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Combined surface sewerage: a low-cost option for effective sanitation in semi-urban areas of India

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Abstract Current prescriptions for sanitation technologies in developing countries are predominantly in the context of either large cities or rural areas. In India, however, there are a large number of small cities and towns with population in the range of 20000–100000 that account for over 50 million of the country's urban population. This paper discusses the inappropriateness (in terms of techno-economic viability and environmental desirability) of commonly recommended on-site sanitation technologies and capital intensive conventional sewage collection systems for these 'semi-urban' areas. While emphasising the need for a different approach for provision of sanitation services to such cities and towns, it identifies the limitations of recent developments of non-conventional sewerage systems. Based on the field research carried out in four 'semi-urban' towns in India, the paper proposes the concept of 'combined surface sewerage' that can utilise existing infrastructure to a maximum to effect better sanitation at lower costs. The suggested system involves converting the existing open drains on the roadsides, as decentralized networks with simple structural modifications and covering them with concrete slabs. These decentralized networks would convey sullage, septic tank overflow and storm water run-off for appropriate low-cost treatment prior to disposal.

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1
Introduction

The public health and environmental pollution problems that arise in developing countries due to inadequate provision of urban liquid and solid waste management services, have been a matter of global concern for over half-a-century now. Despite the laudable efforts made during the International Drinking Water Supply and Sanitation Decade (IDWSSD), by the early 1990s, more than 1.7 billion people were estimated to be without adequate sanitation facilities in developing countries (World Bank 1992). During the IDWSSD (1981–1990), attempts to provide and improve waste management services concentrated mostly on mega-cities of the developing countries and their smaller cities and towns were often ignored. The fact that about 80% of India's budget allocation for the provision of sanitation services during the IDWSSD went only to the four major cities, namely Delhi, Mumbai (formerly Bombay), Chennai (formerly Madras) and Calcutta, (Bharadwaj et al. 1990), indicates the low priority accorded to the provision of sanitation facilities in small and medium cities and towns. Lower than targeted urban sanitation coverage (45% compared to 75%) at the end of IDWSSD in India (Suresh 1998) could be attributed to the relegation of sanitation in small and medium towns to a lower order of priority. Also, the literature on low-cost sanitation for developing countries does not consider the sanitation problems in the context of such urban centres where the commonly prescribed on-site technologies are not adequate to achieve desirable levels of sanitation. An appropriate wastewater collection system is a pre-requisite if off-site wastewater disposal technologies are to be considered. While there is much information about off-site sewage treatment technologies, there is little published on low-cost schemes for sewage collection that may well suit smaller cities and towns. The objectives of this paper are: i) to evaluate the current policies for sanitation in small cities and towns of India with population in the range of 20000–100000 referred as 'semi-urban areas' and their shortcomings; ii) to review the suitability of conventional sewage collection practice and the relatively recent developments of non-conventional systems for off-site disposal of sewage, in light of existing levels of sanitation in semi-urban areas; and iii) to outline the concept of 'combined surface sewerage', developed based on the field study carried out in four small/medium towns in the southern State of Tamil Nadu, India, as an appropriate augmentative sanitation practice for off-site sewage disposal that can effect qualitative changes in the sanitary conditions of a majority of such semi-urban areas.

2
Semi-urban areas of India

Census of India classifies a human settlement in India as urban if:

1. the population is more than 5000;
2. the population density is over 400 per hectare; and
3. 75% of the male population is engaged in non-agricultural activities.

The rapid population growth experienced during the last five decades in India has resulted in the inclusion of many agricultural and rural settlements as urban, based on the population criteria alone. Therefore, an unofficial cut-off population of 20000 for considering a settlement as 'urban' has come into vogue (Rakesh Mohan 1996). There are 1272 small cities and towns (Census of India 1991) having population in the range of 20000–100000 with demographic characteristics (e.g., population density, type of dwelling units, type and scale of economic activities) that are distinctly different from large cities or rural villages. As per the Census of India classification, these urban settlements fall under class II (50000–99999) and class III (20000–49999) urban areas. It can be generally observed that a majority of such urban areas are closer to the rural hinterland, retaining a sizeable population engaged in agriculture and related activities and, therefore, displaying characteristics that are partly rural and partly urban. It is appropriate to speak of 'semi-urban areas' (SUAs) when referring to these small cities/ towns, as it will help to distinguish them from large cities, which are commonly understood as economically and politically important urban areas forming district and state capitals and/or industrial centers. The SUAs, with their aggregate population more than 52 million, (Census of India 1991) comprise about one-fourth of India's urban population. They have typically grown in size with little or no town planning, leading to high densities of population housed in dwellings that generally have no open front or backyards, and that are located along narrow streets. The population density ranges from 6000–10000 per km^2. Groundwater is the main (and, in many cases, the only) source of water in these towns (Central Pollution Control Board 1997a). Details relating to the semi-urban areas in India are presented in Table 1. Field studies were carried out in four of such semi-urban towns (Andipatti, Bodinayakanur, Cumbum and Theni) in the southern State of Tamil Nadu, India with a view to evaluate their current level of sanitation and to suggest improvements. Specific details of these SUAs are given in Table 2.

