Discussion Paper

››› Integrated Urban Sanitation at Scale

Technology

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Introduction

Integrated Urban Sanitation

Development cooperation projects in urban sanitation aim to create adequate living conditions, to protect public health and the environment as well as to foster economic and social development. Inappropriately treated sewerage and faeces can pollute drinking water and pose an acute danger for humans and the environment.

Functioning, area-wide sanitation systems still represent an unsolved problem for many developing countries. The poor living in the fast and unregulated growing outskirts of urban agglomerations are effected the most: Often not enough sanitation facilities are available and the existing facilities are not sufficiently maintained and cleaned. Furthermore, the appropriate disposal of faeces in areas that are not connected to sewers was until recently insufficiently organized.

As outlined by the WHO, investments in developing countries in water and sewerage systems are highly beneficial from an economic perspective. However, in practice there is a lack of technical and financial viable solutions.

Current experiences and observations by KfW show the following challenges during design and implementation of sanitation projects:

- In the past, public financing focused mostly on sewer-based sanitation. For this reason, many poor urban areas were neglected due to the high costs involved. More economic on-site sanitation concepts were not systematically considered and were often limited to demonstration latrines related to water supply projects.
- During project planning, the entire sanitation chain was often not considered appropriately. The outcomes were the financing of latrines not integrated into a sanitation concept and the financing of waste water treatment plants without an adequate treatment of fecal sludge in place.
- Hygiene promotion and sanitation marketing were often not properly integrated into sanitation projects, not adjusted to the specific local challenges and not designed to foster verifiable behavioral change. Unprofessional information campaigns had frequently little impact.
- Economies of scale and potential for scaling up were often not sufficiently exploited due to the application of diverse technologies in the jurisdiction of an operator and due to the fragmented and unclear institutional responsibilities.

Future sanitation interventions in peri-urban areas should therefore more strongly focus on integrated sanitation concepts connecting sanitation chains from an institutional, technical and financial perspective in order to allow for adequate sanitation with affordable capital and operational costs.

Different districts with different population densities and infrastructures have to be provided with different sewer and non-sewer based on-site and off-site concepts. The respective sanitation chains have to be carefully planned and organized up to the final products to avoid health and environmental hazards.

A sustainable improvement of sanitation in poor urban areas is only possible, if the following crucial aspects are considered along the sanitation chain and are adapted to the specific local conditions:

- Differentiated technical solutions
- Regulated institutional responsibilities
- Cost-covering models for operations and financing
- Evidence-based hygiene promotion

Integrated sanitation in this publication does neither refer to vertical or horizontal integration of utilities, nor the integration of waste management related aspects into sanitation systems.

This trilogy of working papers covers the topics of technology, finance and hygiene and gives specific recommendations for the integration of non-sewer-based sanitation in urban sanitation systems as well as recommendations for the conceptual and institutional design of hygiene promotion.

The three working papers build on each other and give an introduction into the respective topics, providing further information and relevant practical knowledge in the respective annexes. The following aspects are addressed:

- TECHNOLOGY: definitions, basic information, planning, operation and design alternatives.
- FINANCING: institutional aspects, market failures, financing instruments and economic assessment.
- HYGIENE PROMOTION: basic information, behavioral change, programme design and institutional set-up.

The working papers address practitioners and project managers in development cooperation and purposely do not choose a scientific representation of content. Selective reading is recommended.

Sector-specific terms:

Term	Explanation
Basic sanitation	Outdated, ambiguous term (= decentralised sanitation in the DC context) replaced in the present document by: **on-site sanitation technology** and **non-sewer-based sanitation**
Community toilet	A public/communal toilet used by families/residents with no toilets of their own; usually in poor, densely populated areas
Decentralised sanitation	Ambiguous term (= on-site in the DC context; pertaining also, in the German context, to small, centralised systems for up to 5000 users) replaced in the present document by: **on-site sanitation technology** and **non-sewer-based sanitation**
Holding tank	A **drainless receiving tank**,serving as a means of interim storage for situations in which sewage cannot infiltrate (into soil lacking absorptive capacity and/ or when there is danger of contamination), periodically pumped completely empty
Institutional toilet	A non-commercial type of toilet for collective use in schools, hospitals, public buildings, prisons, etc.
Mobile toilet	A **portable toilet** with a relatively small collecting/storage container (e.g., bucket or similar vessel) sometimes also serving as a part of the toilet, frequently used with **urine diversion** (UD)
Off-site technology	Sewer-based or non-sewer-based transport of wastewater or fecal material o a treatment plant, discharge or disposal
On-site technology	The storage and treatment of fecal matter and other effluent on private premises or **in the immediate vicinity of the toilet**
Pit	An **absorbing well** for storage of fecal matter
Pit latrine	A **simple sanitary installation**, often consisting only of a slab with a hole and a lid over the pit, usually used "dry", i.e., without flushing
Public toilet	A **toilet at a public place** (market, bus stop), usually with a commercial operational concept
Pour flush	A **water-conserving, manually flushed toilet** (using a bucket or jug of water)
Semi-centralised sanitation	A number of small-scale wastewater treatment plants and sewer systems in a city instead of one large, **centralised system**; the boundary between semi-centralised and **decentralised** not always being clear in the German context (see above)
Septic tank	A **multi-chamber** or **single-chamber settling tank** that allows solids-free wastewater to drain off but retains fecal sludge for anaerobic digestion; the fecal sludge is customarily pumped off at one- to three-year intervals.
Shared toilet	A toilet used jointly by a number of families; usually privately owned, in contrast to a **community toilet**
Sulabh Letrina con arrastre	**On-site treatment of blackwater from pour-flush toilets**; alternately operated soakaways, manual removal of stabilised fecal matter following a quiescent phase, during which the other tank fills up
Lined pit	A **pit** with sealed walls, used for collecting feces and urine in areas with high groundwater levels; vaults (above ground) can be use as an alternative to pits.
UD toilet	**Urine diversion – urine-separating seats (and urinals)** allow separate drainage (diversion) of pure urine, excluding all contact with feces
UD double/single vault	**Urine diversion with two alternately employed, ventilated vaults** for storing and drying fecal matter (also referred to as UDDT- urine diversion dehydration toilets); those with only a single vault have exchangeable containers; the thusly collected fecal matter will usually require further treatment; the UDDT type fills up more quickly
UD-VIP	A **urine diversion ventilation improved pit latrine**, is a VIP type of latrine with a urine-diverting seat
VIP latrine	A **ventilation improved pit latrine**, with a vent pipe in the pit serving to reduce fly-attracting odours
Centralised sanitation	**Centralised discharge** of municipal sewage through sewers leading to one or more municipal wastewater treatment plants; relatively loose demarcation to **semi-centralised**

Technical Aspects of Integrated Urban Sanitation

Competence Center Water and Waste Management

KfW Sanitation Task Force 2013

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1. Sanitation chains in urban settlement structures

Sanitation consists of sewer-based and non-sewer-based sanitation chains. Sewer-based sanitation requires the use of flush toilets and, in turn, a constant supply of water. Non-sewer-based sanitation, by contrast, allows a wide array of different sanitary installations, all of which, however, involve the on-site collection of wastewater, fecal sludge and/or feces either near or underneath the toilet (latrine), where they either undergo a natural process of stabilisation (on-site disposal) or are hauled away for treatment or deposition (off-site disposal).

1.1 Sewer-based sanitation

In sewer-based sanitation, the sewage from a neighbourhood or community is carried off in sewers and has to be cleaned to standard at a wastewater treatment plant. Corresponding treatment of sewage sludge, biogas and refuse, as applicable, must be provided for. Sewer-based systems are relatively time-consuming to plan and expensive to build, and implemented projects are relatively inflexible. Consequently, it can be expedient to adopt a modular approach. This, however, should not consider the sewers, the wastewater treatment plant and the treatment of sewage sludge as separate investments, because that often results in disruption of the sanitation chain. The operation of sewer-based systems requires specialised know-how and stable operator structures.

