

# Water Sector in Small Urban Centres



## Water Supply and Sanitation Options for Small Urban Centres in Developing Countries

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# 1 Introduction

## The size of the problem

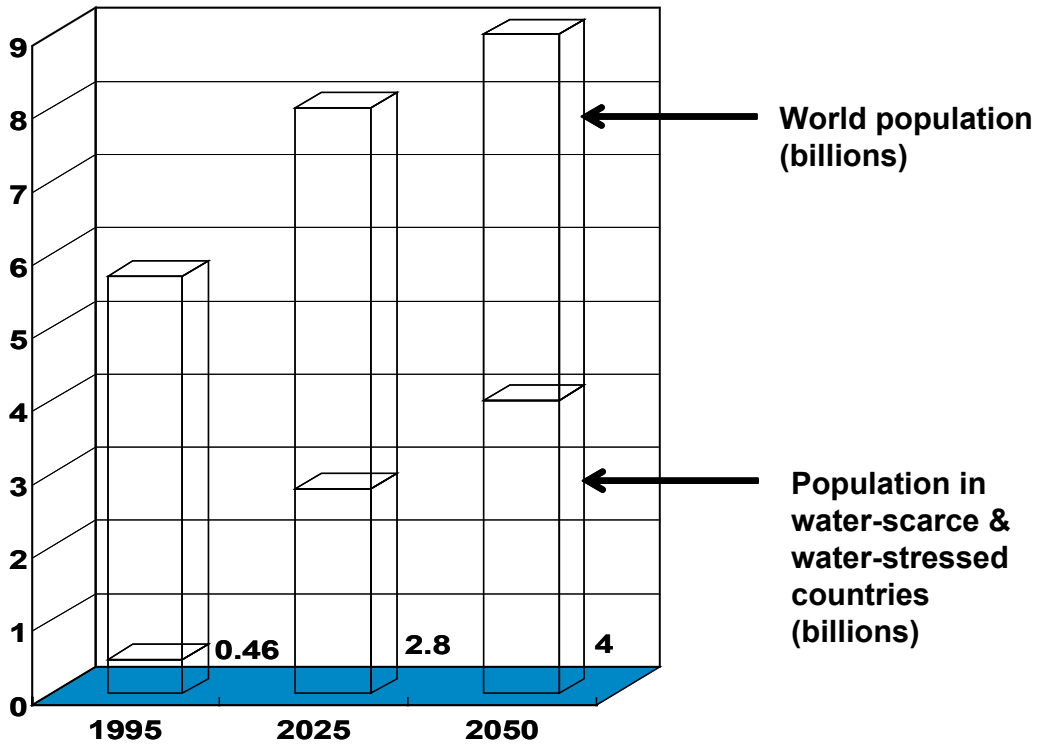
To meet the water and sanitation Millennium Development Goals some 300,000 people have to be provided with improved water supplies and 440,000 with improved sanitation every day during the period 2001–2015. This daily target for water supply was exceeded during the International Drinking Water and Sanitation Decade (1981–1990) (~370,000 people served per day), but the target for sanitation is more than twice the number of people served during the 1980s and the 1990s (~200,000 and ~210,000 people per day, respectively). Achieving the sanitation MDG is thus much more of a problem than achieving the water supply MDG, although water supply nearly to be geared up again to the level of the 1980s as significantly fewer people were supplied in the 1990s (~220,000 people per day). These figures are for ‘improved’ water supplies and sanitation (WHO and UNICEF, 2000, 2004); however, figures for ‘adequate’ water supplies and sanitation are much higher (UN-Habitat, 2003): in urban areas in 2000, 680–970 million were without adequate water supplies (vs 171 million without improved water supplies) and 850–1,130 million were without adequate sanitation (vs 394 million without improved sanitation). Whichever of these descriptors, ‘improved’ or ‘adequate’, is used, the numbers are very large for both water supplies and sanitation.

Unfortunately there are no published figures for the number of people in small towns and large villages (STLV) who require improved water supplies and improved sanitation. There are only overall figures for ‘urban’ and ‘rural’ areas. However, the numbers are likely to be large and most people in STLV can be assumed to be poor or very poor. They therefore require low-cost affordable solutions.

## Increasing global water stress and scarcity

Not only are the numbers of those requiring better water supplies very large, water itself is becoming scarcer. The number of people living in water-stressed and water-scarce parts of the world is estimated to increase approximately six-fold from 1995 to 2025 to reach ~2.8 billions (or nearly a third of the world’s population) (Figure 2.1). This situation must be taken into account when planning and designing water supply improvements for STLV now, otherwise their long-term sustainability is likely to be low.

**Figure 2.1** Population living in water-scarce and water-stressed countries, 1995–2050



Source: Hinrichsen et al. (1998) and United Nations (2000).

## 2

# Domestic Water Supplies

## Design water consumption

In order to minimize the transmission of waster-related diseases, in particular water-washed diseases, a water use (consumption) of around 25–30 litres per person per day (lpd) is generally thought to be necessary (Cairncross and Feachem, 1993; see also Novaic, 2002). Gleick (1996) recommends a design value of 50 lpd, provided flush toilets with a high volume per flush are not used (as may be expected in STLV). This value of 50 lpd seems perfectly reasonable, but hygiene education will be generally required so that the users can maximize the health benefits from the non-wasteful use of this quantity of water.

## Water supply service levels

In general there are four levels of domestic water supply:

- Unimproved water sources (for example, unprotected shallow wells, faecally contaminated surface waters),
- Public standpipes (i.e., taps connected to the town/village piped supply),
- Yard taps (i.e., one tap per household), and
- Multiple-tap in-house supplies.

Level 1 does not provide access to an improved water supply and in most households in STLV Level 4 will never, at least in the foreseeable future, be a feasible solution. The realistic options in STLV are therefore Levels 2 and 3, although in some large villages it may be possible (and the cheapest option) to improve existing unimproved supplies as a short-term measure.

**Level 2 can be subdivided into two 'sublevels', as follows:**

- 2.i. Public standpipes, and
- 2.ii Standpipe cooperatives.