Table 1. Details of semi-urban areas in India

Population range	No. of cities	Population (millions)	% Contribution to the total urban population
i) 20000–49999	927	28.62	13.19
ii) 50000–99999	345	23.67	10.91

Source: Census of India, 1991, Statements 14 and 17, Paper 2, pp 30–32

Table 2. Details of SUAs studied

Name of the town	Population (1998)	Area of the town (km^2)	Population Density (No/km^2)	Percentage population involved in agriculture
Andipatti UTP	25,000	3.41	7331	45–50
Bodinayakanur	65,778	8.74	7526	60–65
Cumbum	59,325	6.48	9162	60–65
Theni	74,723	12.50	5978	30–35

Source: Concerned municipal/ urban town panchayat (UTP) authorities (1998). Population figures are projected from 1991 Census of India data

2.1
Current sanitation practice in SUAs and its shortcomings

While the mega cities with million plus population are still struggling with inadequate sanitation, the SUAs are adding a new dimension to the sanitation issues in India. Until the mid-1980's, most semi-urban cities operated a traditional 'bucket latrine' system for collection of human waste. In this system 'scavengers' employed by the municipal authorities, periodically emptied nightsoil deposited into buckets placed in household latrines. The nightsoil was then carried to outskirts using handcarts or bullock-carts, for dumping. Collection of sullage, the domestic wastewater other than toilet wastes, was through kerb-side open drains that run along both sides of the streets. These open drains also served as storm water drains. Towards the end of the IDWSS Decade, a major program was launched to provide low-cost on-site sanitation aimed at eliminating the manual carriage of human wastes and improving the physical environment of the SUAs. Under this program, all semi-urban areas, with a few exceptions, switched to pour-flush (PF) latrines that discharge into single or two-chambered septic tanks (Fig. 1). Overflow from septic tanks is collected along with sullage through the open drains. As observed during the field study, though the new arrangement has eliminated manual scavenging practices and resulted in odor-free and fly/mosquito-free toilets, its effectiveness in achieving public health and environmental benefits is questionable on the following accounts:

First, the sewage samples collected from the open drains during the field study have shown high levels of Total and Fecal coliforms (in the range of 9×10^3–16×10^3 per 100 ml and 5×10^3–9×10^3 per 100 ml respectively). This is due to the septic tanks not being constructed with adequate retention times to effect the intended level of treatment to the wastewater and the digestion of solids, because of small plot sizes. Hence, the partially treated and pathogen loaded overflow from septic tanks is being drained to the kerb-side open channels, which were earlier carrying only sullage. Pathogen load is also increased by a small section of households that directly flush their toilet wastes into the drains.

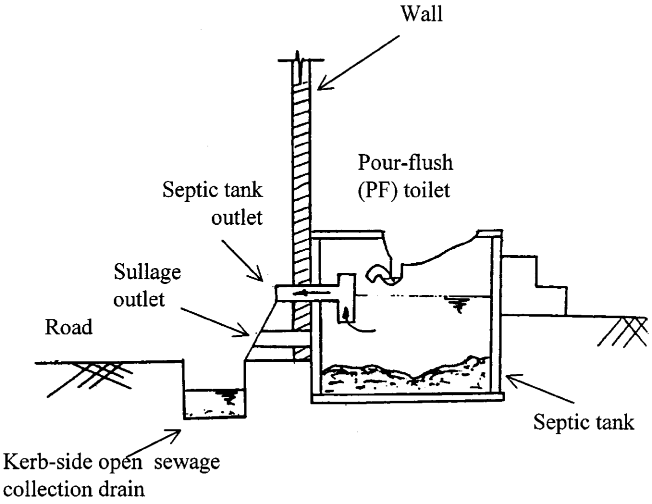

Fig. 1. Current sanitation practice in semi-urban areas of India (not to scale)

Secondly, as these drains are open and located along mostly unpaved roads, they silt easily, which reduces their carrying capacity. Dumping of debris and garbage further reduces their capacity, thus resulting in frequent overflows. During storms, overflows stagnate along the roads and pose a serious public health threat.

