Basic sanitation and human excreta disposal in latrines

Technical Field:
■ Water / Sanitation (W)
☐ Energy / Environment (E)
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1 Introduction

The severe lack of even the most basic sanitation in many developing countries leads to a desolate hygienic situation causing numerous infectious diseases and deaths. In this context, the loss of biomass and nutrients for agriculture can only be considered as being of minor importance.

The absence of toilets may be tolerable for very thinly populated areas, but very quickly becomes an uncontrollable risk with increasing population density.

Only a few years ago, communal toilets were implemented in villages in West-Africa, consisting of a deep ditch with a long wooden beam installed alongside across, a handlebar and a straw roof against sun and rain. In spite of its simplicity, this concept was promoted as progressive innovation, showing that the existence of a toilet is not yet standard, especially not in rural areas and small municipalities of developing countries.

Here, the construction of sewage treatment plants of a comparably high technological standard is even more inappropriate than for urban areas in the same countries, as often capital is more scarce and the infrastructure in many cases does not allow the introduction of systems that require the collection of wastewater in a sewerage system. Often, there is also a lack of required knowledge for operation and maintenance of even simple wastewater treatment plants, thus increasing the risks of low treatment performance and therefore water pollution.

This technical information will present different technological solutions for toilets. The systems range from simple pits up to sophisticated designs, varying decisively in expenditure, environmental and hygienic effects and costs. Generally speaking, all of them may be suitable for household as well as for communal implementation – however always depending on the given local circumstances.

2 General aspects

Generally, faeces are contaminated with pathogens that can be significantly reduced after a retention time of about three months if no fresh material is added. Odour emissions will also be reduced to a minimum after a similar time frame. After another 18 months, the material will have soil quality.

If no structure (lignin) material is added and the liquid fraction is not separated by a drainage system or quickly infiltrated into the underground (sand soil for example), the organic compounds will be degraded mainly by anaerobic bacteria. Only if the provisions named hereafter are taken, aerobic processes are possible (compost toilet, see chapter 3.4).

An average of 15 g of minerals per person and day are contained in the faeces and will remain in the produced substrate. In addition, about twice the amount of minerals has to be assumed for paper, ash, grass or plant residues if they enter the treatment system.

The site for the construction of latrines should be chosen down stream and at a minimum distance of 30-50 m of wells to prevent the pollution of groundwater by seepage water from the latrines if their base is neither consolidated nor lined with brickwork. The site should further be located on slightly raised ground so that the majority of rain water will drain away rather than enter the latrine. The distance to the housing should be comparably short (about 5-20 m for single households), in case of communal toilets for villages or communities, it should not exceed 200 m. For population densities exceeding 150-200 inhabitants per hectare, special care has to be taken concerning drinking water reservoirs and groundwater pollution if latrines are built. Continuous investigation measures with respect to the hygienic situation have to be taken, if possible, the drinking water should be supplied by a piping system from unpolluted areas.
The use of pit latrines has in general to be excluded in areas with a density of more than 250 inhabitants per hectare.

3 Different latrine concepts

3.1 Pit latrines

Pit latrines are the simplest solution for human excreta disposal. They can be implemented not only in rural areas, but also in municipal districts.
A pit latrine mainly consists of an excavated pit, a base slab and a superstructure.
The pit should measure about one meter in diameter and up to three meters in depth. Rectangular design for the pit is possible, although round pits are more stable. Optimum depth choice depends on local parameters like soil structure and groundwater table. The bottom of the pit should be at least 20 cm above the yearly average groundwater level. Due to the danger of collapse, 3 m should not be exceeded. Otherwise, as the steep walls have to be safe in case of rain, brickwork may be necessary. The ground plate is normally neither consolidated nor lined with brickwork so that all liquid substances like urine and cleaning water will seep into the subsoil. The solid substances will gradually pile up and have to be removed manually if two thirds of the height are filled up, because they will otherwise form an ideal breeding environment for insects as they are approaching the source of light.