Level 2.i represents a usually free supply for very poor households, and Level 2.ii is a supply for a defined group of households (the ‘cooperative’) who share a single standpipe and pay for its use. Standpipe co-operatives have been used in the Philippines since the 1970s (Middleton, 2000) and they are recommended in India’s Tenth Five Year Plan 2002–2007 (Planning Commission, Government of India, 2002):

“...the number of stand-posts [i.e., standpipes] should be adequate for the population being served. There are successful examples of community supervision of the stand-posts. Community groups should be made responsible for maintenance and hygiene around stand-posts, for maintenance including prevention of wastage, and for collection of user charges from each household attached to the stand-post” [§6.2.50].

“Community-managed standpipes” are different from standpipe cooperatives as they are community-operated water kiosks where community members come to buy water by the bucket. Often there are too few kiosks in the community and the water is expensive when the cost is expressed per m<sup>3</sup> (however, good practice does exist: two case studies, in Port-au-Prince, Haiti and Dakar, Senegal, are described by Colin and Lockwood, 2002). Standpipes serving standpipes cooperatives, on the other hand, essentially belong to the cooperative members. The main planning task is to determine with the communities what is locally considered the maximum number of households in a cooperative; this may be 5–25, for example, but the precise number may be influenced by the water tariff structure (see below).

## Condominial water supplies

Condominial water supplies are the water supply analogue of condominial (i.e., simplified) sewerage (Section 3). They were developed in Brazil in the 1990s (Rooker, 2001; Melo, 2005) and have been used in, for example, La Paz, Bolivia and Iquitos, Peru (Water and Sanitation Program, 2005, www.care.org.pe). The best example is the medium-sized city of Parauapebas in the northern Brazilian state of Pará (population ~100,000), where the cost savings achieved by the condominial water supply network were considerable: the cost per connection was only USD 45 (1997 USD) vs USD 167 for a conventional water supply network (Table 2.1), despite the basic design criteria being the same in both cases (90 percent service coverage and a design supply of 250 lpd).

**Table 3.3 Comparative costs<sup>a</sup> of conventional and condominial water supplies in Parauapebas**

Item	Conventional supply		Condominial supply	
	Total cost	Cost per connection <sup>b</sup>	Total cost	Cost per connection <sup>c</sup>
Excavation	454,000	88	101,000	19
Pipes	407,000	79	129,000	25
<b>Total</b>	<b>861,000</b>	<b>167</b>	<b>230,000</b>	<b>45</b>

<sup>a</sup> 1997 USD; <sup>b</sup> individual household connections; <sup>c</sup> individual condominium connections.

Source: Melo (2005).



These cost savings were achieved because there was a much lower total pipe length for the public distribution network (287 km of streets served with only 43 km of pipes) which meant that substantially less 'public' excavation was required. The condominial branches were routed along the pavements (sidewalks) at a depth of ~400 mm and an entry point for each housing block (condominium) provided. The block residents (i.e., the members of the condominium) purchased all the materials to complete the in-block distribution system and household connections (in this case for a Level 4 supply), as well as contribute their own labour for trench excavation. Initially each household connection was metered and the households paid a monthly water bill made up as follows: (1) a standing charge equivalent to USD 2.78, (2) a charge of USD 0.25 per m<sup>3</sup> for the first 10 m<sup>3</sup>, and (3) a higher charge of USD 0.99 per m<sup>3</sup> above the first 10 m<sup>3</sup>. Later new connections were not metered and the monthly bill was USD 5.28 (i.e., the standing charge plus USD 2.50 for an assumed consumption of 10 m<sup>3</sup> per month).

## Lessons for STLV

The condominial water supply system described above for Parauapebas is not replicable in detail in most STLV especially those in Africa and Asia, – for example, the design water consumption of 250 lpd would be far too high in most STLV. However, the basic concept remains valid: the cost of the public distribution network can be substantially reduced if the supply is to condominiums (or co-operatives) rather than to individual households and if the in-condominium pipework is installed by the condominium members. In any one ST or LV the following questions need to be addressed at the pre-feasibility stage:

- Is the supply to be based on standpipes, standpipe cooperatives or a condominial supply?
- If on standpipes, how many standpipes are required? Will they be managed by the community?
- If on standpipe cooperatives, how many households should there be in each cooperative? (The answer need not be one figure; a range is preferable to allow for variations due to topography and housing density.)
- If on a condominial supply, is the supply to each member household to be a yard tap or a multiple-tap in-house supply? (Presumably in most STLV the supply will be individual yard taps, except in non-poor areas of ST.)
- What should be the design water consumption? Is 50 lpd locally sufficient?
- How are households to be charged for water consumption?
- Will the community contribute labour and/or money to reduce the costs of implementation? If not, will the scheme be viable?

Condominial water supplies based on individual yard taps and standpipe cooperatives clearly have huge potential in STLV, yet they are not well known options.

## Water treatment

Water treatment in STLV has to be simple, effective and reliable. If surface water is to be treated, then often the best option is multiple-stage filtration (Galvis et al., 1998; this reference should be consulted for design details; see also Water and Sanitation Program, 2005). If groundwater, then the ideal solution is to abstract the groundwater from an uncontaminated and protected aquifer, so that treatment is not required. Initial chemical analyses must, however, be undertaken to ensure there are no problems with, for example, arsenic, or to detect high concentrations of iron and manganese (which are easily removed by aeration, even at small-village level; Sarmiento, 2001). Disinfection, although very desirable, may not be practical, especially in LV. For a good review of water quality requirements, including bacteriological quality requirements, see Nozaic (2002).

## Water supply tariff structures

Water supply tariff structures are important as they determine what consumers pay for their water and how the amount they pay changes with the amount of water they consume. Mara (2005) examined urban and periurban water supply tariffs and considered that an urban water supply authority could charge three groups of consumers having different levels of service:

- Non-poor households with metered multiple-tap in-house supplies,
- Poor households with unmetered yard taps, and,
- Poor households in unmetered standpipe cooperatives.