Thirdly, the high density of not-so-water-tight septic tanks will allow pollutants and pathogens to leach away from the site, causing groundwater contamination. A recent study in Australia has confirmed that towns and cities with septic tank and trench systems in densities of about 15 systems per km^2 are most likely causing nitrate and bacterial contamination of the local groundwater systems (Hoxely et al. 1994).

2.2
Issues of current sanitation policy for SUAs

The Government of India promotes low cost on-site technologies as the sanitation policy for SUAs at national level. This policy formulation is based on the suggestions made in the National Master Plan-India (1983) and by National Institute of Urban Affairs (NIUA) (1986). Their suggestion might be influenced by the wealth of information available on low-cost sanitation technologies (Winblad et al. 1980; Kalbermatten et al. 1982; Mara 1984, 1985; Roy 1984; Franceys et al. 1992) for developing countries that has resulted from studies of many international organisations. A critical look into the policy of promoting on-site sanitation technologies in SUAs reveals the following drawbacks:

(i) While the system of PF toilet with septic tank is a widely recommended on-site sanitation practice for developing countries, it was envisioned to dispose the overflow from the septic tanks through soak pits and other land applications within the households. The variation that allows the septic tank overflow into open drains (adopted in SUAs of India) is not a recommended practice.

(ii) On-site sanitation can be promoted basically for rural areas and slum/squatter settlements of large cities with a view to improve the basic health issues related to sanitation. As discussed earlier, the semi-urban areas fit neither the rural setting nor the squatter settlement setting. For the SUAs with high density small plot size households, on-site technologies are environmentally undesirable on a long term basis, especially as groundwater is the main source of water supply for the majority of such areas. It is pertinent to note that because of the concern about effects of on-site facilities on groundwater quality, the US Environmental Protection Agency (USEPA) has recommended not more than 15 septic tanks and trench systems per km^2 (USEPA 1992). Similarly, the West Australian Water Authority has set a limit of 25 septic tank and trench systems per km^2 where there are significant potable water supplies from groundwater (Rawlinson 1994). A comparison of existing situation in SUAs (1200–2000 systems per km^2) with these recommendations will reveal the gravity of groundwater pollution problems that may be currently accruing in the SUAs and could threaten their water supply sources in a near future.

(iii) It appears that while the local authorities asked the households to change over to the PF toilet system with septic tanks, the new municipal service requirement for de-sludging these tanks was not realized. None of the four municipal administrations studied was equipped with mechanical desludging machinery (liquid waste collection truck with vacuum/suction pump). The result is that the households are having to resort to manual de-sludging and disposing into the open drains, thereby effectively nullifying the major objectives of changeover to PF toilet system from ‘dry (bucket) latrine’ system.

3
Sanitation options for semi-urban areas

The only option, other than low-cost on-site sanitation, which had been considered for SUAs was conventional sewerage (Planning Commission 1983; NIUA 1995). In the absence of any specific attempts to identify or develop alternative low-cost approaches for effective sanitation in semi-urban areas, it is no wonder that the planning and policy making authorities developed a misconception that any further improvement of sanitation in semi-urban areas only meant the provision of capital intensive conventional sewerage. This has led to the adoption of ad-hoc and inappropriate on-site sanitation measures and the resultant adverse public health and environmental conditions in SUAs. The situation therefore warrants investigations for some sort of non-conventional, off-site disposal practice that can provide effective sanitation at lower financial and environmental costs. A brief review of conventional sewerage and the attempts to develop alternative sewage collection systems, at this juncture, will evaluate their suitability in providing sanitation services in SUAs in developing countries like India.

3.1
Conventional sewerage

The concept of conventional ‘self cleansing’ sewers, as found in most modern cities, was developed more than a century ago. It was based on the ‘filth theory’ of the 18th century, according to which rotting of human and animal waste results in the emergence of noxious vapours that cause diseases (Brace 1995). Sewers with steep gradients that use water as the flushing agent were therefore installed to swiftly remove human excreta before it started to putrefy (Tarr 1979). The conservative engineering design criteria that were initially developed for city sewerage have undergone little change in over a century (Otis et al. 1996).

