SHALLOW SEWER SYSTEM
– A COST EFFECTIVE SOLUTION FOR SEWERAGE SYSTEM
(Abstracted from Technical Manual for Design of Shallow Sewer System–
Published by United Nations Centre for Human Settlements (habitat))

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Population densities in these settlements show wide variations between sparsely built peripheral settlements, with densities around 20 persons per hectare, to urban types of shantytowns exceeding 2,000 persons per hectare. The standard of squatter-settlement housing is much lower than that of slums, services are rarely available and opportunities for connecting into municipal utility networks are poor. Sanitation in squatter settlements, where it exists at all, is generally very primitive.

One of the fundamental problems in increasing sanitation coverage in urban areas is the high cost of conventional sanitation services. Very huge investment would be needed to provide sewerage in a conventional manner to all urban settlements. Since the annual level of investment required to achieve such coverage in most developing countries is somewhere between 3 and 6 per cent of the gross domestic product of those countries, governments wishing to address the problem of sanitation would have to forego opportunities to invest in other unsatisfied basic needs, such as food, housing, health and education, and in the industrial, energy and transport sectors. Few countries are likely to make this priority decision. One of the most effective means of overcoming this problem is to reduce the cost of providing sanitation, while maintaining, if possible, the convenience offered by conventional sewerage. In a bid to address the problem, a study undertaken by the World Bank identified over 20 different sanitation technologies. Unfortunately, however, most of the technologies, while having the capacity to provide a comprehensive solution to sanitation in both rural and low-density to medium-density urban areas, are inappropriate in areas where the density of settlement is high, incomes are low and the need for wastewater disposal is most urgent. The principal reason for this is that a majority of low-cost technologies are on-site systems, such as the ventilated improved pit latrine and pourflush toilet, which dispose of excreta but cannot cope with wastewater. Unfortunately, the soil has limited capacity to absorb this wastewater as population densities increase, crowded housing conditions worsen, and water use rises. Therefore, the problem of excess wastewater intensifies. Past efforts to build open drains for wastewater drainage have mainly been unsuccessful because, besides being expensive, they rapidly become clogged with sand and blocked with refuse. Moreover, because a majority of the slum and squatter areas demonstrate little intentional planning, even the implementation of high-cost waterborne systems, such as conventional sewerage, present problems. Few, if any, sanitation technologies are currently available which can be considered well suited to the physical peculiarities of these deprived areas.

## Purpose and scope of the manual

The specific objective of this publication is to introduce an innovative low-cost sanitation technology, known as shallow sewerage, and to present a methodology and criteria for its planning, design and implementation. The technology has emerged through research conducted over the past five years, and it has been successfully applied in Brazil and Pakistan.

Shallow sewerage eliminates the public health risks usually associated with inadequate excreta and wastewater disposal in areas of high population densities and inadequate water supply, and it achieves this at only a fraction of the cost of conventional sewerage. The technology is eminently suited to the requirements of a majority of urban slums and squatter settlements of developing countries. This manual has been prepared as a design tool for national planners and engineers engaged in the provision of infra-structural services to these settlements. Shallow sewerage offers the same level of user convenience as conventional sewerage.

Relaxations in technical standards adopted in its planning and design achieve considerable reductions in cost, and the methods employed in implementing shallow sewerage systems, which promote the active participation of the community at all stages, guarantee that a very high level of service is provided to the community in the short term. These and other characteristics of shallow sewerage which make it a cheap and effective means of sanitation are discussed in chapter 1. The factors which distinguish shallow sewerage from other sanitation technologies, the prerequisites for the satisfactory functioning of this system and the conditions under which it is particularly effective are also discussed in detail in chapter I. Criteria for the design of shallow sewers and specifications for their construction are presented in chapter II. Project implementation strategies, which will ensure the successful introduction of the technology in low-income settlements, are discussed in chapter III. Details of construction and maintenance procedures are presented in chapter IV, and economic and financial aspects are considered in chapter V. Finally, studies of examples where the technology has been successfully introduced and observed to perform satisfactorily are presented in chapter VI.

The Bank of Creditand Commerce International (BCCI) Foundation with whose collaboration UNCHS (Habitat) has also successfully demonstrated the use of the technology in Orangi, a large squatter settlement on the periphery of Karachi, Pakistan.

(Basic details which are covered in Chapter I only are reproduced here.)