Centralised sanitation: Here, the sewage is discharged to one or several large wastewater treatment plants serving either an entire urban area or certain parts of a town or city. As a rule, the specific cost of sewage treatment decreases with the size of the service area. If, however, a centralised wastewater treatment plant is operated either improperly or not at all, the discharge of concentrated sewage into receiving waters can jeopardize both the population and the environment.

Semi-centralised sanitation: The installation of semi-centralised wastewater treatment plants is potentially advantageous in fringe areas of megacities marked by rampant growth, where water-using toilets with no connection to a central wastewater treatment plant are in widespread use. It is often expedient in such cases to divide the city into a number of different sanitation zones, e.g., on the basis of residential areas. Like centralised systems, semi-centralised systems can be modularised. It is also possible to employ less maintenance-intensive forms of sanitation technology such as constructed wetlands. Integration into urban sanitation concepts requires active participation on the part of the community – or of its authorised municipal sewage utility company - with regard to decisions concerning the construction and operation of semi-centralised wastewater treatment plants.

<u>Practical tips for decisions regarding sewer-based sanitation:</u>

The investment in sewers and a wastewater treatment plant is only an option, as long as there is a continuous supply of drinking water (60 - 100 lpd). In addition, the local population should be capable of carrying the associated costs (monthly rates, financing of flush toilets and, as the case may be, house connections). The benchmark cost of construction for sewers and a wastewater treatment plant comes to 100 – 300 €/p, with the sewers normally costing more than half of the total. There are no generally valid decision-making criteria or parameters in favour of or against sewer-based or non-sewer-based sanitation.

Consequently, only two examples are given below: One of them is a KfW project in Tunisia, where a centralised system was decided on for a specific population density of 40 p/ha. In Germany, the economic efficiency of systems is usually regarded with scepticism, if the specific length of sewer exceeds 10 m/p. Most such decisions, however, are not arrived at primarily according to economic criteria, because there are also numerous boundary conditions to consider. Frequently, the main limiting factor is either the amount of space available or the degree of acceptance for wastewater treatment plants in settled areas. The use of water-saving sanitation technology, possibly including the separation/diversion of greywater in households (potentially for subsequent reuse) is also important, as is the control of environmentally relevant emissions (e.g., the biogas generated in anaerobic processes must either be flared off or collected as a source of energy).

1.2 Non-sewer-based disposal of feces and fecal sludge

If only a little flushing water is used, feces remain nonfluid and have to be stored directly beneath the toilet (latrine), where the fluid fraction usually seeps away, while the remaining fecal matter experiences a certain degree of stabilisation. In an urban situation, it is often necessary to empty the container before the stabilisation process is finished. Rarely is there sufficient room for adding new toilets, and high user frequencies mean that the available units fill up quickly. Untreated or improperly treated feces pose major risks for human health and the environment. Consequently, the on-site technologies that are regarded as preferable for promotion are those that accelerate the stabilisation of fecal products, prevent both odour nuisance and contact with fecal bacteria, and make it possible to use the toilet hygienically and to keep it clean. If off-site disposal of fecal matter is necessary, it must be based on and secured by a sound functional concept, and attention must be paid to the disposition of greywater (washing water) that might not be able to infiltrate on site.

On-site storage and disposal: If the premises in question are large enough, it is frequently possible for the fecal matter to either be stored on site, i.e., in a sealed vault, or buried by the user. Integration into an urban sanitation concept requires that the community decide on a suitable form of sanitary installation. In that connection, risk reduction is of key interest, whereas such factors as effluent infiltration and the potential need to have the fecal matter removed by private parties must be given due consideration. Stabilisation of fecal matter in the vault can be improved by ventilation, extended storage periods (alternating use of two vaults) and urine diversion. If properly installed and operated, such sanitary facilities ensure safe access without need of public expenditures for operation, treatment and disposal.

On-site storage and off-site disposal of fecal matter: In the case of limited private space, the stored fecal matter has to be hauled off for appropriate treatment and/or deposition/recycling. Depending on the nature of on-site storage, different products will arise and call for different forms of collection, conveyance and treatment. At present, these aspects are rarely approached in an organised, controlled manner. They are usually paid for privately, and the institutional responsibility is often unclear. The objective of integrated concepts is to establish an organised, overarching form of disposal for wastewater and feces, with controlled access for all, subject to socially compatible user fees (perhaps comparable to collection tariffs for sewage or refuse).

Practical tips on the urban use of pit latrines

- Pit latrines are the world's "classic" solution for areas in which water is scarce. Originally developed for rural use, they are basically designed for households with five to ten people. The infiltration and (aerobic) stabilisation of feces should be kept in step with the filling rate. Once full, the vault is sealed, and a new latrine built at a different location is put into use. In today's urban reality, this approach is limited by the fact that the vaults are almost always overburdened, while the absorptive capacity of the surrounding soil for leachate and greywater is also limited. When numerous heavily frequented latrines have been built and used within a confined are, there is major risk of contamination, and the size of the available property imposes limits on the defensible number of new vaults/latrines.
- The use of more efficient technologies depends on the risk of contamination in the residential area:

  a) The extent to which infiltration from existing pits remains acceptable depends on the groundwater level, the distance to springs and wells, and the precipitation situation. Other points to be clarified include the question of adequate access and how the pit latrines are designed with regard to the safety and comfort of their users.

b) Assuming only a low risk of contamination, primary importance should be attached to establishing a technically, financially and institutionally viable form of fecal sludge management for keeping the pits in good condition and for removing fecal sludge from the residential area. Structural improvements making the structures safer and more comfortable to use and empty also need to be investigated. If there is high risk of contamination, it is wise to invest in sealed vaults or lined pits, even if this does increase the cost of sanitation. When new toilets are needed, it is also advisable to invest in such efficiency enhancing technologies as ventilation for the vaults, double-vault systems and urine diversion.

All these technologies are explained in detail in the appendix.

1.3 Hybrid forms of sewer-based and non-sewer based sanitation

For such development-related reasons as reducing costs and/or enabling potential reuse, various hybrid forms of sewer-based and non-sewer-based sanitation have emerged. These options are based on the on-site separation of solid and liquid effluent, either directly at their points of origin (e.g., greywater or urine) or after they have become mixed in the pit or vault (e.g., settling of sludge in a septic tank). Solids-free effluent makes it possible to adopt less expensive forms of discharge and treatment. The solids collected on site can either remain on site or be removed by non-sewer-based means.

On-site storage and disposal: If flush toilets are available but sewers are not, the effluent can be discharged to septic tanks. If possible, the solids-free effluent is allowed to infiltrate on site. In many cases, prior cleansing in a percolating filter or constructed wetlands, for example, is necessary. Alternatively, solids-free effluent can be discharged via small-bore sewer systems leading to wastewater treatment plants. Every one to three years, the fecal sludge must be hauled off in a vacuum tanker for further treatment, e.g., at a wastewater treatment plant.

On-site feces treatment and channelling of liquid flow: Even in waterless approaches to sanitation, various forms of greywater (e.g., washwater) still occur. Such effluent, though not contaminated with fecal bacteria or laden with solid material, often still requires discharge and treatment. The term solids-free effluent also covers the hitherto rarely implemented discharge of urine from urine-diverting (UD) toilets for such purposes as semi-centralised storage/reuse.

