand while urinating. However men should ideally sit in order to have a good separation of urine and faeces. Urination while standing can quickly led to urine entering into the faeces vault or it can cause splashing of urine which is unhygienic.

Therefore installing urinals, preferably waterless, are always a good idea, and these can even work for girls (squatting position) particularly in school and public toilet settings.

3.6 Material options

In order to be a durable and easy to clean toilet bowls or pans should be made of a material with smooth surfaces such as porcelain, plastic, fibre class, tiles and concrete

[15] Note: many "washers" also wash their genitals after urinating alone.

with a smooth and sealed finish. Concrete has the disadvantage of quick abrasion and having an absorptive surface making it prone to odour and dirty appearance. Smooth concrete surfaces however can be regularly treated with wax to avoid odour. Plastic, porcelain and fibre glass units are a preferred material which are easily cleanable and a status symbol. Colour can be an additional product aspect for plastics that enhances marketability.

3.7 Toilet cubicle design

The toilet superstructure provides privacy and comfort for the users. Several design aspects have to be followed to allow the proper function of the UDDT:

- The toilet slab should have a sufficient slope to drain water to the outside of the toilet cubicle either through a floor drain or some kind of outlet. This is important to assure that water does not enter into the faeces vault. Water can be generated from toilet washing, showering or anal cleansing. The drainage can be lead into a soak pit / area. Alternatively the water can also be drained into the urine collection if direct reuse of urine is not the main objective or an underground infiltration/irrigation system is implemented.
- The floor of the toilet slab shall have a smooth and durable surface for ease of cleaning (see Section 3.6). In public or institutional toilets a ground, polished or tiled concrete surface is of advantage for its durability and attractiveness.
- The orientation of the squatting pan is normally such that the user's face is pointing towards the door or the side walls. See version for double vault UDDT in Section 3.4.2 for further specification.
- The toilet cubicle should be well ventilated (see Section 4.6).
- The toilet seat or squatting pan should be placed at sufficient distance of at least 30 cm to walls and doors to avoid unintentional contact.
- The minimum space requirements of a toilet cubicle are about 80 cm wide and 120 cm long in order for a person to move freely.

Figure 12 Sketch of standard size UDDT toilet cubicle for two pans in parallel and a double drop hole pan with dimensions

3.8 General rules for installation and usage of UD bowl and pan

3.8.1 Water in a "dry" bathroom

Since there is always the possibility of water being used in the toilet such as from handwashing, showering and cleaning it must be safely drained and kept out of the faeces vaults (see Section 6.1). Accordingly toilet bowls (pedestals) and pans should be well sealed at their base in order to prevent the leakage of water. Special attention has to be taken when bowls or pan are moveable as e.g. the model of Envirosan Sanitation Solutions from South Africa (see Figure 34)

3.8.2 How to prevent blockages in the urine outlet

The only real malfunction of a urine diversion seat or pan occurs when the urine drainage and subsequent urine piping gets blocked. Stagnant urine in the urine outlet is the result. This happens mainly when user accidently drop ash, dispose waste products or even defecate in the urine section. This is a direct result of improper usage or rather misuse. Secondly urine stone (struvite) can develop over time and block the urine outlet as well. There are various measures on how to best prevent such blockages by the installation rules. These are:

- Use a rather small urine outlet diameter of 1 – 2.5 cm with a larger subsequent urine piping system (see Section 5.1). Thus large objects and big quantities of foreign materials cannot enter the urine piping. It also makes it for users more obvious that this is not the faeces drop hole (in case the drop hole is covered with a lid)
- It is recommendable to provide a removable coarse sieve for the urine outlet to minimise risk of blockages by foreign materials. It also encourages proper usage by the visual impression of "liquids only". The disadvantage of this option is that the sieve needs regular cleaning since various materials such as pubic hair, blood clots and urine stone (struvite) frequently block the sieves.

3.8.3 Odour control at toilet bowl and squatting pan

Whilst waterless urinals need to have an odour seal to prevent urine odour emanating from the storage tank (von Muench and Winker, 2011), such odour seals are not commonly found for UDDTs. Toilets in outdoor locations are usually well ventilated or do not have a urine storage tank. Indoor locations often have electrical fans to expel odours and might as well infiltrate the urine and not store it.

Basic odour control measures at the user interface level are cleanliness and type of material is smooth and not absorptive (see Section 3.6). Moreover the use of lids can provide odour control to a certain extend which is described in the next section.

3.8.4 Use of lids to cover faeces holes

As the faeces pile up inside the vault they eventually become more easily visible to the users. A lid on the faeces hole of the pan or bowl can be a good option to conceal the sight of faeces. A lid also helps in prevention of possible odour coming from the vault and of water or urine from entering the vault. It is therefore recommended to strictly use lids for UDDTs with an anal cleansing area where the risk of water splashing into the faeces vault is high.

Lids do also help in preventing flies and other insects to enter the vaults. However if the vaults are dry and covering materials are use the infestation with insects is minimal.

It is of advantage to enable the user to operate the lid on squatting pans with his or her foot. This is more user-friendly and reduces risk of disease transmissions. For schools and public toilets it might be wiser to not use lids at all (for the active vault), as users may not operate them properly and may get confused. Lids can also get lost or break apart in such environments.

Lids are also used for the purpose of covering the resting vaults in double vault UDDTs in order to indicate that the vault is not in use and thus avoid the addition of fresh faeces. The lids must be firmed fixed so that they are not accidently removed (see various lids in Figure 10 and Figure 11).

3.8.5 Using the toilet

The user must mindfully use the toilet seat or squatting pan to **prevent liquids (urine or water) from entering the faeces vault** when using or cleaning the toilet. Small amounts of urine (dribble) or menstrual blood entering the faeces vault do not cause any problems.

The user throws toilet paper and other wiping material like leaves or paper into the faeces vault. Some users may use stones and sticks for wiping which may also go into the faeces vault. However this should be an exception rather than the rule since it fills up the vault more quickly and will make the emptying and reuse of the dehydrated faeces more difficult. Other wastes like kitchen waste, sanitary napkins and other debris should not be thrown into the vaults (see Section 6.6).

Figure 13. Poster on usage and operation of toilet by ROSA Project in Eastern Africa

The user should **cover fresh faeces** with a scoop of locally available dry and absorbing covering materials like wood ash, lime, sawdust, dry leaves or dry soil[16]. Therefore the user needs to check that a sufficient supply of covering material should is always available.

Figure 14. A school student demonstrates on how to spread sawdust over the faeces, Tajikistan (photo by WECF)

The user may close the toilet seat or pan of the active vault with a lid for blocking direct sight into the vault. Since odour and flies are not a problem in a well operated UDDT a lid is not required for odour and fly control.

The urine diversion toilet seat or pan should be cleaned regularly with a damp cloth, rag or brush in order to remove urine and possible faeces stains. Water should be used very sparingly, avoiding the entry into the faeces vault. Standard rinsing agents can be used.

4 Design of faeces vaults

4.1 Functions of faeces vaults

Faeces vaults have the following functions:

1. Safe containment of faeces: limit undesired external access by humans and animals, flooding, seepage into the groundwater and pollution of the environment in general
2. Keeping the faeces dry from urine, washwater and flooding water minimises odours and makes emptying less offensive as well as safer.
3. A certain storage time of faeces that that ranges from 6 to more than 12 months and which promotes the dehydration of the faeces with the objective of reducing disease causing pathogen levels. However it is not the function of the vaults to fully sanitise the faecal matter.

A standard UDDT has two above ground collection vaults for faeces, so called a double vault UDDT. The vaults are used alternately. Only one vault is used at a time until the vault is full, so that the other vault can "rest" to dehydrate. The period to fill one vault generally ranges from 6 to more than 12 months – this is the same time that the other vault is resting and the faeces are dehydrating.

[16] Note: this is not necessary e.g. in the case of the Separett toilet which has active ventilation and a lid to cover the faeces section.

Figure 15. Double vault UDDT in near Cusco in Peru and at a school in Nizhyn in Ukraine (photo by H.Hoffman and WECF)

The concept of a double vault UDDT is that no fresh faeces have to be handled when emptying the vault but instead only dehydrated faeces are removed at the end, which are a crumbly, dry and odourless material. This is making emptying of the vaults less offensive and of course safer due to die off of pathogens to lower levels as compared to conventional pit latrines, bucket latrines or off-set drainage pits of flush toilets.

Both safe disposal and reuse of faecal matter should be done according to the details given in Section 2.7.

4.2 General rules for UDDT vault design

The following basic design rules should be carefully followed to provide a well-functioning toilet:

- **Above ground location** of vaults is very common to minimise the risk of flooding from heavy rains and for ease of emptying.
- **Vaults** should **not** be **located in depressions** and low points of an area where rainwater usually collects.
- Build the **floor of the vault at least 10 cm higher than the ground level** for protection from flooding. In areas of regular flooding different designs can be utilised (see Section 11.6).
- The **vault floor must not necessarily be sealed** since the leaching of pathogens into the groundwater is greatly diminished by the dry conditions of the faeces.
- If the **vault floor** is sealed then it should **be slightly sloped** towards the vault door to drain away possible excess urine, water and other liquids from the collected faeces in the vault. Such excess liquid can appear in cases of misuse, but usually in small amounts. The leachate must be able to drain into a soaking area attached to the toilet.
- **Installations of vault doors** that will keep the faecal matter safely contained and create a dark interior so that the faecal matter is not easily visible when using the toilet (see Section 4.5).
- **Ventilation of the vaults** through vertical piping that leads above the roof top in order to vent off moisture and odours. Fly traps are not strictly required unless in climates with many insects. Sufficient air supply for ventilation is usually assured either through leakage of vault doors or through the toilet seat or pan. An additional supply air opening is not required. See for more details in Section 4.6.

The physical structure of a vault needs to carry the weight load of user(s) and the toilet superstructure if existing. The use of building materials ranges from permanent structures with bricks and concrete to light-weight structures made from timber, bamboo and other strong materials (see standard list of materials in Section 13.1 and Section 10.1 for cost relevance).

The faeces are usually collected directly in the vault without the use of an additional container. This way almost the entire volume of the vault can be utilised for an extended storage. In contrast a container would significantly reduce the storage volume of the vault leading to shorter storage periods which would limit primary treatment. Containers might also have a negative impact on dehydration efficiency. However it could be relevant for areas with users or service providers that prefer working with containers since they simplify the emptying process.

In some cases also underground vaults or partially underground placement is an option. Here special care must be taken to avoid flooding and environmental pollution as well as ensure user-friendly emptying.

4.2.1 Dimensioning of double vaults

The size and dimension of the two vaults depend on the number of users, their frequency of use and the required storage time of 6 months or up to 12 months in cold climates (see Section 7.5). The dimension should also correspond to the toilet cubicle above the vault (see Figure 16).

The number of users per UDDT can range from usually 1-10 persons for households to 30 students or more in schools.

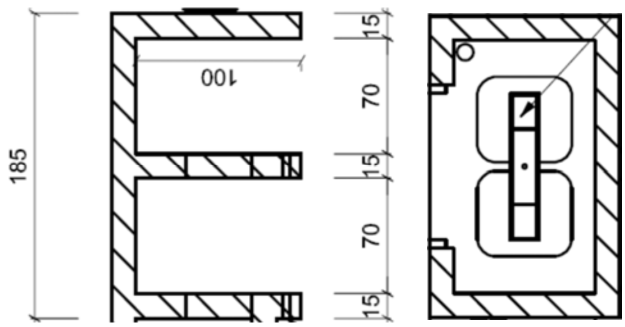


Figure 16. Scetch of vault and toilet cubile with dimensions from EPP in Kenya

For design purposes it is recommended to assume that the average person of a household will require approximately **50 liters of storage space** every six months. See the calculation example for explanation in the following section.