Households in Group 2 would pay a 'minimum tariff' based on a fixed percentage of the local monthly minimum wage (e.g., 5 percent, as in Brazil) and very households in Group 3 would pay a 'nominal tariff' based on a lower percentage of the minimum wage (e.g., 1–2 percent). 'Social supplies' to very poor households served by public standpipes would be free. The authority would know its income from Groups 2 and 3 and, knowing its total costs, could calculate how much it would need to collect each month from Group 1 (and on what basis – i.e., on an increasing or linear block tariff). Connection fees would not be levied as these deter the poor and very poor from connecting; the fees would be included in the total costs and so effectively paid for by Group 1.

However, in STLV the proportion of households in Group 1 would be usually much lower than in cities and large towns, and therefore the authority's main customer base would be Groups 2 and 3. It is therefore extremely important in planning new or extending existing water supplies in STLV that the condominial option is discussed with households in Group 2 – i.e., to determine the local feasibility of Group 2 households forming condominiums which agree to pay for the installation of the condominial network, so that the authority's costs for the public network are reduced (cf. Table 3.3); operational costs could be reduced if the condominium agreed to be charged as a single entity, rather than the authority having to bill individual condominium members – thus the condominium would be responsible for collecting payments from its members; it could do this weekly, fortnightly or monthly, at it wished; arrangements should then be made by the authority to receive payments at the chosen interval even though it would only formally bill the condominium monthly.

Once the authority knows its costs (e.g., monthly loan repayment, monthly O&M costs, less any subsidies received), it can then determine how to recoup these costs equitably from its customers – i.e., how much households in Groups 2 and 3 (and in Group 1 if these exist) should be charged (and this charge should then be expressed as a percentage of the local minimum wage). The authority would also have to agree with its customers how it should treat those who do not pay their bills (e.g., cut off the supply immediately or after 2 or 3 payment defaults). It may be sensible for the authority to collect payments only 10 times per year, rather than 12 (each payment then being 20 percent more than the actual monthly charge) in recognition of local needs (such as expenditures for the principal local holiday or festival and at the start of the school year).

## Aggregation

Aggregation means the grouping of neighbouring STLV, possibly including neighbouring small villages, into one water supply 'zone' under one water supply organization, so that some economy of scale may be realised (ERM et al., 2005). There are various levels of aggregation with different functions and responsibility (e.g., bulk water supply only, or including local distribution, operation and maintenance). Aggregation may be voluntary (local STLV choosing to aggregate) or mandatory (local STLV being told to aggregate by a higher authority – for example, state/provincial or central government). The options are discussed in detail in ERM et al. (2005), and by the Water and Sanitation Program ([www.wsp.org/05\\_Initiatives\\_smalltowns.asp](http://www.wsp.org/05_Initiatives_smalltowns.asp)). If aggregation is not mandatory, then its local advantages and disadvantages should always be considered in detail at the pre-feasibility stage.



# 3 Sanitation

## Available sanitation options

There are only a few available sanitation technology options:

### On-site systems:

- SanPlat' latrines;
- ventilated improved pit (VIP) latrines,
- pour-flush (PF) toilets, and
- ecological sanitation ('EcoSan') toilets;

### Off-site systems:

- communal sanitation facilities,
- conventional sewerage,
- settled sewerage, and
- simplified sewerage.

These technologies are fully described in several documents (e.g., Mara, 1996; Metcalf & Eddy, Inc., 1986; Winblad and Simpson-Hébert, 2004); only a brief description is given here. Conventional sewerage can be immediately eliminated from further consideration for STLV simply on the grounds of its very high cost (Kalbermatten et al., 1982).

Cost is really the most important criterion for sanitation technology selection for poor and very poor households in STLV as, given good design, implementation and operation and maintenance, all of the above sanitation technologies achieve approximately the same level of health benefits (Feachem et al., 1983).

## Comparative costs

There are few relatively recent sets of comparative sanitation costs. Tables 3.1 and 3.2 show costs in India in 2004 and in South Africa in 2002, and Figure 3.1 shows costs in northeast Brazil in 1983. These cost data are very pertinent (although, of course, they need to be verified locally). They suggest

**Table 3.1 Sanitation technology options and costs in India, April 2004**

Sanitation technology	Capital cost (INR)
Single-pit VIP latrine	600–3,000
Single-pit pour-flush toilet	2,000–3,500
Alternating twin-pit pour-flush latrine	2,500–3,000
EcoSan toilet without urine diversion	2,500–4,500

**Notes:** (1) costs are per unit; (2) average exchange rates in April 2004: INR 1000 = EUR 19 = USD 23.

Source: [www.toiletsforall.org](http://www.toiletsforall.org)

**Table 3.2 Sanitation technology options and costs in South Africa, February 2002**

Sanitation technology	Capital cost (ZAR)
Single-pit VIP latrine	600–3,000
Pour-flush toilet	2,000–3,500
Simplified sewerage	2,500–3,000
EcoSan toilet with urine diversion	3,000–4,000
Conventional sewerage	6,000–7,000

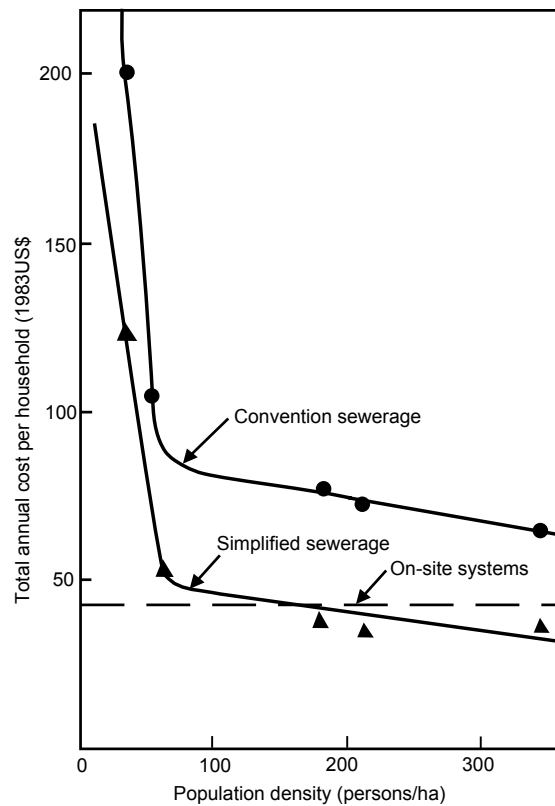
**Notes:** (1) costs are per unit or connection; (2) average exchange rates in February: ZAR 1000 = EUR 100 = USD 87.