Practical tips on interfacing between sewer-based and non-sewer based disposal:

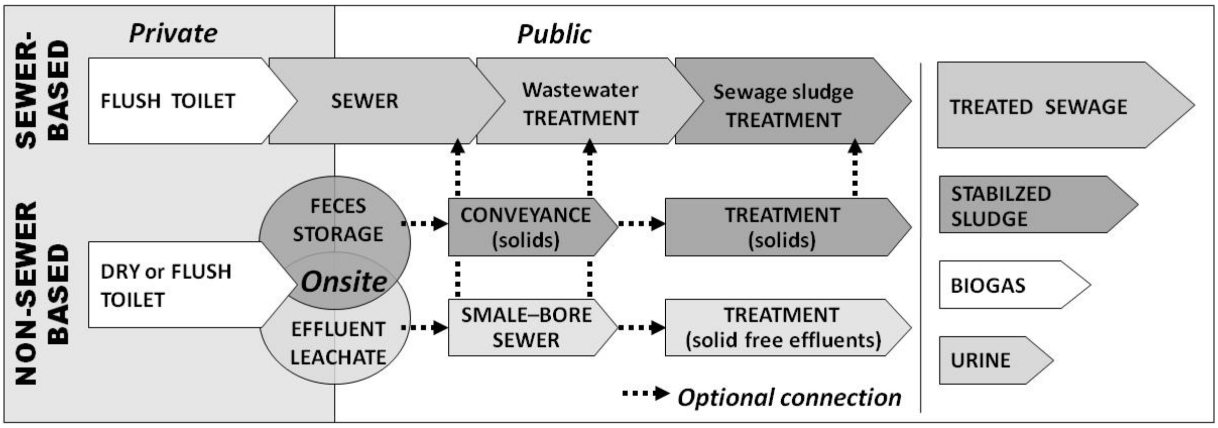
- If the project area already contains septic tanks and perhaps pit latrines, envisaged investments in sewage treatment facilities should always allow sufficient treatment capacity for fecal sludge from non-sewer-served areas. For information on methods of treatment, please refer to section 3.2.
- The discharge of solids-free effluent (small-bore sewer system) can be an economically attractive, sustainable alternative in peri-urban residential areas, e.g., for improving the cleaning efficiency of existing septic tanks or for preventing pollution of the local environment with greywater effluent.

2. Sanitation-system planning in Development Cooperation practice

Most non-sewer-served residential areas of cities in developing countries have no organised form of sanitation, either. They also tend to have numerous different types of on-site technical installations. In areas lacking sufficient supplies of drinking water or which cannot be provided with sewers, the first step must be to plan for "non-sewer-based sanitation management". In the interest of safe disposal, this should be integrated into the sewerage concept, while non-sewer-based sanitation in the form of “sanitation on wheels" is adopted as an interim solution, because it is relatively flexible to implement and can be relocated to a different residential area when a sewer system is installed. Which type of off-site or on-site sanitation technology (meaning, for example, the kind of vaults to be used) is to be implemented in which parts of a city should be defined on the basis of a sanitation master plan designed along the lines of an urban development plan. This provides operators with a planning horizon for organised disposal (what to collect when and how) and gives the authorities, the donors and the NGOs a frame of reference.

2.1 Integration of sanitation systems

The diagram below shows the elements and products of sewer-based and non-sewer-based disposal and points out optional technical interfaces for conveyance and treatment, with the latter also serving as interfaces between system operation and institutional responsibility.



The sewer-based sanitation chain always comprises, in sequence, sewage discharge, sewage treatment and sewage sludge treatment, and the products to be dealt with are: treated (or purified) sewage, stabilised sewage sludge and, in the case of anaerobic treatment, biogas.

Non-sewer-based sanitation offers numerous options, all of which have in common, that the sewage/feces are initially collected on site. Depending on the type, size and number of collecting containers, and on the frequency of use, the local climate, etc., the sewage undergoes stabilisation processes involving the separation of liquid effluent. If greywater or urine (UD toilets) is not directly diverted, the system will produce either leachate (pit latrine, Sulabh) or supernatant (septic tank, biogas plant). Both the solid material and the liquids can be treated completely on site or, if necessary, partially off site.

- Depending on the manner and duration of treatment in the collecting container, stored fecal matter displays different qualities: stored sewage (holding tanks), relatively fresh feces (container), fecal sludge (septic tank, flushed-out sludge from pit latrines), extensively stabilised or mineralised (Sulabh), or even dry fecal matter (UD-double vault). If on-site disposal is not possible, the products will have to be hauled off for treatment or ultimate storage (see diagram in section 3.3). The appropriate type of disposal depends on the quality of the stored fecal matter, how often it is picked up, which means of conveyance and treatment are employed, and the relevant operating costs.

- **Solids-free effluent** (e.g., from a septic tank or greywater/urine) can be discharged into relatively uncomplicated drainage systems (small-bore sewer system or condominial system with little gradient) for further (semi-)centralised treatment and/or reuse

There are some **possible interfaces** with sewer-based disposal; along the transport route for example (e.g., at in-sewer receiving stations for fecal sludge or sewage from septic tanks, holding tanks, etc.) or at the treatment stage (e.g., co-treatment of feces/fecal sludge at sewage or sewage-sludge treatment plants).

<u>Practical tips for planning integrated sanitation-system projects:</u>

- To the extent possible, integrated sanitation concepts should be organised by **a single operator** or community (perhaps including a service contracting scope). Frequently, this prerequisite is lacking, because sewer-based disposal is attended to by a utility company, while the community is responsible for the non-sewer-based sanitation component. Hence, prior to any such investment, the respective interfaces of responsibility must be clarified and coordinated.
- The **sanitation chain begins** on private property, either with the WC and the house connection or with the toilet/latrine and its feces-collecting container. The existence and proper functioning of these elements is of decisive importance for reliable sanitation on the whole. For that reason, the prevailing set of circumstances may make it necessary to subsidise this part for the poor.

2.2 Decisions regarding sanitation concepts

The decision regarding the **feasibility and scope of sewer-based sanitation** forms the basis for any municipal sanitation concept according to a sanitation master plan. Its broad-scale implementation, however, is subject to limitation by the following factors:

- It is unfeasible in areas without a continuous supply of drinking water.
- A lack of urban planning, rampant growth and problematic topographic, geographic and social circumstances (e.g., slums) can render long-term planning impossible.
- Relatively high initial and operating costs for sanitation technologies that can be both expensive and complex (sewers, sewage treatment and sewage sludge treatment) harbour considerable risk for the environment, when, for example, either the sewers are not connected to a wastewater treatment plant or sanitation systems are not operated properly.
- Sewer-based systems are frequently underused, particularly during their early phase of operation, if connection to the sewer system is either not mandatory or not enforced. This places an extreme burden on the system's financing and operation:

  Often, poor households are unable, unwilling or uninterested in paying for their own sewer connection or flush toilet, particularly since it would mean paying a monthly sanitation fee from that point on.

  More well-to-do households may already have invested in a septic tank or some other form of on-site sanitation, so for them, a sewer connection would mean additional expenditures with no immediate improvement in their own, private sanitation situation (except that it would perhaps lower their operational expenditures).

