Low-cost sewerage

—*Duncan Mara*[1]

Research and development undertaken by the World Bank during 1976–1986 (1, 2, 3) has shown clearly that possession, proper use and maintenance of a sanitation facility are more important, in terms of improving health, than the actual sanitation technology employed, provided that it is affordable and socioculturally acceptable. Nevertheless, sanitation technology choices have to be made, and the principal choice is between on-site and off-site systems, as follows:

On-site technologies:
- VIP latrines (or other types of pit latrine)
- pour-flush toilets
- septic tanks

Off-site technologies:
- conventional sewerage
- low-cost (unconventional) sewerage
  - — settled sewerage
  - — simplified sewerage

These technologies are described in the literature (see, for example, Mara (4, 5), Mara and Sinnatamby (6), Otis and Mara (7), Sinnatamby (8), Bakalian et al. (9) and, more generally, Mara (10)). The two low-cost sewerage technologies are less well known. Yet, in low- income areas with an adequate water supply these are viable sanitation options —often, depending on housing density, they are the *only* feasible options. This article reviews these low-cost sewerage options, their potential and their limitations. It also provides guidance on how to choose the most appropriate option, and gives examples of their successful application (see also (16)).

Nomenclature of low-cost sewerage

Both settled sewerage and simplified sewerage use small-diameter sewers laid at shallow depths and in which the flow is, ideally, due to gravity. Other terms, such as small-bore sewerage, small-diameter gravity sewerage or shallow sewerage are unclear. The definitions used in this article follow the Portuguese terminology developed in Brazil (see (11)) and are outlined below.

Settled sewerage: a system in which wastewater from one or more households is discharged into a single-compartment septic tank (usually called a solids interceptor tank). The settled (or solids-free) effluent from the septic tank is then discharged into shallow, small-bore gravity sewers. Settled sewerage is thus the same as small-bore sewerage as described by Otis and Mara (7), small-diameter gravity sewerage (12) and common effluent drainage (13). (In Portuguese it is called *redes de esgotos decantados*; in French, *réseaux d'eaux usées décantées*; and in Spanish (17), *alcantarillado sin arrastre de sólidos*.)

Simplified sewerage describes shallow sewerage as used by Sinnatamby (8) and its in-block variant called backyard or condominial sewerage (15). This system does not

[1] Professor of Civil Engineering, University of Leeds, UK.

convey presettled sewage, and is essentially conventional sewerage stripped down to its hydraulic basics. (In Portuguese, it is called *redes de esgotos simplificadas*; in French, *réseaux d'eaux usées simplifiés*; and in Spanish, *alcantarillado simplificado*.)

Disadvantages of conventional sewerage

Conventional sewerage has two principal disadvantages — high cost and the need for an in-house water supply.

Costs

A World Bank study (1) of eight large cities in Africa, Asia and Latin America showed that, while the costs of conventional sewerage are highly site-specific, they are always very high. Capital costs in the 1980s ranged from US$ 600 to 4000 (1980 $) per household, and annual economic costs (i.e. amortized capital costs plus operation and maintenance costs, including the economic cost of water used for flushing toilets) were US$ 150–650 per household (1980 $). Low-income communities evidently cannot afford such costs, unless they are massively subsidized (which is unlikely in practice).

Water

Generally, conventional sewerage requires an in-house multiple-tap level of water supply service. This is because cistern-flush water-seal toilets (water closets) are normally connected to the in-house water supply. Most low-income peri-urban communities in developing countries do not have this high level of water supply. Instead, they often rely on hand-carried supplies from public tapstands (standpipes), shallow wells or surface waters. At best they may have a yard-tap supply (one tap per household, usually situated immediately outside the house). It has been reported that conventional sewerage can be operated with this level of water supply — for example, at Tondo Foreshore, Manila (17). However, this was before development of simplified sewerage, which is more appropriate with yard-tap water supplies.

Promotion of low-cost sewerage

As with all sanitation technologies, low-cost sewerage systems need to be promoted effectively so that they will be accepted by the community, and operated and maintained properly — this generally requires an effective partnership to be developed between the sewerage authority and the community.

Low-cost sewerage can be cheaper, depending on housing density, than on-site systems; and, when housing densities are too high for on-site systems (as in many peri-urban areas), low-cost sewerage — principally the condominial variant of simplified sewerage — is generally the *only* viable sanitation option.