Source: DWAF (2002).

that a rural Indian would normally choose a single-pit PF toilet and a rural South African a single-pit VIP latrine, and that Brazilians and South Africans living in STLV could be expected to opt for simplified sewerage. Of course, the preferred household-level technology has to be affordable. If it is not, then clearly it is an inappropriate preference; advice on what can be done in such circumstances is given below.

Figure 3.1 shows that in Natal, northeast Brazil, simplified sewerage became cheaper than PF toilets below the relatively low population density of ~160 people per ha. Further details on simplified sewerage costs are given below.

**Figure 3.1 Annual costs per household for conventional sewerage, simplified sewerage and on-site sanitation (PF toilets) in low-income areas of Natal, northeast Brazil, in 1983**



Source: Sinnatamby, 1986.

## Simplified sewerage

Simplified sewerage (also called condominial sewerage) (Figures 3.2 and 3.3) was developed in north-east Brazil in the early 1980s. It was originally developed for use in low-income periurban areas in the state of Rio Grande do Norte (de Andrade Neto, 1985; de Melo, 1985; Sinnatamby, 1986; Melo, 2005), but it has also been successfully used in small villages (populations up to ~1000) in rural areas of the state of Ceará (Sarmiento, 2001).

Simplified sewerage is designed, like conventional sewerage, to receive unsettled wastewater and the current design procedure ensures its blockage-free operation by using a minimum tractive tension (rather than a minimum self-cleansing velocity) of  $1 \text{ N/m}^2$  (i.e.,  $1 \text{ Pa}$ ) which is achieved at least once a day at peak flow. Full details are given in Mara (1996) and Mara et al. (2001); a summary is given in Box 3.1.

### The key features of the hydraulic design of simplified sewerage are:

- a peak flow factor (= daily peak wastewater flow/daily mean wastewater flow) of only 1.8;
- a minimum peak flow of 1.5 L/s in any stretch of the sewer (this approximates the peak flow induced by a single flush of a WC);

- a minimum sewer diameter of 100 mm;
- use of a wide range of the proportional depth of flow in the sewer ( $d/D$  – i.e., the depth of flow  $d$  divided by the sewer diameter  $D$ ): 0.2–0.8;
- a minimum tractive tension of 1 Pa; and
- calculation of  $I_{\min}$  based on  $q = q_i$  (the peak flow at the start of the design period) and selection of  $D$  based on  $q = q_f$  (the peak flow at the end of the design period).

**The minimum sewer gradient ( $I_{\min}$ ) to achieve the minimum tractive tension of 1 Pa is:**

$$I_{\min} = 5.64 \times 10^{-3} q^{-6/13} \quad (3.1)$$

where  $q$  is the peak flow in L/s.

This equation assumes that  $d/D$  is 0.2, Manning's  $n$  0.013, the density of wastewater 1000 kg/m<sup>3</sup>, and the acceleration due to gravity 9.81 m/s<sup>2</sup>. Thus, for  $q = q_{\min} = 1.5$  L/s,  $I_{\min} = 4.68\%$  (i.e., 1 in 214); this value is often rounded down to 5‰ (1 in 200).

**The minimum sewer diameter ( $D$ ) used in simplified sewerage is 100 mm. The relationship between  $D$  (mm),  $q$  (L/s) and  $I_{\min}$  for  $d/D = 0.8$  and Manning's  $n = 0.013$  is (Box 1):**

$$D = 23q^{3/8}(I_{\min})^{-3/16} \quad (3.2)$$

Assuming a mean wastewater flow of 50 litres per person per day (a typical figure for STLW in Africa and Asia) and a peak factor of 1.8, a 100-mm sewer laid at a minimum gradient of 1 in 200 can serve over 3000 persons.



### Box 3.1 Elements of the hydraulic design of simplified sewerage

1. The peak flow (L/s) in the length of sewer being designed is given by:

$$q = k_1 k_2 p w / 86,400 \quad (B1)$$

where  $k_1$  is the peak factor (usually taken as 1.8);  $k_2$  the return factor (wastewater flow/water consumed; usually ~0.85);  $p$  the population served; and  $w$  their water consumption (L/cap. day). With  $k_1 = 1.8$  and  $k_2 = 0.85$ :

$$q = 1.8 \times 10^{-5} p w \quad (B2)$$

• If  $q$  from this equation is  $< 1.5$  L/s, then  $q$  is taken as 1.5 L/s (i.e.,  $q_{min}$ ).

2. Self-cleansing criterion: a minimum tractive tension ( $\tau$ ) of 1 N/m<sup>2</sup> (1 Pa) at peak flow:

$$t = \rho g r i \quad (B3)$$

where  $\rho$  is the density of the wastewater (kg/m<sup>3</sup>);  $g$  the acceleration due to gravity (m/s<sup>2</sup>);  $r$  the hydraulic radius (m) and  $i$  the sewer gradient (m/m). Writing  $r = k_r D$  (where  $D$  = sewer diameter, m) and rearranging:

$$D = (t / \rho g) / k_r i \quad (B4)$$

3. The Gauckler-Manning equation (Gauckler, 1867, 1868; Manning, 1890):<sup>1</sup>

$$v = (1/n) r^{2/3} i^{1/2} \quad (B5)$$

where  $v$  is the velocity of flow in the sewer (m/s); and  $n$  Manning's roughness coefficient.