While the conventional sewerage is an effective system for sewage collection and transport, it also remains as a highly resource-inefficient technology. As per the standard design criteria, the minimum pipe size for sewage collection is 150 mm diameter to be laid at a slope of 1:150 at 0.5 m below ground level (ASCE 1982). These criteria are to generate 'scouring velocity' of the flow so that the sewer can clear itself of silt and solids from depositing. The standard also requires a minimum of 150 litres/capita/day (lpcd) water supply for the area where such systems are to be designed (CPHEEO 1980). The 'self-cleansing' criterion thus results in the need for huge amounts of flushing water and steep pipe gradients, leading to larger pipes running deep underground. Consequentially, high capital cost and continuing significant costs for operation and maintenance of this system prohibit its widespread adoption in all sizes of urban areas. The construction and the operation and maintenance costs for conventional sewer systems vary depending on the demo-geographic features of the urban areas and, hence, are highly location specific. Under comparable terrain features, the per capita cost can be as low as Rs. 190 (US$ 4.75) in the mega cities of India and as high as Rs. 1477 (US$ 36.93) in SUAs (converted to 1998 prices) (Planning Commission 1983; NIUA 1995). Only the large cities can afford to have this system of sewage collection. Semi-urban areas, neither fulfill the water supply criteria (with their per capita water supply in the range 60–100 l) nor the financial and technical strength required of the local administration to implement such schemes. Therefore, conventional sewerage can not be an appropriate choice for the SUAs.

3.2
Non-conventional sewerage

During the 1960s, attempts were made in the United States and Australia to develop alternative off-site sewerage systems to provide sanitation for rural communities and for the areas of lower population density because of the exorbitant costs of conventional systems and technical infeasibility of on-site disposal systems (WPCF 1986). Pressure sewers, vacuum sewers and small-diameter gravity sewers were the results of such attempts. Around the same time, two cities, one in Zambia and one in Nigeria, also attempted to upgrade their on-site sanitation practice of aqua-privy toilets (squatting plate placed over lined or unlined pits) by way of collecting their overflows through a pipe system (Mara 1996a). However, only during the 1980s, were serious thoughts given to the possibility of providing low-cost off-site sanitation in developing countries, through non-conventional sewerage with the design and successful implementation of a 'simplified sewer system' in northeastern Brazil (Sinnatamby 1983). Basically, non-conventional sewers use small diameter pipes laid at shallow depths and relatively low gradients, just adequate for sewage to flow by gravity. The pressure sewers and vacuum sewers mentioned above also have these features, but are not suitable in developing countries, as they depend on complex machinery and operational procedures. Two types of non-conventional sewerage that have been tried in countries like Brazil, Colombia and Pakistan (Reed 1993), are briefly discussed below.

3.2.1
Simplified sewerage

Simplified sewerage is essentially a conventional sewer system without any of its conservative design requirements that have accrued over the past century or so (Mara 1996b). A schematic comparison of the conventional and the simplified sewer systems is presented in Fig. 2a,b. The construction costs of simplified sewerage have been reduced by means of the following design features (Reed 1996):

- Reducing minimum pipe size for collector sewer (into which wastewater from a household is discharged) from 150 mm to 100 mm
- Reducing minimum collector sewer gradient from 1:150 to 1:220 or less

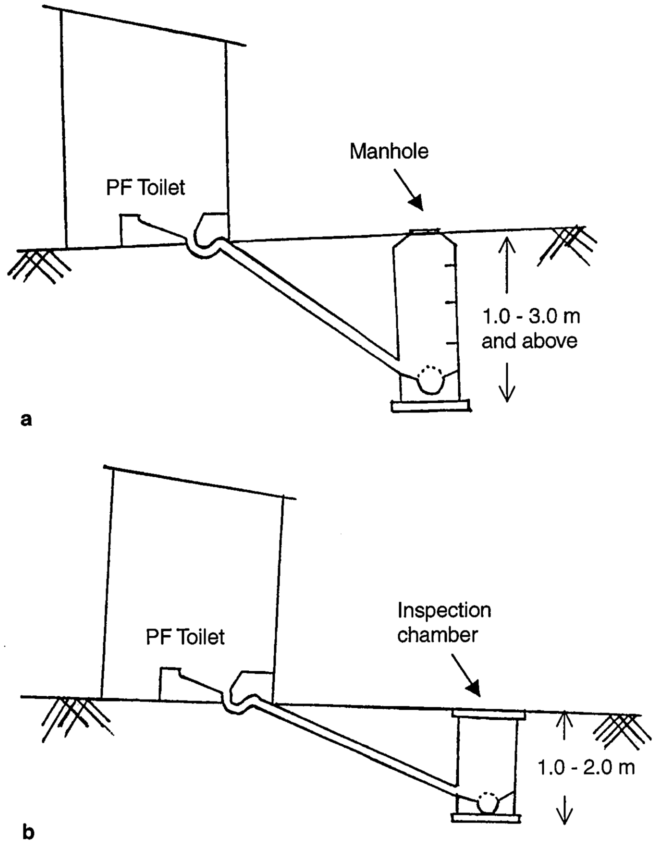

Fig. 2. **a** Conventional sewerage (not to scale). **b** Simplified sewerage (not to scale)