4.2.2 Calculation example for size of double vaults

The daily average amount of defecation ranges from 0.12 up to 0.4 kg/day/person (see Section 7.1). As a common example a rural African family with 10 persons is chosen (or two households of five people each sharing the UDDT) with a mainly vegetarian diet in a tropical climate. Adults are assumed with a daily faeces amount of 0.4 kg per person per day. Children and old people are also part of the family who have a smaller food intake and thus smaller faeces deposits of assumed 0.15 kg per day. The users deposit faeces, toilet paper and covering materials in the vaults. In some cases also sanitary items or even solid waste, which is however not taken into account in this example.

Furthermore not all members of the household will always be defecating at home since they are out for work, at school, are on holidays or otherwise outside of the household. This will further reduce the daily amount of vaults deposits by about 15%.

During filling of the vault it has to be taken into account that a moisture loss of the faeces (through drying) can be assumed at a factor of 30%.

The vaults should be slightly oversized with a safety margin to account for airflow, additional visitors, uneven distribution in the vault (pile) and some distance to the toilet slab. The faeces pile up as a heap and create a non-even distribution in the vault which subsequently reduces the usable volume of the vault unless the heap is manually flattened. Accordingly the vault needs to be increased by an assumed safety margin of 20%. This sums up to about 500 liters of volume per half a year (equals 0.5 m³) for a UDDT that is used continuously by a maximum of **10 persons.** This means a volume of 50 litres per person for dimensioning purposes.

Calculation example household in rural Africa
Covering materials - assumed daily average 0.05 kg ash
Toilet paper - annual average of 8.9 kg *

7 Adults	x	0.4	kg/day	=	2.8	kg/day
3 Children	x	0.15	kg/day	=	0.45	kg/day
				=	3.3	kg/day
					98	kg/month
for absense	-	15	%		83	kg/month
toilet paper	+	0.7	kg/month	=		
covering material	+	15	kg/month	=	**99**	**kg/month**
	x	6	months	=	592	kg/half year
moisture loss	-	30	%	=	414	kg/half year
safety margin	+	20	%	=	497	liter/half year
		vault volume		=	**500**	**liter**

* according to Jönnson, 2004

As a result a vault size could have inside dimensions of 0.9 m long, 0.7 meter wide and a vault height of 0.8 m which would create a total volume of 450 litres for one vault. This corresponds already very well with the required dimensions for the toilet cubicle above the two vaults. However the exact dimensions of the vaults must be adjusted/ extended to the desired dimensions of the toilet cubicle and the setup of either the user facing the entrance door or the side walls (see Section 3.4.2).

Calculations for schools and public toilets must be adjusted accordingly.

4.3 Design of single vault systems

Single vault systems are not UDDTs according to the meaning of “dehydration”. Nevertheless these systems are often used and referred to as UDDTs even though the term should be Urine Diversion Toilets (UDTs). Thus a short overview is given here for clarification purposes.

The single vault UDDT has only one collection vault for faeces which reduces the costs of construction and the space requirement, but requires (external) secondary treatment of the faeces (or alternative disposal). Since the toilet is in principle used continuously it means that fresh faeces have to be handled during the vault emptying and transport. During the period of filling in the vault with faeces only limited sensitization takes place.

To make emptying of the vaults more user-friendly, single vault UDDTs usually have a container (or receptacle) like a bin, barrel and bucket or bag that is placed inside the vault. Depending on the size of the container and the number of users, the container has to be removed in a frequency ranging from once per day to about once every three months.

Often the full container is moved inside the vault to the side for some time for further drying before being taken to an external site for secondary treatment. This can be dehydration, composting or incineration. Depending on the size of containers the vaults can accommodate one or more containers.

Such an intermediate storage of the full faeces container can also take place outside the toilet on the owner’s premises. Then it is necessary to firmly close the receptacle with a lid and store it safely, protected from rain water and human and animal contact.

In some low cost designs the vaults are very simplistic[17] or the toilets are integrated into existing houses which utilises existing walls (see Section 11.6).

The workload to operate single vaults is high due compared to double vaults. They need rather frequent emptying and transport of faeces containers to secondary treatment site or disposal site. Depending on the container size and user numbers this can range from one day to about 3 months. It must be either done by the owner on the plot or requires a well functioning collection and handling service by professional service providers. If these operation requirements cannot be met due to lack of motivation of clients/future users, of available service provider and appropriate treatment or disposal sites or lack of willingness to pay for such services, a single vault UDT should not be implemented.

Examples of single vault systems are given in Section 11.

[17] Example from Ecuador in SSP Toilets and flickr pictures

4.4 Comparison of double vault to single vault system

Both vault designs differ with regard to the storage times and achievement of primary treatment (dehydration) inside the vault as explained above.

UDDT with double vault	UDT with single vault
+ No fresh faeces have to be handled + Dehydrated faeces are – in the ideal case – a crumbly, powdery and odourless material which make emptying less offensive + Disposal and reuse of faeces is more safe due to lower levels of pathogens after primary treatment inside the toilet + Long emptying intervals make them user-friendly - Misuse of toilets can quickly lead to wet and thus stinking faeces which cannot easily be resolved	+ Requires less space for only one (single) vault + Construction costs are slightly lower + Short emptying intervals of containers make misuse less problematic – containers can be easily exchanged - Handling of fresh faecal matter - Requires either a highly motivated user for faeces management or professional and reliable service provider - Faecal material (partly fresh) poses major health risks if not disposed of adequately or treated for agricultural reuse purposes (see Appendix 13.1)

4.5 Design of vault access doors/ openings

4.5.1 General requirements

Vault access doors and openings must provide a range of conditions to keep the faeces dry by protection from rainfall and flood water intrusion as well as protection from access by people and animals.

The general requirements for vault access doors are:

- Lock vault doors firmly to avoid accidental opening by children or roaming animals – use of hinges, rails or hooks as well as semi-permanent solutions
- Protect the vault from rainwater intrusion through good craftsmanship of doors and shielding doors from direct rainfall. This can be done best through straight vertical vault doors and standard roof overhang.
- Vault doors must be placed above flooding water levels in areas where flooding occurs regularly (see design recommendations in Section 4.2)
- Vault doors do not need to be completely air tight since additional supply air for ventilation of the vault is beneficial.
- Vault doors should be installed in a way that day light is largely blocked from entering the vault in order to avoid the visibility of faeces by the user.

Moreover it needs to be considered that construction mistakes, cracks, rusting and other damages or simple fatigue of materials can lead to intrusion of rainwater after some time thus causes malfunction of the UDDT. It has been often witnessed that after months or a few years vault doors start leaking rainwater which leads to the wetting of faecal matter thus causing odour and flies (malfunction). Therefore, the protection from direct rainfall is the best and most simple way to assure that. Otherwise the doors must be timely repaired or replaced after some time.

4.5.2 Materials for vault doors

Various materials can be used for doors ranging from galvanised and painted steel sheets, treated wood, concrete slabs, masonry and plastic sheets.

Figure 17 Example of metal vault doors with looks at a school in Lima, Peru and semi-permanent doors made from concrete slabs at a household in India (photos by C. Olt, 2009 and Lucas Dengel, 2009)

It is important to provide easily maintainable doors that are resistant to:

- Weather conditions. For example humid climate causes corrosion of metal. Action: Use rust-proofing paint.
- Vandalism or accidental damage from sitting or placing heavy objects on vault doors e.g. in the case of inclined vault doors. Action: vertical doors and robust make
- Effect of insects such as termites damaging untreated timber. Action: Anti-termites treatment of wood

4.5.3 Semi-permanent fixed doors

The vaults can also be closed with semi-permanent doors made from masonry or slabs made from concrete, stone or wood. They are fixed with weak mortar and clay soil or nails which can be easily broken off and removed when the vault needs to be emptied. Re-sealing is done with the same materials that must be available. Such semi-permanent doors are a good option for long emptying intervals which apply for UDDTs. However there is a risk that resealing of the doors is not done properly.

4.5.4 Should vault doors be inclined or vertical?

Inclined vault doors were initially the most commonly used design for UDDTs. It was the objective to face the vault door towards the sun at a certain angle in order to absorb the sun heat that can heat up the vault contents. To support the heating the doors are made of metal, painted black or in dark colours. This is supposed to lead to pathogen removal and accelerated dehydration.

In order to reach necessary the high temperatures (above 45°) for pathogen die-off in the faeces content the vault must be exposed to the sun for long periods of the day and the absorption area of the door must be of sufficient size. These kinds of UDDTs are sometimes also called "solar latrines" or UDDTs with solar panels[18].There are so far no well documented examples of UDDTs with inclined vault doors that achieved sufficient temperatures.

Figure 18: Left: UDDT with slightly inclined metal vault doors in Chwele, Western Province. Right: ‚Toilet in eThekwini (Durban) in South Africa with vertical and sideways sliding plastic doors (photos by C.Rieck, 2010 and EWS, 2009)

Moreover most of the times the toilets are not properly aligned towards the sun for many practical reasons and end up predominantly shaded thus are not serving the original purpose of solar absorption. In addition inclined vault doors face challenges with increased risk of rainwater leakage, vandalism (people sitting on it, placing or storing objects) and additional costs as compared to vertical doors.

Vertical vault doors have the advantage that they are generally not exposed to direct rainfall, hence there is no requirement to be rainwater tight. Accordingly, the requirements for construction are fairly simple. The absorption of solar radiation is not a design objective, hence the toilet can be placed in any suitable location. The size of doors is also not critical.

As a result GIZ does recommend building UDDTs with inclined vault doors.

4.6 Ventilation

The ventilation system of the vaults is important for the function and user comfort of a UDDT. It provides the exhaust of odours and moisture which supports the dehydration process of the collected faecal matter. The ventilation should never be omitted, even in very dry climates in order to guarantee exhaust of odours at all times.

Ventilation can be natural or mechanical. Natural ventilation is more common. However for indoor installations and especially multi-storey buildings the natural ventilation might not be sufficient and can be upgraded with mechanical ventilation systems like wind-propelled or electrical fans.

The natural ventilation consists of a pipe that leads from the collection vault(s) vertically up above the roof. The *wind* creates a draft that extracts air from the vault and thereby leads out moisture and odours. There is also the *stack effect* due to difference of pressure (or temperature)[19] that enables ventilation.

The ventilation pipe should be at least 100 mm (4") of diameter. The material can be plastic PVC or PE pipes or even locally made concrete pipes (Morgan and Shangwa, 2010). For best performance the pipe should be straight without sharp bends which would increase friction and thus reduce effect of draft. A minimum of 1 m extension above the top line of the roof is recommended.

Figure 19. Different options of vent caps and wind-propelled ventilator

The ventilation pipe outlet should be covered with a vent cap, cowl or T-joint to prevent rain water from entering the vault (see Figure 15). A suitable mosquito proof mesh can be placed on top of the vent pipe to act as fly trap (see Section 4.7).

A single vent pipe is sufficient to ventilate a single and double (interconnected) vault (see Kenya example in Figure 18). The interconnection of double vaults is done through an opening through the central wall between the two vaults. The pipe can then be place in either vault or in the centre. Alternatively, each vault can have its own vent pipe.

