SANITATION PRACTICES
Good and Poor

Good practices

1. Arborloos
2. Ventilated improved pit latrines
3. Urine-diverting ventilated improved vault latrines
4. Pour-flush toilets
5. Biogas toilets
6. Greywater systems
7. Rural ecological sanitation (EcoSan)
8. Simplified sewerage
9. Low-cost combined sewerage
10. Community-managed sanitation blocks
11. Settled sewerage

Poor practices

1. Conventional sewerage
2. Periurban EcoSan

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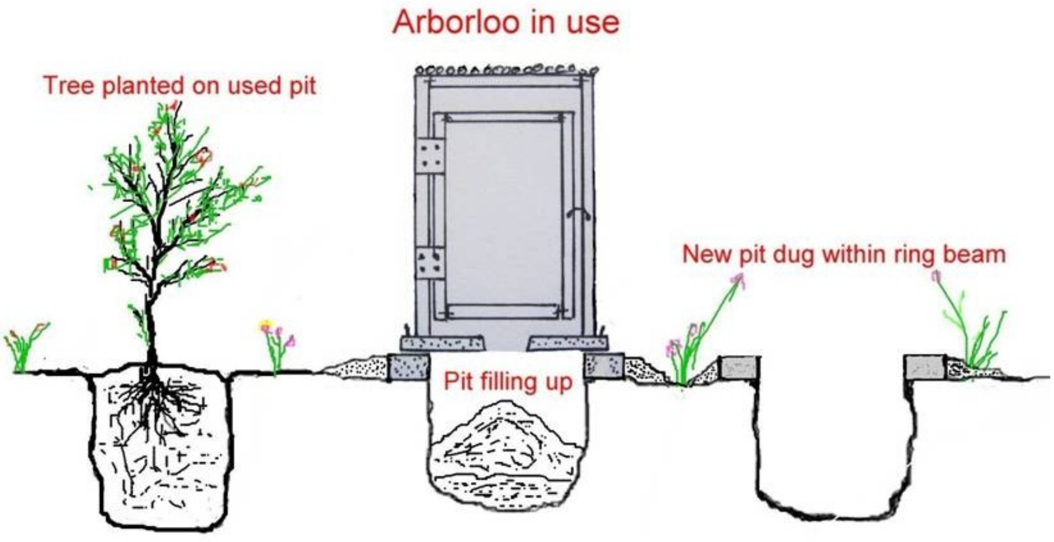
Good Practice 1

Arborloos

Arborloos are small, short-life, and extremely low-cost pit latrines specifically designed to cultivate high-value trees (fruit trees, for instance, or medicinal trees - see 'Further Information' below) (Morgan, 2007a,b; Simpson-Hébert, 2007). With greywater use for irrigation (see 'Good Practice 6') Arborloos are a highly sustainable sanitation system and one that is probably the most appropriate to use in dispersed rural communities. Arborloos can be considered a very simple EcoSan system (see 'Good Practice 7') and one in which there is no handling of either the faeces or urine.

The Arborloo functions as shown in the figure below: a shallow pit (0.8 m dia. and 1- 1.5 m deep) is dug and a coverslab and portable superstructure (made from local materials) placed over it. This Arborloo latrine is used for 6- 12 months (soil, leaves and/or ash are regularly added to the pit to accelerate the composting process - ash is a good source of potassium), after which time a new pit is dug and the coverslab and superstructure placed over it. Soil is added to the full pit to just above ground level and a young tree planted; its roots grow down into the composted excreta/soil/leaves/ashes in the pit and, as a result, the tree grows quickly (greywater can be used to water it) and it soon provides an income for the farmer. This process is repeated until the farmer has an orchard of the desired size. (Detailed construction advice is given in Morgan, 2007a.)



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P. R. Morgan (2007b). Ecosan at low cost – with the potential for upgrading. *Waterlines* **26** (2), 6-7.

M. Simpson-Hébert (2007). Low-cost Arborloo offers Ethiopians health and agriculture benefits. *Waterlines* **26** (2), 12-14.

Further information

University of Leeds Arborloos webpage:
http://www.personal.leeds.ac.uk/~cen6ddm/Arborloos.html

Prepared by Duncan Mara, University of Leeds, UK, April 2008.

Good Practice 2

Ventilated Improved Pit Latrines

Ventilated improved pit (VIP) latrines are one of the simplest improved sanitation options for excreta (faeces and urine) management. When combined with good greywater management (see 'Good Practice 6') they form a sustainable sanitation system. VIP latrines can be either single-pit units or alternating twin-pit units.

Figure 1 shows a single-pit VIP latrine. The superstructure is slightly off-set from the pit to permit the installation of a vertical vent pipe which is fitted with a fly screen at its top. The vent pipe has two functions: odour control and fly control (in contrast traditional - i.e., unventilated - pit latrines generally have serious odour and fly problems). The wind blowing across the top of the vent pipe sucks air out of the vent pipe, so creating a flow of air from outside the superstructure, down through the squat hole (or pedestal seat unit), and up and out of the vent pipe, taking with it all the malodorous gases from the decomposing faeces in the pit, so leaving the superstructure completely odour-free. Gravid female flies are attracted to the top of the vent pipe by the faecal odours coming out of it, but the fly screen blocks their entry, so they cannot enter the pit to lay their eggs. A few flies will, however, enter the pit via the squat hole and lay their eggs in the pit; eventually these eggs become newly emergent adult flies, which always fly in the direction of the strongest light they can see. Provided the superstructure is kept reasonably dark, the strongest source of light they are able to see is the shaft of light coming down the vent pipe and so the newly emergent adult flies fly up the vent pipe, but the fly screen blocks their exit; due to a lack of food they quickly die and fall down into the pit. In all other respects VIP latrines function like any other pit latrine: the faeces slowly decompose in the pit and the urine and any water used to clean the squat slab or pedestal seat infiltrate into the surrounding soil. Design details are given in Mara (1984); typically the pit is 1- 1.5 m in diameter, with a depth of ~3 m, and the vent pipe diameter 100- 150 mm (or ~225 mm square if the vent pipe is made of locally burnt bricks). The pit is lined with brickwork or blockwork (with the vertical joints unmortared) if the soil is unstable. The cover slab is raised 300 mm above ground level if the groundwater table is within 300 mm of ground level (either permanently or seasonally).