Since  $q = av$  (where  $a$  is the area of flow, m<sup>2</sup>):

$$q = (1/n) a r^{2/3} i^{1/2} \quad (B6)$$

4. Minimum sewer gradient:

Writing eq. B6 with  $a = k_a D^2$ ,  $r = k_r D$  and  $D = (t / \rho g) / k_r i$  (eq. B4);  $\rho = 1000$ ,  $g = 9.81$  and  $n = 0.013$ ; and with  $k_a = 0.1118$  and  $k_r = 0.1206$  for  $d/D = 0.2$  and  $\tau = \tau_{min} = 1$  Pa, so that  $i = I_{min}$  (the minimum sewer gradient), and rearranging:

$$I_{min} = 2.33 \times 10^{-4} q^{-6/13} \quad (q \text{ in } m^3/s) \quad (B7)$$

In eq. B7  $q = q_p$ , the flow at the start of the design period.

5. Selection of sewer diameter:

Writing eq. B6 with  $a = k_a D^2$ ,  $r = k_r D$  and  $i = I_{min}$ , and rearranging:

$$D = n^{3/8} (k_a)^{-3/8} (k_r)^{-1/4} [q / (I_{min})^{1/2}]^{3/8} \quad (D \text{ in } m, q \text{ in } m^3/s) \quad (B8)$$

In eq. B8  $I_{min}$  is given by eq. B7;  $q = q_p$ , the flow at the end of the design period; and  $k_a = 0.6736$  and  $k_r = 0.3042$  for  $d/D = 0.8$ . The diameter calculated from eq. B8 will not be a standard diameter, so the next largest locally available diameter is chosen.

• Full details are given in Mara (1996) and Mara *et al.* (2001).

<sup>1</sup>“Slum networking” sewers in India are designed using the Colebrook-White equation (Colebrook, 1939) but, as shown by Mara *et al.* (2001), there is essentially no difference in design outcome if this equation or the Gauckler-Manning equation is used.

## Costs

Simplified sewerage is low-cost: when it was first installed in 1981 in northeast Brazil the cost was USD 325 per household (compared with around USD 1500 per household for conventional sewerage), with a monthly payment by each household of only USD 1.50 (Sinnatamby, 1986). Costs have since fallen slightly – for example, current costs in Brasília are USD 200–300 per household (Maurício Luducice, Water and Sewerage Company of Brasília and the Federal District – CAESB, quoted in McCann, 2005); and in South Africa they were USD 220–260 per household in 2002 (DWAF, 2002). Costs in India, where simplified sewerage is known as “slum networking”, are around USD 150 per household (Parikh *et al.*, 2002).

The cost of simplified sewerage in small villages (populations up to ~1000) in rural Ceará, northeast Brazil, was BRL 120 (~USD 80) per connection in 1999 (Sarmiento, 2001). The monthly charge to householders was BRL 1.50 (USD 1). In the city of Parauapebas in the northern Brazilian state of Pará (population ~100,000), where condominial water supply was first implemented (Section 2), the cost of condominial sewerage was much lower than the figures given above: only USD 56 per connection in 1997, and condominial sewerage was 40 percent cheaper than conventional sewerage, as shown in Table 3.3 (Melo, 2005). To place this 1997 cost for condominial sewerage of USD 56 per connection into context, the minimum salary in Brazil was then BRL 120 (~USD 110) per month, so the cost for each household was about half one month’s minimum salary.

**Table 3.3 Comparative costs<sup>a</sup> of conventional and simplified sewerage in Parauapebas, Pará**

Item	Conventional sewerage		Condominial sewerage	
	Total cost	Cost per connection	Total cost	Cost per connection <sup>c</sup>
Excavation	263,000	39	186,000	28
Inspection chambers	181,000	27	85,000	13
Sewers	185,000	28	102,000	15
<b>Total</b>	<b>629,000</b>	<b>94</b>	<b>373,000</b>	<b>56</b>

<sup>a</sup>1997 USD. Source: Melo (2005)

## Adoption of simplified sewerage in various countries

Simplified sewerage is now regarded as an acceptable sanitation technology throughout Brazil where it has been successfully used for over 25 years (Sarmiento, 2001). The reasons for its widespread adoption in Brazil are outlined in Box 3.2. Following early experience in Brazil, simplified sewerage was transferred to Pakistan (Sinnatamby *et al.*, 1985), where in early 1985 in the low-income area of Christy Nagar in Karachi the cost, including primary wastewater treatment was USD 45 per connection and the residents obtained their water (~27 litres per person per day) from public standpipes. The concept of simplified sewerage was embraced by the Orangi Pilot Project (Khan, 1996; Zaidi, 2001), and to Sri Lanka where there are now around 40 schemes. Simplified sewerage was used in the El Alto Pilot Project in Bolivia (Canelli, 2001); one of the outcomes of this was the development of a Bolivian stand-

ard for simplified sewerage (DGSB, 2001). Simplified sewerage has recently been developed in South Africa (Brocklehurst, 2001; Anon., 2004; WRC, 2005).

Community-based sewerage schemes have been developed in Indonesia (Foley *et al.*, 2000) and “slum networking” schemes in India (Parikh *et al.*, 2002; Kakumbi, 2005). While not designed precisely according to the principles of Brazilian simplified sewerage, these have been nonetheless very successful.

## Application to STLV

Simplified sewerage has been implemented in a variety of locations in Brazil, from small villages, through medium-sized cities, to low-income periurban areas in major cities. This, together with its replication in other countries, including low-income areas with low water consumption, show that it is clearly applicable to STLV, provided of course that it is locally affordable and cheaper than other household-level options.

## National sewerage design codes

Hydraulic theory and visual observation both indicate that small wastewater flows flow better in small diameter sewers. Yet many national sewerage design codes specify a minimum sewer diameter greater than 100 mm in the mistaken belief that larger is *ipso facto* better, whereas in fact small flows flow better in small sewers. Such codes need to be altered to take into account present practice in simplified sewerage; otherwise local design engineers will be forced to continue to develop very conservative, and hence expensive, ‘solutions’ for the poor in STLV.

### Wastewater treatment

The wastewater collected by simplified sewerage should be treated prior to surface-water discharge or reuse in horticulture, agriculture and/or aquaculture. In STLV the best option for wastewater treatment is generally waste stabilization ponds as these are especially effective in removing or destroying faecal pathogens. Full details are given in Mara (1997, 2004).