## CHAPTER 1 : CHARACTERISTICS OF SHALLOW SEWERAGE

### A. System description

Shallow sewers are designed to accept all household wastewaters -excreta, toilet flush water, and sullage - in their fresh state for off-site treatment and disposal. They consist of a network of small-diameter pipes laid at flat gradients in locations away from heavy imposed loads, such as vehicular loads, usually in the backyards and narrow back alleys of both planned and unplanned settlements. This allows short overall lengths of pipework to be laid in shallow trenches(hence the name) with small inspection chambers provided along their lengths to facilitate access for maintenance. Most high density, low-income housing areas have few motor-accessible roads within them and, hence, a majority of the sewers may be laid at shallow depths throughout most of their length. Typical layouts of shallow sewer systems are presented in figure 1.

Shallow sewers are designed to be flushed frequently: essentially, all households within a block are connected to the sewer that passes through it..This is required not only to ensure trouble- free operation but, more important, to interrupt intra-community contamination. Several houses are connected to the same sewer which, when it emerges from the block, has several options:(a) to be connected to a conventional street sewer;(b) to be discharged into a community septic tank and thence, by a small-bore sewer to waste- stabilization ponds or other treatment process; or (e) to be discharged straight into ponds. The choice is site-specific. The shallow depths of the emerging sewers can often be maintained by locating them in streets in places not subject to vehicular loadings, such as along footpaths immediately adjacent to property boundaries. Where it is unavoidable to cross streets subject to such loadings, suitably designed concrete collars are provided around the pipe to serve as protection.

## B. Mode of operation

Shallow sewers do not rely on large quantities of flushwater for trouble-free operation; instead, they rely on the high frequency with which wastewaters pass through the system.

Densely populated areas offer ample opportunities for such operation. At the head of the sewer network, wastewater solids are flushed along by successive waves of wastewater, and, if any solids settle out in the sewer invert, wastewater builds up behind the deposit until the pressure is great enough to set it moving again. Such back pressures are easily established when the diameter of the pipe is small, since leakages past the deposited solids are minimized and an effective backpressure can be built up. Solids progress along the top end of the sewer line in a sequence of deposition- transport –deposition transport, and this continues until the sewer has drained a sufficiently large area for the flow to cease being intermittent. Shallow sewers are also laid out in such a manner that they are located adjacent to the wastewater generating points within households. Hence, peak discharges created during flushing assist solid transport even when water consumption and, hence, wastewater generation are limited.

## C Potential for reduced treatment requirement.

Where communal septic tanks are located at the points where the sewers emerge from blocks of houses and discharge their effluents to off-site treatment via small bore pipes, then screening, grit removal and primary sedimentation or treatment in anaerobic ponds are not needed at the treatment works, because these processes are performed in the septic tank. Clearly, the decision to incorporate community septic tanks in the system needs careful evaluation, to assess cost trade-offs and local capacity to maintain the tanks.

Thus, relaxations in technical standards, brought about by diligent location of sewers and careful incorporation of recent research findings in the design and operation of sewers, have resulted in the development of an acceptable means of providing sanitation facilities at a level of service comparable with conventional sewerage but at a much lower cost. Because of their low costs of construction and maintenance and their ability to function with little water, shallow sewers can be used where conventional sewerage would be inappropriate. Shallow sewers, therefore, offer an opportunity of improving sanitation in a majority of low-income urban settlements in developing countries. The principal disadvantages of the shallow sewer system are that it requires extensive promotion of community awareness, together with house-to-house and physical surveys, at the planning stage, and good quality control during construction.However, the efforts devoted to promoting the system amongst low-income communities will enable them to identify themselves with the system, which, in turn, will result in its improved operation and maintenance in the long run.

### D. Component parts

Shallow sewer systems consist of the following components:(a) house connections; (b) inspection chambers; (c) common block sewer lines; (d) street collector sewers; (e)pumping stations(on occasions); and (f) a sewage treatment plant (see figure 3).Pumping stations are only necessary if the collected sewage cannot be treated and disposed of within the same drainage basin. They may, also, be required in the sewer system itself in extremely flat areas, but this is very rare.

(a) House connection. All household wastewaters are connected to the common block sewer line at an inspection chamber along its length (figure 4). Low-volume pour-flush or cistern-flush water seal toilets ( either pedestal seat or squat pan units) are connected to the inspection chamber via a 75 mm diameter, PVC or asbestos cement pipe. A vertical ventilation column of the same diameter is provided somewhere along the length of the house connection. (Conventional flush toilets may also be connected, but because the system does not require large quantities of water for its operation, their use is not prudent. A variety of low-volume water seal pedestal seat and squatpans are available, and these are more than adequate.) All sullage generated on the premises is also connected to the inspection chamber by a suitable pipe, usually a50mm diameter PVC pipe. Where water consumption is large (greater than75 lpcd), the sullage may be connected directly to the inspection chamber. However, where consumption is low (25-30 lpcd), it is advisable to pass the sullage through a grit/ grease trap which acts as a sullage collector and also serves as a preventive maintenance device. Low levels of water consumption are usually associated with settlements served with a community-standpipe level of water supply.