Ventilation pipes can be installed inside or outside the toilet superstructure. However pipes can be easily broken if placed in unfavourable spots. Preferably they should be placed tightly into a corner or wall to give protection from accidental breakages. Especially outside plastic pipes are prone to vandalism and also fatigue of material which is caused by the exposure to sun light. Even though they might have the slight advantage of increased air draft due to heating of the pipe → stack effect, the placement of **ventilation pipe inside the cubicle** is recommended.

The supply air for ventilation comes through the toilet seat or pan in the toilet cubicle. It is sucked through the faeces drop hole - which is either uncovered or has a lid (usually not airtight) into the vault and then into the vent pipe. Moreover the vault doors usually provide supply air through leakages since they are often not air-tight. An additional air supply opening is not necessary.

The toilet cubicle should be also well ventilated to provide a fresh and odour free environment. There are options to create vent openings above the door, along the walls with vent blocks or gaps in the walling as well as openings around the roof fitting (for warm climates only). However privacy must be ensured in particular for schools and at

[18] See examples of UDDTs with solar panels here: http://www.flickr.com/photos/gtzecosan/galleries/72157626102034702/.

[19] SSWM http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/processes/drying-and-storage-faeces

public toilets. In cold climates ventilation is rather done through windows, a passive ventilation system or electrical fans.

4.7 Fly traps

Fly traps are not strictly required for UDDTs unless in climates with many insects. Generally the dry conditions of the faeces and the covering with dry absorbing materials do not attract flies and other vectors in the first place.
However it is often see that fly traps are place in ventilation pipes with a mosquito proof mesh. Fly traps can also be placed inside the vault walls, which may consist of a plastic bottle of 2.0 L with the top part cut off and inverted. The bottle is placed with a bottom in direction to the light, in this way it can catch vectors which may come in the house through the faeces drop hole.

4.8 Golden rules for odour control from vaults

The basic odour control for the faeces vault is provided by

1. **the DRY CONDITIONS IN THE VAULT,**
2. **the USE OF DRY COVERING MATERIAL and**
3. **the WELL DESIGNED VENTILATION SYSTEM.**

Odour can however originate from the faeces collection vault during misuse or detrimental wind conditions that push air through the vault doors into the toilet cubicle. Here a tight-fitting cover lid for the defecation hole(s) is an option but not a must (see Section 3.8).

5 Design of urine collection system

The urine collection system has the objective to drain the urine either directly into a disposal system or into a storage system for purpose of reuse or disposal (see Section 8). Generally the urine collection system should be designed to minimise the occurrence of odour.

Urine can be collected in pure form or diluted with other wastewater streams according to objective of reuse or disposal. This leads to common configurations of urine collection which are are:

- Pure urine is collected from UDDTs and urinals with subsequent storage within or attached to the toilet structure for the purpose of direct reuse or collection by farmer or service provider
- Pure urine is collected from UDDTs and urinals for direct disposal in soak pits
- Urine is mixed with hand-wash water, shower water, anal cleansing water and other wastewater streams and is led into a subsequent underground irrigation system for reuse or disposal or into a soak pit or sewer.

5.1 Urine piping

The piping system should be designed in such a way that blockages are minimised. This length, diameter, number of bends and slope are crucial factors. A comprehensive description of the technical details for urine pipes and tanks is available in Kvarnström et al. (2006). The following main recommendations can be summarised:

Figure 20. Plastic urine piping with slope and diameter of 5cm visible inside the vaults, Peru (photo by H.Hoffman, 2009)

Materials: Plastic pipes from polyethylene (PE) and polyvinyl chloride (PVC). They can be stiff or flexible pipes. Metal pipes should be completely avoided due to the corrosive nature of urine[20]. However some types of hose pipes with thin walling easily create sharp bends, and in combination with their small diameter of 1 inch (3cm) or less, they often get blocked. Therefore preferably only stiff hose pipes should be used.

Length/Bends: The piping system should be short, preferably less than 10 metres, to limit the time the urine is in the piping system and thus the degradation of urea and risk of precipitation in the system. Bends should be limited in number as they are common points of blockage. For inspection and cleaning of pipes they should have inspection openings at accessible bends.

Connections: It is crucial to provide water tight inter-connections of the pipes to avoid leakages which can cause odour if urine drips into the faeces vault. Plastic pipes can be fitted together with rubber rings or appropriate sealant glue. It is important not to expose plastic pipes to sun light and to install them well protected in order to prevent accidental breakage and vandalism.

Diameter: The minimum recommended diameter of the pipes is 50 mm (2”), but the optimum range is from 75 mm (3”) to 110 mm (4”). The larger diameters will limit the effect of fibres and other foreign materials such as ash, toilet paper and faeces to block the piping.

Slope: A minimum slope of 4% is suggested (4 cm height difference on 1 meter length). This will counteract the effects of chemical precipitation in urine, i.e. struvite and calcium phosphate crystals which also cause viscous sludge.

Alternatively to piping the urine can also be drained in open shallow trenches similar to a wall urinal. This can however

[20] In theory, stainless steel could be used but this is to expensive.

cause some odour nuisances, which might not be critical in a well ventilated toilet building or outdoor installation.

5.2 Odour control for piping and storage system

In general odour nuisances from the urine collection system are caused through exposure of urine to air that leads to ammonia emissions. Ammonia emissions also lead to loss of nitrogen and thus fertiliser quality.

Odour can be emitted from urine puddles that accumulate in sections of the piping with insufficient slope. This is only a problem in longer piping of toilet blocks in schools or public toilets. The piping can be also be ventilated over the roof together with the faeces vaults (see Section 4.6).

If the urine is disposed in soak pits there is no relevant odour problem. In the case that urine is stored in containers and tanks, odour can come through the piping system into the toilet room. This makes it necessary to:

1. Install a simple odour seal at the tank by submerging the urine inlet pipe into the liquid of the storage tank (close to the bottom of the tank), thus creating a liquid seal inside the pipe.

2. To ventilate the location of the tank. The tank and pipe system are usually not completely airtight. When the urine fills the tank air will vent off into the environment (pressure equalisation). This means for indoor locations some minor odour occurrences then urine runs into the tank.

3. To ventilate the tank itself over the roof, if the fertiliser quality of the urine is not critical since nitrogen will be lost.

Another option to odour seal the system is to place a conventional water seal such as a p-trap, u-bend or “bottle” trap after the urine outlet of the user interface. However such seals are prone to blockages when small diameters are used and require well accessible inspection opening.

Charcoal has the ability to absorb odours from urine as well (Gensch et al., 2010). In the Philippines a bag of charcoal is placed at a crucial spot in the piping. After some time the absorption capacity of the charcoal is exhausted which requires replacement.

More information on odour control measures like curtain valves are found in Muench and Winker (2011).

5.3 Set up of storage system for reuse purposes

5.3.1 Urine storage containers and tanks

For reuse purposes the urine is drained into storage containers or tanks. Urine storage tanks have three main purposes:

1. To sanitise the urine through storage (time varies, see Section 8.5) with the objective of using urine as a fertiliser
2. To bridge the periods where plants are not fertilised. This is especially relevant in areas with seasons of winter and extended dry periods that prevent agricultural activities for several months.
3. To bridge the time until emptying by a service provider.

To calculate the required storage volume, multiply the daily urine production rate of the household with the number of desired storage days (see Section 8.5.3). For example, a family of five produces about 7.5L of urine per day (5 x 1.5 liter/person/day). To obtain a storage time of one month (30 days), a storage volume of 225L (7.5L x 30) would be needed. This would equate to 12 jerricans of 20L each.

Figure 21 Examples of urine piping into jerrican Left: underground location with PVC piping in Peru. Right: above ground collection from hose pipe in extra chamber in Zambia (photos by H. Hoffmann, 2009 and R. Ingle 2010)

Urine storage containers and tanks should be completely water-tight to avoid leakage into the environment. Moreover they should have a lid in order to prevent odour and loss of nitrogen via ammonia emission as well as allow access and removal of urine (see following Section). Hence ventilation of the tanks should be avoided as much as possible if urine is to be used for agricultural purposes. Furthermore a urine overflow pipe into a soak pit should be provided for the event of overflow.

It is very common to reuse and recycle available plastic containers from households in particular jerry cans of 20 litres for short term urine storage. They can be easily moved by hand. For bigger storage tanks it is possible to use rainwater harvesting tanks or former septic tanks.

The containers can be placed in a separate chamber of the toilet, or outside next to the toilet, either on the ground level or dug in. To allow gravity flow the tanks must be placed on a level that provides sufficient slope of the piping (see Section 5.1). In some cases the tanks must therefore be located underground.

In practice, containers can be easily stolen. Hence they should be locked up or securely tightened. This should however be done in way that will not make the regular exchange and emptying of containers inconvenient.

More details on tanks are provided by Muench and Winker (2010).

Three scenarios for urine collection are most common:

- Two to three jerry cans (each 20 Litres) per UDDT which are alternately filled, manually removed, stored for a relatively short period (1 week to 1 month) and used in own farm (Rieck, 2010) or collected by service providers and then transferred into bigger tanks (Fall and Coulibaly, 2011, Kanzler and Martinez, 2009 and Stintzing et al., 2007). See Figure 21.

- Two middle sized tanks for a certain number of UDDTs that are alternately filled to provide one or more months storage time before use in agriculture (Figure 22).
- One tank which is emptied by a service provider / farmer and transported to an external storage tank once it is full (refer to ROSA project in Ethiopia) or for the case of boys urinals (storage not strictly required) by schools with hand pumps for fertilisation of school farm (Morgan and Shangwa, 2010).

Figure 22 Example of underground with plastic urine storage tanks at Gradanitsy school in Ukraine (photo by WECF 2010)

5.3.2 Urine withdrawal from tanks

The urine tanks are either emptied by the users themselves (household systems) or a pump or suction truck arrangement. Short-term odour nuisance is an issue during withdrawal which can hardly be avoided. This is a fact that must be considered for operational planning and awareness creation of users and service providers.

For manual withdrawal the urine tanks can be fitted with outlets in several ways. A simple method is to fix a flexible pipe from the outside to the bottom of an above ground tank, then lift and tie it up. The pipe should be longer than the height of the tank, so that the open end of the pipe is above the maximum urine level in the tank. By lowering the pipe the urine can be easily discharged (see Figure 23).

Plastic water taps can be another option for bigger tanks which are not supposed to be moved. Metal material should be avoided due to corrosion problems. Plastic taps are generally at high risk of breakage and material fatigue by exposure to UV light. Hence the taps should be heavy-duty, sun-shaded and tightly attached to the tank to avoid leakages. Fixing can be done with proper brackets, cement mortar or other protective installations.

Options for underground tanks are mobile plastic or metal hand pumps which are only used during the emptying process and stored otherwise (Morgan and Shangwa, 2010). The most simplest way however is the use of buckets similar to water fetching from a well.

Figure 23 Manual withdrawal from above ground tank via hose pipe in Sodo, Ethopia and piston pump from underground tank in India (photo by rosaafrica (account youtube) and S.M.Navrekar, 2010)

6 Other design aspects

6.1 Integration of showers

For some users it is interesting to use the toilet also as a shower facility in order to save costs of construction and due to lack of space. However there is a high risk of water entering the vaults mostly due to carelessness of users or simple design shortcomings.