For the dimensioning of a pit, mean values for the volume required per capita and year can be assumed as 0.06 m^3 per capita and year for dry pit latrines, 0.04 m^3 for wet pit latrines, where degradation processes are faster, and 0.40 m^3 for wet latrines without any infiltration in areas with impermeable soils (vault toilets). A dry pit with a diameter of 1 m and a depth of 3 m can be used by a five person family for a period of about six years (keeping in mind it has to be closed after 2/3 are filled up).

Surface water should not be allowed to enter the pit, as it would then fill up with accumulating sediments. A cemented brick layer of some 20 cm around the pit should be enough as protection against rain water. Depending on the climate, groundwater may eventually enter the pit during rain season which can only be controlled by integrating an overflow, designed as ditch filled with stones for minimisation of loss of solid substances.

The base slab covers the pit and provides the squatting hole. It is constructed of locally available building material. The surface should be smooth and easy to clean.

The superstructure is basically a small hut with a height of about 2 m. The roof structure should not rest directly on the walls in order to allow ventilation, daylight should be able to illuminate the interior.

3.2 Ventilated Improved Pit Latrine

The development of the ventilated improved pit (VIP) latrine managed to substantially reduce two main disadvantages of traditionally designed pit latrines as described in 3.1, namely the odour problem and fly nuisance.

The pit is equipped with a vertical vent pipe at the highest level possible. To permit the installation of the pipe, the VIP latrine can either be slightly offset from the superstructure (see Fig. 1) or the pit can be displaced in relation to the latrine (see Fig. 2).

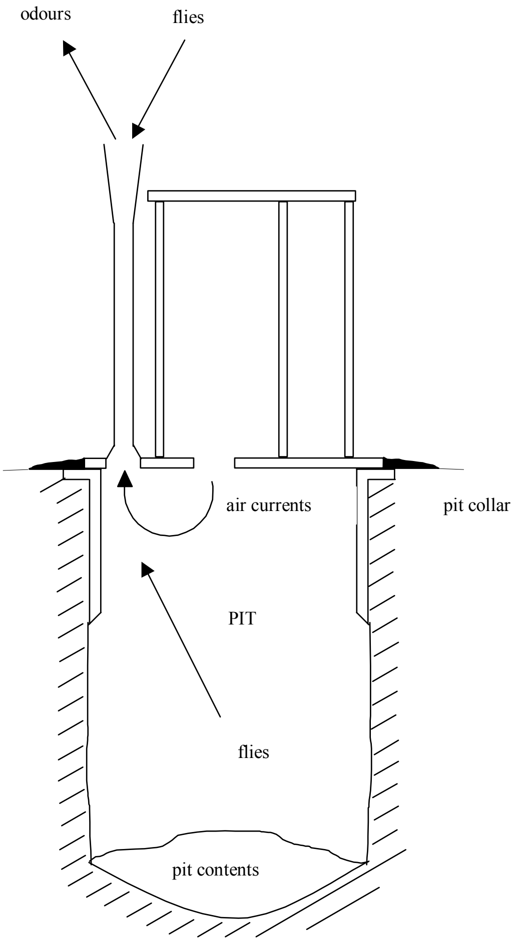


Fig. 1: Ventilated improved pit (VIP) latrine. [7]