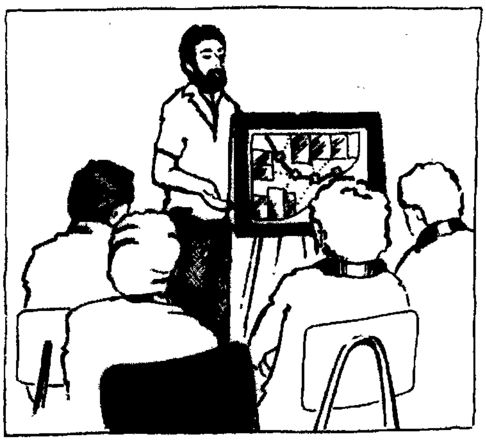

Figure 1. Promotion of lost-cost sewerage — here an engineer from the sewerage authority explains to the community how the system works, why it is appropriate, how much it will cost and what the operation and maintenance requirements are.

The sewerage authority must work closely with the community to promote low-cost sewerage (Figure 1). Costs and operation and maintenance responsibilities must be carefully explained, and an explanation also has to be given why other sanitation technologies are inappropriate.

Low-cost sewerage — technical descriptions

Settled sewerage

In a settled sewerage system (Figure 2), the sewers receive only settled sewage, and are designed very differently from conventional sewers. The most obvious differences are that they are not designed for self-cleansing velocities (i.e. velocities to ensure transport of solids), and that the flow in the sewers can change along their length, from normal gravity open-channel flow to full-bore pressure flow and then back to open-channel flow. In comparison with conventional sewerage costs, settled sewerage costs are quite low. This is mainly due to the shallow excavation depths and the use of small-diameter pipework (commonly 75–100 mm PVC), and the use of simple inspection boxes instead of large manholes. The pipes are carefully laid and simply embedded to avoid damage (this is usually easy as they are laid away from vehicular traffic).

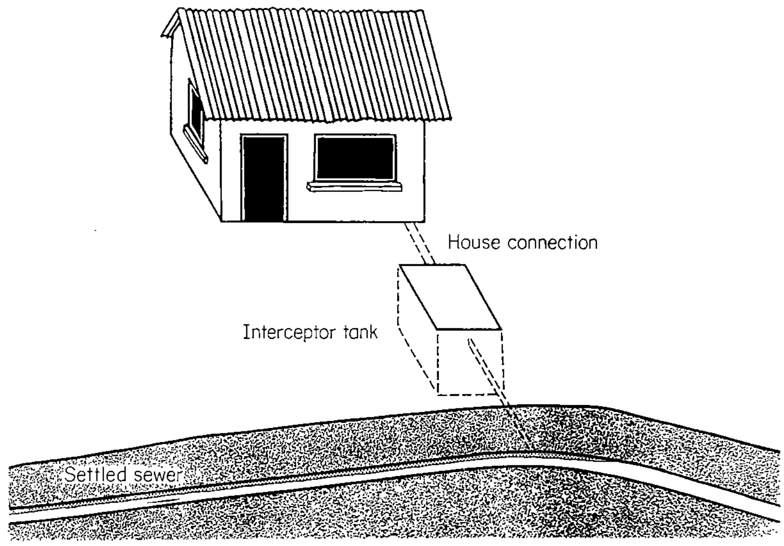

Figure 2. Schematic diagram of settled sewerage. The interceptor tank can be shared between adjacent houses to reduce costs in peri-urban areas.

Settled sewerage is most appropriate for areas which already have septic tanks, but where the soil can no longer accept all the septic tank effluent. So it is often a lower-cost solution in middle- or upper-income areas. Saving money in this way should mean that more public funds become available which can be used to serve low-income areas.

Settled sewerage was developed in Zambia (see below), and is now frequently used in Australia (where it is called common effluent drainage), and also in the United States, Colombia and Nigeria. Its increasing use in the United States for new housing developments is due to its low cost (around 50–60 per cent of conventional sewerage) and the fact that, from the users' perspective, it differs little from conventional sewerage.

Simplified sewerage

Simplified sewerage systems are designed to receive all household wastewater without settlement in solids interceptor tanks. Small-diameter sewers laid at shallow gradients are used to convey the sewage. The sewers are often laid inside housing blocks (Figure 3), when the system is known as condominial sewerage; or they may be laid outside the block, usually under the pavements on both sides of the street, rather than in the middle of the road, as is the case with conventional sewerage.