There are two ways of integration. One is to install a separate shower area inside the toilet (see Figure 25) and the other directly over the seat or squatting pan. Here it must be ensured that the faeces drop holes are slightly elevated over the floor level (see Section 3.4.4) and have well functioning lids that do not let shower water into the faeces vault.

A few designs show promising simple technical solution like the "easy shower" in Cambodia designed by International Development Enterprises (IDE)[21] where the shower water is collected in the urine collection hole and led to a drip irrigation system. Alternatively a separate floor drain must be installed.

A separate shower, which is not situated on top of the faeces vault, is in any case the safer option.

[21] http://blog.ideorg.org/2011/03/

Figure 24. Bench UDDT with an attached shower under construction in San Juan de Mirafores, Peru (photo by H. Hoffmann, 2011)

6.2 Anal cleansing water and greywater treatment or disposal

The anal cleansing water can be collected pure or in mix with urine and/or greywater (e.g. hand-wash water and shower water). On average two to three litres of washwater are used for anal cleansing per defecation event (Rosemarin et al., 2007).

Due to the faecal content of anal cleansing water with high pathogen levels it should be handled safely. In the case that anal cleansing water is mixed together with urine and greywater it contaminates these waste streams with pathogens, hence rendering urine unsafe for manual application as fertiliser unless underground irrigation is used.

In most cases the washwater is drained into a soak pit or mulch bed for disposal. There are examples of planted (evapotranspiration) beds so that plants or trees can benefit from the water and nutrients content.

Since also more solid particles are carried along the greywater the risk of the soak pit to get clogged is great. Thus a pre-treatment with shallow grit and grease removal chambers or alternatively a larger soak pit should be provided. Clogging will eventually happen in most soak pits thus requiring relocation. For more details on infiltration as well as reuse option see or Morel and Diener (2006). Tilley et al. (2008) and Hoffmann et al. (2011).

6.3 Indoor applications

Indoor set ups must take into consideration the increased ventilations requirements to keep possible odour out of the house. These locations usually lack a good passive ventilation of the vault and cubicle as provided e.g. in outdoor UDDTs (see Section 4.6).

If the location does not allow for appropriate ventilation the user should use plenty of covering material to absorb odours, and ventilate through windows. Especially suitable as covering material for indoor UDDTs seems to be compost which absorbs odours very well (anecdotal evidence).

Ventilation systems for prefabricated indoor UDTs with single vault system often provide an electrical fan to vent off moisture and odour. Wind propelled ventilation systems are also available but do not provide a continuous air flow which can lead to temporary odour.

Moreover in most prefabricated UDDT toilets the faeces vault is closed off with a lid to slow down odour transmission into the interior of the room.

6.4 Using bench design to eliminate stairs

The bench design uses a flat UD insert which is fitted on the vault whereby the user sits directly on the vault. This has the advantage of reducing the number of stairs. The user requires a sitting height of about 40 to 50 cm. With the vault having a height of around 80 cm it requires about 2 to 3 stairs to bridge the gap to the sitting height. If the toilet is build in a sloping terrain stairs can be even completely eliminated.

Figure 25 Bench UDDT with entrance and sitting levels near Cusco in Peru (photo by H. Hoffman, 2010)

The stairs can be either placed inside the toilet in front of the bench so that the user places his feet on the last stair when sitting on the toilet. Alternatively the stairs can be placed in front of the toilet or it is a combination of the two. In designs from Peru showers are often integrated in front of the toilet seat with the greywater draining into a constructed wetlands or soak pit. More design information are available in the publications of Rotaria[22].

6.5 Bucket and scoops for covering materials

A bucket or similar container must be made available to store dry covering materials that needs to be applied after defecation (see Section 7.3 for types of covering material).

The amount of dry materials to be added after each defecation is roughly a handful. Hence, tools like scoops, cups, spates, cut open plastic bottles or similar can be used for withdrawing the required amount from the bucket. Ideally the bucket shall be heavy so that it does not move

[22] www.susana.org/library?search=Rotaria

when withdrawing dry materials. Then only one hand is needed, preferably the “clean” one.

6.6 Waste bin for disposal of solid waste, sanitary napkins and alike

Solid waste, sanitary napkins and other sanitary products used in the toilet should be collected separately in a waste bin as they are not biodegradable, hence should be handled like solid waste. This is especially important when faecal matter is reused in agriculture. When faecal matter is disposed or buried, this sanitary waste may also be disposed into the vault even though it is not the ideal scenario.

In this case it must be remembered that vaults would fill up faster. It must be assured however that the minimal storage period of 6 months (see Section 7.5.3) is still realistic.

6.7 Menstruation management and gender issues

Waiting for Input!

6.8 Modification for people with disabilities

Waiting for Input!

Figure 26 UDDT with barrierless ground level entry. Though not designed for people with disabilities it can be easily modified with handrails and bars (photo by H. Hoffman, 2011)

6.9 Modification for small children

Small children in primary schools and kindergartens have a small body size that requires a reduction of seat size and sitting height for comfortable usage. For squatting pans the drop hole size needs to be reduced and the indication of footsteps adjusted according to the body size. An example of a simple seat adapter is shown in figure

Figure 27. Use of a movable seat adapter in Peru and sunk in UD pedestals in Georgia (photo by H.Hoffmann, 2009)

6.10 Signage for inexperienced users

It can easily happen that untrained persons use the toilet. In order to minimise risk of misuse a clear signage should be provided inside the toilet cubicle such as indicated footsteps (see Section 3.4.4) and a clear indication of which vault is in use and which is not (see Section 3.8.4).

Instruction posters are useful to provide background information on covering materials, cleaning and other general instructions in the form of sketches, pictures and minimal written descriptions. It is however not useful to write directions on lids or use arrows or similar signage since it might confuse the user who wants to quickly use the toilet.

Website links to such instruction posters are provided in Section 12.2.5.

6.11 Handwashing

Handwashing facilities are a must for toilets to enable good hygiene behaviours. Such facilities should be located attached or inside the toilet in order to foster usage. Furthermore a steady supply of water and soap is mandatory. See Section 12.2.7 for relevant publications.

7 Faeces material management

This section focuses on the basic faeces management principles, the scientific background of the treatment process and practical aspects of reuse and disposal. The objective of faeces material management was already described in detail in Section 4.1. In short the faeces management aims at safe containment, to, keep the faeces separate from urine and other liquids, dry storage conditions in order to facilitate relatively safe and inoffensive handling of faeces for the purpose of either disposal or reuse.

7.1 Quantity and quality of faeces

Every person excretes on average between 0.12 to 0.4 kg of faeces per day depending on the diet (high protein in temperate climate or vegetarian diet in a tropical climate respectively) and amount of food intake (WHO, 1992 and Geurts, 2005). Highest values were given by Geurts for Kenya with 0.53 kg/person/day. In the absence of local information the figures in Table 1Table 1 Average values of excreted mass can be used as reasonable averages.

Table 1 Average values of excreted mass

Parameter	Unit	Faeces	
		High protein diet	Vegetarian diet
Wet mass	kg/person/day	0.12 *	0.4 *
	kg/person/year	44	146
Dry mass	kg/person/year	9	29
Water content	percent (%)	80 **	
Nitrogen	g/person/year	550 ***	
Phosphorus	g/person/year	183 ***	

* WHO, 1992
** Jönsson et al, 2004
*** Swedish values from Vinneras 2002

After dehydration in UDDT the water content reduces to 20-40% and leaves an annual mass per person of about 20-35 kg for high protein diets in temperate climates and 70-110 kg for vegetarian diets in tropical climates. The weight and volume is comparable with a heavy backpack or suitcase. At least in the case of industrialised countries this quantity is much lower than the household solid waste production.

Faeces can contain pathogens which can transmit numerous diseases including diarrhoea and intestinal worms. Pathogens are infectious organisms and divided into four categories being viruses, bacteria, protozoa and helminths (intestinal worms)[23]. Their presence is naturally dependent on whether the users are infected or carriers of the organisms in question. They are easily passed from person to person via the faecal-oral route, either directly through contact of contaminated hands, or indirectly, via contamination of food and water through faecal pollution of the environment and transfer by flies. The main cause for waterborne like typhoid fever and cholera is the faecal contamination of water.

After excretion, the number of pathogens in faeces usually declines with time by natural die-off (Niwagaba, 2009). Pathogens often have a limited life span outside the human body, are not tolerant to low or high temperature and are exposed to a wide range of microorganisms contained in faeces that cause antagonism, competition, consumption and antibiotic inhibitors (Jenkins, 2005). Therefore time is a crucial factor for treatment.

Protozoa and viruses are unable to grow in the environment outside the host, thus their numbers will always decrease, whereas bacteria may multiply under favourable environmental conditions (Schönning and Stenström, 2004).

Parasitic roundworms (geohelminth/ nematodes) and especially their eggs need an effective treatment in order to entirely render them infective. Helminths eggs are more persistent than others due to their shell (Cisneros et al, 2007) and consequently also more resistant to treatment. The eggs of e.g. *Ascaris lumbricoides* and *Trichuris trichiura* can survive for years in the environment as they are soil-transmitted. Only moisture levels of below 5% can can assure removal (Feachem et al., 1983).

7.2 Disposal of toilet paper and other wiping materials in the vaults

The user shall dispose also the toilet paper or other wiping materials like leaves and paper into the faeces vault. The mass of toilet paper in Sweden amounts to 8,9 kg per year (Vinnerås, 2002).

Some users may use stones and sticks for anal wiping which may also go into the faeces vault. However this should rather be an exception than the rule since it fills up the vault more quickly. It will also make the emptying and reuse process of the dehydrated faeces more difficult.

Similarly other wastes like kitchen refuse and non-biodegradable materials like sanitary napkins and other debris should not be thrown into the vaults. This however happens often in schools and public toilet so that the faecal material can only be disposed off.

A separate collection of the toilet paper in a bucket is not necessary, since the toilet paper itself is contaminated with faecal material and must be safely contained and treated. The vault is the best place for that. The toilet paper also acts as an additional absorbent material for moisture and will easily decompose.

After dehydration some of the toilet paper will be still intact and visible which might lead to acceptance problems when selling the dried faeces directly as soil conditioner to a third party. Apart from that no other negative aspects are arising.

7.3 Covering materials like ash and woodchips

One compulsory measure for keeping the faeces dry is to cover them properly with a cup of dry covering material in order to speed up the drying process and also to control initial odour, keep flies and other vectors away and to get them out of sight. Covering materials are for example wood ash, sand, soil, saw dust, lime, leaves or rice hulls which cover the faeces and absorb moisture.

[23] For more details on pathogens in faeces and wastewater, see WHO (2006) or Hoffmann et al. (2011).

Figure 28 Examples of dried faeces covered with ash inside the vault in the Philippines and a soil and ash mix in Burkina Faso (photo by E. Sayre, 2008 and S. Tapsoba 2009)

7.4 Recommended hygienic quality of treated faeces for safe disposal and reuse

When handling faeces with the objective of disposal (through burial in the ground, see Section 7.9) the hygienic quality is not of primary interest rather the dry state and inoffensive conditions of faecal material.

When the objective is reuse the content of pathogens should be brought to an acceptable level as shown by the guiding values for large scale systems in Table 2. A sufficient or complete removal of pathogens can hardly be achieved during storage in the vaults (see Section 7.5.3). In order to achieve the guideline values a secondary treatment step such as post-composting is required (see Section 7.6 and **Fehler! Verweisquelle konnte nicht gefunden werden.**).