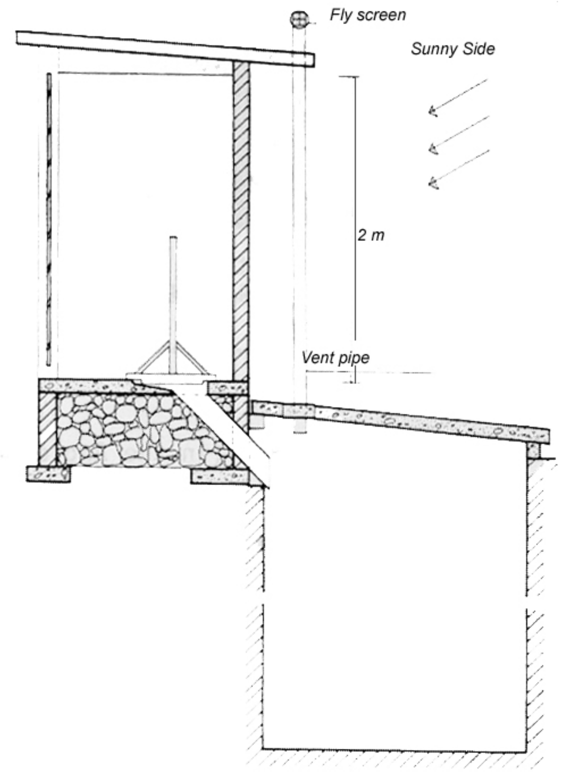


Fig. 2: Ventilated improved pit (VIP) latrine with displaced pit. [1]

The pipe should be at least 15 cm in diameter (DN 150) and should allow the toilet gas to escape without obstruction or turbulence, this being significantly promoted by the length of the pipe and its exposure to sunlight (supported by black paint for improved heat absorption). During night time, odour problems may still occur as the vent pipe will not be warmed up and buoyancy will not be sufficient.

The upper end of the vent pipe should be covered by an insect screen. If in addition the inside of the superstructure is kept comparably dark so that the main source of light in the pit is the pipe (phototrophism of insects!), this will prevent the development of fly nuisance in the surroundings of the VIP.

The VIP concept still requires manual removal of the excreta after a considerable degradation period, removal conditions being significantly improved in case of displaced pits (see Fig. 2).

The superstructure as well as the base slab do generally not differ from those described above.

In Zimbabwe, experiences were made with two different designs of VIP latrines, one suitable for peri-urban areas, the other for rural areas, being a low-cost version of the first. [7]

The peri-urban VIP latrine (see Fig. 3) consists of a circular pit that is lined with cement mortar and covered by a concrete slab, and a spiral shaped superstructure constructed of ferrocement or brick with a flat roof slab placed on top. The vent pipe of asbestos cement (standard design in Zimbabwe), PVC (UV-stabilised), galvanised iron (danger of corrosion) or brickwork (in case of brickwork superstructure) is installed immediately adjacent to the outside of the superstructure.

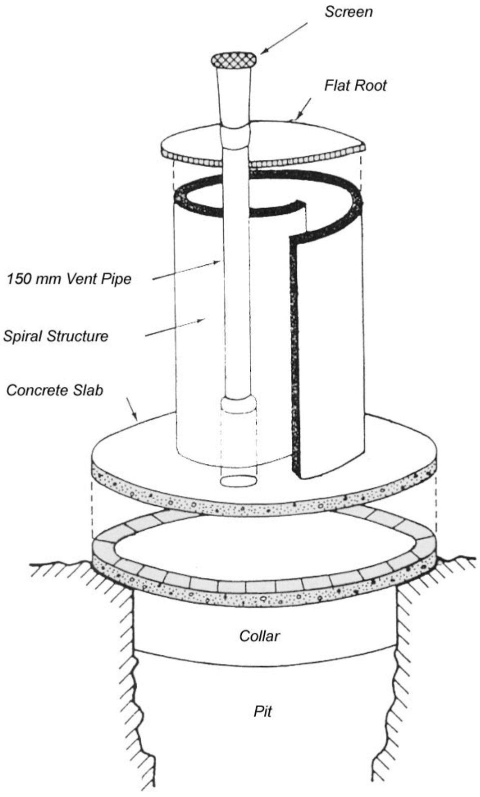


Fig. 3: Exploded schematic diagram of ferrocement spiral VIP latrine. [7]

The rural version (see Fig. 4) consists of a rectangular pit covered by a slab made of wooden logs, anthill soil and a thin layer of cement mortar. The spiral superstructure is made of either mud and wattle, thatch, soil or local brick, covered by a thatched roof, the vent pipe can be built using local reed rendered with cement mortar.