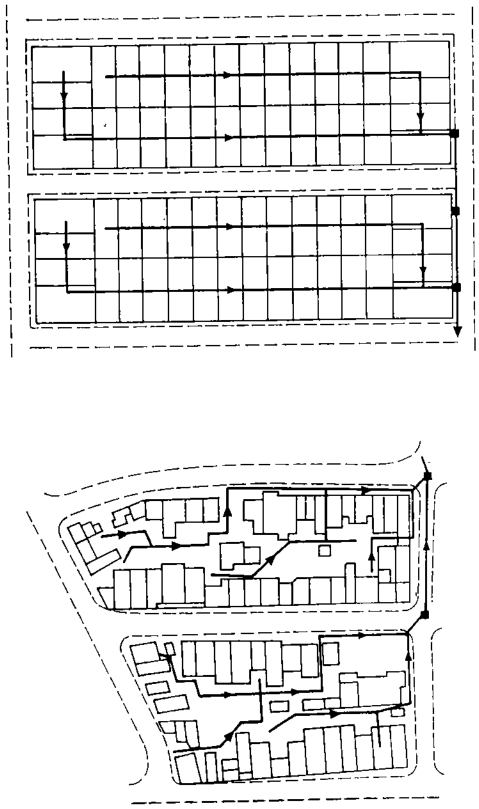

Figure 3. Schematic diagram of condominial sewerage in both planned (top) and unplanned (bottom) peri-urban areas.

The costs of simplified sewerage systems are low (see below), sometimes even lower than those of on-site sanitation (Figure 4). This is because simplified (especially condominial) sewerage, in common with settled sewerage, uses shallow excavation depths, small-diameter pipework and simple inspection units (in place of large manholes). Additionally, the sewer gradients of a simplified sewerage system are much flatter than those of a conventional sewerage system. For example, UK practice for conventional sewers is to lay a 150 mm diameter sewer at a gradient of 1 in 150 (i.e. 1 m vertical to 150 m horizontal, or nearly 0.007 m/m) (18). In contrast, the earliest simplified sewerage schemes in northeast Brazil used 100 mm diameter sewers laid at 1 in 167 (0.006 m/m), and more recent schemes (based on minimum tractive tension, rather than minimum self-cleansing velocity) use a 100 mm sewer laid at 1 in 255 (0.004 m/m).

Simplified sewerage is most appropriate in high-density, low-income housing areas which have an on-plot level of water-supply (i.e. one tap or more per household) and no space for on-site sanitation pits or for the solids interceptor tanks of settled sewerage. It was developed as condominial sewerage in the early 1980s by CAERN, the water and sewerage company of the state of Rio Grande do Norte in northeast Brazil, as an affordable solution to the until then intractable problem of how to provide sanitation in high-density low-income areas (see below). It works well owing to the high initial rate of connection to the network (often well over 90 per cent; with conventional sewerage it can take many years to reach this level of connection), and when resulting sewage flows are correspondingly high. Blockages are very rare, even in the upper reaches of the network where the flow is intermittent: solids progress in a sequence of deposition, transport, deposition, transport until the sewer has drained a sufficiently large area for the flow to cease being intermittent. This deposition-transport-deposition -transport sequence is more efficient in small-diameter sewers than in large-diameter sewers.

Simplified sewerage systems are now used widely in Brazil and elsewhere in Latin America, and were introduced to Pakistan in 1985 in Christy Nagar, a very low-income slum area of Orangi in Karachi (see below). Simplified sewerage, especially its condominial version, without doubt represents one of the most important advances ever made in sanitation. Given the extremely high rate of urbanization which is creating high-density

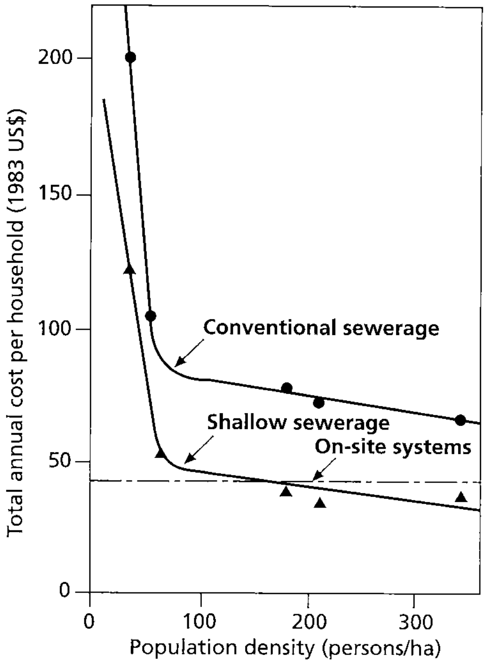

Figure 4. Variation of annual costs per household of conventional sewerage, condominial sewerage (formerly called shallow sewerage) and on-site sanitation systems with population density. Data from Natal, northeast Brazil, showing that in this case condominial sewerage becomes cheaper than on-site sanitation at a population density of 160 persons per hectare.

low-income areas in many developing countries, it will often be the only technically and institutionally feasible, economically appropriate and financially affordable sanitation option.

The case for settled sewerage

The case for settled sewerage has to be made on financial grounds. If the community already has septic tanks, and assuming the soil can no longer accept the septic tank effluent, settled sewerage will probably be cheaper than simplified sewerage. This must of course be checked in each case.