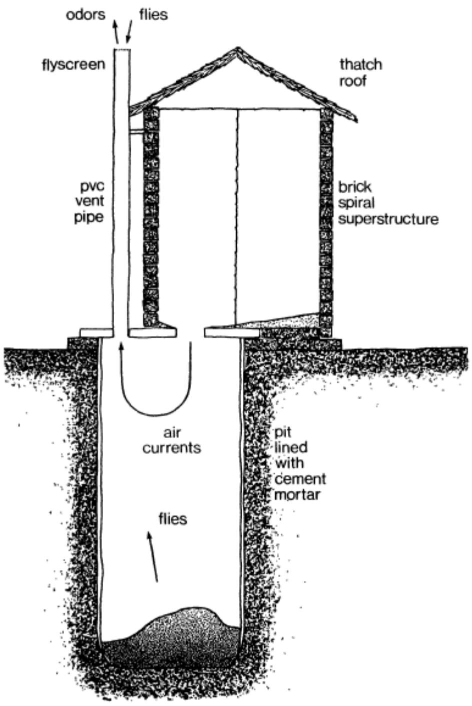

Figure 1. A single-pit VIP latrine, showing the superstructure off-set from the pit and the air flow down through the squat hole and up and out of the 100-mm diameter PVC vent pipe. The superstructure can be made out of any suitable local materials (generally the same materials as used for the construction of the users' house); the interior of the superstructure has to be reasonably dark for good fly control, so often a spiral superstructure is used:

Single-pit VIP latrines are commonly designed for a life of 10 years. When the pit is full (to within ~300 mm of the cover slab), the superstructure is dismantled and a new latrine built over an adjacent new pit, reusing as much as possible from the old pit (cover slab, vent pipe etc.). Thus single-pit VIPs are most suitable for use in rural areas where there is normally space for a second pit. They can also be used in periurban areas or small towns and large villages if the pit is emptied mechanically [by a high-powered vacuum tanker - such as the 'Vacutug' (UN Habitat, 2002); see also Pickford and Shaw (undated)].

If mechanically emptying is not possible, then in low-density periurban areas or small towns and large villages alternating twin-pit VIP latrines (also called 'ventilated improved double pits' or VIDPs) can be used. They are a permanent sanitation facility as they do not need to be relocated. Within the single permanent superstructure there are two squat-holes, each above their own pit which extends sideways beyond the superstructure; each pit has its own vent pipe (Figure 2). One squat-hole and its pit are in use at any one time for 1- 2 years, and the other squat-hole is blocked off; after the 1-2 years the second squat hole and pit are put into service, and towards the end of the second 1-2-year period the first pit is emptied - this can be done either mechanically or manually (manual emptying is not hazardous as all the excreted pathogens, with the exception of just a few *Ascaris* eggs, will have died during the 1- 2 years the pit was not in use). At the beginning of the third 1-2-year period the first squat-hole and pit are put back into service.

Figure 2. An alternating twin-pit VIP latrine. Each of the two pits has its own 100-mm diameter vent pipe with a fly screen at its top. The external pit cover slabs are only weakly mortared so they can be easily removed when the pit is to be emptied:

Solids accumulate in the pit at a rate of 0.02- 0.06 m^3 per user per year - lower in wet pits (those that penetrate the groundwater table) than in dry pits (those wholly above the groundwater table). The material removed from the pit is totally different from what went into the pit: it is odourless and much more like soil than faeces. It is either buried on-site if there is space for this, or carted away to landfill or used as a soil conditioner (in, for example, periurban agriculture).

Operation and maintenance are simple: regular cleaning of the squat-hole or pedestal seat and the cover slab, and visual inspection of the fly screen and removal of any material (e.g., fallen leaves) from it. Pit emptying (either manually or mechanically) is required every 1-2 years.

References

Mara, D. D. (1984). *The Design of Ventilated Improved Pit Latrines* (TAG Technical Note No. 13). Washington, DC: The World Bank; available at: http://go.worldbank.org/NYU395FV90.

Pickford, J. and Shaw, R. (undated). *Emptying Pit Latrines* (Technical Brief No. 54). Loughborough: WEDC; available at: http://www.lboro.ac.uk/well/resources/technical-briefs/54-emptying-latrine-pits.pdf.

UN Habitat (2002). *Operating and Maintenance Manual for the Mark II Vacutug Latrine Emptying Vehicle*. Nairobi: UN Habitat; available at: http://www.personal.leeds.ac.uk/~cen6ddm/PitEmptying/VacutugManual.pdf.

Further information (and links to other publications): On-site Sanitation (University of Leeds webpage at: http://www.personal.leeds.ac.uk/~cen6ddm/WatSan.html).