<u>Practical tips on decisions concerning non-sewer-based sanitary installations:</u>

As long as investments in sewers and wastewater treatment plants remain unachievable, the following recommendations apply:

- **Existing flush toilets** require appropriate on-site sewage treatment (e.g., septic tank or, for pour-flush toilets, a biogas plant or Sulabh). This can be expected to involve relatively high specific costs. If on site infiltration of the overflow is not possible, it must be discharged and possibly subjected to further treatment. The fecal sludge must be removed periodically and, as necessary, also subjected to further treatment.
- If the **use of flush toilets is uncustomary**, assistance should continue to focus on efficient dry sanitation solutions, even if a drinking water supply system is implemented. This is because the specific rate of drinking water consumption is much lower by comparison, and the specific cost of on-site disposal also tends to be lower.
- If **no drinking water connection is planned**, dry sanitation technologies are the preferred option. Wherever possible, collecting containers enabling stabilisation or on-site storage should be promoted, because they can guarantee safe disposal independent of the operator. Densely populated areas, however, usually require off-site disposal of accumulated fecal matter, in which case technologies enabling low-cost adherence to an appropriate sanitation chain should be promoted (see section 1.2).

3. Use of non-sewer-based sanitation chains in DC

The type of collecting container used in the on-site installation is a crucial factor regarding the various options available for non-sewer-based sanitation. It must be appropriate to the local situation and in conformance with the technologies encountered along the path of disposal. This requires close coordination at the planning stage.

3.1 On-site sanitary installations and the implicit sanitation chain

For situations involving a lack of adequate access to sanitary facilities, DC investments/subsidies appropriate to the given situation must be considered. In an urban situation, the first things to ponder are the **various organisational and ownership options for toilet facilities**, as systematised in the following table (source: IWA, WSUP 2011):

<table>
<tr><th>NAME/ Type of use</th><th>Owner/Operator</th><th>User/ access</th></tr>
<tr><td rowspan="2">Household toilet</td><td>Landlord</td><td rowspan="2">Single or extended family</td></tr>
<tr><td>Tenant</td></tr>
<tr><td>Landlord toilet</td><td>Landlord</td><td>Group of tenant families</td></tr>
<tr><td>Community toilet</td><td rowspan="3">Varied (e.g. municipality, community, others)</td><td>Residents living close to toilet</td></tr>
<tr><td>Public toilet</td><td>Mostly transient users</td></tr>
<tr><td>Institutional toilet</td><td>School children, hospital patients, visitors to institutions, others</td></tr>
</table>

Practical tips on collectively used toilets

- While access to household sanitary facilities is the main-focus consideration, the existence of collectively used toilets is also indispensable. A **lack of public sanitary facilities endangers everyone.** Women and girls are the most disadvantaged, because they tend to avoid such situations by not attending school or not going to market.
- Collectively used toilets must be embedded in an **operational concept** that ensures proper maintenance and disposal. That, however, is frequently not the case for landlord toilets (shared toilets) used by a number of tenant families or for institutional toilets (in schools,

etc.). The municipal authorities are usually responsible for community toilets, e.g., for ensuring that users live within an acceptance distance (approx. 300 m or less) and that all local residents, including children, can use them (e.g., monthly tariffs). The use of public toilets (at public open spaces, markets, bus stops, ...) should always be subject to charge (pay toilets). That way, they can be operated on private license, though that does not relieve the public institution of its supervisory responsibility.

- **Overloaded collecting containers** in heavily frequented dry toilets keep the fecal matter from stabilising and can be quite disagreeable for the users, because, unlike flush toilets, dry toilets have no water seal (trap). The collecting container of a pit latrine, a UD double-vault or a Sulabh latrine should be large enough for daily use by 3 – 4 families or, in the case of a school, hospital, etc., by not more than 10 – 25 persons per day (depending on how long it is present at a given location).

Practical tips on user acceptance from a technical perspective

- **Comfort of use** (toilet seat, lid, washable surfaces, light, water) is good for acceptance. The construction material should reflect local standards (no "white elephants"). User habits (e.g., squatting) and religious/cultural precepts (e.g., washing) must be heeded, and attention should be paid to making (public) toilets accessible for children and handicapped persons.
- The toilet's technology must be accounted for in the **hygiene promotion measures**. Technical advances like UD seats should be introduced if they inexpensively contribute to safe disposal. Indicators should be formulated in an objectives-oriented manner (e.g., "number of families using the new sanitary facility" or "willingness to pay for the use of public toilets"). The installation of "demonstration toilets", as favoured in DC projects, has shown little effect in this connection and should only be further pursued in terms of targeted marketing/promotion and for partners with a financial interest in their further dissemination.
- Sanitation technology must always be incorporated into a sanitation chain, and urban concepts in particular should be based on the development of **appropriate service packages.** Particularly in urban situations, the emphasis on re-use aspects of fecal sludge, feces or urine can lead to acceptance problems of the sanitary facility.

Finally, the nature of the on-site technology and disposal must be accommodated to the prevailing circumstances (risk of contamination, acceptance, user frequency, collection method, conveyance, treatment, etc.). Problems encountered in the field are often attributable to pertinent mistakes (see also section 1.2). Please consider the following **systematised table of typical applications** and recommended technologies.

Practical tips on appropriate on-site technologies for urban application			
Situation	Recommendation	Options	Selection criteria
Peri-urban settlements with relatively large lot sizes and regulated property ownership	Minimise conveyance: as far as possible, treat fecal matter and **leachate directly on site**	1. Use of large dry collecting pits (> 3 m deep pit; UD-VIP) 2. Double, alternating containers (UD double-vault or pour-flush 3. Septic tank for sewage from flush WCs	Availability of water for the toilets (pour-flush) Potentials and risks of on-site infiltration Cost of on-site installation and effectively available space
Growing and/or densely populated slums	Flexible, low-cost on-site solutions	1. Mobile toilets (5-20 l); 2. Single vault/container (20-200 l)	Technical and institutional options for conveyance + treatment

lacking regulated property ownership	with **off-site treatment**	Wherever possible, with UD and on-site infiltration of urine and greywater	Accessible for all residents Potentials and risks of on-site infiltration
Communal toilets in densely populated areas	**Volume-appropriate** on-site treatment or **reduced-volume off-site treatment**	1. Pour flush toilets with holding/ or septic tanks, or biodigesters 2. UD-single vault, i.e., urine diversion and feces container	Technical and institutional options for conveyance + treatment Potentials and risks of on-site infiltration Local demand for biogas

3.2 Organisational aspects of non-sewer-based sanitation

The integrated sanitation model, with its potential technical, financial and socioeconomic interfaces, can only function properly, if either the local authorities or a utility company is responsible for drinking water supply and sewage/feces disposal in the entire city. Frequently, however, there are separate responsibilities for water and sanitation (Africa). Even where both are supposed to be established as an organisational unit (Latin America), at least the disposal of fecal sludge remains largely unorganised, and little willingness to carry the relevant responsibility is encountered. Here, appropriate DC service offerings need to be developed.

Practical tips on the comparability of urban sanitation:

- Sewer-based toilets produce 25 – 70 m³ of sewage per person and year, resulting in 75 – 150 l of sewage sludge per person and year, all of which requires treatment (Kroiss, 2006). Fecal sludge (FS) from septic tanks, if stored on site with a large residual water content, amounts to 75 – 300 l FS per person and year, while pit latrines produce only 25 – 70 l FS per person and year (Still, 2012), and feces from UD double-vault toilets are comparatively dry, hence amounting to only 20 – 100 kg per person and year (Rieck et al., 2012). Technically uncomplicated, variably adaptable means of conveyance and treatment can be applied to highly concentrated sludge and dry feces with **extremely reduced volumes** (see section 3.2). If such products can be disposed of completely on site, there will be no public operating costs to defray.
- **Water-based on-site treatment** (holding tank or septic tank) involves relatively high specific costs. While drainable sewage does enable group solutions, this always requires the availability of public property and viably organised operational management. In peri-urban areas, by contrast, private investments in septic tanks can be economically attractive, and the overflow can be carried off through a public investment (solids- free effluent/ small-bore sewer system) at some later date (see section 1.3).
- When **dry sanitation** or pour-flush solutions are the only options (see section 2.2), the operator or the local authorities (not the individual user) should decide whether to introduce an integrated sanitation concept with appropriate on-site sanitary installations. Debates regarding "second-class solutions" or "cultural rejection" do little good as long as the water-based sanitation option is unavailable, and the local population would otherwise remain excluded from a vital urban service.