If the soil can no longer accept septic tank effluent because in-house water consumption is high (>100 litres/caput/day) and wastewater generation correspondingly high, in-house water conservation techniques, such as the installation of water-saving plumbing fixtures (see (19)) should be seriously considered in order to reduce the wastewater flow so that the soil's capacity to accept the septic tank effluent is restored.

The case for simplified sewerage

Simplified sewerage is worth considering as the sanitation technology of first choice for low-cost urban sanitation programmes and projects, especially those for high-density areas. But only if simplified sewerage is confirmed as:

— cheaper than on-site sanitation, and

— cheaper than settled sewerage.

Generally, though, the only areas for which simplified sewerage would not be the cheaper alternative are areas of low population density or areas already served by septic tanks (even currently malfunctioning septic tanks).

A decision must also be made concerning whether to adopt condominial (or backyard) sewerage or in-street sewerage. The former is more generally favoured in northeast Brazil, for example, and the latter in southern Brazil where SANEPAR, the water and sewerage company of the State of Paraná, often installs "double sewers", i.e. a sewer on each side of the street under each pavement. Whether the reasons for this are always valid is not clear, but "double in-street simplified sewerage" is around two-thirds more expensive than condominial sewerage (10, 20).

Selection criteria for low-cost sewerage

Costs

Cost — both economic and financial — is the most important criterion (1, 2). Costs must be evaluated with care taken to ensure that all costs, including, for example, those borne by the householders are taken into account. Generally, the most appropriate method is to determine the total annual economic and financial costs per household based on average incremental costs using the techniques of discounted cash flow analysis (i.e. converting future capital and operation and maintenance costs to their present values — see (2), chapter 4).

Unfortunately such annual costs are not usually calculated. The World Bank (9) and the Pan American Health Organization (21) quote the following ranges for the capital (i.e. investment) costs of sewerage (excluding the cost of sewage treatment) in Brazil:

Settled sewerage (northeast Brazil)	US$ 35–85 per person
Condominial sewerage (northeast Brazil)	US$ 65–105 per person
Simplified sewerage (southern Brazil)	US$ 170–240 per person
Conventional sewerage (southern Brazil)	US$ 240–390 per person

The costs of settled sewerage obviously depend on whether or not households already have septic tanks. As for simplified sewerage, the condominial (backyard) version is significantly cheaper than the non-condominial version (and very much cheaper than conventional sewerage). Condominial sewerage is therefore generally to be preferred. The financial costs of condominial sewerage are still very low though. In Natal in northeast Brazil (where condominial sewerage was developed in the early 1980s), capital costs in 1981 were USS$ 325 per household; the Water and Sewerage Company was able to recover its costs over a 30-year period by surcharging the water bill by only 40 per cent (rather than by the 100 per cent for households served by conventional sewerage). The charge for water was the "minimum tariff" (i.e. an assumed unmetered consumption of 15 m^3 per household per month) of US$ 3.75. So the financial costs of simplified sewerage were really low: only US$ 1.50 per household per month (8, 22, 23).

Water supply

Ideally, an on-plot level of water supply should be available, although in Pakistan, simplified sewerage works well with a hand-carried water supply service level (see below).

Population density

As shown in Figure 3, population density is a key parameter in determining the cost and appropriateness of low-cost sewerage. In Natal in northeast Brazil, condominial sewerage was cheaper than on-site sanitation systems at a population density of 160 persons per hectare, but this must be checked in each particular case.

Community participation

The success of condominial sewerage in northeast Brazil is the result of an effective partnership between the sewerage authority and the community. The community is responsible for the operation and maintenance of the condominial sewers within the housing block. The sewerage authority is responsible only for the public sewers (i.e. the sewers outside the housing block). Assignment of these responsibilities must be discussed with the community before such a scheme is implemented. Community members must understand what their responsibilities are to be and why these responsibilities have been assigned to them (generally to reduce sewerage costs and enable a service to be provided). Essentially these responsibilities tend not to be great, involving only the removal of blockages (which are extremely rare and normally due to wilful abuse of the system). In Brazil, the community usually devolves its responsibilities to individual householders. In practice, this means that they are responsible for operation and maintenance of the length of condominial sewer which passes through their property (24, 25).

Institutional appropriateness

Usually, sewerage authorities are perfectly willing to accept responsibility for low-cost sewerage schemes. This is very important as they do not generally accept responsibility for on-site sanitation systems, leaving this to the municipal council, which may or may not be able to discharge the associated tasks (especially emptying of latrine pits) effectively. On-site systems are consequently often not fully satisfactory. In contrast, a good partnership between the sewerage authority and the community means that low-cost sewerage systems are operated and maintained very well (25).