For all types of treated excreta, additional safety measures apply in order to minimise disease transmission on the route of "toilet to table" such as wearing protection gears, hand washing, withholding time etc. (see multi-barrier approach in Section 2.7.1).

For large scale systems (see footnote 24 for definition) the WHO has set up guideline values shown in Table 2. Helminth eggs are a crucial indicator parameter due to their resistance to treatment (see Section 7.1). The treated faeces should contain very low levels of viable helminth eggs and e.coli.

Table 2: Guideline values for verification monitoring in large-scale treatment and reuse systems of excreta and faecal sludge for use in agriculture (WHO, 2006- Volume 4, page XVI).

	Helminth eggs (number per gram total solids)	**E. coli** (number per 100 mL)
Treated faeces and faecal sludge	< 1/g total solids*	< 1000/g total solids

* This means for example less than 100 eggs in 100 g of solids.

For household systems (see footnote 25 for definition) there are no clear recommendations. A single family will most probably transmit diseases more easily between each other through direct routes (such as by handshakes, hugs and coughing) and not through the use of collected faeces (exception worms). Therefore the guideline values are less binding, however with emphasis on additional safety measure according to the multi-barrier approach (see Section 2.7.1).

7.5 Treatment of faeces during storage in double vaults

7.5.1 Treatment processes during storage

There are two main treatment processes important for pathogen reduction during primary treatment inside of the vaults:

- Firstly the natural evaporation in the ventilated vaults causes the gradual **dehydration** (drying out) of faeces over the time of filling and storage this leads to a gradual reduction of water and pathogen content in the faeces. Generally moisture levels of 25-40% are realistic.
- Secondly, simply the **time factor** of storage also leads to pathogen die-off.

There are two more possible processes in the vaults which should, however, not be relied upon as they are much harder to control:

- The addition of **alkaline covering material** like wood ash and lime is leading to elevated **pH levels of above 9** which reduce pathogen levels.
- In some designs with inclined vault covers **heat** is generated inside the vault through sun radiation (see Section 4.5.4). In order to achieve pathogen die-off temperatures of above 45°C over a certain period of time must be established. These temperatures are not reliably achievable via inclined doors. Heat is successfully used via composting in a secondary treatment process (see Appendix 13.1).

7.5.2 How effective is treatment in double vaults?

UDDTs should not be expected to provide *full* pathogen removal: this might in theory be achievable for double vault UDDTs but is in practise very unlikely due to varying climate conditions and user habits. Accordingly the main objective for primary treatment in double vaults is to generate a dry and odourless material that can easily be handled and reduces the health risks for disposal and reuse purposes (see Section 7.4). Furthermore the remaining health risks should always be minimised with additional safety barriers according to the multi-barrier approach (see Section 2.7.1)

7.5.3 How long should faeces be stored?

Recommended storage times to achieve a dry and odourless material are:

A ***minimum storage time of 6 months*** in the vault (time after the last addition of fresh faecal matter) will render the faeces into a dry, crumbly, odourless and inoffensive material. Storage times of *6-24 months* are also common in cooler and wet climates.

This is sufficient storage time for safe disposal of faeces or reuse in agriculture in a household level system. In large scale systems the use of faeces in agriculture requires a secondary treatment in order to reach stipulated guidelines values of WHO (see Section 7.4).

Figure 29. Dehydrated faeces from a UDDT in India. It contains no toilet papers as the users are `washers`(photo by J. Littmann). See also the opening of a vault here http://www.youtube.com/user/susanavideos#p/f/22/RRTPFs6JRX0

7.6 Transportable containers and external post-treatment of faeces from single vault systems

Faecal matter from single vault systems is collected in moveable and transportable containers like buckets, containers, sacks or bags. During filling of the containers with faeces a slight dehydration and reduction of odour takes place which makes handling rather inoffensive. Nevertheless there will be always fresh faeces on top of the container.

The single vault system requires the regular exchange of the containers with transport to the disposal site or treatment location such as the household compost pile or an external site. The external post-treatment (secondary treatment) include methods of drying, composting, vermi-composting and incineration (see Appendix 13.1).

7.7 Transportation of faeces via vehicles

In areas where faecal matter from UDDTs is not used or disposed on-site there is a need for transport to disposal sites or external treatment facilities. This is a service provision most relevant in urban and peri-urban areas where agricultural activities and areas for disposal are limited. Transport should be done in closed containers in order to avoid spillage and contamination of vehicles, environment and handling persons with faecal matter. It is essential to provide an economically sound transport system which guarantees appropriate long-term services (Section 10.2).

There is a great risk of dumping of excreta in the environment by user or service providers in order to save costs for disposal. The lack of law enforcement and also the missing demand and value as fertiliser in farming are main reasons for this risk. Experience shows that faecal sludge from pit latrines and septic tanks is often illegally dumped into water courses and the environment with serious implications for public health. This must be avoided for UDDT installations by taking transportation and other relevant operation and maintenance activities and their costs into consideration right from the start of the project planning.

Figure 30. Collection of faecal matter and urine (in yellow containers) by a private service company Abona with subsequent reuse in agriculture, Bolivia (photo by A. Kanzler, 2009)

7.8 Reuse of treated faeces and composting products as soil conditioner

The use of dried faeces from a UDDT as a source of organic matter and nutrients is a viable option. In case of a double vault UDDT the dried faeces can be directly applied to the field on a household level. It is recommended to use it in the following way in order to minimise risk of disease transmission by the remaining content of pathogens:

- Treated faeces should be worked into soil and not left on the soil surface, best would be burial in soil under at least a hand high of top soil (Schönning and Stenström, 2004).
- Not be used on fields where through tillage buried faeces can be re-exposed to the surface
- Preferably used for fruit trees and not used for vegetables or root crops.

The faeces are rich in nutrients and in particular in phosphorus which is that are less readily available for plants. The nutrients are slowly released as they are degraded in the soil by microorganisms. If ash has been added it also contains a high content of potassium.

Moreover, faeces are highly valued for their high content of organic matter which acts as a soil conditioner. The organic matter increases the water holding and ion-buffering capacity of the soil, serves as food for soil microorganisms and improves soil texture (WHO, 2006).

The safety barriers like hand washing etc. (see multi-barrier approach in Section 2.7.1) should be strictly adhered to during any kind of handling of faecal matter.

7.9 Safe disposal of faeces

Ideally even the disposal should be done “productively” by burying faeces close to fruit trees, bushes or other plants that can make use of the nutrients and organic matter.

Untreated, dried or otherwise treated faeces can be easily buried under soil (at least 30 cm) to avoid contact with humans and animals and to prevent washing out through erosion during rains and flooding. The relatively small volume of faeces per year and person compared to the urine volume makes handling fairly easy, at least in a small scale system. The burial location should be always above the groundwater table and with a certain distance to wells. Alternatively faeces can be burned and the ashes buried. If handling of fresh and fairly untreated faeces is required, it should be done with appropriate safety measures to protect the involved people and the environment.

There is substantial experience on this disposal method in eThekwini Municipality of South Africa (Roma et al., 2011).

8 Urine management

This section focuses on the basic urine management principles, the scientific background of the treatment process and practical aspects of reuse and disposal. The objective of urine management is the drainage of urine into either onsite disposal systems or the storage offsite disposal system or reuse purposes. It should provide an easy, inoffensive and relatively safe handling of urine.

8.1 Quantity and quality of urine

Each person excretes on average between 0.8 to 1.5 L of urine per adult per day depending on the amount of liquid a person drinks (WHO, 2006). This corresponds to 290 to 550 L/person/year.

Urine from a healthy person, as it leaves the person’s body, is **sterile** meaning it contains no pathogens. However urine can be contaminated with pathogens through faecal cross-contamination that can occur while using the toilet as described in the following Section. In addition, there are diseases that in some regions in the world are spread with urine from a sick person.

Schistosoma haematobium is a parasite that is found only in African tropical areas. Its life cycle requires a suitable intermediate snail host in water courses whereas with soil application in agriculture this risk is greatly diminished (Richert et al., 2010) as well as for urine disposal via infiltration.

Other disease transmission risks come from bacteria called Salmonella typhi/paratyphi, which also have short survival rates in stored urine with one week.

Another aspect of quality concern is the contamination with micropollutants such as hormones and pharmaceuticals that are predominantly excreted via urine (Winker, 2009). They may be taken up by plants and could in theory enter the human food chain. However the risk is very small compared to other environmental health risks (von Muench and Winker, 2011). In areas with minimal use of pharmaceuticals this is not an issue.

8.2 Risk of faecal cross-contamination

When urine is collected using a urine diversion squatting pan or seat, faecal matter can be deposited unintentionally in the urine collection area. Especially when a person has violent diarrhoea some faecal material can easily contaminate the urine collection area of the bowl and pan during use. This is called faecal cross-contamination. If urine is used in agriculture this poses a potential health risk due to faecal pathogen content. Therefore appropriate treatment measures must be taken to reduce health risks (see Section 8.5). It is not a main issue for disposal of urine.

The risk of faecal cross-contamination of urine is higher for large-scale systems[24] with urine collected from many different, trained or untrained users in public and institutional environments with a high fluctuation of users.

In household systems[25] and urinals there is less faecal cross-contamination.

In summary, the main risks of disease transmission from handling and using human urine are related to faecal cross-contamination of urine and not from the urine itself (Schönning and Stenström, 2004).

8.3 Collection of pure urine or mixed with other wastewater

Urine collected in pure and undiluted form is a high quality fertiliser. If it is diluted with other wastewater streams it gets contaminated with pollutants and pathogens and also a larger volume needs to be handled thus making agricultural use rather unfavourable.

Urine can also be disposed off if reuse is not favourable. Then the joint collection with anal cleansing water, hand washing or greywater from showers is not a problem.

8.4 Recommended hygienic quality of treated urine for safe disposal and reuse

The hygienic quality for disposal of urine through infiltration into the ground (see Section 8.8) is not of primary interest.

With regard to use of urine in plant production the hygienic quality depends largely on the extent of faecal cross-contamination. If there is no or little faecal cross-contamination health risks are low. Storage in containers

[24] **Large scale systems:** Handling and reuse or disposal of urine and faeces by third parties
[25] **Household system:** Handling, disposal or reuse with comsumption of fertilised products within the household

for periods of several weeks will lower health risks substantially as described in the following Section.

8.5 Treatment and sanitisation of urine during storage

If urine is to be used in agriculture it is recommended to reduce health risk through treatment. Storage of urine in closed containers at ambient temperature is considered a viable and practical treatment option.

8.5.1 Treatment process during storage

The main determinants affecting the survival of pathogens in collected urine are temperature, pH and ammonia over time which is affected by the dilution of the urine (Niwagaba, 2009). Research and practical experience has shown that higher temperature (>20℃), low or no di lution with water, high pH (above 9), high concentration of ammonia and a prolonged storage time decrease pathogen persistence.

The sanitisation of urine is attributed to a rapid conversion of urea to ammonia by the enzyme urease, which **increases the pH to above 9**. The ammonia content together with the increase in pH have a sanitising effect.

8.5.2 How effective is storage in closed containers

Urine storage in closed containers can provide an effective reduction of pathogen. However it cannot provide *full* pathogen removal due to varying climate conditions, user habits and other variability's. Accordingly the remaining health risks should always be minimised with additional safety barriers according to the multi-barrier approach (see Section 2.7.1).