The main advantage of putting the responsibility for all sanitation products in the hands of a professional operator is that it promotes safe disposal. While the logistics of non-sewer-based sanitation is similar to that of waste management, sewage products call for special handling and special treatment. Under someone's overall responsibility, perhaps including the introduction of a city-wide, socially acceptable system of tariffs, individual links of the sanitation chain can be allocated to private service providers, e.g.: operation of public toilets, conveyance of fecal sludge, operation of a mobile toilet system in slums with decentralised treatment stations, operation of semi-centralised wastewater treatment plants, etc.

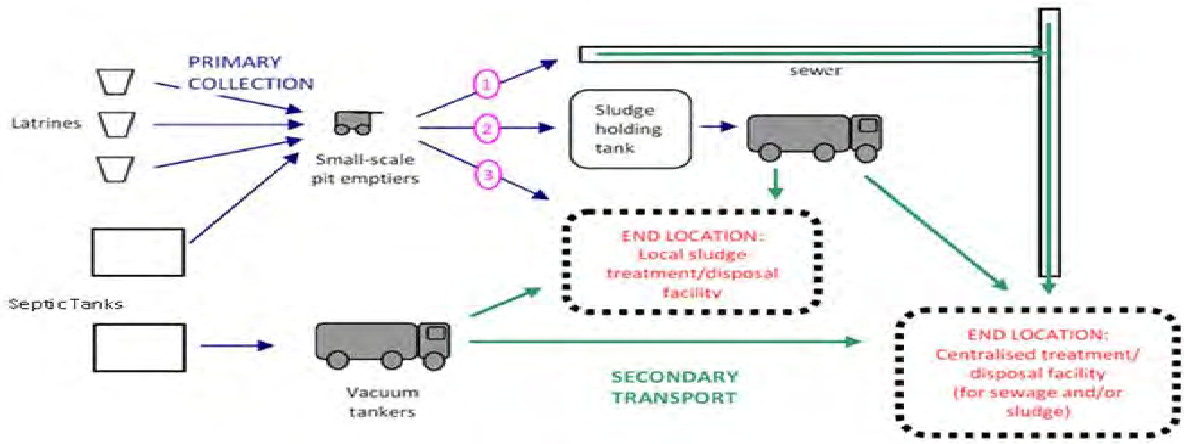
3.3 Off-site treatment of fecal sludge and feces

Frequently, there is a lack of **conveyance and treatment capacity** for the area-wide disposal of fecal sludge from pit latrines or septic tanks. While interfaces with sewer-based sanitation must be utilised, the associated treatment is not always both economical and technically optimal.

Practical tips:

- The use of **suction tankers** is really only practical for relatively thin fecal sludge / sewage from septic tanks or holding tanks. With regard to hygiene, vacuum extraction from pit latrines is advantageous (= less physical contact), but that approach is hardly feasible in the case of lined pits. Thick sludge first has to be thinned with water, thus increasing the cost of extraction, conveyance and treatment.
- The **sludge** encountered at the bottom of exfiltrating pits can be spadeably compact. Moreover, few pits are in a condition to allow complete extraction. Often, household refuse having been "disposed of" in the pit further complicates the process. Another problem is that vacuum tankers are not always able to access informal settlements. Flexible, small-volume "vacs" (vacuum cesspit emptiers) have a short radius of action and therefore need to be separately incorporated into operational concepts.
- Alternatively, pits can be **emptied** by hand with a shovel, if the sludge is spadeable, or with a "gulper" (= hand pump, for viscous sludge), but both of those options should, if possible, be avoided for systems to be newly installed. The product can be filled into hand-filled buckets or, as the case may be, shoveled onto a coverable flat-bed for transport. In that case, co-treatment with sewage sludge and/or organic waste would be feasible, as would composting or drying as forms of separate fecal-sludge treatment. This involves less technical input but more manual labour. Moreover, the workers emptying the pits and handling an inadequately stabilised product are at relatively high risk of contamination, and their work therefore requires supervision. Appropriate instructions, personal protective gear and medical monitoring are absolutely essential.

The diagram below illustrates some potential **interfaces of fecal sludge management** along the sewer-based path of disposal. Source: IWA, Water and Sanitation for the Urban Poor (WSUP, 2011).



Co-treatment with sewage: Liquid/liquefied fecal sludge can either be treated together with municipal sewage at an (aerobic or anaerobic) wastewater treatment plant or fed into a sewer system via receiving stations. However, this type of treatment is only adequate for fecal sludge and sewage that has just been stored for a relatively short time (e.g., in holding tanks). Even fecal sludge from septic tanks differs decidedly from the characteristics of municipal sewage by reason of its longer storage time. For pit latrines, too, the aim and purpose of co-treatment depends on the nature of the fecal sludge. If only the upper, relatively "fresh" layer is extracted, this approach can be acceptable, but any household refuse contained in fecal sludge from pit latrines must have been removed beforehand.

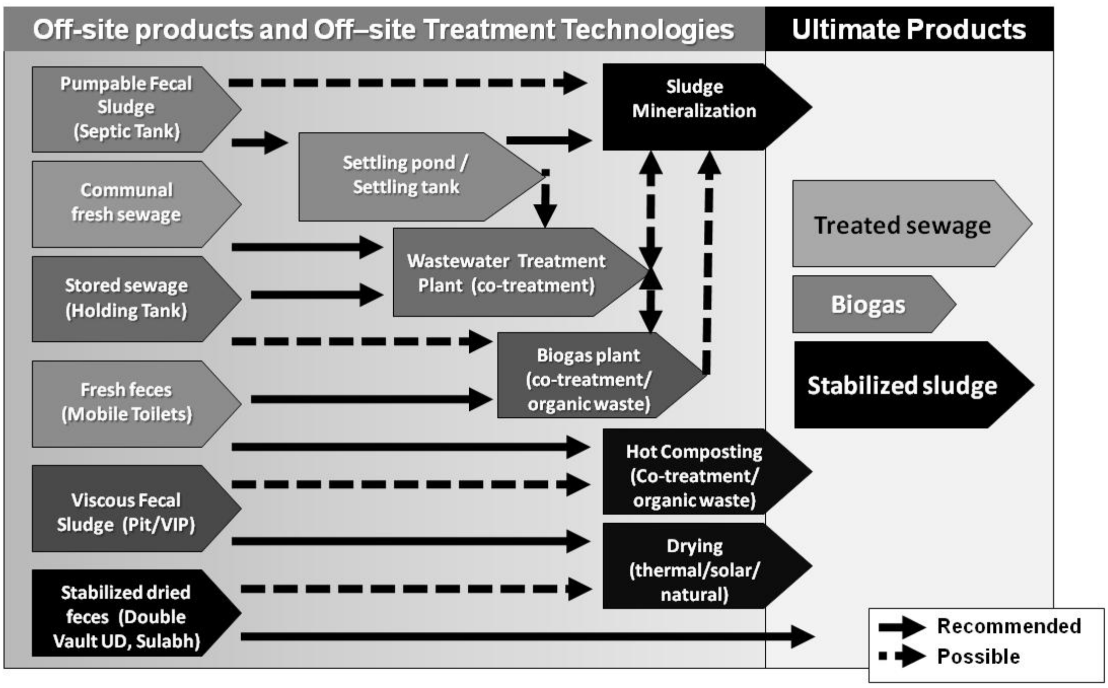
From a processing standpoint, the co-treatment of fecal sludge that has already undergone decomposition processes is all the more critical; the greater its volume is in relation to that of the overall sewage/wastewater. As a rule, sludge amounting to 10 percent or less of the incoming pollutant load is acceptable. Apart from the fact that a batch may contain toxic substances, stabilised fecal sludge also contains high levels of non-biodegradable organic residues and nutrients that emburden the wastewater treatment plant and affect the effluent. The latter can be particularly problematic in the case of stringent effluent quality requirements.