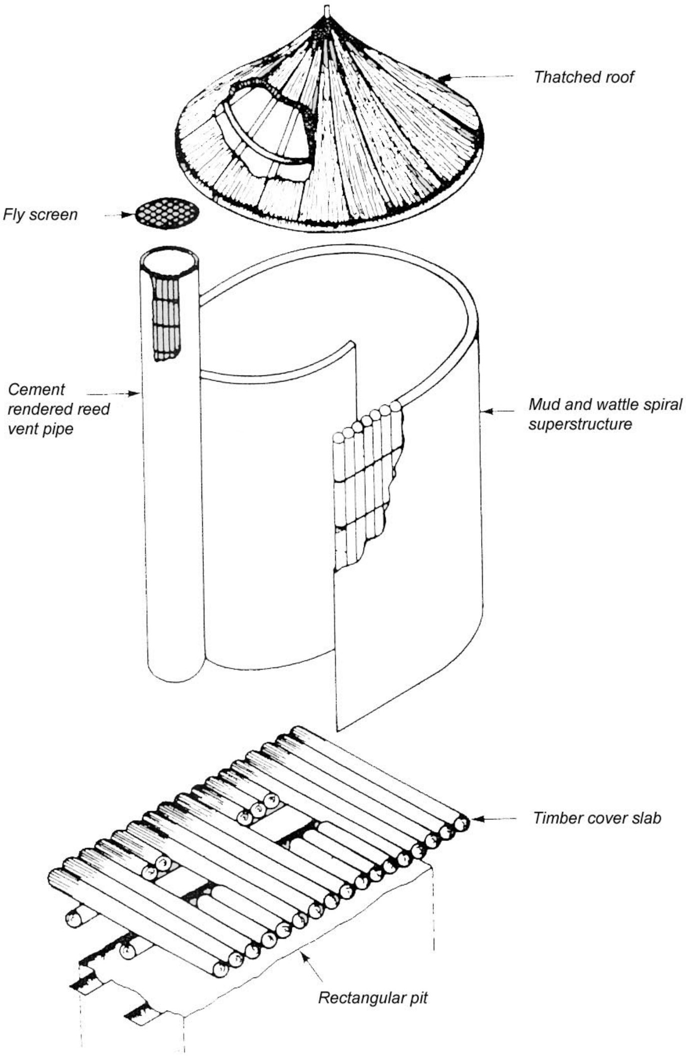


Fig. 4: Exploded schematic diagram of mud and wattles spiral VIP latrine. [7]

3.3 Double ventilated pit latrine

In order to avoid the necessity to move the site of the sanitation facility at regular intervals, a double VIP can be built, consisting of one superstructure for two neighbouring pits which are used alternately. Only one of the pits at a time will be in use while the contents of the other is left for degradation – given a proper dimensioning, for a period of several years. The well degraded material will be a lot easier to remove than mixed rotted and fresh material.

3.4 Compost toilet

Should the recycling of nutrients contained in the human excreta into agri- or horticulture be intended, a compost toilet may be an appropriate solution for basic sanitation if there are no culturally conditioned reservations against reutilisation of excrements.

The composting of human excreta requires additional organic matter for a favourable nutrient ratio (C:N) in the substrate, which can be provided by regular addition of ash, sawdust, peat, straw, organic household waste or similar substances every time the toilet is used. To achieve an acceptable state of maturity of the compost, a retention time of two to five years has to be assumed.

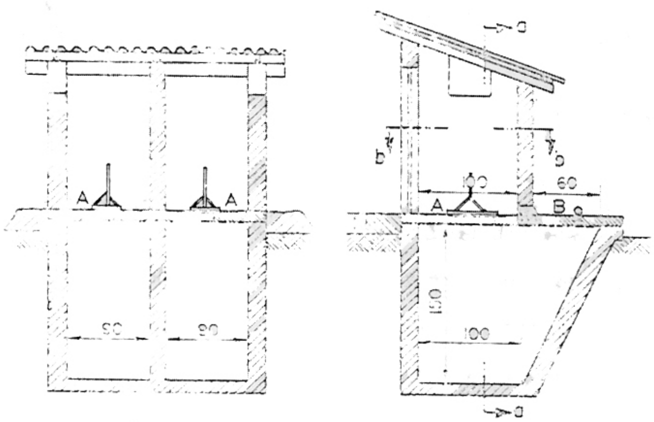
An important aspect to be taken into consideration is the pathogen content of the compost if directly applied to crop meant for human consumption. In order to minimise the health risk, it should not be applied later than three weeks before harvesting [1] and in general with focus on soil improvement rather than immediate fertilising.