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Good Practice 3

Urine-diverting Alternating Twin-vault Ventilated Improved Vault Latrines

Urine-diverting alternating twin-vault ventilated improved vault (VIV) latrines [UD-VIVs] are, like VIP latrines (see 'Good Practice 2') and pour-flush toilets ('Good Practice 4'), one of the simplest improved sanitation options for excreta (faeces and urine) management. When combined with good greywater management (see 'Good Practice 6') they form a sustainable sanitation system. They are sometimes known as 'eThekwini latrines' after the municipality in KwaZulu Natal in South Africa where they were developed.

UD-VIVs have two separately ventilated above-ground vaults used alternately, each for a year. The UD-squat pan or UD-pedestal seat is located above the vault in use and the entrance to the vault not in use is closed off. The diverted urine is discharged to an adjacent soakaway (the eThekwini UD-VIVs have a urinal as well as a UD-pedestal seat, but this feature is optional). The faeces (plus any anal cleansing materials) partially decompose in the vault when it is in use in 'year 1' and this process is completed when this vault is not in use in 'year 2' (when the other vault is in use). Towards the end of 'year 2' the vault is emptied manually (by using a long-handled shovel) and the decomposed contents are buried on-site. At the start of 'year 3' the vault is put into use once again. Urine diversion ensures that the vault contents are essentially dry and so permits their easy removal. Maintenance requirements are minimal: regular cleaning of the squat-pan or pedestal seat, plus annual emptying of the vault not in use.

The eThekwini UD-VIV latrine is shown in Figures 1-6.

Figure 1. Front view of eThekwini UD-VIV latrine.

Figure 2. Front view of eThekwini UD-VIV latrine with the door open, showing the UD-pedestal seat and urinal, also the closed-off entrance to the vault not in use

Figure 3. Close-up view of the UD-pedestal seat (front compartment for urine, rear compartment for faeces).

Figure 4. Rear view of eThekwini UD-VIV latrine, showing the two above-ground separately ventilated vaults and, between them, the pipe taking the diverted urine to an adjacent soakaway.

Figure 5. Close-up of one of the vaults with its sliding door partially open. The urine-diversion pipe is clearly visible on the right.

Figure 6. Poster (in Zulu, the local language) telling the users how to use the UD-VIV latrine correctly.

Further information:

eThekwini's Water & Sanitation Programme, Water Information Network - South Africa, Pretoria; available at: http://www.dwaf.gov.za/Events/SanitationWeek/2006/documents/WINSAlesson2.pdf.

eThekwini Water and Sanitation: A Case Study, University of Leeds website available at: http://www.personal.leeds.ac.uk/~cen6ddm/WatSan.html.

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Good Practice 4

Pour-flush Toilets

Pour-flush (PF) toilets are one of the simplest improved sanitation options for excreta (faeces and urine) management. When combined with good greywater management (see 'Good Practice 6') they form a sustainable sanitation system. PF toilets can be either single-pit units or alternating twin-pit units (Figure 1). Single-pit units are used in rural areas, where there is space for a second pit to be constructed when the first is full, or in periurban areas if there is sufficient space for them and they can be emptied mechanically. Squat-pans with an integral water seal (Figure 2) or pedestal seat units, also with an integral water seal (Figure 3) are used, depending on the users' preference; the eater seal prevents insects and odours from the leach pit entering the superstructure. The excreta (faeces and urine) are manually flushed with 2- 3 litres of water into an adjacent leach pit (Figure 4).

Alternating twin-pit PF toilets are used in exactly the same way as alternating twin-pit VIP latrines ('Good Practice 1'); they are especially suitable in low-density periurban areas (provided they are cheaper than simplified sewerage - see 'Good Practice 8'). The only difference is the flow--diversion box: this directs the wastewater (faeces, urine, flush water) flow to the leach pit in use (the outlet to the pit not in use is blocked off – for example, by a brick wrapped in hessian).

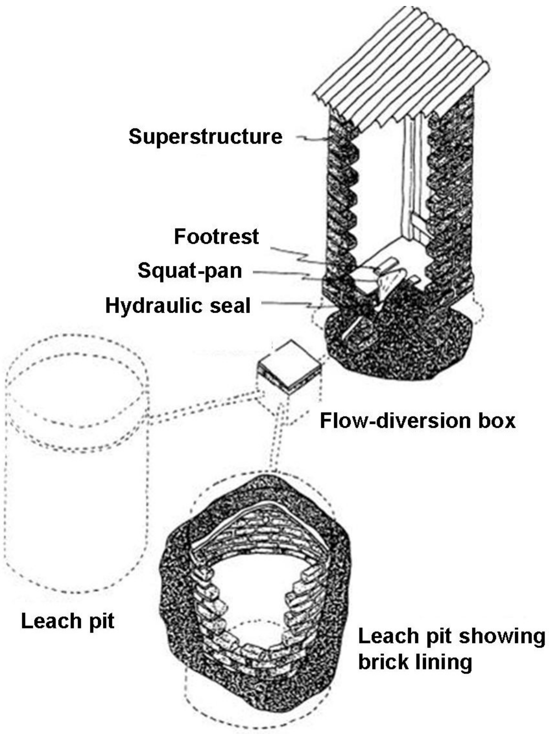

Figure 1. Schematic diagram of an alternating twin-pit pour-flush toilet.

Figure 2. Low-cost polypropylene squat-pans and traps (Gramalaya).

Figure 3. Colombian ceramic pour-flush pedestal seat unit.

Figure 4. Excreta being flushed into the leach pit.

PF toilet leach pits are designed differently from VIP latrine pits as they have to have sufficient infiltrative capacity for the flush water, in addition to sufficient solids storage capacity. Leach pit design life is normally ~10 years for single-pit units and 1- 2 years for each pit in alternating twin-pit units. The latter can be emptied manually as all excreted pathogens, with the exception of a few *Ascaris* eggs, die within 12 months.