8.5.3 How long should urine be stored for use in plant production

In summary, the recommendations for storage times are directly linked to origin of urine (households or large-scale communal collection systems), agricultural use, own or third party consumption, choice of crop, temperature and additional safety barriers. Accordingly and based on WHO (2006):

In general unstored urine should never be used as fertiliser in areas where typhoid/paratyphoid cases are suspected (Richert et al., 2010).

Household systems/urinals require a short storage of 1-2 weeks when the family is using urine in a local garden und the produce is used for family purpose only. Moreover a single family will most probably transmit diseases more easily between each other through direct routes (such as by handshakes, hugs and coughing) and not through the use of collected urine. The same storage time applies for urine from urinals which has no or very low faecal cross-contamination.

Large-scale communal systems require a storage of urine for at least 1 month if it is used on food and fodder crops which are processed (cooked, roasted and similar). For raw eaten crops storage of up to **6 months** is recommended. This also applies for cold climates since temperature is also a governing factor in the die-off.

Further information on storage intervals for urine collected in large scale systems as recommended by WHO (2006) is provided in Schönning, C. and Stenström, T.-A. (2004).

8.6 Transport of urine via vehicles

As the UDDT users are often not the farmers especially in urban areas the urine may be transported to farmers who are interested in using urine as a fertiliser or to intermediate and external treatment and storage facilities. This would involve transport over some distance via vehicles. It can be done by using jerry cans on a truck or donkey cart or by a modern suction truck. Well documented examples are available from Burkina Faso (Fall and Coulibaly, 2011) and Bolivia (Kanzler and Martinez, 2009 and .

8.7 Reuse of treated urine as fertiliser

The use of treated urine as a fertiliser in plant production is very well documented in numerous publications, see for example Gensch et al. (2010), Richert et al. (2010), von Muench and Winker (2011) and Dagerskog et al. (2010). Moreover extensive experience with urine fertiliser is available from Niger in English and French[26].

For this reason, only some key aspects are repeated here:

- Urine is a well balanced nitrogen-rich fertiliser, containing nitrogen (N), phosphorus (P) and potassium (K) as well as micronutrients, which can replace and give the same yields as chemical fertiliser in crop production.
- The urine from one person during one year is sufficient to fertilise 300 – 400 m² of crop[27] to a level of about 50-100 kg N/ha.
- Crop and local factors determine the way of fertilisation and means of providing additional safety barriers to minimise risk of pathogen transfer.
- Urine can be applied pure or diluted with water.
- For the best fertilising effect and to avoid ammonia losses and plant injuries, urine should be applied close to the soil. Subsequent irritation with water and incorporation into soil is a plus. Common practice is to make a small depression next to the plant, apply the urine and cover with soil.
- The longer the time between application of urine and harvest, the less risk of disease transmission. A withholding period of at least 1 month prior to harvest time is recommended as a safety barrier.
- Generally fertiliser nutrients are only needed just before sowing and in the beginning of the growth period.

8.8 Safe disposal of urine

Ideally even the disposal should be done "productively" by infiltrating urine close to fruit trees, bushes or other plants that can make use of the nutrients.

There are several reasons why urine reuse as fertiliser might not be viable, such as land limitation in urban areas,

[26] www.susana.org/library?search=Niger
[27] 1 acre = 4,046 m², 1 hectare (ha) = 10,000 m²

distances to agricultural areas, reservations and taboos or simply no need for a fertiliser.

In those cases, urine infiltration via a soak pit, also known as a soakaway, leach pit or subsurface infiltration, can be a good and valid option if groundwater pollution can be ruled out. This way the urine does not need to be stored or treated. For example, this has been practised since 2003 with the 75,000 UDDTs in the peri-urban and rural areas of eThekwini (Durban) in South Africa (Roma et al., 2011).

Just like with pit latrines, urine infiltration from UDDTs can cause high nitrate levels in the groundwater if the hydrogeological conditions are conducive for groundwater pollution. If the same groundwater is a source of drinking water, this can cause a disease known as Blue Baby syndrome (methaemoglobinaemia) in babies. This is well documented for villages in Romania and Bulgaria for example (Bruitenkamp et al. 2008). Hence it is recommended that wells should also be at least 30 m away from urine soak pits[28]. Also, the soak pit should be at least 1.5 m above the groundwater level and be located at a safe distance from a drinking water source (ideally 30m) (Tilley et al., 2008).

Figure 31. Infiltration trench for greywater and urine at a school in Peru (photo by H. Hoffmann, 2009)

A soak pit is a covered or uncovered pit of about 1.5 to 4 m depth depending on the amount of urine and other wastewater streams and the absorptive properties of the soil (see Tilley et al., 2008 for technical details). A soak pit for urine and hand washwater alone requires no pre-treatment. If anal cleansing water or shower water are mixed with urine please refer to Section 6.2.

A ring beam should be placed slightly elevated above ground level together with a moveable concrete lid to provide protection and mark up a designated area. The pit is either left unlined or lined with a porous-walled chamber to provide support this allows the urine to slowly soak into the ground. The soak pit can be left empty or filled with coarse rocks or gravel. In many cases the pits are not covered making them prone to entry of foreign materials which increases the risk of clogging.

[28] See http://www.akvo.org/wiki/index.php/Soak_Pit

9 Operation and Maintenance

9.1 Overview O&M

UDDTs provide their full benefits when they operate continuously and at full capacity in conformity with acceptable standards of quantity and quality. Therefore, O&M tasks must be carried out effectively and efficiently. The operation of a UDDT is relatively simple with certain rules that apply during using the toilet (daily routine), and rules for regular routines taking place at longer intervals. Main aim of proper operation is to keep the toilet free of odour and flies. The entire operation can be done by the user. The emptying routines may alternatively be executed by local service providers especially in urban areas.

The UDDT is not intuitive or immediately obvious to some users who are used to conventional systems with one drop hole and a drop-and-forget attitude. Therefore the users, toilet owners and if possible the wider community should be made aware of the technology and users as well as service providers trained on operation and maintenance. It is useful to provide simple **instruction posters** with illustrations and sketches on O&M (see Section 12.2.5).

In case of shared toilets like for tenants of residential plots the O&M works well if the toilets are allocated to specific family(ies) so that they feel responsible for cleaning and instructing guests on how to use “their” toilets.

9.2 Regular operation routines

The daily routines to operate a UDDT include the provision of covering materials, toilet paper or water for anal cleansing as well as water and soap for handwashing. Moreover the cleaning of the toilet interior is of course an important routine. The UD bowl or pan should be cleaned with a damp cloth and minimal water

9.2.1 Emptying of vault

The users should observe and monitor the filling of the vaults when using the toilet and change the vaults in time. The vault is changed by placing a lid very tightly on the toilet seat or pan of the full and “resting” vault. If only one interface is installed and moved to the active vault a lid must be placed on the hole in the toilet slab. It is very important to fix the lid very tightly so that a user can hardly removed it by mistake and hence cannot contaminate the “resting” vault with fresh faeces or liquids.

After resting of the vault for at least 6 months it must be emptied. If no receptacle is used then shovels or scoops need to be used to empty the dry faeces into a wheelbarrow for direct onsite use as soil conditioner or for disposal into buckets or bags for further storage and transport.

During handling of faeces the person should wear gloves, boots and other adequate clothing as protective equipment to minimise health risks. After handling of excreta the person should wash their equipment and hands carefully with soap. These measures are important safety barriers (see Section 2.7.1) to limit risk of disease transmission.

For the situation that containers are used for faeces collection, they must be cleaned afterwards. If lining for the container is used, there is less work with regard to cleaning it since the soiling of the container is avoided.

Where necessary, households should be given the option to pay a service provider to do the vault emptying for them. This is already very common practise for the emptying of septic tanks and pit latrines. Examples of such UDDT vault emptying services exist in Ouagadougu (Burkina Faso), eThekwini, Durban (South Africa) and in Bolivia, and are described in Fall and Coulibaly (2011), Roma et al. (2011) and Kanzler and Martinez (2009), respectively.

Figure 32. The inactive vault is manually emptied after a storage of 6 month and then taken to external treatment stations for another 2 months of dehydration prior to reuse, Burkina Faso (photo by S. Tapsoba, 2009).

9.2.2 Emptying of urine storage

When urine is collected in containers or tanks, the user must empty or replace the containers in time before they overflow unless the storage system has a security overflow. The emptying can also be done by a service provider as the example of Quagadougu (Burkina Faso) shows.

9.3 Regular maintenance routines

Regular maintenance tasks for a UDDT by the user, toilet owner or care taker include:

- **Checking the level of urine in the urine tanks, as well as the level of faeces in the faeces vaults**. If the levels are close to full, then emptying events must be scheduled (see Section 9.2.1).
- **Unblocking urine pipes**: It is important to keep the urine piping free of blockages, or unblocking it in case that ash, faeces or dirt have entered and clogged the piping. Over time the urine itself can also cause blockages due to deposits of urine stone and struvite on the inner pipe surface thus slowly reducing the diameter of the pipe and eventually blocking the flow. Therefore diameters of more than 2” (5 cm) are recommended (see Section 5).
- **Keeping the vault doors intact** mainly to protect the vaults from rainwater intrusion and from access by animals. This means repainting metal doors or replacing broken plastic doors or rebuilding concrete doors.
- **Maintaining the ventilation pipe** and its cover to protect against rainwater since weather and vandalism can cause breakage.
- Any other kind of repairs like fixing broken doors, the roof, door handles and locks as well as water taps from the handwashing unit are general routines that are known from any other toilet system.

9.4 Common problems and trouble shooting

The most common complaints about UDDTs are odour and flies or blocked urine pipes. Unblocking the urine pipe is usually straight forward with a rod, wire or similar, although someone needs to feel responsible to act.

The single main cause for odour and flies from a UDDT is a faeces vault that is too wet. This can stem from the following causes:

- Repeated misuse like urinating into the faeces vault.
- Anal cleansing water or other wastewater entering the faeces vault.
- Rainwater or flooding water entering the faeces vault.
- Poor ventilation of vaults.
- Covering materials are not available or not being used.
- Use of a big container that does not allow for sufficient drying of faecal content.

Once the faeces vault is very wet, it is usually best to empty it completely and start again, after having eliminated the root cause(s) of the wet faeces vaults.

Another commonly experienced problem in public or institutional UDDTs is when users open the wrong faeces hole cover and start using the faeces vault that is meant to “rest” and dry. This can in the worst case lead to both vaults being filled to the brim with fresh faeces. Therefore the lid for the resting vault should be firmly fixed so that it cannot be removed easily by users.

As with any sanitation system, appropriate O&M is key, but often difficult to ensure. This can be due to a lack of “maintenance culture”, lack of ownership, training (knowledge), funds and motivating factors. Successful models for operation and maintenance of sanitation systems are explained in detail in Kläsener-Metzner et al. (2010) and Muellegger et al. (2011).

10 Costs of UDDTs

By comparing the costs and benefits of UDDTs decision makers are enabled to make an informed choice. Especially the widely held view that UDDTs are expensive needs to be challenged as there is in fact a wide range of designs and costs, depending on available budgets.-When compared with simple and unlined pit latrines the costs of a UDDT are naturally higher due to more extensive construction work. However the benefits and advantages can be a buying argument. As UDDTs can be built to varying standards and with varying designs, the cost range can be very large as shown in Table 3.