The available areas should be sufficient for the application of the produced compost.

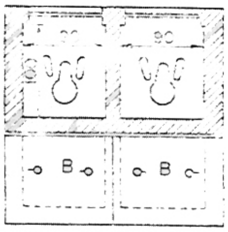
Compost toilets can be operated in batch or continuous mode.

3.4.1 Batch composting

The design of batch compost toilets is comparable to pit latrines, usually consisting of a two-pit or a double-vault system (see Fig. 5) and a superstructure. The vaults are built next to each other and usually used alternately year by year, allowing longer composting periods. They are accessible from outside for substrate removal which has to be done manually. A pit will be topped up with earth when it is filled up to 2/3 – 3/4 with excreta and additional organic matter. As neither aeration nor substrate mixing is realised in the pits, the composting process will partly be anaerobic and will only reach temperatures of approximately 35 °C.



section a-a



A = sqatting plate
B = Removable cover

section b-b

Fig. 5: Double-vault composting toilet. [1]

Prior to the first use, the base of a composting pit has to be covered with peat or humus and grass in order to provide proper conditions for a composting process. The volume approximately required per person is 0.4 m³, assuming 0.3 m³ of waste is produced per person and year and considering that the pit has to be emptied if it is filled up to 3/4.

3.4.2 Continuous composting

For continuous operation, only one pit is required which is accessible for regular removal of compost. The different modifications are principally all based on a Swedish design, the so-called "multrum toilet" (see Fig. 6).

The main difference of the multrum toilet to double-vault compost toilets is the design of the pit, consisting of a composting chamber and a humus pit. The ground of the composting compartment is inclined by about 20°, the vault being traversed by grates separated by narrow slits. The excreta and additional organic matter is held back by the grates, aerobic conditions are maintained due to the slits. After composting, the degraded material will fall into the humus pit, having to be removed at regular intervals.

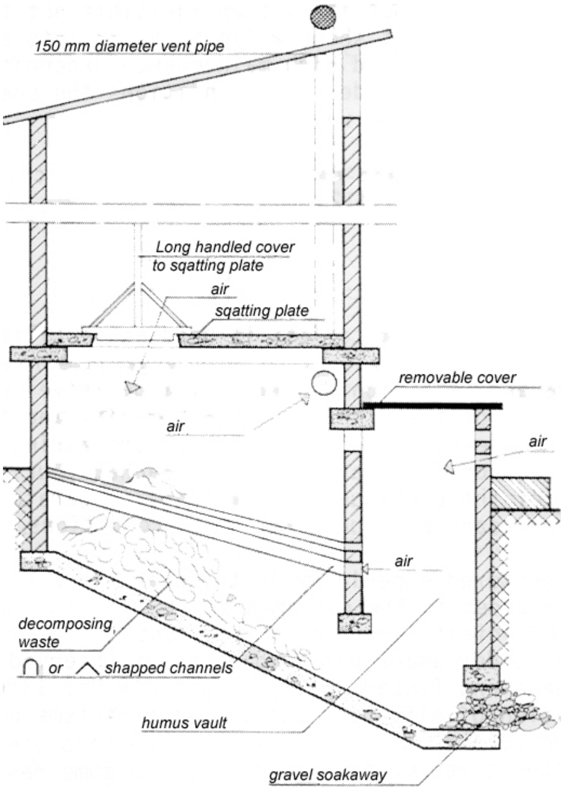


Fig. 6: Continuous composting toilet, „Multrum“-design. [1], p. 19

The design allows aerobic degradation of the substrate with temperatures rising up to 50-70 °C during the composting process. This thermophilic environment substantially adds to removal of even resistant pathogen species. However, false or insufficient servicing may lead to anaerobic conditions and incomplete degradation. Baumann and Karpe [1] recommend not to construct continuous composting toilets in any developing countries as batch composting is simpler and safer from the hygienic point of view.