The wastewater collected in low-cost sewers requires **treatment** before discharge into a surface watercourse or reuse for crop irrigation or fish culture. Usually, the most appropriate treatment process is carried out by **waste stabilization ponds** (see 26, 27 and 28). It is also worth noting that on-site systems can be upgraded over time, with corresponding improvements in water supply, to settled sewerage systems (see 2, 10).

Table 1 summarizes the characteristics, advantages and disadvantages of both settled and simplified sewerage.

Field examples of low-cost sewerage

Settled sewerage in Zambia

Settled sewerage was originally developed in the late 1950s by Mr L J Vincent, Manager of the then African Housing Board of Northern Rhodesia (now the Zambian National Housing Authority) (29). Conventional and sullage aqua-privies did not work well in Northern Rhodesia and so settled sewers were developed to remove the settled wastewater (toilet wastes and sullage) from the aqua-privy tanks. The first such system was installed in 1960 at Kafue, an industrial township 50 km south of Lusaka (30). The land here, known as the Kafue Flats, is very flat, with a fall of only 1 in 2000. The sewers were designed for daily peak velocity of 0.3 m/s, and the pipes were 100 mm minimum in diameter, laid at a minimum gradient of 1 in 200. They were designed to flow when only partially full and not, unlike the more recent North American systems described by Otis (7), for surcharged flow. The system at Chipanda in Matero Township, Lusaka, is described below; but several others exist and are described elsewhere (31, 32, 33).

The Chipanda system was installed in 1960 and serves 532 households. Each aqua-privy block serves four households. Each household has a water tap and a sink immediately outside its toilet compartment which discharges its sullage into the aqua-privy tank (Figures 5 and 6). The tank effluent discharges, via a 100-mm diameter asbestos cement connector pipe, into a 150-mm diameter asbestos cement lateral sewer which runs between most of the compounds. Originally the settled sewage was treated in a series of waste stabilization ponds, but these were abandoned when the settled sewers were connected to the city's expanded conventional sewerage system.

Table 1. Summary of characteristics, advantages and limitations of settled and simplified sewerage

	Settled sewerage	Simplified sewerage
Initial requirements:	Adequate water supply (preferably on-plot, although the system can work with hand-carried supplies).	Adequate water supply (preferably on-plot, although the system can work with hand-carried supplies).
Main characteristics:	Household wastewater is settled in a solids interceptor tank (single-compartment septic tank). Tank effluent discharged into small-diameter (75 mm minimum) commonly plastic pipes laid at shallow depth, at an inflective gradient. Wastewater treated in facultative and maturation ponds (or discharged into conventional sewer system).	Household wastewater discharged directly (i.e. without settlement) into small-diameter (100 mm minimum) plastic or vitrified clay pipes laid at shallow depth and low gradients (e.g. 1 in 270 (0.0037 m/m) for a 100-mm diameter pipe serving up to 1200 people). Wastewater treated in anaerobic, facultative and maturation ponds (or discharged into conventional sewer system).
Suitability criteria:	Most suitable in areas with existing septic tanks.	Most suitable in high-density low-income areas.
Principal limitations:	Sewerage authority has to assume responsibility for regular (e.g. annual or biennial) emptying of solids interceptor tank, and ensure that only settled sewage connections are made to the sewers.	Community has to accept responsibility for operation and maintenance of condominial sewers laid within the housing block.
Requirements for operation and maintenance:	Sewerage authority: regular inspection of sewers; maintenance of any lift stations; interceptor tank desludging; operation of treatment works.	Community: removal of any sewer blockages within housing block. Sewerage authority: regular inspection of ex-block sewers;* maintenance of any lift stations; operation of treatment works.
Costs: (These are indicative costs. Local costs must be properly estimated).	USA: capital costs of around 50–60% of conventional sewerage in areas where new solids interceptor tanks are installed (less in areas with existing septic tanks).	Northeast Brazil: capital costs of US$ 300–500 per household (compared with US$ 1500 per household for conventional sewerage).

* Ex-block sewers are laid in the public domain, i.e. under a pavement or street, as opposed to inside a housing block or within a private domain. The community would be responsible for maintaining sewers inside housing blocks.

Condominial sewerage in Natal, Northeast Brazil

Shallow sewerage was first developed in the low-income settlements of Rocas and Santos Reis in the city of Natal, the capital of the northeast Brazilian State of Rio Grande do Norte, by the Sanitation Research Unit of the State Water and Sewerage Company (CAERN) (8, 22). Rocas and Santos Reis are two neighbouring squatter settlements where approximately 15 000 people have settled, giving an overall population density of 350 persons per hectare. These settlements were spontaneous and essentially wholly unplanned.

The 3100 houses and buildings in the area were distributed over 86 blocks. Over half the houses were located on plot sizes less than 80 m^2 and had constructed areas of less than 60 m^2. They were therefore contiguous on at least one side with neighbouring properties with little or no space between them. Some space was usually available at the back of the house for a small garden. Income levels were exceptionally low, with two-thirds of the population earning subsistence wages below the country's poverty line.