Further information:

Jah, P. K., *Sustainable Technologies for On-site Human Waste and Wastewater Management: Sulabh Experience*, Asian Development Bank, Manila, 2005; available at: http://www.adb.org/Documents/Events/2005/Sanitation-Wastewater-Management/paper-jha.pdf

University of Leeds, *On-site Sanitation*, webpage, with links to several PF publications, including World Bank design manuals, at: http://www.personal.leeds.ac.uk/~cen6ddm/WatSan.html.

See also:

Sitters & Squatters and Washers & Wipers, University of Leeds webpage at: http://www.personal.leeds.ac.uk/~cen6ddm/SitSquatWashWipe.html,

Pit Emptying, University of Leeds webpage at: http://www.personal.leeds.ac.uk/~cen6ddm/PitEmptying.html.

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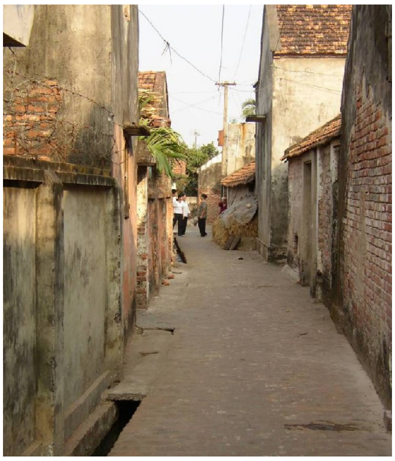
Good Practice 5

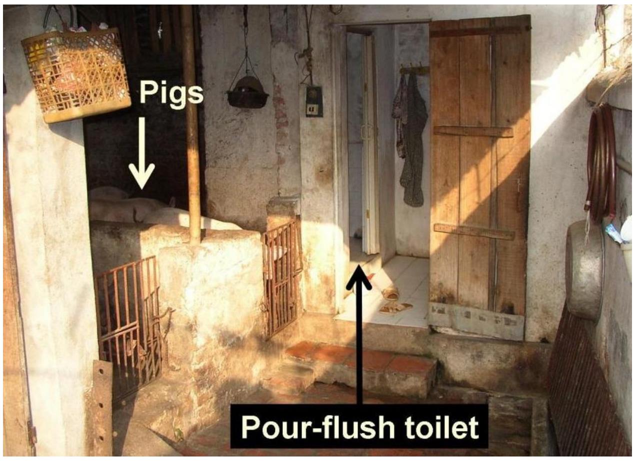
Biogas Toilets

Biogas toilets are another simple option for excreta (faeces and urine) management. When combined with good greywater management (see 'Good Practice 6') they form a sustainable sanitation system. Households have pour-flush toilets (see 'Good Practice 4') which discharge into a small, typically a 1-m^3, anaerobic digester from which the biogas is collected and used for cooking and/or other domestic purposes (e.g., lighting). To increase biogas yields animal excreta are also often added to the digester. At intervals of 1-2 years the digester is desludged and the sludge so removed is either buried on site or used to fertilize a small garden plot. This sanitation system is especially suitable for use in small towns and large villages.

There are many such biogas toilets, especially in the Far East. In small towns in Vietnam many households have 3-4 pigs and both the pig and human excreta are discharged into a ~1-m^3 anaerobic digester, and the resulting biogas is used for cooking, as shown in Figures 1-4.



1. Lane in a small town near Hanoi, Vietnam (notice partially covered drain at left used for both greywater and stormwater)



2. View inside the household compound, showing the pour-flush toilet and the area where pigs are kept

3. Household anaerobic digester for biogas generation and collection

4. Biogas used for cooking

Prepared by Duncan Mara, University of Leeds, UK, December 2007

Good Practice 6

Greywater Systems

Greywater is all household wastewater excluding toilet/latrines wastewaters, so it comprises wastewater from sinks, showers and, in houses not connected to a piped water supply, from bowls used for food preparation and cleaning cooking utensils, plates, etc. The type of water supply generally determines the amount of greywater produced and thus the options for its collection, treatment and disposal or reuse.

The simplest method of greywater disposal, suitable for households whose water consumption is low (~25 litres per person per day or less) is an on-plot soakaway (50- 80 cm diameter, 1- 1.5 m deep and filled with large stones or brickbats). Alternatively, the greywater can be used to irrigate vegetables in a garden plot (a "greywater garden") or field. For households with a pour-flush toilet (see 'Good Practice 3'), greywater can be used to flush the toilet, with any excess being used on a greywater garden.

Simplified sewerage ('Good Practice 8') and settled sewerage ('Good Practice 11') remove all household wastewaters, so separate arrangements for greywater are not necessary, although, if water is scarce and/or expensive, some of the greywater can be used to flush pour-flush toilets.

In periurban areas and in small towns and large villages greywater could be removed in 'greywater drains' or greywater sewers, but these are likely to cost much the same as simplified sewerage and are therefore unlikely to be the greywater solution of choice. Stormwater drains can be easily designed to carry greywater flows by modifying the cross-section of the drain (Figure 1), but it is important to keep the drain free of garbage, leaves, etc., otherwise the greywater will pond and culicine mosquitoes breed, with a resulting risk of the transmission of Bancroftian filariasis.