3.5 Biolatrine

The biolatrine is in principle the centre part of a sanitary biogas unit for safe human faeces disposal, degrading the excreta anaerobically, thus producing biogas and digested substrate that may be utilised as fertiliser. The main focus is however mostly on sanitary aspects, i.e. clean toilets with low maintenance demand, rather than a high gas productivity. The soil conditions should however allow effluent and slurry absorption so as to prevent a disposal problem.

Biolatrines are designed as integrated fixed-dome biogas plants (see Fig. 7), where up to 6 latrines can be installed around a dome.

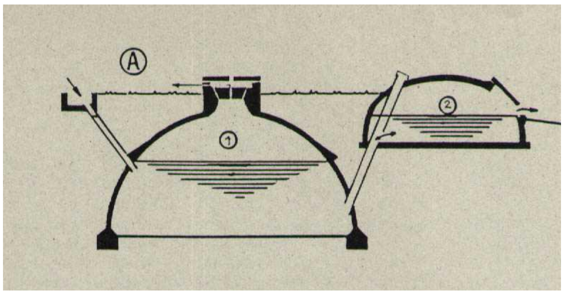


Fig. 7: Fixed-dome biogas plant. [8]
(1) digester; (2) expansion chamber.

The main advantage of biolatrines is that they are generally run without water (except for the start-up phase), i.e. also not in connection with flush toilets, thus substantially reducing water demand and related costs. The urine will provide sufficient liquid for the substrate to be able to flow. Both inlet and outlet of the biogas plant will have to be dimensioned accordingly to prevent clogging.

Prior to be taken into operation, the toilet will once have to be filled with water – for a better and faster gas production, cow dung can be added in the beginning. Organic household waste and grey water can be added for joint treatment and will in addition further increase gas productivity by optimising the C:N ratio. Provided that no sand or stones enter the plant, it can be operated without major maintenance demand for a period of 10 to 20 years.

The toilet chamber is connected to a vent pipe corresponding to those of the VIP latrine as described in 3.2. For the main design criteria of the toilet, see Fig. 8.

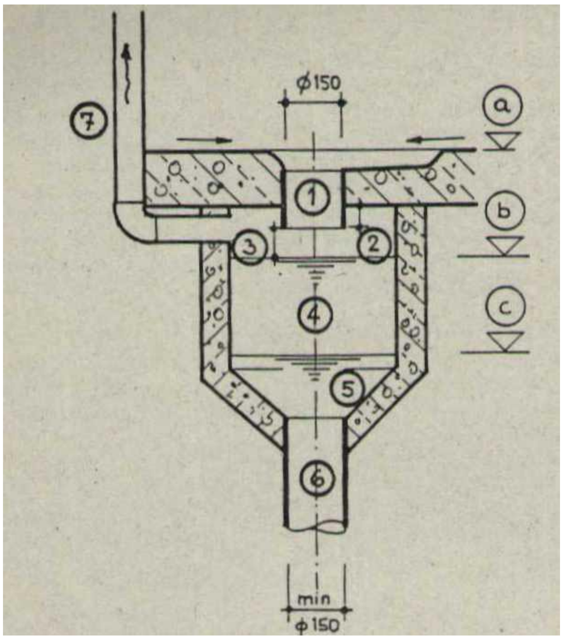


Fig. 8: Construction details of toilets for a biolatrine. [8]
(a) toilet floor; (b) highest and (c) lowest slurry level; (1) inlet pipe; (2) bottom rim of inlet pipe ; (3) inlet piece always above highest slurry level; (4) feeding chamber; (6) down pipe; (7) vent pipe.