10.1 Capital costs for UDDTs

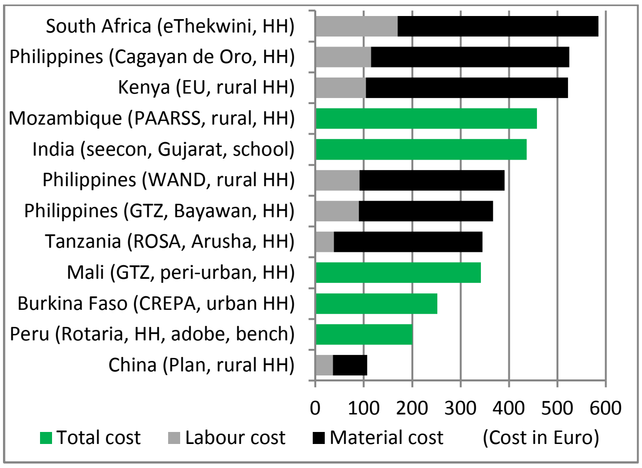
The cost overview of double vault UDDTs in Table 3 shows a range of costs worldwide **from EUR 120 to above EUR 500** depending on material choice, local prices, contribution in locally available materials and unskilled labour as well as desired level of "beauty and comfort". Various design options from simplistic up to modern and luxurious are possible (see Section 11 for various examples). It must be noted that the displayed examples were often build purposely fancy for promotion reasons.

Some designs **can cost less than EUR 50** in construction like the example of the double vault UDDT called "Easy Shower" of IDE in Cambodia. Here the availability of cheap building materials and cost-efficient production methods of pre-fabricated items enable low costs which are more affordable than standard toilets costing around 220 Euro (US $300) in Cambodia.[29] See link to construction guidelines with detailed costs in Section 12.2.4. In comparison to Asia the materials costs in Africa are generally much higher. See further details in the Appendix 13.1 on materials for the construction of UDDTs.

A worldwide list of suppliers and prices for urine diversion squatting pans and seats (pedestals) as well as waterless urinals is being maintained by GIZ [30]. Some products from India show a mass scale production with competitive low prices (less than Euro 10) and other products lack this economy of scale and are rather expensive.

In general it can be summarised that affordability for lower income level can be achieved with the adaption of design that use extensively cheap or cost-free locally available materials (e.g. sun-dried earth-bricks/adobe, wooden poles, bamboo etc.) and as minimal purchased building materials and skilled labour input. See the material list table in Section 13.1 for more details.

Table 3: Comparison of costs of double vault UDDTs for documented projects around the world (adjusted from Rieck et al., 2011)



[29] http://blog.ideorg.org/category/water-and-sanitation/
[30] http://www.susana.org/library?search=appendix+urine

10.2 O&M costs of UDDTs

Operation and maintenance costs for UDDTs in general consist of: minor repairs and replacements (such as vault doors, vent pipes), dry covering materials (usually for free), labour for cleaning and removal, transport and disposal/reuse of excreta (if not done by households themselves onsite). In general the toilet owners can execute all necessary operation and maintenance activities themselves without the need for external services provided their willingness to do so (see Section 9). This scenario is most likely for rural and peri-urban situations where sufficient area for reuse or disposal of excreta is available.

Table 4 O&M costs for a household toilet in an urban context

Operational cost items	**Rate**	**Costs**
Dry covering materials (e.g. wood ash, dry soil, leaves, lime, wood chips etc.)	weekly	often available for free
Toilet paper and soap	weekly	varies
Water for cleansing / cleaning	daily	varies
Cleaning	daily-weekly	usually done by households
Clearing of urine pipe blockages	rarely	usually done by households
Emptying and transport of urine (in case it is not disposed or used onsite)	daily-weekly	***Service provider per month, e.g.:*** Euro 2 (Peru) Euro 1,95 (Burkina Faso)
Emptying and transport of faeces (in case it is not disposed or used onsite)	every 6-12 months	
Regular maintenance cost items		
Repair or replacement of door locks, vault doors, ventilations, doors and other usual maintenance work	in terms of years	varies

In an urban context service provider are often engaged who deal with collection, transport and disposal or reuse of excreta. These costs may vary widely:

- In a theoretical study on the comparison of water borne systems to dry sanitation the operation and maintenance costs were calculated including costs for transport and treatment (Platzer et al., 2008). The approximate service cost was calculated to be EUR 2 per household per month (with four persons per household in a small city in Peru). The income from a possible sale of excreta as fertiliser is not included.
- In an existing service provision scheme in Ouagadougou, Burkina Faso (Fall and Coulibaly, 2011), the costs for collection and handling amount to approx. 1.95 EUR per household per month. Here the collection from over 900 households is done by associations who work with donkey carts and decentralised eco-stations. They also sell the fertiliser to local small and medium scale farmers. The costs are recovered through a fixed monthly fee by the toilet owners and the sale of urine as fertiliser. However, major problems arose due to insufficient willingness to pay by the users.
- Schroeder has examined the logistical costs for separated human excreta factoring in the value of excreta for the theoretical case of a slum in Kampala, Uganda (Schroeder, 2011). The value of urine and

faeces alone would not cover the entire logistical costs (collection, transport, intermediate storage etc.) to unless very large systems (up to 400,000 persons) with big fertiliser consumers like flower farms or similar are applied. The transport distance to the consumers is one of the major determinants for logistical costs.

If farmers value urine and faeces as a valuable fertiliser for crop production they may be willing to pay for the fertiliser product or directly for the transportation costs (or collect it themselves at a collection point). This could considerably lower the service costs for the toilet owners that are not reusing or disposing excreta on their compound.

10.2.1 Making UDDTs more affordable

UDDTs can become more affordable with some creativity of the owners, the contribution of own unskilled labour and the use of locally available building materials such as adobe and recycled materials like plastic containers or sacks for urine and faeces collection. There are examples from Ecuador (Canaday et al., 2011) and the Philippines (Sayre et al., 2011) that showcase how “minimalist”, cheap UDDTs can be built with available local material at prices **below EUR 25** (Appendix 13.1).

Figure 33. Low cost model of a single vault system in the Philippines by WAND (photo by R. Gensch, 2009)

10.2.2 Economic benefits

The life span of a UDDT can extend under usual circumstances easily over 15 years and longer. It depends on the quality of materials as well as craftsmanship and the regular emptying of the faeces vaults. In comparison pit latrines have usually very short life spans since they often get abandoned when full, or might collapse when an attempt is made to empty the pit. Therefore capital investment in a long-term context is reasonably lower for UDDTs than for example pit-latrines.

Other economic benefits derived from improved sanitation like health and environmental benefits are common to all types of sanitation systems except that the environmental benefits may differ. A specific economic benefit of a UDDT is the improved crop production through excreta reuse. This has been quantified by Schuen et al. (2009).

The economic value of urine alone produced by one person per year will usually be in the range of **4-7 Euros** if put in comparison to nutrient value of conventional fertilisers (Richert et al., 2010).

Over time, the value of excreta-derived phosphorus fertiliser is expected to rise, as the cost of mined phosphate ore will increase due to the fact that it is a limited resource (Rosemarin (2010) and UNEP (2011)).

11 Project examples for different settings

11.1 UDDTs outside the house

In cases that users prefer to place the toilet outside of the house (outhouse toilets) there is a wide range of examples to draw information and lessons learnt from. Outhouse UDDTs are currently the most common set up. They have the advantage of good passive ventilation (no odour problems), but several disadvantages with regard to convenience generally associated with outdoor toilets.

South Africa. Large project with more than 75,000 UDDTs built for households by the municipality of eThekwini (Durban). No substantial contributions by the owners. There is currently no focus on waste reuse. Urine is infiltrated and dehydrated faeces buried on the plot either users or trained service providers paid by users. Roma et al. (2011) http://www.susana.org/lang-en/case-studies?view=ccbktypeitem&type=2&id=791

Figure 34. Peri-urban UDDTs constructed by eThekwini municipality on large-scale (photo by EWS). See also Figure 18.

Kenya. Household and school UDDTs with reuse focus were implemented by EU-Sida-GTZ Ecosan Promotion Project in mostly rural areas with user that have subsistence agriculture. A piloting project with 20% contributions by toilet owners. Case study Rieck, C. (2010) http://susana.org/lang-en/case-studies?view=ccbktypeitem&type=2&id=129

Philippines. UDDTs with reuse focus were built in allotment gardens in peri-urban areas of Cagayan de Oro. The toilets in this project were purposely designed in a “luxurious”, and therefore expensive, manner (e.g. use of tiles) since they served as a showcase for decision makers.

Holmer, R. et al. (2009) http://susana.org/lang-en/case-studies?view=ccbktypeitem&type=2&id=47

11.2 UDDTs inside or attached to the house

UDDTs have been installed indoors in private houses and public buildings. Specific care must be taken to avoid odours as it is described in Section 6.3 on ventilation. The designs range from double vault UDDTs in bench design to standalone single vault units like many prefabricated and electrical van operated models produced in Scandinavia like the Separett brand and multi-story arrangements like the Gebers housing project[31] in Stockholm, Sweden.

Peru. A PPP project implemented with a wide range of household and school toilets at a piloting scale. The designs are mostly sitting types build as benches for double and single vaults systems. The hardware of the toilets was financed by the customers, only software was subsidised. http://www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=1251 (in Spanish)

Central and Eastern Europe, the Caucasus and Central Asia. The NGO Women in Europe for a Common Future (WECF) has implemented UDDTs in households and schools at a piloting scale. The focus areas were characterised by high nitrogen content and poor hygienic quality mostly caused by pollution from existing pit latrines.. Many interesting indoor and attached toilets were built.The toilet owners had to contribute 25%-100% of construction costs. Wendland et al. (2011) http://www.ecosan.at/ssp (Issue 6)

11.3 Schools

In school settings UDDTs can work well if operation and maintenance routines are strictly followed which requires a constant training of new students, teachers, staff and service providers in order to understand the system and its requirements. This is important to prevent misuse and trouble shoot quickly. This training can be part of the curriculum or regular school activities. In terms of cleaning the school itself through their support staff, school clubs or other internal arrangements can manage unless the school has funds to outsource such activities. A cleaning schedule and clear distribution of roles is crucial.

With regard to emptying the faeces vaults and regular maintenance and technical trouble shooting schools often prefer external assistance from service providers. This requires a solid financing arrangement through parents or school budgets on a long term basis. Private service providers usually require upfront training and O&M manuals on the special characteristics of servicing UDDTs.

O&M is commonly the weak point in schools and institutional settings which often leads to the neglect of toilets after misuse or malfunction. UDDTs do require more attention than pit latrines, but the users usually appreciate the cleaner and less smelly toilet experience.

Besides daily cleaning activities it is necessary to immediately react if UDDTs are misused like children urinating into the faeces vault or the urine outlet being blocked.

The following design recommendations apply to UDDTs for schools:

- Ideally both faeces drop holes are integrated into one toilet cubicle which is cheaper (no need for two doors etc.) and creates more space inside.
- Burial of dehydrated faecal material instead of reuse which minimises possible risk of disease transmission in school environments.
- Use of robust and easy to clean materials for toilet pan or seat which are well fixed and mounted.
- Squatting pans: Evaluate the advantages and disadvantages of using a lid on the drop hole of the active vault. In general lids can easily get lost (unless fixed like the Chinese models) and can lead to confusion of students who might be used to uncovered faeces drop holes of pit latrines. It might be especially confusing for twin drop hole squatting pans with similar lids for the inactive and active vaults. Experience shows that students have defecated in the urine outlet since they did not know or remembered about the function of the lid on the faeces hole.
- Installation of an overflow of urine collection tanks into soak pits if reuse is aimed for but not properly implemented. The large quantities of urine generated in schools usually cause challenges of management and would often overload the available farm size on the school plot.
- Use of large diameter urine piping with sufficient slope to minimise risk of blockages – use of flexible hose pipes is not advisable due to small diameters. Use of sieves for urine outlet at toilet seat / pan level is recommended (see Section on user interface 3.8.1).
- Always provide a sufficient number of toilets per students in order to reduce user frequency and pressure which can lead to quick misuse and malfunction as shown in Kraft and Rieck (2011).