- Replacing conventional access points (man holes) with ones of smaller diameter or with underground inspection chambers
- Increasing the spacing between access points

As reported by Otis et al. (1996), the State Water Company of Sao Paulo, Brazil estimated the construction costs for small towns to be about US$ 150–300 per household for conventional sewerage and US$ 80–150 for simplified sewerage (1988 dollars). They also reported that the construction costs have proven to be 30–40% cheaper than conventional systems. Though no specific operation and maintenance costs have been reported, it has been generally indicated to be cheaper than conventional sewerage. A variant of this simplified sewerage, adopted by many cities in Brazil is the ‘condominial sewerage’ in which the collector sewer runs within properties (at the rear of houses), close to the point of sewage generation, thus reducing the cost of house sewers.

3.2.2
Settled sewerage

In this system, sewage from one or more households is discharged into some form of settling tank for removal of floating and suspended solids, which then overflows into shallow, small diameter collector sewers. The obvious advantage of this system, compared to the conventional and simplified sewer systems, is that it need not be designed for the ‘self-cleansing’ criteria to ensure conveyance of solids. This allows the design criteria of the downstream sewer network to be relaxed, producing savings in capital and operating costs. The system is schematically presented in Fig. 3.

Settled sewerage is the same as what used to be referred as ‘small-bore gravity sewers’ and as ‘common effluent drainage system’ (Otis et al. 1985; South Australian Health Commission 1982) in other contemporary literature. With the basic concept of intercepting sewage solids through settling tanks remaining intact, many variations of subsequent sewer arrangements have emerged at every site, where this system has been tried (Taylor 1996; Pombo 1996). The savings in construction costs of settled sewerage compared to the conventional system have been reported to be in the range of 50–70% (Mara 1996c). Pombo (1996) reported that the per capita construction cost of settled sewerage in Cartagena, Colombia was US$ 10, while the estimated cost for conventional system was about US$ 19.6 (1982 dollars). In case of Brotas, Brazil, the construction cost has been reported to be as low as 22% of that of conventional sewerage (Reed 1996). However, this cost calculation does not include the cost of settling tanks.

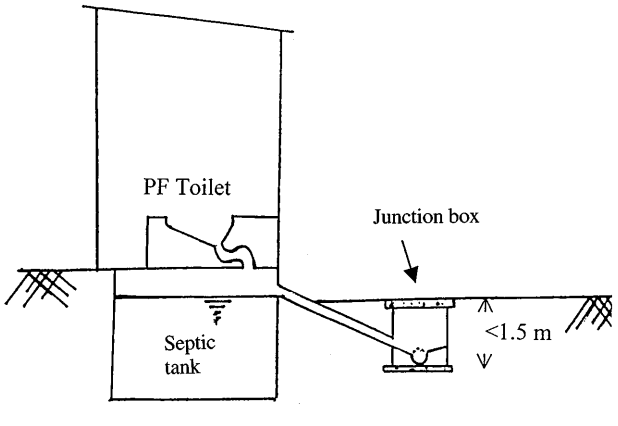

Fig. 3. Schematic diagram of a settled sewer (not to scale)

3.3
Case for non-conventional combined sewerage

A critical evaluation of the non-conventional sewage collection approaches attempted so far implies that there, invariably, is a perception that sewage has to be collected and transported in pipes running underground for its off-site management/disposal. So, while liberalizing many criteria to minimize installation cost, these approaches do not envisage eliminating components that are parts of conventional sewerage. Hence, they still have all the features of conventional sewer system leading to costs of excavation, however shallow the depth may be, and also of appurtenances for house connection and sewer inspection/maintenance purposes. Furthermore, these non-conventional systems are conceived and designed as ‘separate’ or ‘sanitary’ sewers that exclude stormwater.

Without proper arrangements for stormwater drainage, complete and effective urban sanitation can not be achieved. Therefore, opting for ‘simplified’ or ‘settled’ sewerage for semi-urban areas means that there would have to be another system for stormwater collection. Though existing open drains could be used for this purpose, converting these drains into a proper stormwater collection system would require considerable repairs, adding to the costs of the non-conventional ‘separate’ sewerage. Instead, converting these open drains with appropriate structural modifications to overcome their current deficiencies and utilize them to collect both the domestic wastewater and the stormwater, i.e. as a ‘combined’ sewer would be, in all probability, more cost-effective than having two separate systems.