Despite such a low level of income, the granting of land titles to the householders had, over the years, encouraged the use of good quality construction material throughout most of the two areas. A yard-tap level of water supply was available and only a minimum water tariff levied from the majority of the premises, because of the small sizes of the plots. A quarter of the houses were not connected to any water-supply service, but shared supplies with their neighbours. Most houses had a conventional but manually-flushed ceramic toilet bowl which was connected to leachpits constructed within the plot area; sullage was discharged into the street in front. The high density of the settlement and the need for frequent leachpit desludging meant that the community was very dissatisfied with the system.

Although CAERN had a plan to serve the area with conventional sewers, it was evident that this would prove neither technically nor economically feasible, and that only a small proportion of house connections could be made. Meetings were held with the community to discuss the problem of sanitation in the area, and the advantages and disadvantages of various sanitation systems, including conventional and condominial sewerage. A condominial sewer system was proposed but the community feared that its operation might not be trouble free. One block, consisting of 28 houses, was therefore selected for a pilot test, and plans for laying in-block sewers were prepared. Each household consented to the construction of a common house connection in its backyard and agreed to be responsible for the

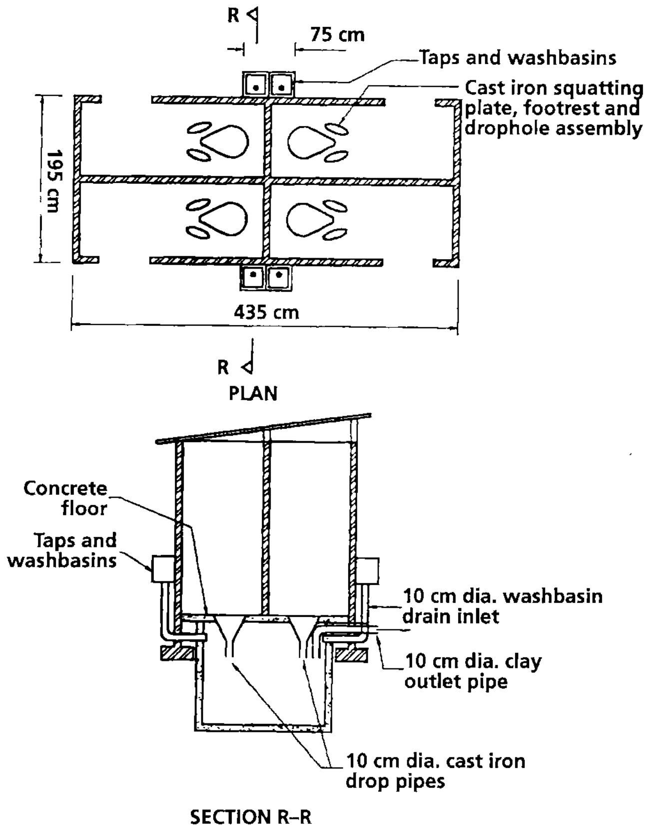

Figure 5. Typical sewered aqua-privy in Chipanda, Matero (Zambia).

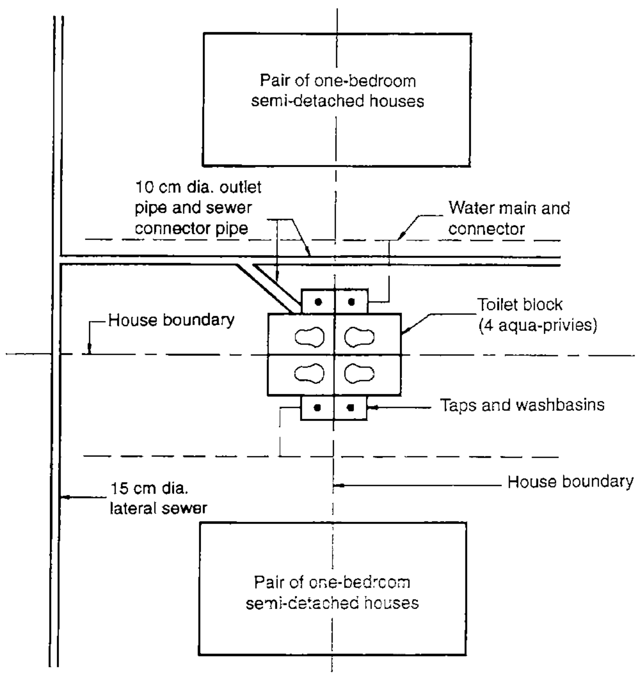

Figure 6. Typical sewered aqua-privy block in Chipanda, Matero (Zambia).

maintenance of the length of sewer laid within its property; a simple inspection chamber was built for this purpose at each household connection to the sewer.