Co-treatment with sewage sludge: This type of treatment is more suitable in principle but also depends on the available capacities. Again, prior removal of all domestic waste is imperative. Less well-stabilised, high-energy fecal sludge (and grease from fat traps) can be fed into a sludge digester. Biogas can be utilised or flared off. Fecal sludge stored for long periods, particularly in warm-climate regions, can be co-treated in sludge drying and mineralising beds.

Co-treatment of feces and organic waste: Technically, feces collected on site with little or no pre-treatment (UD container, mobile toilets) can be treated together with organic waste (from markets, kitchens, etc.). It can also be either co-fermented with biogas products or hot composted, the latter being less technically complicated. In actual practice, however, it is often potentially troublesome to mix hygienically safe waste (biowaste) with feces.

Separate treatment of feces and fecal sludge: The concept of separate treatment for highly concentrated fecal products should always be taken into consideration. If, for example, pit latrines can be emptied by hand, there will be less transport volume to handle. Nor will vacuum tankers be needed, because a flat-bed transport vehicle will suffice. Moreover, various separate-treatment technologies like solar drying or the kind of technical drying process employed in Durban, South Africa, are available. Similarly, hot composting and fermentation (biogas reactors) present themselves as options for fresher forms of feces (from UD or mobile toilets). As long as the selected form of treatment produces no leachate (perhaps prevented by adding organic waste, prunings and straw), treatment can be attended to with no need for a wastewater treatment plant. This is particularly practical when it reduces the transport requirement.

The following diagram provides an overview of available on-site treatment technologies for fecal products.



The vertical arrows indicate a need for additional treatment (treatment of sewage and settled sludge from the settling pond; treatment of sewage sludge and treatment of sludge from biogas plants). Sanitation chains that yield useful products with little resource expenditure are inherently attractive for pertinent management concepts.

3.4 Objectives of treatment and aspects of sanitation-product recycling

Path-of-disposal planning must focus on the targeted quality of the end products. This applies in particular to sewage containing fecal bacteria and to sewage/fecal sludge posing an immediate danger of infection, as well as to the release of biogas, urine, greywater and feces-contaminated refuse.

Practical tips:

The **purpose of integrated sanitation concepts** is to ensure low-risk disposal of all sanitation products from the entire city. In strategic terms, this defines the requirements for on-site disposal on private property or at a privately operated, semi-centralised wastewater treatment plant. If several disposal/recycling options are available, the decisive criterion is how much it would cost to meet the respective standards of treatment. For the operator, the recycling option is only relevant to the extent that it would save money or, in other words, that any other means of disposal (discharge to a receiving water, dumping at a landfill, ...) would incur higher costs. Some form of income generation (sale of treated effluent, compost, urine, biogas, etc.) would be ideal for the financial sustainability of such disposal operations. In practice, however, this is rarely of relevance, because its implementation would require a good deal of institutional inputs.

Local laws and legal constraints govern the required quality of effluent (e.g., for the discharge of effluent or sludge from treatments plants into receiving waters and landfills). Pertinent regulations should always be scrutinised for appropriateness, especially with regard to possible requirements regarding further treatment (example: Tunisia, where the regulation governing the discharge of nitrogen and phosphorus into receiving waters is too strict). In the absence of local regulations, recycling can be oriented on relevant WHO guidelines (Safe Use of Wastewater, Excreta and Greywater Volumes 1 – 4), which distinguish between risks for the workers involved (in irrigation, for example) and for the users (park visitors, food consumers). The requirements are scaled accordingly.

Regarding sewage, the main purpose of sanitisation is to reduce the incidence of fecal bacteria by application of suitable effluent treatment processes. Reuse should be limited to areas that users consider acceptable and which do not require thorough sanitisation (hence excluding, for example, vegetables intended to be eaten raw), because that would only be achievable by means of processes involving either undesirable side effects (e.g., chlorination – not recommended) or high outlays for application and control (e.g., UV treatment or ozonisation).

Regarding sewage/fecal sludge, the main purpose is to inactivate the parasitic ova (helminths) that tend to accumulate in sludge. This problem is often underestimated. In a warm climate, between 80 % and 100 % of the population actually can be infected with parasites, and the danger for children and weakened individuals can be life-threatening. Parasitic ova and cysts provenly can remain viable for up to 8 years in sludge or soil. They can be effectively inactivated by processes involving heat, e.g., hot composting, burning and technical drying. Other options such as solar drying and long-term mineralisation in dry beds are less effective but may still be adequate for some specific purposes (e.g., afforestation).

One focal point is **the protection of workers and farmers** who use recycled sanitation products (e.g., no spraying of treated sewage and no manual spreading of fecal sludge that has not been heat treated) **and of potential consumers** (preferably no applications involving edibles that ripen on the ground or are intended for raw consumption). These rules apply to all feces-polluted products. Purified greywater and pure urine from UD toilets that has been stored for two months (NPK fertiliser) are subject to no further limitations (cf. WHO guidelines and appendix).

National guidelines on reuse/recycling are important for initiating public consensus on these issues, some of which are taboo in public. While sewage and fecal sludge are reused in practically every country, it is often done privately, with substantial risk for the entire population. Safe reuse, however, requires professional know-how, understandably worded and enforced laws and regulations, and established control mechanisms.

Annex: On-site installations and sanitation chains – technical details

The use of diverse on-site sanitary installations implies the various sanitation chains described below. The illustrations stem from the recommended-reading source entitled:
EAWAG, 2012 - Compendium of Sanitation Systems and Technologies.

Annex 1: Flush toilets and pour-flush toilets

<u>Pros & cons</u>: Flush and pour-flush toilets offer a number of advantages: numerous different commercial-type models made of sanitary ceramic material are available; the deposited feces-containing material is conveyed directly to its place of treatment; and they have a water seal separating the toilet bowl from the sewer or collecting container. This trap also effectively prevents the introduction of household waste into the system. Pour-flush systems can also be used without a household connection to the drinking water network (wells, for example). The drawback of flush and pour-flush toilets is that they only work properly in areas with a continuous (or otherwise adequate) supply of water, and that they produce large volumes of sewage requiring relatively cost-intensive treatment.

<table>
<tr>
<td rowspan="3"><u>Flush toilets:</u>

Consumption: 6 – 12 l water per flush, often mixed with greywater (kitchen, shower, laundry) and conveyed to a wastewater treatment plant. In the absence of a sewer, the toilet can be connected to an individual/ private or communal septic tank.

Septic tanks separate the solid and liquid phases and enable anaerobic stabilisation. The biogas problem must be kept in mind and the digested sludge periodically removed.