The question of sanitary (separate) versus combined sewers was settled long ago in favor of sanitary sewers, but there is a need to re-open the debate in the context of semi-urban cities. Early this century, the conventional ‘combined’ sewer systems of the European and North American countries were simply discharging untreated sewage into rivers and streams. Conventional ‘sanitary’ sewer systems were adopted by cities which could not afford to install larger combined sewer system. Because of the rising environmental concern for water quality of rivers and streams, cities were urged to treat sewage before disposal. At this juncture, separate sanitary sewer systems became a recommended practice so as to exclude stormwater from the requirement of treatment, hence reducing the cost of sewage treatment. Nonetheless, many cities in these countries continued with ‘combined sewers’ and did not convert to ‘separate sewer’ systems, where the conversion was estimated to be economically infeasible (ASCE 1982). In 1989, more than 1000 such cities in the U.S. alone had combined sewer systems (Department of Environmental Protection 1997).

This historic background considered with the current status of sewage treatment in SUAs of India demonstrates the advantages of a simplified version of combined sewers as a pragmatic option for these areas. Available data on sewage treatment and disposal by SUAs and other cities with populations of up to 200000 (Table 3) shows that more than 90% do not have any sewage treatment facility. Further, the sewage from these cities is extensively used, either directly or indirectly, for irrigation of agricultural crops. Disposal of sewage into lakes/ponds and partial disposal into rivers/streams is for storage and to manage the non-irrigation (monsoon) periods. Under the circumstances, combined sewerage in which stormwater joins sewage will, in all probability, result in a positive dilution effect on sewage that is currently being utilized untreated by these cities. It is not argued that there is no need to treat the sewage from SUAs. The technological approaches for treatment of sewage from semi-urban areas with non-conventional combined sewerage will be discussed in a separate paper (forthcoming). It is only to emphasize that the combined sewer approach will be an appropriate augmentative development to achieve low-cost sewerage for SUAs since it can be implemented with effective utilization of already installed/available infrastructure. Unlike the conventional 'combined' sewers, the system for SUAs will run at surface level, and therefore can be differentiated as 'combined surface sewers'. A schematic presentation of a combined surface sewer is shown in Fig. 4. The concept is further detailed below.

4
Combined surface sewerage for semi-urban areas

The combined surface sewerage is envisaged as a network of hydraulically well designed channels covered with concrete slabs. They will carry sullage and the overflow from septic tanks attached to PF latrines during dry weather and also carry the stormwater during wet weather conditions. Taking full advantage of the settled (solids free) sewage, the sewers can follow natural gradients and, in any case, the slope of the sewer need not exceed 1 in 500. This is consistent with piped settled sewers, which have been laid and successfully operated at gradients as flat as 1 in 1000 (Pombo 1996). The functioning of these low-gradient combined surface sewers can be made more efficient by way of planning them as decentralized networks. It will be advantageous if many independent networks cover a semi-urban city, each ideally draining a population of about 10000–20000, thereby restricting the depth of the sewer at the tail end to not exceed 1.0 to 1.5 m. The decentralised collection of sewage will also facilitate adoption of simpler, low-cost sewage treatment systems such as waste stabilisation ponds and constructed wetlands by avoiding the need for large area requirement at one location, if centralized.

Table 3. Status of sewage treatment and disposal in semi-urban and other small cities of India in 1995

Treatment and Disposal	No. of cities in the population range	
	50,000–99,000	100,000–200,000
Total no. of cities	345	163
(i) Level of Treatment:		
Primary and secondary treatment	4	12
Only primary treatment	13	15
No treatment	328	136
(ii) Mode of disposal:		
In to rivers/streams	12	26
On land for irrigation	54	54
Partially into river and partially for irrigation	18	12
Into water-bodies other than rivers (lakes, ponds etc)	258	59
Into sea	3	12

Source: Central Pollution Control Board, India, 1997a, b

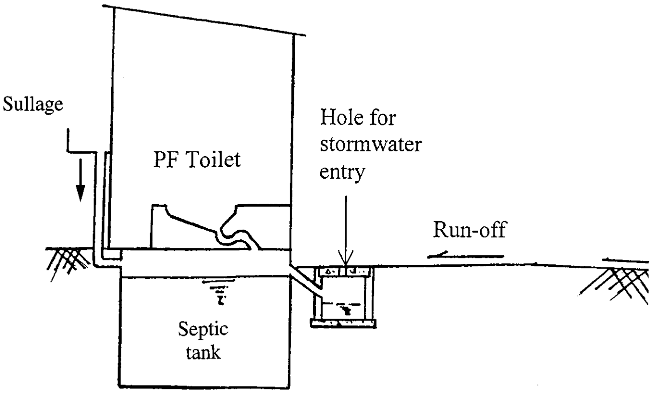

Fig. 4. Schematic diagram of the proposed combined surface sewer (not to scale)