The pilot in-block condominial sewer was constructed in 1981 and operated for over a year while the planning of other block and street sewers proceeded. Block meetings were then arranged for the remaining 85 blocks, and residents in these blocks were encouraged to visit the pilot block and talk to the people living there to obtain their views on the system. This led to spontaneous acceptance of the system and a great demand to extend it to the remaining blocks. An unprecedented connection rate of 97 per cent was achieved in the first year of construction.

Within five years, the shallow sewer system was also being used in other towns within Rio Grande do Norte and was being implemented in all low-income housing schemes in the State without exception. During this period, it also began to be used in other states in Brazil such as Pernambuco, Rio de Janeiro, Minas Gerais and Sergipe. More recently, condominial sewerage has been used on a very large scale in Brazil through the World Bank PROSANEAR I Project (Table 2).

Table 2. World Bank PROSANEAR Project statistics

State	City	Number of beneficiaries	Capital cost per person (US$)
Pará	Belem	126 000	232
Ceará	Fortaleza	186 000	78
Pernambuco	Recife	9 000	209
Rio de Janeiro	Rio de Janeiro	445 000	87
Angra dos Reis		70 000	61

Source: World Bank. *People, poverty and pipes: the power of community participation and low-cost technology to bring water and sanitation to Brazil's slums.* Washington, D.C., The World Bank (Infrastructure and Urban Operations, Department 1, Latin America and Caribbean Region), 1996.

Condominial sewerage in Orangi, Karachi, Pakistan

Approximately 40 per cent of Karachi's population lives in squatter settlements (locally termed "katchi abadies"). Orangi, the largest squatter settlement in Karachi and in Pakistan, is situated 12 km from the centre of the city. It has an estimated population of 800 000, settled in sub-standard conditions in an area covering approximately 2000 hectares. At the start of the project, average household incomes were at subsistence levels, and infant mortality and the incidence of excreta-related infections were both high.

The settlement was a result of migration from the former East Pakistan, which had taken place during the period immediately before and after the creation of Bangladesh. Although the largest of the katchi abadies, Orangi lacked the minimum of basic infrastructure and essential amenities. In March 1983, the Bank of Credit and Commerce International Foundation (BCCI), in collaboration with UNCHS (Habitat), initiated a three-year community development project, aimed at improving the living conditions of the people of Orangi (see (8)).

The project aimed to promote implementation of low-cost infrastructure interventions, particularly for sanitation, given the urgent need for sanitation improvement in the project area. The water supply to Orangi was via unevenly distributed communal standpipes which operated for four hours a day only, in the afternoon. Water was stored in in-compound tanks in most of the houses; on average, 20 to 30 litres were used by each household member each day. Only rudimentary plumbing fixtures were present in the area, and most washing was confined to a special wet room used for both bathing and washing clothes and utensils. The most common form of sanitation in the area was bucket latrines and the socio-religious custom of using water for anal cleansing necessitated the carrying of water to the toilet. "Scavengers", who undertook the removal of excreta from the bucket latrines, charged US$ 1 per month for the service, but no provision existed for the disposal of sullage.

In 1984, Chisty Nagar, a Bihar community within Orangi, was selected as the first location to start the condominial sewerage programme. The project area contained 555 plots, 408 of which had houses built on them, and an average gross population density of 193 persons per hectare. A remarkable feature of the area was the regularity of its urbanization, with average plot sizes of 100 m^2, 50 per cent of which, on average, was occupied by the house. Even more remarkable was the existence of a service lane, designed to provide access for nightsoil removal by the scavengers.

General community meetings were held after midday prayers at the mosque on Fridays. Local community leaders were selected and the programme was described. Discussions held with the community revealed a preference for some form of waterborne sanitation, but conventional wisdom dictated that the unreliable intermittent water supply and low levels of water consumption in the area would rule out use of conventional sewerage. Average water consumption was found to be 27 litres per person per day; with conventional sewerage, consumption is much higher, generally over 100 litres per day.

Only condominial sewerage offered any chance of success. Although condominial sewers had not been previously installed under conditions of such limited water use, and with manually flushed ceramic toilet squat pans, their mode of operation suggested that they would nevertheless function satisfactorily. An analysis of the costs of various sanitation options also indicated condominial sewers to be one of the cheapest options. It was therefore decided that condominial sewerage should be implemented in Chisty Nagar.

Meetings were held with the community to present the proposed designs and to establish a procedure for raising the required capital which had to be found in full by the community. The community nominated a trusted member to be the custodian of the funds raised. It was also envisaged that maintenance committees would be established as social mobilization advanced, in order to maintain the condominial sewers after installation.