Depending on local circumstances, the sludge and/or effluent may require additional treatment. In settled areas, solids-free effluent from septic tanks can be discharged to a (semi-)centralised wastewater treatment plant, for example.</td>
<td></td>
<td></td>
</tr>
<tr>
<td colspan="2">On-site treatment of sewage involves relatively high specific costs, usually sewage and the sludge will require further treatment.</td>
</tr>
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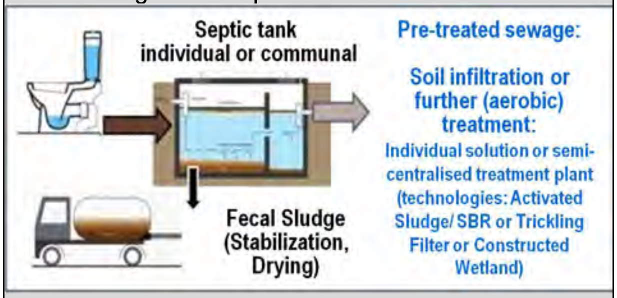
<td colspan="2">
</td>
</tr>
<tr>
<td><u>Pour flush toilets</u>

Flushed with jugs or buckets of water, using 2 – 5 l per flush. Concentrated blackwater (containing no greywater) can be discharged over short distances and either treated in a biogas reactor or Sulabh or stored in holding tanks. .</td>
<td></td>
<td>Advantage: little water required, water seal

Disadvantage: does not work without water; costly, time-consuming treatment</td>
</tr>
<tr>
<td colspan="3">Biogas reactors are particularly well suited for service with heavily frequented pour-flush toilets (e.g., public toilets), if the generated biogas can be used locally. The Sulabh system is based on alternately used leach pits from which the flush water and urine can soak away. Their use is not recommended in areas with high water tables. Also, care must be taken to ensure that the greywater is diverted. Alternatively, drainless holding tanks can be employed, but their conveyance involves relatively substantial cost and effort.</td>
</tr>
</table>

Annex 2 Dry latrines: pit, VIP, vault and double-pit/VIP/vault types

<u>Pros & cons:</u> Dry latrines have the advantage of not requiring a constant source of water. The fact that the excreta accumulate directly underneath the toilet, however, is disadvantageous. The wetter the container, the worse the odour nuisance. Originally, pit latrines were not intended to be emptied. The frequently encountered practice of throwing household waste into the pits is a major problem for operational concepts (emptying, treatment). Wherever vacuum tankers are normally used, care must be taken to ensure contactless emptying and that both the pit and the floor slab are adequately sturdy. Low-cost operational concepts are based on manual emptying (shovelling or Gulper), which, of course, requires infiltration (solid sludge) and well-monitored worker safety (protective clothing, medical supervision).

Photos of possible user interfaces over pit latrines

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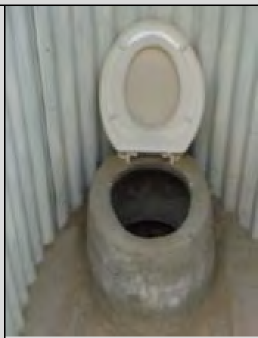
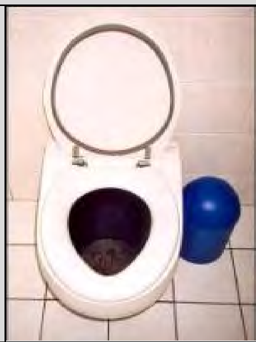
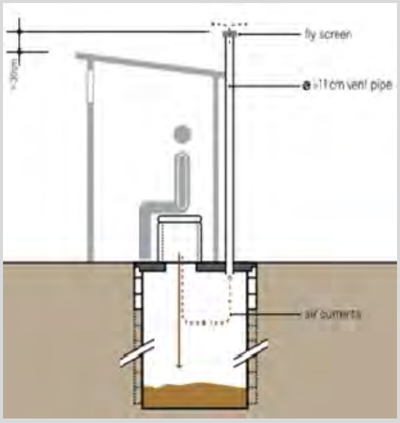
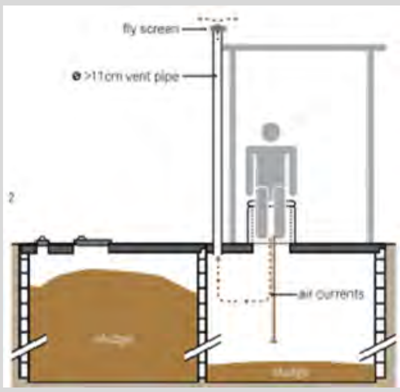
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Pit latrine with concrete floor and cover for closing off the opening
Lima, Peru</td><td>Concrete slab over a lined pit, no cover, Kampala, Uganda</td><td>Toilet seat mounted on a self-built concrete "bowl" over a vault pit, Bolivia</td><td>Dry-toilet accessories produced by Berger Biotechnik</td></tr>
<tr><td colspan="4">A simple hole can serve as a "user interface", as long as there is no contact between the user and the collected feces and, of course, that cleaning is possible. The sturdy floor slab must be mounted over the storage unit in a permanently safe manner. The hole should have a cover, and the storage container should be ventilated. Cheap solutions are often neither sustainable nor do they help develop an appreciation of hygiene.</td></tr>
</table>

If the pit or vault is not sealed off, or at least not correctly, there is danger that effluent containing fecal bacteria could infiltrate into the surrounding soil. If the storage unit is fully sealed (= lined pit or vault installed, for example, in a high-groundwater area), urine should be kept out of the toilet as well as possible (perhaps by providing urinals for men and/or separate installations for urinating by men and women alike), because wet storage usually leads to major hygiene problems for the users. Anaerobic processes are initiated, odours become a nuisance, and flies are attracted.

One possible, very simple form consists of pre-fabricated slabs – called "sanplats" – installed over a lined pit. The sanplats could perhaps be built by local craftspeople, and the superstructure constructed by the users themselves.

<u>Pit latrines:</u> The 1 – 4 m-deep pit must be stable enough to keep the surrounding soil from caving in beneath the floor slab (mortal danger). Slow filling and percolation is customary, but only works in areas with a dry climate and absorbent soil, and when user frequency is appropriately low. The pit can be sealed off and replaced with a new one at the users' discretion. If, however, the pit needs to be emptied, this should be attended to by a service provider. Section 4.1 offers information on upgrading and off-site disposal.	 Home-built pit latrine in Lima
<u>VIP latrines / ventilation improved pit latrines:</u> A vent pipe leading out of the pit provides for continuous airflow through the pit. The inside of the superstructure is kept dark to discourage flies from migrating up out of the pit. A solid floor slab is installed, and the walls of the pit should be lined as reinforcement. Compared to a pit latrine, a VIP latrine is somewhat more expensive to build, but is normally intended for permanent use, i.e., for repeated emptying. It should, however, be cleared out by a qualified service provider. In that connection, this situation is the same as that described above for pit latrines.	
<u>Vault latrines:</u> In areas with high groundwater levels or which are susceptible to flooding, toilets are often equipped with a roughly 1 m^3 aboveground vault for limiting in- and exfiltration. The resultant sludge, though, is viscous/ pasty and cannot be adequately ventilated by the vent pipe. In addition, this type of construction enables illegal "disposal" by breaking open the vault during heavy rains, for example. Consequently, this type of construction should always be made dependent on a concept in which clearing out is attended to by a service provider.	 Single vault latrine in Kampala
<u>Double pit (Fossa Alterna), VIP and vault:</u> Double storage containers (underground vaults or pits) enable better stabilisation of fecal matter prior to emptying. The objective is to reuse the emptied vault or pit, hence increasing the sustainability of the sanitary installation. Its efficacy is dependent on relatively dry material (by leaching or the introduction of only little urine) and very good ventilation coupled with long alternate periods of non-use. As long as that is the case, the users can do the emptying themselves and dispose of (or use) the dry fecal matter on site.	