4.1
Construction

The covering slab for the channel is to prevent roadside dust and soil and, garbage and debris from getting dumped into the sewer, which is the main reason for the failure of existing systems in semi-urban cities. To present a sense of permanence to the community, the slabs should be permanently fixed to the drain. The households have to discharge sullage and septic tank overflow directly into the sewer through slots, of say 100 mm diameter, made in the side wall of the sewer channel. Fig. 5 presents the salient features of a combined surface sewer. It is envisaged that the open drains on both the sides of a road need to be converted as sewers, because it will help to:

1. avoid disruption of road surface during construction and hence the cost of its restoration;
2. reduce the cost of house connections; and
3. avoid damage to the sewer due to the peculiar traffic conditions of the semi-urban cities. Bullock/camel carts with iron-rimmed wooden wheels still ply the narrow streets of semi-urban areas that could potentially damage the sewer and its covering slab.

Arrangement for stormwater entry into the sewer has to be made depending upon the level difference between

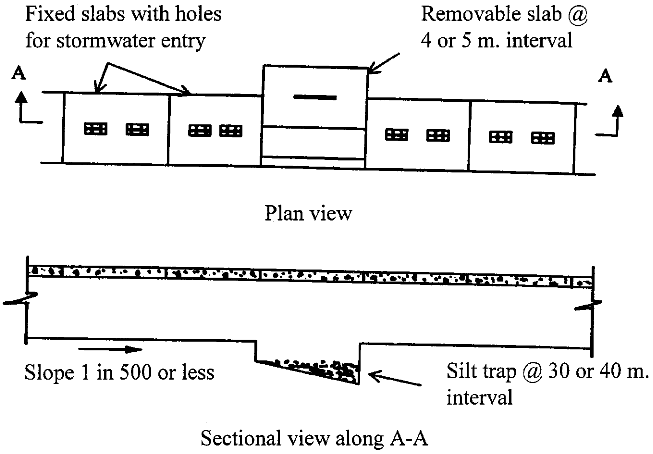

Fig. 5. Details of the combined surface sewer system (not to scale)

the top of the sewer and the road. If the top level of the combined surface sewer were flush with or lower than the street level, the covering slabs with circular or rectangular holes with cross rods would serve the purpose. The slabs with holes for stormwater entry can be placed either consecutively or alternatively. The holes can also serve for ventilation of the sewer line. The cross rods are to prevent the entry of large size objects and debris into the drain. If the top level of the combined sewer is higher than the road level, then the entry for stormwater can be along the sidewall of the sewer.

It would be ideal if the sullage is also drained into the sewer through the septic tanks. This is presently not the case. Therefore, apart from the soil and silt carried by stormwater, solids from sullage will also enter the sewer system. A silt trap arrangement within the sewer is envisaged at regular intervals, say at every 30 or 40 meters and at all junction points, to take care of these solids. A silt trap is nothing but a slightly deeper cross section of the sewer (Fig. 5), which will act as a collection pit for the silt and solids entering the sewer. The covering slab over the silt traps has to be removable for cleaning or emptying the trap as required, or at regular intervals.

Given the existing conditions of drains in semi-urban towns, converting them into a combined surface sewer network would require simple structural modifications to provide silt traps and to fit with concrete covering slabs. Basically, three or four standard cross sections of the combined sewer could serve as collector sewers and main sewers. The standardization can be done based on a survey of existing sizes of the open drains. The semi-urban towns being studied have reported three standard cross sections (i.e. 0.3 m width × 0.45 m depth, 0.45 × 0.6 m and 0.75 × 1.0 m) for all of the open drains. Size standardization would help in mass production of covering slabs to reduce the cost of manufacturing. The specifications for covering slabs can meet minimum requirements for structural stability, except at road crossings, where they may have to be capable of bearing loads.

4.2
Maintenance

A major problem that would arise due to the permanent fixing of covering slabs would be one of sewer maintenance. This must be overcome by providing a removable slab for every 4 or 5 meters of length of permanently fixed slabs. The removable slabs must also be provided at the junction points of collector sewers and main sewers. This would make every section of the sewer approachable, for cleaning purposes, by a manual scrap cleaner attached to a 1.5 to 2.0 meter length of wooden or bamboo stick. This method is currently being used to clean the open drains in the semi-urban cities. Apart from cleaning sewers, maintenance will also include desludging the septic tanks at regular intervals.