Differences in day and boarding schools should be considered when designing facilities. In day schools the amount of faeces is often surprisingly small as students rather defecate early morning or evening at their homes. Installing waterless urinals are always a good idea, and these can even work for girls (squatting position).

Instruction posters should be hung inside the toilets and O&M manuals must be available to the school and their health and environmental clubs. Other usual design recommendations for toilets in schools apply like gender separated facilities, screen walls in front of toilet doors for privacy, menstrual hygiene management, facilities for pupils with disabilities, provision of urinals and hand wash facilities etc.

More information on the required considerations in regards to school sanitation can be found in Wendland et al. (2011)

[31] Project description from 2005: http://www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=1216 and additional photos from 2007 here: http://www.flickr.com/photos/gtzecosan/sets/72157607823061531/

and on the website "wash in schools" [32]. and from WASH publications.

India. The NGO Wherever the Need (WTN) has implemented medium to large school toilet blocks and urinal complexes including female urinals. The designs are appealing and with high building standards. A project evaluation is currently not available. See images and drawings here http://www.susana.org/lang-en/library/rm-technical-drawings?view=ccbktypeitem&type=2&id=674.

Further examples can be found in projects in **Peru**, **Kenya** and **Eastern Europe** as mentioned in the two prior sections. Other examples of school UDDTs are available in several case studies[33].

Figure 35 UDDTs in schools are attached to school building so that students can enter the restrooms from indoors, Ukraine (photo by WECF, 2006)

11.4 Accessible toilets for people with disabilities

With regard to UDDTs the greatest challenge for users with disabilities are the stairs due to the above ground vault system. However stairs are not strictly required since alternative designs exist (see Section 6.8 on bench UDDTs). Yet there are no well documented examples of UDDTs purposely build for people with disabilities.

An excellent solution for disability-friendly UDDTs can be bench UDDTs which allow access almost at ground level (barrier free) just like any other toilet. One or two steps might be required to be able to sit on the bench which is still manageable with a standard set of handrails, support handles and ramps. There are only marginal differences in costs for this design as compared to designs with stairs (larger superstructure but cost saving on stairs etc.).

A great advantage of UDDTs for people with disabilities is their suitability for indoor locations which provides very short access routes. This is especially important in areas where the terrain is difficult, the pavement is missing or there are security problems, particularly for women and girls. In comparison standard pit latrines are usually located far away from houses due to their odour.

Sufficient moving space should be provided for wheel chair and crutch users. Otherwise the standard considerations and design recommendations for inclusive sanitation facilities should always be followed (see GIZ factsheet[34]).

Figure 36 Drawing of a double vault bench UDDT with a ramp for a public toilet near Lima, Peru which could be easily modified with handrails and handlebars to make them accessible (photo by Rotaria del Peru SAC, 2010)

11.5 Toilets which can easily be moved

Mobile toilets are often required in situations of total lack of space and insecure tenure like in informal settlements, events (for example festivals or alike) or emergency situations. Mobile toilets can be manually shifted or are installed on wheels to be moved by hand, bicycle, draft animals or engine arrangement.

UDDTs can be designed to serve as a mobile unit. However commonly single vault designs are used due to minimal space requirements and light weight. It will hardly be possible to have a mobile unit that can store faeces for more than 6 months as required for a double vault system.

As for all single vault toilets, an appropriate collection, treatment and reuse or disposal service arrangement must be available in order to manage the excreta adequately. Otherwise single vault systems should be avoided.

Burkina Faso. During the annual film festival in Ouagadougou (Burkina Faso) light-weight mobile UDDTs have been used http://www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=1214.

32 http://www.washinschools.info/
33 http://www.susana.org/lang-en/case-studies?showby=default&vbls=5-7&vbl_7=28&vbl_5=22
34 http://www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=1210

Figure 37. Mobile unit from Separett in a German household and a design from India in a spot previously used by the women for open defecation (photo by E.v. Muench, 2008 and NGO Wherever the Need, 2009)

Technically all types of UDDT designs are applicable. Ideally single vault systems are recommended for public toilets since the high frequency of user of up to 100 persons per day will cause large deposits of faecal matter which a normal sized double vault system cannot absorb. Thus a service provider needs to be engaged to exchange the faeces containers and provide proper disposal or treatment and sale of waste products.

Public toilets work best when they are operated by a permanently present service person that is able to instruct users and quickly reacts to cases of misuse. It must be the aim of the operator to keep the faeces vaults as dry as possible thus rendering the toilet odour free. If on the other hand the vaults get wet then odour nuisances will lower acceptance by users and lower his/her income (pay-per-use model).

Good examples of public UDDTs are still lacking or not sufficiently documented.

11.6 Flood plains and "floating villages"

Locations with recurrent flooding events and lasting more than a few hours require a different structural engineering to keep the faeces vaults dry and the toilet structure stable.

In flooding areas such as shore line's houses or huts are built on pillars as common architecture. UDDTs can be built in the same way or even better be integrated into such housing structures. Single vault designs with faeces containers are e.g. an appropriate solution as documented from the Philippines[35]. The choice of material ranges from wooden poles, bamboo to stones and cast concrete.

[35] http://www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=964

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12.2 Further resources for UDDTs

12.2.1 Case studies

Case studies for UDDTs are available here:

http://susana.org/lang-en/case-studies?showby=default&vbls=7&vbl_7=28&vbl_0=0

12.2.2 Photos and videos

Pictures only on UDDTs http://www.flickr.com/photos/gtzecosan/collections/72157626092760863/

Videos on UDDTs (search for UDDT) http://susana.org/lang-en/videos-and-photos/resource-material-video and on SuSanA youtube channel http://www.youtube.com/user/susanavideos (check uploads and favourites)

12.2.3 Software components with project implementation, awareness creation and behaviour change

Hygiene and Sanitation Software. An overview of approaches by WSSCC (2010) http://www.wsscc.org/node/745

12.2.4 Construction manuals / guidelines

Philippines "Low-cost sustainable sanitation solutions for Mindanao and the Philippines" by Gensch et al. (2010) http://www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=964

Rotaria del Peru SAC manuals www.susana.org/library?search=Rotaria

Toilets that make compost by Peter Morgan (2007) http://www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=195

Urine diversion toilets on principles, operation and construction by Deegner et al., 2006 (WECF) http://www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=770

UDDT – construction manual (with anal cleansing) by Panse et al. (2009) http://susana.org/lang-en/library?view=ccbktypeitem&type=2&id=384 WASH in schools

Easy shower latrine - technical handbook by IDE and GRET including costs http://xa.yimg.com/kq/groups/4934159/133569305/name/Easy%20shower-latrine%20technical%20handbook.pdf

More manuals on construction and other issues are available from http://www.susana.org/lang-en/library?showby=default&vbls=7-3&vbl_3=60&vbl_7=28

12.2.5 Drawings, BoQs and instruction posters

http://susana.org/lang-en/library/rm-technical-drawings?vbls=7&vbl_7=28&vbl_0=0 (BoQs are not always included – please use the search function)

http://susana.org/lang-en/library/rm-posters

12.2.6 Sanitary products

Worldwide list of suppliers for waterless urinals, squatting pans and seats: http://www.susana.org/library?search=appendix+urine

12.2.7 Handwashing units

WSP database on handwashing http://www2.wsp.org/scalinguphandwashing/enablingtechnologies/index.cfm?Page=Browse

Publications collected in SuSanA library www.susana.org/library?search=handwashing

13 Appendix

13.1 Materials for construction of UDDTs

There is a wide range of materials necessary for construction ranging from raw materials like sand or concrete to fabricated products like sanitary fittings or pipes see Table 5). Most materials can be sourced locally and pre-fabricated on-site. Alternatively commercial hardware shops usually provide most necessary materials. Often urine separation pan or seats are not commonly available and must be sourced from the producer itself.

The construction of a UDDT can easily be done with locally available materials like clay, wooden poles, stones and thatch which are simple, durable and cheap or free of charge. For example `adobe` is a traditional building architecture that uses sun-dried bricks containing sand, clay and fibrous materials like straw, rice husks or manure as binding materials. Such material has been used successfully for double vault UDDTs for example in Peru with overall construction costs of about 200 Euro. Several construction guidelines have been published like from the Philippines (Gensch et al., 2010), Peru (Rotaria, del Peru SAC, 2010), India (Panse et al., 2009) or Eastern Europe (Deegener et al., 2006) which are listed in Section 12.2.4.

Other parts have to be purchased or can be fabricated onsite (e.g. through moulding) being urine separating toilet seats or pans, ventilation pipes, urine piping system and roofing materials. If prefabricated parts do not need to be imported from abroad, they are usually cheap and sometimes even cheaper than on-site moulded parts. For example in India ceramic urine diversion squatting pans cost less than 10 Euro making them an affordable material choice (see Section 10.1).

Table 5 Standard Materials for UDDTs

Item	Materials
Strip- or slab foundation (if applicable)	Concrete or ballast/gravel layer, compacted subsoil with no organic substrate
Vaults	Adobe structure with clay bricks or traditional wood-clay architecture with or without cement plastering, cement or burned bricks, cement slabs, natural stones (chiseled), bamboo or wooden or plastic structures
Toilet slab	Prefabricated or onsite moulded concrete slabs with reinforcement, plastic slabs or traditional adobe architecture with wood and clay, optional finish with tiles or painting
Superstructure (if applicable)	See materials for vaults
Stairs (if applicable)	See materials for vaults
Sanitary fittings with piping (urine diversion pan/seat)	Prefabricated in plastic, glass fibre, ceramic or concrete; onsite moulded in concrete, piping in plastic
Ventilation pipe	Plastic or onsite moulded concrete pipes
Doors with fittings (ironmongery) for superstructure and vaults	Prefabricated wooden or metal doors, onsite fabricated from wood and/or cloth, G- or round superstructure which require no doors
Roof and carpentry (if applicable)	Iron sheets roof, thatch roof, concrete roof or roof tiles and timber
Urine containers / tanks (optional)	Plastic containers (1-20 litres) or larger tanks
Faeces containers (optional)	Plastic containers (up to 100 litres)
Hand wash facility (optional)	Tanks or piped water with taps, simple bucket / can / bottle combinations, tippy taps etc.
Unskilled labour	Inexperienced persons
Skilled labour	Experienced masons and artisans

The set up of an indoor design or mobile unit in an existing house or structure requires considerably less materials since superstructure walling, roofing and doors are already in place.

Examples for cost breakdowns and lists of materials for UDDTs in many countries are provided in the case studies and technical drawing section of the Sustainable Sanitation Alliance about projects with UDDTs[36].

[36] http://www.susana.org/lang-en/case-studies and http://www.susana.org/lang-en/library/rm-technical-drawings (search for UDDT)

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Dag-Hammarskjöld-Weg 1-5
65760 Eschborn / Germany
T +49 6196 79-0
F +49 6196 79-1115
E info@giz.de
I www.giz.de

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sanitation
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