## Settled sewerage

Settled sewerage (also called ‘solids-free sewerage’; in the United States ‘small-diameter gravity sewerage’, and in Australia ‘septic tank effluent drainage’) is a sewer system that conveys only septic tank effluents. As these effluents are solids-free the sewer is designed differently from conventional and simplified sewers (which convey all the wastewater solids). Each house or a small group of neighbouring houses has a septic tank which discharges into the settled sewer. The minimum sewer diameter is 75 mm and the sewer gradient closely follows the ground slope, with the flow in the sewer alternating as necessary between open channel flow and pressure flow. Full details are given in Otis and Mara (1985), Mara (1996) and US EPA (2000).

Settled sewerage is best applied in areas already served by septic tanks. Thus it is unlikely to be applicable to poor and very poor households in STLV, for which simplified sewerage is generally a better and cheaper alternative.

### Box 3.2 Development and dissemination of simplified sewerage in Brazil

Simplified sewerage was developed by the R&D Division of CAERN, the water and sewerage company of the northeastern state of Rio Grande do Norte. It was first field-tested in the low-income areas of Rocas and Santos Reis in Natal, the state capital, in the early 1980s. The CAERN team presented its experience at the biennial Congress of the Brazilian Association of Sanitary and Environmental Engineering (ABES) held in Balneário Camboriú, Santa Catarina in November 1983, and also described the system in the ABES technical journal *Engenharia Sanitária* (de Andrade Neto, 1985; de Melo, 1985).

CAERN's development of simplified sewerage in Natal was partially funded by the World Bank Medium-sized Cities project, which also saw the implementation of condominial sewerage in the city of Petrolina in the state of Pernambuco. The Brazilian Office of the World Bank/UNDP Technology Advisory Group evaluated the Rocas and Santos Reis scheme very positively. This led to the production of the Brazilian national design manual for simplified sewerage (Guimarães, 1986) and the formation of the ABES Low-cost Sanitation Committee (1984-1986), which in turn led to the adoption of a minimum sewer diameter of 100 mm in the revision of the Brazilian national sewerage design code (ABNT, 1986) (previously it was 150 mm). A further key feature in the development of simplified sewerage design in Brazil was the realisation by the late Brazilian sanitary engineer Eugênio Macedo that the sewer gradient should be based on the initial design flow and the sewer diameter on the final design flow; this is an important consideration (incorporated into the 1975 Brazilian national sewerage design code) as in low-income areas the latter may be up to five times the former. The hydraulic design basis was changed from a minimum self-cleansing velocity of 0.5 m/s to a minimum tractive tension of 1 Pa (Machado Neto and Tsutiya, 1985), a change which was also included in the 1986 Brazilian national sewerage design code.

CAESB, the water and sewerage company of Brasilia and the Federal District, started implementing simplified sewerage in poor areas in 1991 and now it considers simplified sewerage as its "standard solution" for rich and poor areas alike (see Figures 3.2 and 3.3). CAESB now has over 1,200 km of condominial sewers in operation – the largest example of simplified sewerage in the world.

Simplified sewerage has now been successfully adopted into mainstream Brazilian sanitary engineering. The reasons for this success have been:

- the ease of dissemination of innovative technologies at the biennial ABES Congresses which are attended by all the state water and sewerage companies,
- the relatively small number of leading Brazilian sanitary engineers who have been committed to, and have been excellent advocates of, the technology, and
- the keen interest shown in the technology since its beginning by the World Bank and UNDP which has acted within Brazil to give the system a 'seal of international approval'.

A recent survey of simplified sewerage schemes in Brazil (Sarmiento, 2001) found user satisfaction levels high, even after ~20 years operation.

## On-site systems

On-site sanitation systems are ‘SanPlat’ latrines, VIP latrines, pour-flush toilets and ecological sanitation toilets. Septic tanks are not appropriate in STLV (except in non-poor households)

### SanPlat latrines

‘SanPlat’ (*Sanitation Platform*) latrines are simply traditional (i.e., unventilated) latrines provided with a concrete cover slab (the ‘sanplat’). Details are given in Brandberg (1996) and at [www.sanplat.com](http://www.sanplat.com).

### VIP latrines

Ventilated improved pit latrines were developed in rural Zimbabwe (Morgan and Mara, 1982). They have also been used in low-density low-income urban areas in Botswana (van Nostrand and Wilson, 1983). The vent pipe effectively controls odours and flies. There are single-pit and alternating twin-pit versions; design details are given in Mara (1985a, 1996). They are applicable in low-density STLV, provided that they are cheaper than simplified sewerage (emptying costs must be included in this cost comparison).

### Pour-flush toilets

On-site pour-flush toilet systems comprise the toilet itself, with its integral water-seal, a discharge pipe and either a single leach pit or alternating twin leach pits (the toilet bowl or squat pan can be and is used in other situations – for example, simplified and settled sewerage). The volume of flush-water is ~2–4 litres per flush and the leach pits are designed both for solids digestion and storage and infiltration of urine and the flush-water (details are given in Roy *et al.*, 1984 and Mara, 1985b, 1996). As with VIP latrines, PF toilets are only applicable in low-density STLV if they are cheaper than simplified sewerage.

### Pit emptying

The pits of SanPlat and VIP latrines and PF toilets require emptying when they are full; the faecal sludge is removed manually (alternating twin-pit version only), or mechanically by high-powered vacuum tankers (both versions) (Carroll, 1989). However, in practice pit emptying is not well planned: the vacuum tankers are not properly maintained and poor households are often disadvantaged as they are the last to be serviced (Jones, 2005). This alone should militate against on-site sanitation systems in STLV.

### Ecological sanitation toilets

The basic philosophy of ‘ecological sanitation’ (‘EcoSan’) is to recycle all the nutrients in human excreta as each person excretes almost enough NPK to produce all the cereals he or she needs (Drangert, 1998). A consequence of this is that the various ‘streams’ of excreta and wastewater should not be mixed as they differ greatly in their volumes and nutrient loads. Thus “yellow water” (urine), “brown water” (faeces and toilet flush waters) and “grey water” (wastewater from sinks and showers or baths) should be kept separate to facilitate nutrient and water treatment and reuse (Otterpohl, 2001), although in some EcoSan systems yellow water and brown water are combined to form “black water”.