4.3
Costs

As the combined surface sewer system is envisaged to utilize existing open drains in SUAs, the major cost components will be lining the side walls and the bed of these drains with cement mortar, and casting and installing silt traps and covering slabs. Cost estimates for implementation of a combined surface sewer system for the four towns studied are presented in Table 4. The cost of purchasing a sludge collection truck with vacuum/suction arrangement has also been included in construction costs. Operation and maintenance costs include: running the truck for sludge removal, personnel for cleaning and repairing the drains.

5
Combined surface sewerage and other systems – a comparison

For semi-urban areas that have only recently converted from dry (bucket) latrine to PF latrine/septic tank systems of sanitation, the next best option to 'combined

Table 4. Details of cost estimates of combined surface sewer systems for the study area in India

Town	Total length of drains (km)	Length of drain per capita (m)	Cost per capita	
			Construction	Annual Maintenance
Andipatti UTP	26.82	1.1	6.74	0.47
Bodinayakanur	97.96	1.5	9.20	0.59
Cumbum	98.70	1.6	9.80	0.64
Theni	79.86	1.1	6.74	0.45
Average	–	1.3	8.12	0.53

Note: All costs are in 1998 US dollars

Table 5. A comparison of non-conventional sewerage systems as options for semi-urban areas of India

Combined surface sewerage	Settled sewerage
Existing infrastructure can be effectively utilised for collection of both wastewater and stormwater; so implementation will cost less	New infrastructure needs to be developed along with separate system for stormwater; so final costs may be higher.
Much less excavation will be involved, thus reducing a major construction cost.	New reticulation will involve excavation and significant cost.
No damage to road surface during installation of the system.	Depends whether planned to run along both the sides of the road or along the centre of the road. However, the case of both the sides of the road, will result in high construction costs
No sewer appurtenance required leading to reduced cost.	Appurtenances for house connection, sewer inspection and maintenance are required.
Simple and minimal maintenance that would require simple tools/ equipment/ training	Maintenance may not be as simple as for the system being compared.
Envisaging as a 'decentralised' system will help implementation of low-cost sewage treatment options, with less land requirement at any one location.	It would be the same case. However, current literatures do not elaborate on the aspect of 'decentralised' systems.

Table 6. Comparison of estimated costs of various sewerage systems for SUAs

System	Cost per capita	
	Construction	Maintenance
i) Combined Surface Sewers	8.12	0.53
ii) Settled Sewers[a]	31.72	N.R.
iii) Conventional Sewers[b]	36.93	1.89

Note: All values in 1998 US dollars. N.R. – Not reported

[a] As reported by Pombo (1996) for the Colombian project at Cartagena

[b] Planning Commission (1983); NIUA (1995)

surface sewerage' would be the 'settled sewerage'. A comparison of features and perceived advantages of the two systems are presented in Table 5. A comparison of costs for different sewer systems in SUAs (Table 6) clearly establishes the cost-effectiveness of the proposed combined surface sewer system as an appropriate augmentative approach. It is pertinent to note that the installation costs of the competing systems must be further revised, as there may be a substantial cost involved for road repairs and reconstruction, in cases of their installation. Though the cost of settled sewerage used for comparison is from a project outside of India, it is reasonable to assume that it will be more costly than the recommended system under the Indian conditions as well.

6
Conclusions

It is clear that extensive conventional sewerage networks are neither feasible nor viable for semi-urban areas. Realistic alternatives to augment the existing PF toilets and septic tanks/soak pits include combined surface sewer systems. The design proposed for such a system would require minimum technical skills and engineering expertise for installation. However, there would be two main pre-requisites for adoption of this system: i) the section of the population that has not converted to the PF toilet and septic tank system also needs to change over to the PF toilet and septic tank system; and ii) the municipal authorities should be equipped with mobile de-sludging machinery for regular and hygienic emptying of septic tanks/soak pits. Comparison of the cost of the combined surface sewerage with other systems clearly indicates that it will be a much less expensive and more appropriate option for most of the semi-urban areas in India. The ease of construction and maintenance of such a system falls well within the technical and operative territory of local governments, which will make it more acceptable to them. Envisioning the combined surface sewer system as a 'decentralized' one will also facilitate easy installation of low-cost sewage treatment options such as waste stabilization ponds and constructed wetlands that can be easily managed at the local level to bring further health and environmental benefits.

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