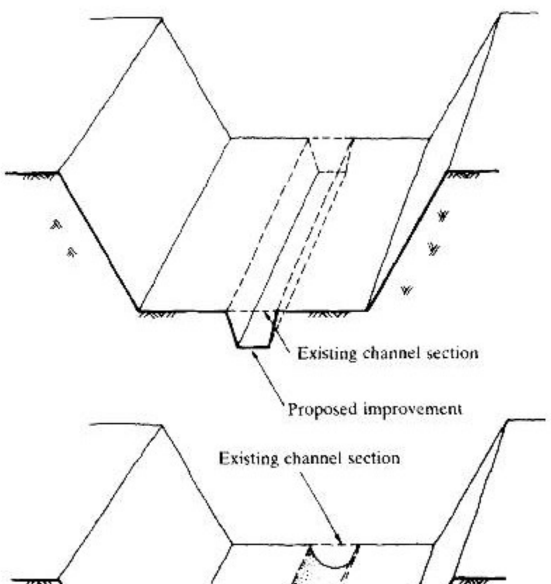


Figure 1. Stormwater drain modified to carry greywater flows (Kalbermatten et al., 1982).

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Kalbermatten, J. M., Julius, D. S., Gunnerson, C. G. & Mara, D. D. (1982). *Appropriate Sanitation Alternatives: A Planning and Design Manual* (World Bank Studies in Water Supply and Sanitation No. 2). Johns Hopkins University Press, Baltimore, MD; available at http://go.worldbank.org/7B6FR34OO0.

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Carden, K., Armitage, N. and others (2007). The use and disposal of greywater in the non-sewered areas of South Africa: Part 2 – Greywater management options. *Water SA* **33** (4), 433- 442; available at: http://www.wrc.org.za/downloads/watersa/2007/Jul%2007/2123b.pdf.

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Ridderstolpe, P. (2004). *Introduction to Greywater Management.* Stockholm Environment Institute, Stockholm; available at: http://www.ecosanres.org/pdf_files/ESR_Publications_2004/ESR4web.pdf.

University of Leeds, Greywater Management, webpage at: http://www.personal.leeds.ac.uk/~cen6ddm/GreywaterManagement.html.

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Good Practice 8

Simplified Sewerage

Sewerage is a network of pipes ('sewers') that takes away all the domestic wastewater (i.e., mixed yellow, brown, beige and grey waters) from the houses where it is generated, to be treated and then disposed of elsewhere (often into a surface water or for use in aquaculture and/or agriculture). With conventional sewerage very conservative values for minimum sewer diameters, gradients and depths have accrued in design codes of practice over the last hundred years or so, with the result that per household construction costs are extremely high (see 'Poor Practice 1'). With simplified sewerage (also known as 'condominial' sewerage), which was developed in Brazil in the early 1980s to serve high-density periurban areas (Figures 1- 3), these conservative design codes are relaxed in order to reduce the sewer diameter, minimum gradient and depth, while maintaining rigorous hydraulic design principles - in fact simplified sewerage is more rigorously designed than conventional sewerage (Mara et al., 2001).

The minimum sewer diameter used in simplified sewerage is 100 mm and, for a minimum tractive tension of 1 kN/m^2 (which ensures self-cleansing of the sewer), the minimum sewer gradient is 1 in 200 (i.e., 5‰). A 100-mm diameter sewer laid at this gradient can serve ~200 households of five persons with a water consumption of 100 litres per person per day. A cost comparison between conventional and simplified sewerage for the mining town of Parauapebas in the northern Brazilian state of Pará is given in Table 1 (Melo, 2005), which shows that the cost of simplified sewerage is ~60% of that of conventional sewerage. Similar cost savings have been reported in South Africa (ZAR 2500- 3000 vs. ZAR 6000- 7000) (DWAF, 2002). Depending on the population density, simplified sewerage can be less expensive than on-site sanitation systems such as VIP latrines and pour-flush toilets (see 'Good Practice 2' and 'Good Practice 4', respectively) (Figure 4).

Table 1. Comparative costs (1997 USD) of conventional and simplified sewerage in Parauapebas

Item	Conventional sewerage		Simplified sewerage	
	Total cost	Cost per connection	Total cost	Cost per connection
Excavation	263,000	39	186,000	28
Inspection chambers	181,000	27	85,000	13
Sewers	185,000	28	102,000	15
Total	629,000	94	373,000	56

Source: Melo (2005).

Simplified sewer networks are very flexible, with the sewers often laid inside a housing block, in the front garden, or under the pavement (sidewalk), rather than in the centre of the road as with conventional sewerage. This results in considerably less disruption to existing structures and major cost savings in construction. Simplified sewerage is appropriate both for existing unplanned periurban settlements and also for new housing estates with more regular layouts (Figure 2).

In upstream parts of the network, where the flow is intermittent, wastewater solids are gradually moved along the sewer each time a toilet is flushed. This transport process of 'move→ settle→move→settle' is much more efficient in small diameter sewers than in unnecessarily large diameter sewers - "small flows flow better in small sewers". PVC pipes are normally used, with simple joints and minimal resulting leakage or infiltration. Simple low-cost sewer junctions and cleanout and inspection units are used in place of expensive manholes (Figure 3). The water and sewerage company for Brasília and the Federal District uses simplified sewerage in both rich and poor areas.

Operation and maintenance is straightforward. In Brazil the state water and sewerage companies (SWC) use several methods of O&M. For example, in Brasília residents report blockages to the local SWC office which then despatches a van equipped with a water-jet unit; this is inserted in a junction box upstream of the blockage which is jetted to the next downstream junction box from where it is

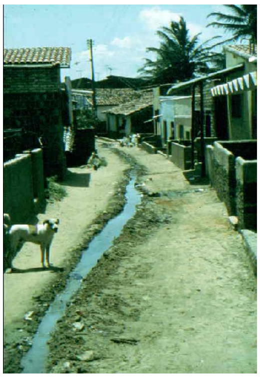

Figure 1. Typical situation in periurban areas: a stream of wastewater in the road.