Full details on EcoSan are given in Winblad and Simpson-Hébert (2004) and at [www.ecosanres.org](http://www.ecosanres.org) and [www.gtz.de/en/themen/umwelt-infrastruktur/wasser/8524.htm](http://www.gtz.de/en/themen/umwelt-infrastruktur/wasser/8524.htm).

EcoSan can be either on-site or off-site, and it can even be partially on-site and partially off-site. There are many EcoSan variants: some are 'high-tech' and high-cost; others are 'low-tech' and low-cost, and may or may not include urine diversion; on-site treatment options for brown waters include double-vault dehydrating and composting toilets, and anaerobic digestion (possibly supplemented by domestic animal excreta) and use of the resulting biogas for cooking (as in some STLV in northern Vietnam).

There is currently much discussion on whether 'ecological sanitation' refers *only* to those systems in which yellow, brown and grey waters are source-separated and reused separately, or whether it can also refer to *any* sanitation system in which all (or almost all) the nutrients are reused (and so would include, for example, simplified sewerage + wastewater treatment in waste stabilization ponds + reuse of the treated wastewater in horticulture, agriculture and/or aquaculture).

However, the cost data in Tables 3.1 and 3.2 suggest that EcoSan toilets, either with or without urine separation, are too expensive for use in STLV.

## Communal sanitation facilities

In almost all STLV there are many very poor households which are unable to afford any kind of individual household-level sanitation, whether it be an on-site or off-site system. In such areas, the only option is the construction of communal sanitation blocks of the type implemented in India by Sulabh International (Pathak, 1991, 1999; Singh, 2000; [www.sulabhinternational.org](http://www.sulabhinternational.org)). There are now ~6,400 such sanitation blocks throughout India, used by over a million people every day.

The blocks provide toilet and washing facilities; soap is provided to all users. There is a charge of INR 1 (~USD 0.02) per use (other than use of urinals), but children, disabled people and those unable to pay are not charged. The blocks are maintained 24 hours per day by caretakers who are employed by Sulabh and live on the premises. The caretakers also collect the user charges and the blocks are regularly inspected both by Sulabh and the local council (United Nations, 2004; [www.sulabhinternational.org](http://www.sulabhinternational.org)).

## Sanitation selection algorithm

**Figure 3.5** shows the sanitation selection algorithm developed by Mara et al. (2005). It is based on the premise that human wastes and household wastewaters should be treated and reused in horticulture, agriculture and/or aquaculture. Such reuse may be decentralized, centralized or intermittent, depending on user preference, local feasibility and the type of sanitation technologies used. Decentralized reuse is reuse at household or local community level (a housing estate, for example). Centralized reuse is reuse at the level of either natural drainage basins within an urban area or the whole urban area (town, city, metropolitan area); it will normally require wastewater collection in a sewer system followed by wastewater treatment, possibly with biogas production and collection, and then aquacultural and/or agricultural reuse of the treated effluent. It may also refer to grey water collection within a natural drainage basin followed by treatment and reuse. Intermittent reuse refers to on-site systems, including pit latrines, pour-flush toilets and septic tanks, which provide biosolids for agricultural or horticultural reuse only when they are desludged every few years.

The algorithm is a series of boxes containing abrupt questions (for example, “Decentralized reuse?”) with up to four symbols which indicate the criteria which should be used to answer the question. The symbols are

⌘ (to indicate cost and affordability),

😊 (socio-cultural acceptability)