Due to a required minimum flow rate, a biolatrine may only be an appropriate solution if at least 25 people are connected to its use. The excreta of 25 people will produce an average of about 1 m³ of biogas per day (40 l per person and day), representing the approximate cooking energy demand of one household. Speaking of institutions with 500 or more attendants (depending on the type of institution and the mean time people spend at the location), the produced biogas may supply sufficient energy for a canteen. Application may occur for institutions like schools, prisons, religious centres, or for public facilities like markets. Special attention has to be given to the daily cleansing of the slabs to avoid bad hygienic conditions.

Fig. 9 shows a biolatrine under construction in Ghana

Fig. 9: Biolatrine for 2x3 toilets, 200 people in Kumasi, Ghana (under constr.)
front: digester, rear: influent shaft
(Source: [3])

Two different strategies have been developed, the first one with a very short hydraulic retention time (HRT) of 1-3 days, where the digesters have roughly the same functions like a septic tank plus biogas production, the second with HRT of at least 30 days (usually about 60 days).

For the first technology, solid substances will sediment to the bottom where anaerobic reduction processes take place. The gas collects in the upper part of the digester and displaces the slurry into the expansion chamber. As soon as the expansion chamber is full, the slurry can flow via a slurry channel to direct application as manure (not recommended due to the remaining content of pathogenic germs) – otherwise, the overflow will be conveyed into a drying bed, the material accumulating there being also suitable for use as fertiliser.

The second technology does not require a slurry channel, but a larger digester volume, as the storage capacity includes the higher volume of liquid due to the longer retention time and an additional sludge volume of about 0.04 m³ per capita and year. Once a year, a tank lorry has to pump out the settled and partially stabilised sludge for further treatment like composting before being used as fertiliser. Danger of clogging is avoided, as the whole sludge remains in the digester. Liquid overflow is usually infiltrated into the underground by a soak pit.

In the context of dry sanitation concepts, biolatrines are the most cost-intensive solution concerning investment costs, but are at the same time the most common installations and also represent a highly appropriate option for simultaneous disposal of excreta and household wastewater in the absence of public disposal installations.
Furthermore, the biolatrine concept allows the reduction of cooking costs by a partial substitution of firewood. This aspect will in future increase its importance due to a general lack of knowledge about sustainable timber production on one hand and overuse of natural wood resources on the other hand, occurring in the majority of the developing countries.

4 References and further information

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[8] Sasse, L.; Kellner, C. Kimaro, A.: Improved biogas unit for developing countries. GATE/GTZ, Eschborn, Germany, 1991.

4.1 Institutions and Organisations

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, German Appropriate Technology Exchange GATE Information Service
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4.2 Useful links

http://www.lboro.ac.uk/departments/cv/wedc/specialist-activities/ws/low-cost-sanitation.htm
Water, Engineering and Development Centre (WEDC), Loughborough University, UK. Training, research, consultancy for planning, provision, management of infrastructure for development in low- and middle-income countries, rural water supply and sanitation (many latrine projects), urban infrastructure education.

http://www.irc.nl/
IRC International Water and Sanitation Centre, Netherlands. Numerous publications and online documents.

http://www.irc.nl/lgfr/projects/guinunicef/index.html
Evaluation of community programme for latrinisation (French), final report.

http://www.wsscc.org/
Water Supply and Sanitation Collaborative Council, c/o WHO. Further institutions, links, publications.

http://www.wsscc.org/gesi/index.html
Global Environmental and Sanitation Initiative (GESI).

http://www.wsp.org/english/eap/sanitationladder/san_ladder.html
http://www.wsp.org/english/eap/sanitationladder/san_ladderoptions.html
Water and Sanitation Programme. The Sanitation Ladder: Rural Sanitation Options in Lao PDR (six options with increasingly higher levels of service options are presented)

http://www.un-urbanwater.net/resources/pollution.html
Joint initiative of United Nations Environment Programme (UNEP) and United Nations Centre for Human Settlements UNCHS (Habitat): Managing Water for African Cities (MAWAC)

http://207.158.226.219/profiles/prj.drylatrine.htm
„Coffee Kids“ and AUGE (Desarrollo Autogestionario/Self-managed Development): Composting latrine project in Cosautlán, Veracruz, Mexico.