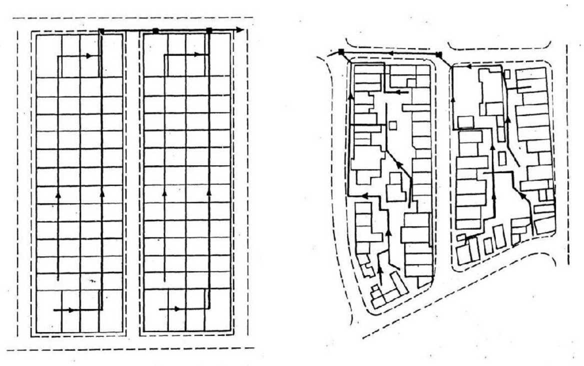

Figure 2. Simplified sewerage can be installed in new well-planned areas (left) and also in existing unplanned areas (right).

Figure 3. Low-cost plastic sewer junction which is now commonly used in Brazil.

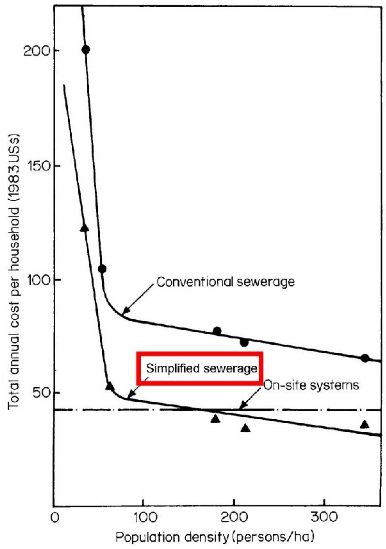

Figure 4. Variation of costs of conventional sewerage, simplified sewerage and on-site sanitation with population density, Natal, northeast Brazil, 1983. In this case simplified sewerage was cheaper than on-site systems above the relatively low population density of ~160 persons per hectare.

removed. In Recife in the northeastern state of Pernambuco the SWC employs small local engineering firms to do the O&M: typically a firm locates a technician engineer and 1- 2 labourers in the area it is responsible for to whom residents report any blockages; the team then visits the blocked sewer and cleans it manually.

The wastewater collected by simplified sewers can be discharged into a conventional trunk sewer if there is one nearby, or it can be treated at a (new) local wastewater treatment plant.

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DWAF (2002). *Sanitation for a Healthy Nation: Sanitation Technology Options*. Pretoria: Department of Water Affairs and Forestry, Government of South Africa; available at: www.dwaf.gov.za/dir_ws/content/lids/PDF/Technical.pdf.

Mara, D. D., Sleigh, P. A. and Tayler, K. (2001). *PC-Based Simplified Sewerage Design*. Leeds: School of Civil Engineering, University of Leeds; available at: www.efm.leeds.ac.uk/CIVE/Sewerage/.

Melo, J. C. (2005). *The Experience of Condominial Water and Sewerage Systems in Brazil: Case Studies from Brasília, Salvador and Parauapebas.* Lima: Water and Sanitation Program Latin America; available at: http://www.wsp.org/filez/pubs/BrasilFinal2.pdf.

See also:

Mara, D. D. (2007). Simplified sewerage, website at: www.personal.leeds.ac.uk/~cen6ddm/simpsew.

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Good Practice 9

Low-cost Combined Sewerage

A. Unsettled wastewater

In low-income coastal areas in the state of Rio de Janeiro, Brazil, low-cost combined sewerage has been successfully used and shown to be less expensive than simplified sewerage and separate stormwater drainage (Guimarães and de Souza, 2004). The design basis is as follows:

1. The drainage area should not exceed 12 km^2;
2. The design stormwater flow is that resulting from the local 10-year flood [determined, for example, by the Wallingford modification of the rational (Lloyd Davies) method (May and Kellagher, 2004)];
3. The minimum sewer diameter is 400 mm;
4. The sewer gradient is determined for the peak daily wastewater flow in the dry season and the sewer diameter selected to carry the 10-year storm flow [thus the design calculations are similar to those for simplified sewerage ('Good Practice 8' - see also Mara et al., 2001)].

B. Settled wastewater

In India the solids-free effluent from a pour-flush toilet leach pit is discharged into a stormwater drain (Sundaravadivel et al., 1999), and in Vietnam household wastewater is settled in a small solids interceptor (septic) tank prior to discharge into a stormwater channel (Beauséjour and Nguyen, 2007; Beauséjour, 2008). The septic tank could be the dwarf unit developed in India (Sagar, 1983). Otherwise the design should follow the principles in A above.

Low-cost combined drainage at Lai Xá, Vietnam

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Good Practice 10

Community-managed Sanitation Blocks

In high-density low-income urban areas, including slum areas, often the only viable sanitation system is community-managed sanitation blocks of the type promoted by SPARC, the Society for the Promotion of Area Resource Centres, an Indian NGO (www.sparcindia.org). These sanitation blocks are designed, built, owned and managed by the communities they serve: they are for the use of the community members, who pay for its upkeep - they are in no sense public facilities, although a community may allow casual use on payment of a per-use fee. The basic reference is Burra et al. (2003) which is detailed below.

These sanitation blocks are better designed and managed than conventional government-funded and contractor-built communal toilet blocks and they cost less. This model of community-designed, built and managed sanitation blocks is easily adaptable to other sociocultural settings: the key point is that each sanitation block is designed, built and managed by the community it serves. Generally help from a local NGO is required initially to catalyze community activity and to interact, on behalf of the community, with and obtain financial support from the local city or town council, which may not at the beginning take the views of poor and very poor communities seriously.