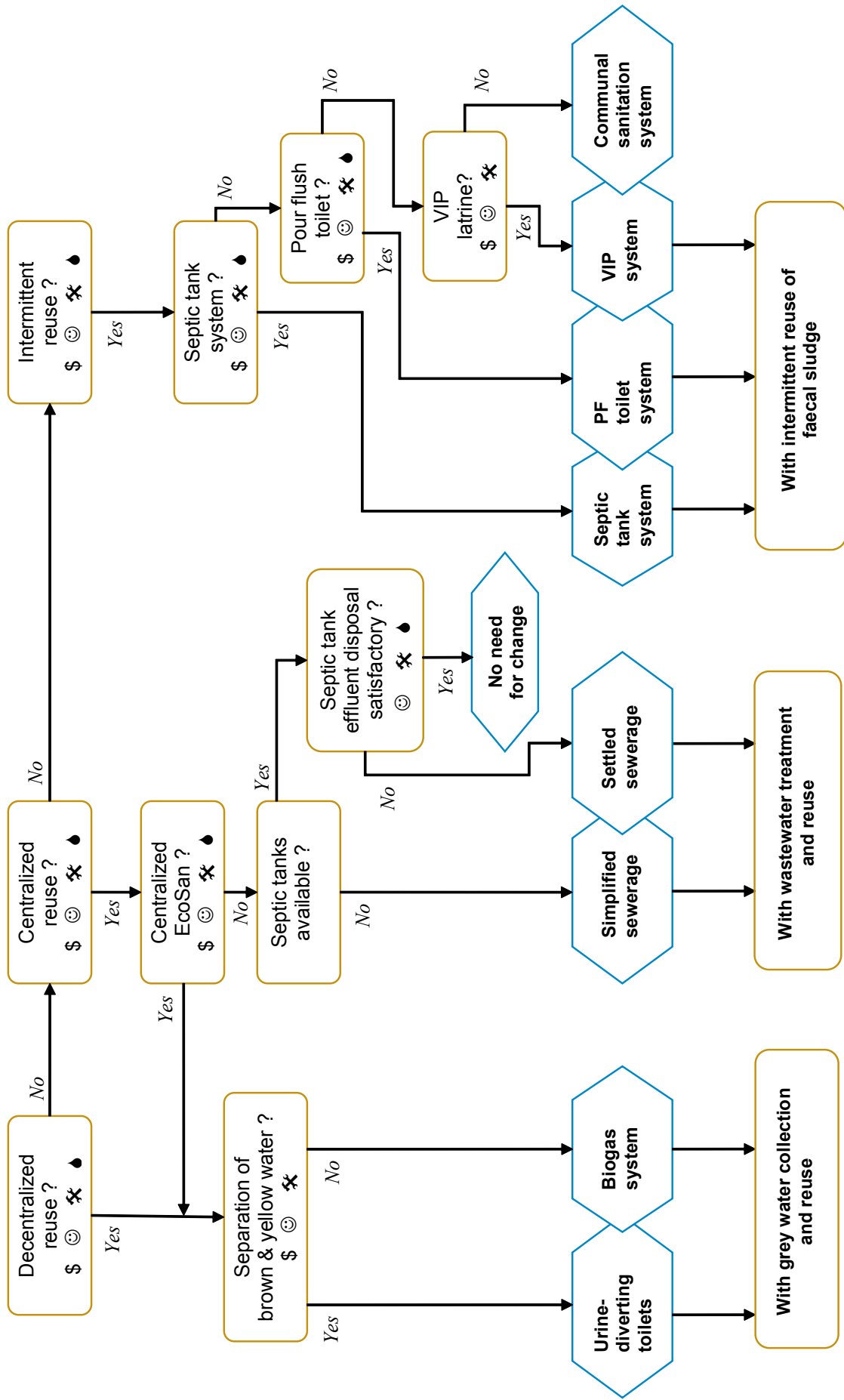
🔧 (technical feasibility) and

☯ (environmental impact and reuse potential).

The ‘answers’ given by the algorithm are likely to be correct, but they are no substitute for ‘engineering judgement’ and they must always be carefully checked in the local sociocultural and socio-economic situation. Nonetheless the algorithm is a useful tool in sanitation programme and project planning as it prompts planners and engineers to answer questions that they might not generally consider asking.

In many situations in STLV use of the algorithm, following a local sociocultural and socio-economic survey to determine user preferences and affordabilities, can be expected to result in a recommendation for either simplified sewerage, wastewater treatment and reuse of the treated wastewater in horticulture, agriculture and/or aquaculture, or communal sanitation (unless the housing density is low enough for on-site sanitation to become feasible, both technically and financially).

**Figure 3.5 Sanitation selection algorithm**



Source: Mara et al., 2005.



## 4 Constraints

There are a number of constraints currently adversely affecting the achievement of the Water and Sanitation MDGs in STLV. These include:

### A. Technical

- There is currently a general lack of knowledge amongst sector professionals, especially in Africa and Asia, of condominal water supplies and condominal (i.e., simplified) sewerage (and, indeed, of many other pro-poor interventions). Simplified sewerage has not been promoted as vigorously and as effectively as, for example, ecological sanitation, yet it has to be known much more widely if the poor in STLV are to receive improved water supplies and sanitation. (Condominal water supplies and sewerage are both very close in theory and design to conventional piped water supplies and conventional sewerage, so that, once they are understood, they should be readily embraced by design engineers.)
- Many, if not most, national water supply and sewerage design codes do not currently permit the adoption of condominal water supplies and sewerage. Even in the case of India, where the national sewerage code at least mentions both simplified and settled sewerage (as 'shallow' and 'small bore' sewerage, respectively), so little detail is given that these options are in practice ignored (both these technologies are covered in just 7 pages, whereas over 100 pages are devoted to conventional sewerage) (Ministry of Urban Development, 1993).

### B. Financial

- Too little money is budgeted for water supply and sanitation improvements in STLV by national, provincial/state and local governments. (Yet there is plenty of money in the world – see Feachem, 2004).
- National financial systems are not geared to support the poor (see Basu, 2005, for a review of the situation in India). A notable exception is the Grameen Bank in Bangladesh and its replicates in other countries ([www.grameen-info.org](http://www.grameen-info.org)). Varley (1995) discusses household credit for water supplies and sanitation.
- Current water supply and sanitation/sewerage tariffs are often structured in a way that disadvantages the poor.

### C. Institutional

- STLV are, essentially by definition, too small to be able to employ design engineers of their own and they are unable to judge whether any consultants they might engage are sufficiently

knowledgeable about water supply and sanitation improvements in STLV; nor are they able to be critical of, or even understand in detail, any consultant's recommendations.

- Poor governance, combined with an absence of explicitly pro-poor policies, often excludes poor and very poor households from water supply and sanitation improvement projects.
- The lack of planning at local level often means that one year's budget allocation remains largely untouched until just before the end of the financial year, with the consequence that it is seldom spent wisely, and often not on pro-poor projects as these are commonly felt to be too 'difficult' to design and implement in a short time period.

## 5 Recommendations

- Condominial water supply and sewerage schemes need to be disseminated widely at “grass roots” level, so that local design engineers understand, and have the confidence to implement, them. National design codes need to be altered to permit their use (however, code change is a lengthy business, even in industrialized countries; an initial first step would be to permit their use for demonstrational purposes).
- Local research needs to be undertaken to develop condominial models best suited to local conditions – for example, condominial yard-tap supplies or condominial standpipes, and operation and maintenance responsibilities for the in-condominium networks. Socially and financially appropriate water and sewerage tariff structures need to be developed locally. (Alternatively, several regional models could be developed, from which local design engineers and communities could select the one most suited to their needs.)
- In all STLV sanitation programmes it should be ascertained whether condominial sewerage is cheaper than on-site systems (i.e., to determine a local version of Figure 3.1). If it is not, then on-site systems should be used.
- Microcredit facilities need to be developed locally (ideally under the aegis of the local water and sewerage/sanitation authority) so that credit can be provided to householders to permit them to install their in-condominium networks for water and sewerage, or construct their on-site sanitation systems.
- Aggregation of neighbouring STLV into a single operating water and sanitation/sewerage authority should always be investigated as it has the advantage of economy of scale, especially for design engineers and the operational staff of the authority.



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**Note:** historical foreign exchange rates were obtained from: [www.oanda.com/convert/fxhistory](http://www.oanda.com/convert/fxhistory)





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