Annex 3: Dry urine-diversion toilets: UD-VIP, UD single- or UD double-vault types

<u>Pros and cons:</u> Here, too, no flushing water is needed, but a special type of divided seat for diverting the urine away from the feces is required. This decisively reduces the requisite storage volume (0.15 kg feces and 1.5 l urine per user and day). Following a two-month period of safe storage, pure urine can be used as liquid fertiliser, and on-site infiltration is usually also safe and acceptable. Dry feces store well without odour nuisance, so UD toilets can be installed directly in or beside the house. The drawbacks include the fact that the availability of urine-diverting seats is still limited. They are difficult to build at home and can turn out to be unhygienic (e.g., when cement is used). Errors made in the use of mostly communal/shared units lead to negative opinions regarding UD toilets, so good, practical familiarisation with the use of such toilets is indispensable.

UD school toilet, Bolivia urine diversion along floor slab

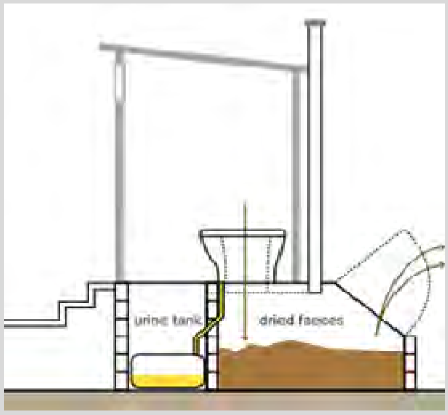
Envirosan, South Africa

UD double vault bench with shower, Rotaria, Lima, Peru

Mobile toilet by X Runner, Lima

<u>UD double vault:</u>

Feces collect in two aboveground vaults (usually masoned; 600 – 800 l), each with an easily accessible, reliably sealed access opening for feces removal, and each with its own vent pipe. When one vault is full, the user moves the UD toilet seat over to the other vault. The first vault is not emptied until the second vault is full. It should take between 9 and 18 months (climate-dependent) to fill one vault, at which point the dry, stabilised fecal matter from the other vault can be removed and disposed of by the user or a service provider.



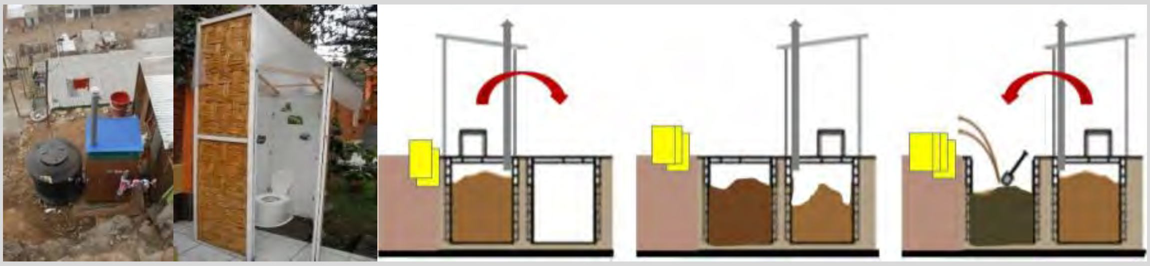
<u>UD single vault/ mobile UD:</u>

The feces collect in a bucket or other container placed in a chamber below the seat. Depending on the means of conveyance, the container has a volume of 50 – 200 l (mobile toilets: 10 – 20 l). Treatment of the fecal matter is not concluded in the container, so safe further treatment/disposal normally has to be attended to by a service provider. Customary treatment consists of hot composting or earthworm composting, though co-fermentation with organic waste is also technically possible. Collection in containers can be recommended for public toilets, for example, because this relocates feces treatment away from the toilet and makes it independent of chamber size and user frequency.

UD container and feces treatment in La Paz, Bolivia, (NGO Sumaj House, 2012, Service provider für 1.000 toilets); treatment via earthworm composting and feces drying process.

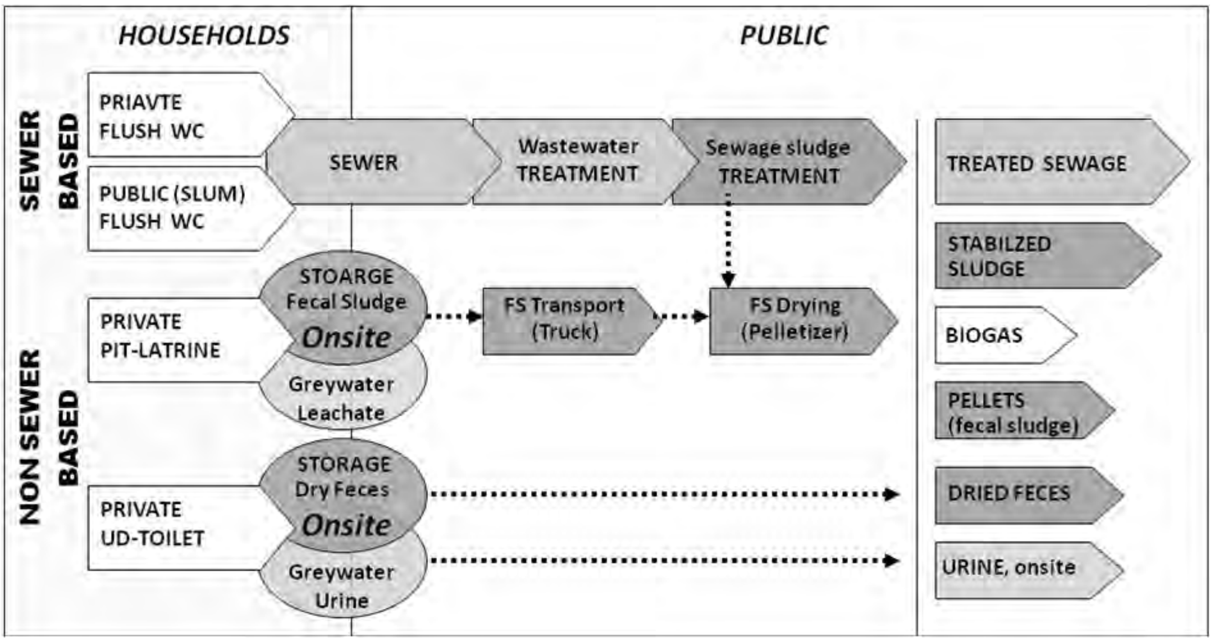
UD-VIP:

In areas with low precipitation rates, the use of UD seats in VIP latrines is advisable, because urine diversion suppresses odours, and the pit fills up more slowly. When full, the pit is sealed off and the seat relocated. Alternatively, the use of a double UD-VIP type allowing alternate use and emptying at 2- to 3-year intervals (see sketch below) is also possible. Both versions are suitable for on-site operation. The advantages include the comfortable UD seat and the potential for reusing the urine without having to remove the feces, as well (the latter being more difficult).



Annex 4: **An example of integrated sanitation,** eThekwini Municipality, Durban, South Africa

eThekwini Municipality (Durban, South Africa) has a comprehensive, integrated sanitation concept. The sewage from the city (population of 1.2 million, including 450 slums equipped with public toilets) is discharged through a sewer system and treated at 27 semi-centralised wastewater treatment plants. Thirty-five thousand peri-urban households with pit latrines are entitled to free emptying at five-year intervals. In future, the fecal sludge will be pelletised, in part together with sewage sludge, in a mobile drying system (8 l diesel/m^3; LaDePa = latrine dehydration and pasteurisation). Agricultural use of the product is safe and unobjectionable. Some 90,000 households in the region's drinking water catchment areas have been equipped with free UD toilets, the products of which (pure urine and dry feces) can be disposed of on site by the users. The cost/benefit effect of urine collection is being investigated. The disposal concept is subject to limitation by the rural settlement structure (long distances) within the UD toilet area. The diagram below illustrates a successful, if heavily subsidised, appropriate form of integral disposal based on this concept.



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