The SPARC approach has been successfully transferred to Africa, in Kibera slum in Nairobi, by the Kenyan NGO Maji na Ufanisi ('Water and Development') and the UK organization Water and Sanitation for the Urban Poor (see Further information below) (Figures 1-2 on next page).

Reference – essential reading

Burra, S., Patel, S. & Kerr, T. (2003). Community-designed built and managed toilet blocks in Indian cities. *Environment & Urbanization* **15** (2), 11-32; available free at:
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Further information

Maji na Ufanisi, 'Kibera Integrated Water, Sanitation & Waste Management Project', webpage at:
http://www.majinaufanisi.org/projects/k-watsan.htm

SPARC, 'The Sanitation Crisis in Indian Cities', webpage at:
http://www.sparcindia.org/iprojects.html

Water and Sanitation for the Urban Poor, 'Gatwekera, Kenya', webpage at:
http://www.wsup.com/projects/gatwekera.htm

University of Leeds, 'Community Sanitation Blocks', webpage at:
http://www.personal.leeds.ac.uk/~cen6ddm/CommunalSanitation.html

Figure 1. Community-managed sanitation block in Gatwekera village, Kibera, Nairobi. The ground floor is the sanitation compartment, and the top floor is a 'community room' used for meetings, weddings, parties, etc. Underneath the ground floor is …

Figure 2. Anaerobic digester which receives all the wastewater from the sanitation block. The biogas generated in the digester is used for cooking.

Figures 1 & 2 by courtesy of Rob Clarke, Halcrow/WSUP

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Good Practice 11

Settled Sewerage

Settled sewerage (also called solids-free sewerage and small-bore sewerage) is a sanitation system in which discharges all the wastewater from a household, or from a group of adjacent households, into a 'solids interceptor tank' (essentially a single-compartment septic tank) which discharges its liquid effluent into a 'settled sewer' (Figure 1). As all the settleable solids are removed in the interceptor tank, the sewer is designed to convey only settled (i.e., solids-free) wastewater, and this means it can be designed in a completely different way from the design of either conventional or simplified sewerage which convey unsettled wastewater and therefore have to be designed to be 'self-cleansing' - i.e., to prevent solids settlement in the sewer and consequent blockage of it. Thus the achievement of a 'self-cleansing velocity' or a 'minimum tractive tension' is not required for settled sewerage. Instead a settled sewerage network is designed using the 'inflective gradient' design approach, as follows:

(1) there must be an overall fall between the upstream and downstream ends of the sewer;
(2) the sewer is laid to closely follow the ground contours;
(3) as a result of (2), the flow in the sewer may vary between open channel flow (i.e., where there is a free wastewater surface in the sewer) and full-bore pressure flow (where the sewer flows full and under pressure);
(4) along sections of the sewer where the flow is pressure flow the design has to ensure that the hydraulic gradient of the wastewater does not rise above the level of the invert of the outlet from any interceptor tank discharging into this section of sewer (if it did, then wastewater would flow from the sewer to the interceptor tank) - this is easily achieved either by locally increasing the sewer diameter or by locally laying the sewer at a greater depth;
(5) using simple inspection points in place of manholes (but not at every junction or change of direction); and
(6) using a minimum sewer diameter of 75 mm.

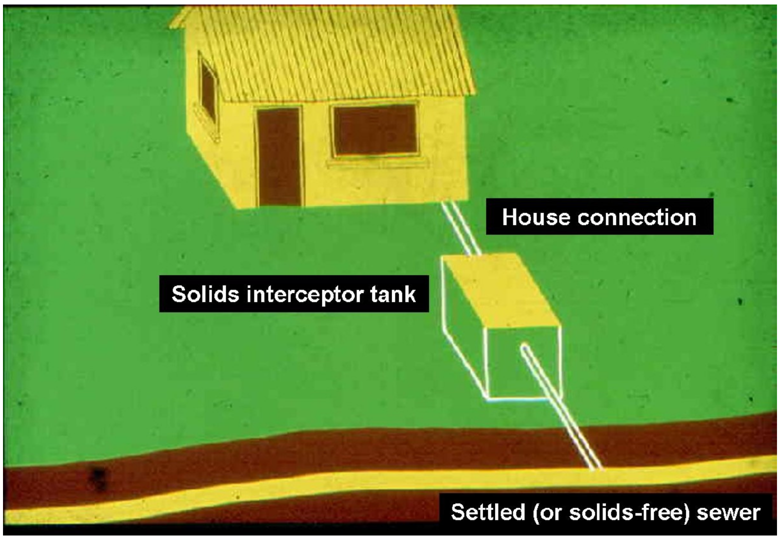

Figure 1. Schematic diagram of settled (or solids-free) sewerage.

Figure 2 shows a settled sewerage scheme in a village in the Nile Delta region of Egypt.

Operation and maintenance is straightforward: the local sewerage agency has to (1) assume the responsibility for regular desludging of the interceptor tanks (as individual householders cannot be relied on to do this on time) - this ensures that no settleable solids from full tanks enter the settled sewer; these desludging costs can be recovered from the householders via their monthly water and sewerage bills; and (2) ensure that no illegal connections are made to the settled sewer (as these would typically be of unsettled wastewater and would therefore block the sewer).

Figure 2. A village house in the Nile Delta, Egypt with its solids interceptor tank.

Settled sewerage is commonly more expensive than simplified sewerage in areas without existing septic tanks. However, in areas with existing septic tanks (and these are generally non-poor areas), settled sewerage is often a financially competitive solution (as the cost of the existing septic tank is a 'sunk' cost and it is economically and financially prudent to take maximal advantage of existing infrastructure components, rather than simply abandon them).