(b) Inspection chamber. Inspection chambers are provided at frequent intervals along the length of the common block sewer line. They serve both to provide access to the sewer line for the house connections and to facilitate sewer maintenance. Usually one inspection chamber is provided for each house, although, depending on the sewer layout, two or more houses may share a single inspection chamber. The dimensions of the chambers vary with depth. A tightly fitting reinforced concrete cover is provided to the chamber.

(c) Common block sewer line. The block sewers are small- diameter (minimum of 100 mm) clay or concrete pipes which are trenched into the ground at a depth sufficient to collect wastewaters discharged from the house connections by gravity and laid at a uniform gradient between adjacent inspection chambers along their length. Usually, a minimum depth to pipe invert of 0.4 m is provided to avoid accidental damage, although this may be reduced in special circumstances. The block sewers, while following a straight alignment between inspection chambers, rarely follow an overall linear alignment in unplanned settlements and are usually contoured around existing buildings. The objective in such a layout is to ensure that the block sewers are laid adjacent to all wastewater-generating points within the block: some straightening out of the sewer line will, however, is desirable. The sewer line will inevitably be required to pass under property boundary walls and, possibly, under future building extension areas: however, this does not usually pose any serious problem. Stone or brick arching of the wall or foundation will assist in avoiding the transmission of dead loads directly on to the pipe. The inspection chamber must, however, always be located in an open area.

(d) Street collector sewers. Street collector sewers are usually provided to a minimum diameter of 150 mm, although it is possible, where hydraulic capacities permit, to adopt 100mm diameter pipes. They are laid at a depth compatible with their location. Wherever possible, they are laid under sidewalks away from vehicular traffic, at a depth which ensures the continuation of the flow within them and which is also adequate to receive the discharge from the block sewers. Where the depth to pipe invert exceeds 0.8 m, the sewers may be located, without protection, in streets subject to vehicular loadings. Where pipes are laid at depths less than 0.8 m a concrete surround is provided at selected locations, for example where they pass under vehicular traffic, in order to protect the pipe. Inspection chambers are provided along the street collector sewers at intervals not exceeding 40 m, although, where mechanical sewer cleaning devices are available, this distance may be increased. Where communal septic tanks are provided at the point of emergence of the block sewers, the street sewers should be designed in accordance with the principles of small-bore sewers.

(e) Pumping stations. Pumping stations may be necessary where the sewers become very deep or when it is required to transport the collected sewage to a different drainage basin for treatment and disposal. The use of pumping stations should, however, be eliminated, as far as possible, through careful sewer depth minimization and by treatment of all wastewaters within the same drainage basin.

(f) Treatment plants. In certain circumstances, it may be possible to discharge the wastewater into an existing conventional sewer system and, thus, be able to treat it at the works receiving the unsettled sewage. Where this is not possible, waste stabilization ponds are generally the wastewater treatment option of choice in developing countries. If the number of houses served is small, treatment may also be provided by means of a communal septic tank and effluent infiltration trench.

## E. Applicability in developing countries

(a) A recent study undertaken by the World Bank identified a variety of on-site and off-site excreta and sullage disposal systems. On-site excreta and sullage disposal systems were found to be much less expensive in developing countries than off-site systems. However, shallow sewerage, which was developed after this study, is probably the only off-site system which, in certain conditions, is cheaper than on-site systems. There are also situations where on-site systems are technically unfeasible, and in such circumstances some form of off-site disposal is required. Shallow sewers are usually the most economical of all off-site disposal technologies and are therefore an obvious choice for consideration. Fortunately, it is precisely the same conditions which render on-site systems unfeasible or too expensive that make the shallow sewer system attractive in. both technical and economic terms. These conditions include:

(b) High population densities. All on-site waste disposal options require adequate space within the lot for their installation. Such space is usually available in rural and low-density to medium-density urban areas. However, as the density of settlement increases, such space is not readily available, and, even when it is available, on-site systems are likely to meet with community opposition especially because they need desludging at some stage during their operation. All forms of pipe networks demonstrate marked reductions in unit household costs as the density of settlement increases, because the same length of pipe work serves an increased number of houses. On-site systems, however, maintain a constant unit household cost irrespective of the density of settlement. At a given density of settlement, piped networks become more economical than on-site systems. Unfortunately, in the case of conventional sewerage this transition only takes place at extremely high population densities. Shallow sewers, being much cheaper than conventional sewers, become cost-effective at much lower densities. The population density at
which this transition takes place varies with the physical conditions of the settlement (such as soil permeability, topography etc.), but in Natal, Brazil, this transition point occurred at a density of 160 persons per hectare (see figure 5).In areas with shallow rock ,shallow sewers have even proved more cost-effective than on-site systems at population densities as low as 110 persons per hectare.