Condominial sewers, laid in the service lanes (until then only used by scavengers for emptying nightsoil buckets), were designed according to criteria similar to those developed in Brazil; they received the wastewater from the manually flushed squat pans and all household sullage. A grit/grease trap, made of cement mortar (including fine aggregates) was provided in each house, as the main point of sullage collection and as a preventive maintenance device. One inspection chamber was provided to serve two plots, and each water closet connection was appropriately ventilated. In addition to the service lane sewers, an interceptor sewer was constructed to drain the lane sewers into a communal septic tank. The effluent from the tank was discharged to the nearby dry water course.[1] The shallow sewer layout adopted in Chisty Nagar is shown in Figure 7.

The internal plumbing and lane sewers comprised 30 and 31 per cent respectively of the total cost, which amounted to approximately US$ 45 per plot. An alternating twin-pit pour-flush toilet, which disposes of excreta only, would have cost approximately US$ 51. As in northeast Brazil, condominial sewerage was cheaper than on-site sanitation.

[1] In most circumstances this is not the best solution. Whenever possible, wastewater should be treated before discharge.

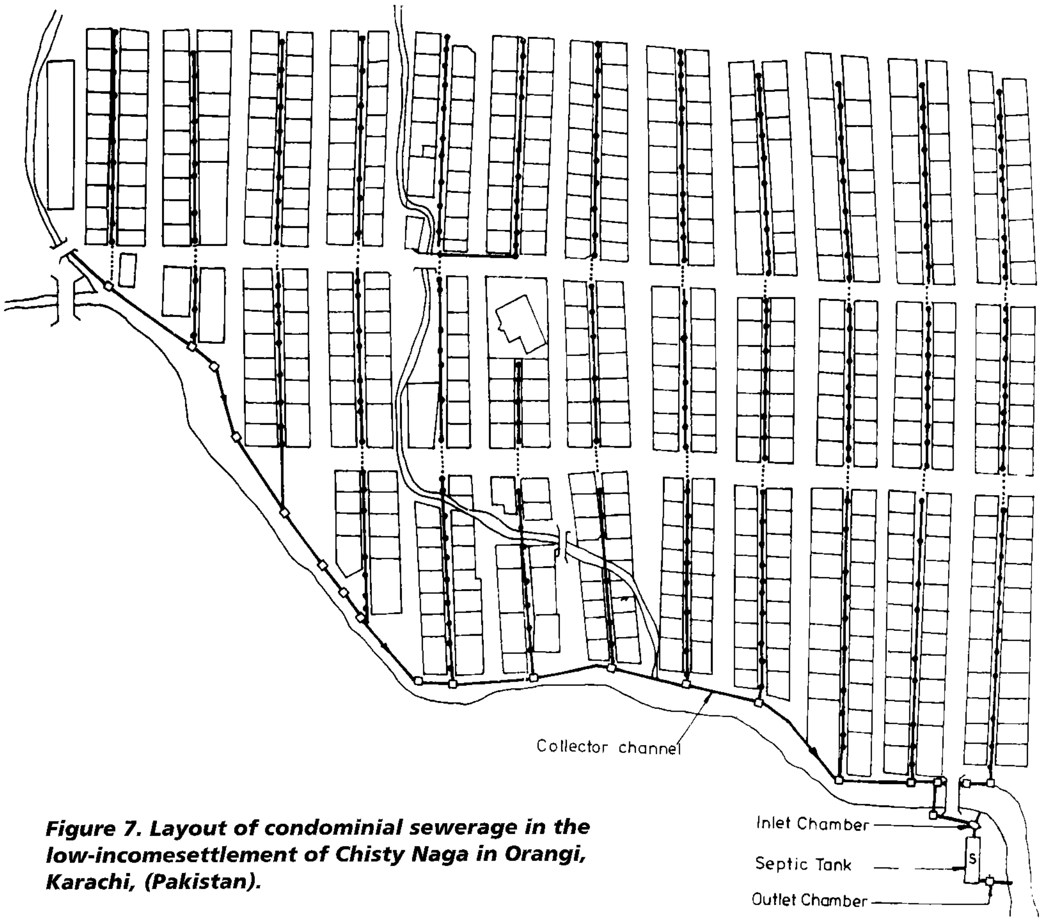

Figure 7. Layout of condominial sewerage in the low-incomesettlement of Chisty Naga in Orangi, Karachi, (Pakistan).

Following the success of this first BCCI/UNCHS condominial sewerage project in Chisty Nagar, the system was soon also applied in other parts of Orangi, eventually becoming known as the Orangi Pilot Project. So far, around 750 000 poor people have been served by condominial sewerage — a very successful example of technology transfer from one developing country (Brazil) to another (Pakistan).

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