Further information

University of Leeds, *Settled Sewerage*, webpage (with links to several publications, including design manuals, on settled sewerage) at: http://www.personal.leeds.ac.uk/~cen6ddm/settsew.html.

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Poor Practice 1

Conventional Sewerage

Conventional sewerage is the sanitation system most commonly used in urban areas in industrialized countries and in non-poor urban areas in developing countries. It comprises a flush toilet which discharges, together with all the other household wastewater, into a network of underground pipes (called 'sewers') which transports the wastewaters from all households in the area to a centralized wastewater treatment plant, from which they are usually discharged into a receiving surface water (less commonly they are used for crop irrigation or fish/aquatic vegetable culture).

Work by John Kalbermatten and his colleagues at the World Bank in 1976- 78 found that the investment costs of conventional sewerage were always *very* high: in a survey of eight capital cities in Africa, Asia and Latin America investment costs were in the range USD 600- 4000 per household, with annual economic costs of USD 150-650 per household (1978 USD).[a] Thus, while conventional sewerage is an excellent form of sanitation for those able to afford it and who have plenty of water for its operation, these figures show that it is *not* an appropriate form of sanitation for poor households, simply because it is wholly unaffordable.

In the past there have been countless sewerage master plans recommending conventional sewerage as the *only* form of sanitation suitable in urban areas - most simply gathered dust on shelves in ministry offices, but a few were put into practice, generally with less than satisfactory results. The basic reasons for this were that the investment costs estimated in the master plan turned out to be gross underestimates, that poor households could not pay the high one-off connection fee (so they did not connect), and that operation and maintenance costs were unaffordable. Thus a very expensive system is actually even more expensive, in fact far too expensive for poor households, and the local sewerage agency could not afford proper, especially preventive, operation and maintenance, with the result that the system quickly deteriorates.

Actually, we do not need to worry about the inappropriateness of conventional sewerage in poor periurban areas as there are several alternative sanitation systems suitable for such areas. These are described in the seven 'Good Practice' boxes in this series.

Reference

J. M. Kalbermatten, D. S. Julius & C. G. Gunnerson, *Appropriate Sanitation Alternatives: A Technical and Economic Appraisal* (World Bank Studies in Water Supply and Sanitation No. 1). Baltimore, MD: Johns Hopkins University Press, 1982 (available at: http://go.worldbank.org/JKSLGN4OF0).

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[a] In 2007 dollars these figures become USD 1800-12000 per household and USD 450-1950 per household, respectively (conversion factors from http://www.oregonstate.edu/Dept/pol_sci/fac/sahr/infcf16652005.pdf).

<u>Poor Practice 2</u>

Periurban EcoSan Systems

Periurban EcoSan systems are currently very expensive, as shown by the costs in Table 1 taken from a report by the Stockholm Environment Institute (SEI, 2005). In fact these very high costs may even be serious underestimates (Arno Rosemarin, Stockholm Environment Institute - and one of the authors of this SEI report, personal communication, 2007).

In high-density periurban areas two sewers are required, one for urine and one for greywater. The minimum recommended diameter for urine sewers is 50 mm, but "the optimum range is from 75 mm to preferably 110mm", and the gradient must be at least 1 in 100 (GTZ, 2005). A similar-sized sewer is also required for the greywater. Two separate sewers increase costs dramatically (especially when compared with the single 110-mm sewer laid at a gradient of 1 in 200 needed for simplified sewerage - see 'Good Practice 8'). This is exemplified by a cost-comparison study in Germany between urban EcoSan and conventional sewerage which found capital costs to be higher for urban EcoSan: "the multiple sewer systems resulting from the separation of urine, brown [and] greywater are responsible for [the] higher investment costs." (Oldenburg et al., 2007).

Periurban EcoSan systems are therefore currently considered 'poor practice' for exactly the same reason as conventional sewerage (see 'Poor Practice 1'): they are simply much too expensive for use in poor periurban areas. Simplified sewerage (see 'Good Practice 8') was developed to bring affordable sewerage to the periurban poor, but to date there has been no analogous development of "simplified EcoSan" for use in high-density periurban areas.

Table 1. EcoSan household unit costs in urban areas

United Nations World Region	Urban household unit cost (USD)
Sub-Saharan Africa	350
Southern Asia	440
East Asia	650
Eurasia	725
South-East Asia	800
Oceania	875
North Africa	900
Latin America & Caribbean	1,000
West Asia	1,200

Source: Table 4-5 in SEI (2005).

References

GTZ (2005). *Urine Diversion: Piping and Storage* (Technical Data Sheet for Ecosan Components). Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Eschborn, Germany; available at: http://www.gtz.de/de/dokumente/en-ecosan-tds-01-b3-urine-diversion-piping-storage-2005.pdf.

Oldenburg, M., Peter-Fröhlich, A., Dlabacs, C., Pawlowski, L. and Bonhomme, A. (2007). EU demonstration project for separate discharge and treatment of urine, faeces and greywater – Part II: Cost comparison of different sanitation systems. *Water Science & Technology* **56** (5), 251–257, available at: http://www.iwaponline.com/wst/05605/wst056050251.htm.

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Further information (with links to many publications on EcoSan systems) is available at:

Stockholm Environment Institute 'EcoSanRes' (http://www.ecosanres.org)

GTZ EcoSan (http://www.gtz.de/en/themen/umwelt-infrastruktur/wasser/8524.htm)

University of Leeds (http://www.personal.leeds.ac.uk/~cen6ddm/EcoSan.html)

WASTE (http://www.ecosan.nl/) - "This site focuses on Ecological Sanitation especially in urban areas"

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