(b) Adverse ground conditions.All on-site excreta and sullage disposal systems rely on the ability of the soil to absorb all wastewaters generated on the premises. They also require some form of excavation for excreta storage. Under adverse ground conditions, such as shallow rock, high groundwater table and low soil permeability, on-site systems may become unfeasible. The shallow sewer system is one of the off-site options, which may be adopted in such circumstances.

(c) High water consumption. Most low-cost, on-site waste disposal systems, such as pit latrines and pour-flush latrines, only handle the disposal of excreta. Sullage is usually left to infiltrate into the ground at the surface or via some form of on-site sullage soak away. As water consumption increases, the need for such soak aways increases. In areas of adverse soil conditions and high densities of population, the space for soak aways may not be readily available. Further, because low-income communities do not see the need for
investing in soak aways for the disposal of sullage, it is not uncommon to see large quantities of sullage flowing in the streets. Such uncontrolled disposal of sullage can give rise to diseases such as filariasis, as well as erode the usually unsurfaced alleyways found in these settlements. Shallow sewers, because they dispose of both excreta and sullage, can be adopted in settlements where average levels of water consumption are high. A minimum average water consumption of at least 25 lpcd is required, however, to be available for shallow sewers to operate without blockages.

(d) Varied socio-cultural settings.Shallow sewer systems maybe applied under most socio-cultural settings. It is especially suited to cultures where anal cleaning by water or soft materials is used. No experience is available on which to assess their suitability in areas where bulky anal cleaning materials are used.

When on-site disposal technologies prove unfeasible or when density of settlement suggests that off-site systems may prove cost-effective, the full range of off-site disposal technologies has to be evaluated in technical, financial and economic terms. The available off-site disposal technologies are the following:

(e) Vault toilets and cartage systems. These require a high degree of organizational capability within the institution (usually a municipality) responsible for operating the system: the vault-emptying equipment (commonly a vacuum tanker) has to arrive at each vault very close to the chosen emptying frequency (two to four weeks), otherwise the system fails, and the emptying equipment must be properly maintained. In many developing countries, such a level of institutional competence is lacking, and very often the system cannot be considered feasible for this reason. Narrow access roads to most low-income settlements in developing countries would also suggest that the system may not always be appropriate.

(b) Conventional sewerage systems. These are so expensive that they are economically inappropriate in low-income communities. For example, studies undertaken by the World Bank showed that investment costs for conventional sewerage in eight capital cities in developing countries ranged from $600 to$4000(at 1978prices) per household, with corresponding annual costs between $150 and $650per household. Such costs are clearly unaffordable when it is remembered that total annual household incomes are frequently less than $500 and are often below $200.Further, the unfeasibility of constructing deep sewers in high-density areas with precarious housing stock also precludes the use of conventional sewerage in low-income settlements.

(c) Small-bore sewers. These offer a feasible means of upgrading on-site systems, such as pour-flush toilet and septic tank systems, when improvements in the water-supply distribution system or increased housing densities have occurred. In new schemes, however, small-bore sewerage offers little advantage over conventional sewerage in terms of overall cost. Small-bore sewerage, as with the vault system, also necessitates frequent desludging. The equipment and organizational capability for this task may not be readily available in developing countries, and access for purposes of desludging individual household septic tanks may not be adequate in most low-income, high-density settlements. In these circumstances, small-bore sewerage not only will prove to be only slightly cheaper than conventional sewerage but, more often than not, may prove technically inappropriate.

(d) Shallow sewer systems. These become increasingly economical as the density of settlement increases. In high-density slums and squatter settlements, they are often cheaper than on-site systems: typical investment costs are in the range of $125 to $325, with corresponding annual economic costs between $15 and $35 per household. The very high rates of user connection, usually achieved through community Involvement at the planning and implementation stages, ensure that a comprehensive sanitation solution is provided for the whole community and that maximum health impact is achieved immediately upon completion of the scheme. Besides being considerably cheaper than conventional sewerage, shallow sewers do not require excessive quantities of flush water for trouble-free operation.